JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

MoTeU
Mobile Telemedicine Unit

Sergio Sicard
MSc Systems Engineering Capstone Project

Agenda

- Introduction
- Needs Analysis / CONOPS
- Requirements
- Functional Analysis
- Trade Study
- Conceptual Design
- Test Plan
- Risk Analysis
- Conclusion

About Myself

Born and Live in Bogotá, Colombia - May 20th 1978

Education

Telecommunications Engineering (2010)
Universidad Piloto de Colombia

UNIVERSIDAD Piloto DE COLOMBIA

MSc SE:
2012 – 2013 / 2018 - 2019

Work

Cisco
11 años y 1 mes

Manager, Systems Engineering
oct. de 2016 – actualidad · 3 años y 1 mes
Bogotá D.C., Colombia

Consulting Systems Engineer
nov. de 2011 – oct. de 2016 · 5 años
Bogotá, Colombia

Systems Engineer
oct. de 2008 – feb. de 2012 · 3 años y 5 meses

Especialista de HUBs
Telmex Colombia
jul. de 2007 – feb. de 2008 · 8 meses

Hobbies & Interest

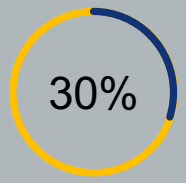
- Road cycling
- Photography
- Audio & Music

Needs Analysis & CONOPS

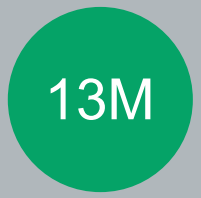
Need Analysis

Characterization of the Problem

The majority of the population located in remote rural areas in Colombia has no access to specialized medical attention, in many cases not even access to basic medical and health services



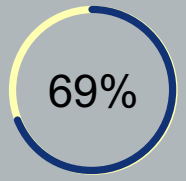
Lives in rural areas



Rural Inhabitants

Largest rural population among 33 countries of LATAM & the Caribbean

Only



of such rural population had access to effective health services

About

inhabitants don't have access to health services / very limited coverage

Colombia's tropical location makes it vulnerable to the spread of endemic diseases such Malaria, Dengue, Yellow Fever among many others

Major challenges treating chronical patients in rural areas in Colombia

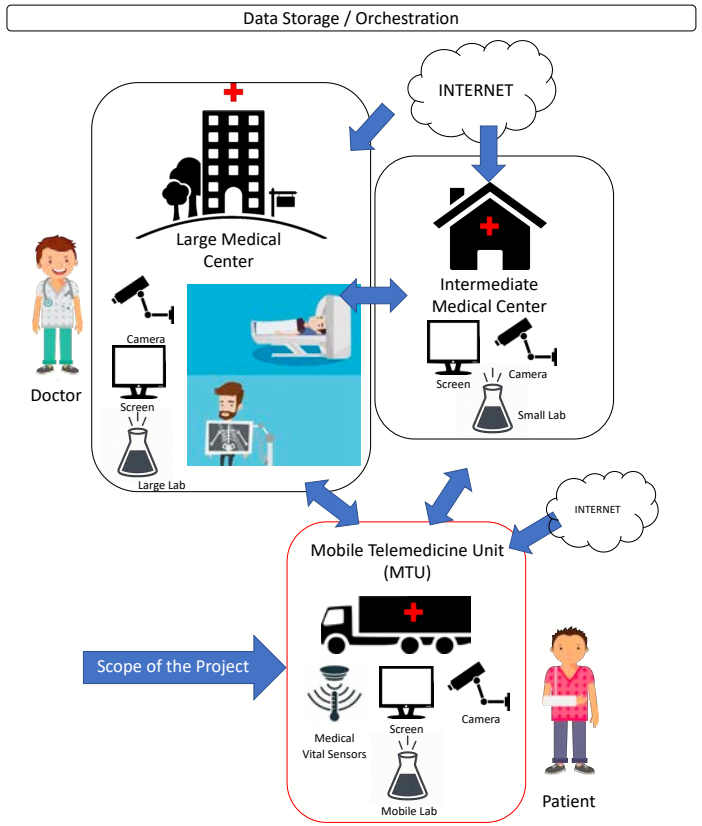
- Rough and diverse environment
- Lack of transportation infrastructure
- Lack of specialized equipment
- No local presence of specialized doctors and personnel

Need Analysis

Mission Needs Statement

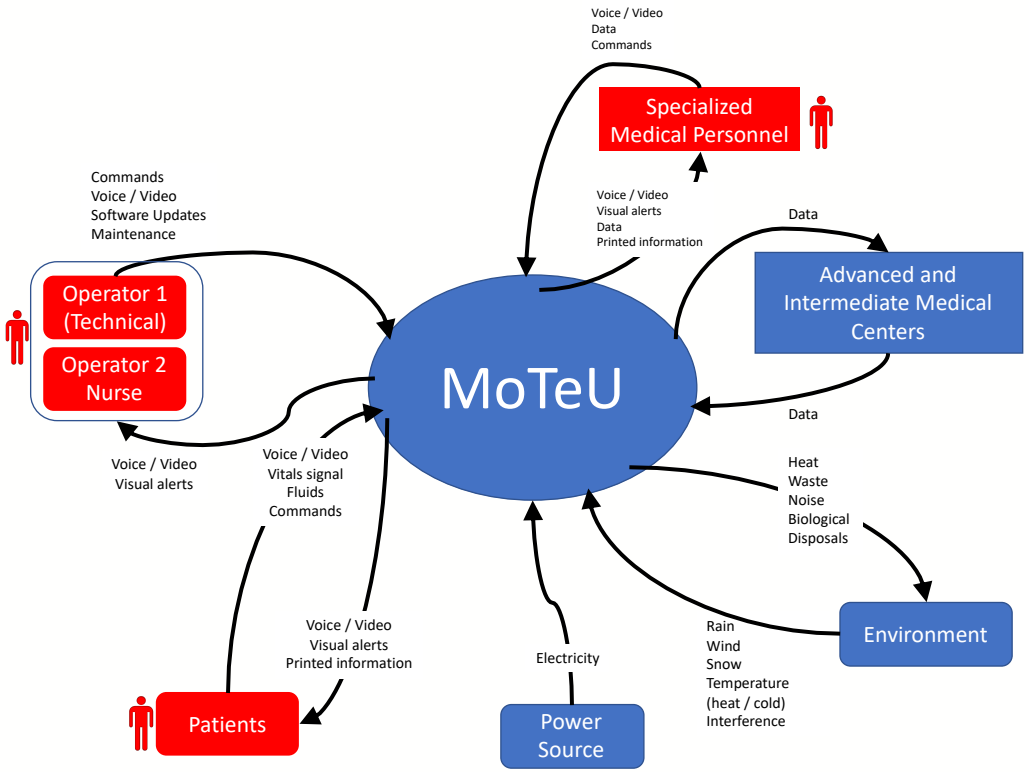
The proposed system shall provide remote medical attention to patients suffering from chronical diseases located in remote and difficult-to-access areas of Colombia, by allowing them to connect with specialists and advanced medical centers located in remote, urban locations using technology tools such networking, satellite communications, telepresence (audio and video conference), immersive communications, cyber security, and internet of things (IoT), among others.

The main purpose is to develop an affordable, compelling and effective system that could benefit the inhabitants of remote locations by interconnecting them with specialist, laboratories and medical center using Information and Communication Technologies.



CONOPS

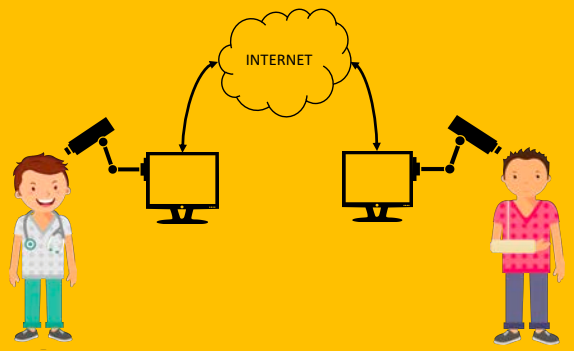
The scope is to provide remote medical attention to patients suffering chronic diseases that require periodic medical consultation and examination but are located in remote areas with limited access to this medical services. The MoTeU system should be a mobile system, easy to transport, deploy and operate, capable to carry portable medical equipment, communications equipment, medical supplies and all the necessary resources needed to provide remote consultation and diagnosis as well as to provide remote treatment to the user population.



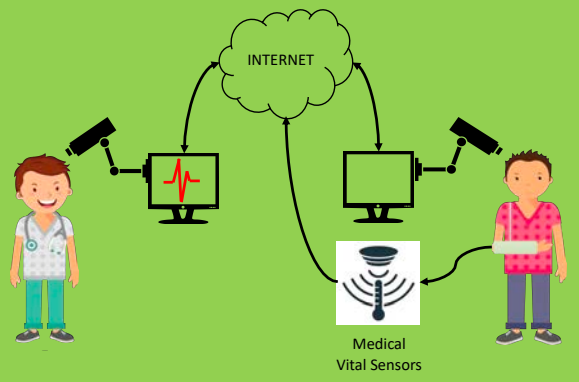
MoTeU System Context Diagram

Scenarios

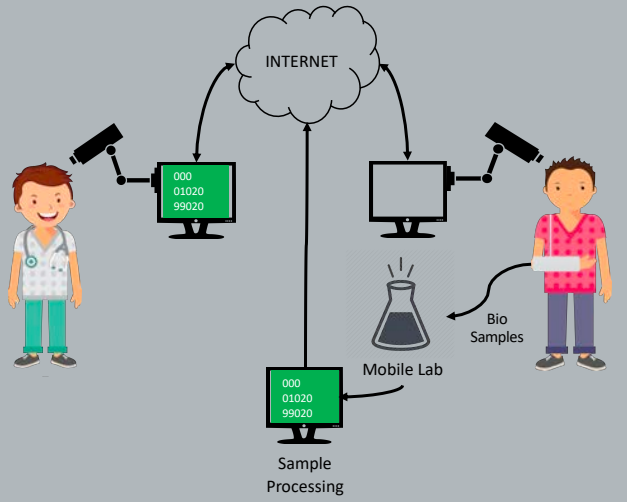
Scenario 1.
Basic consultation



Scenario 2. Consultation with the aid of auxiliary medical equipment

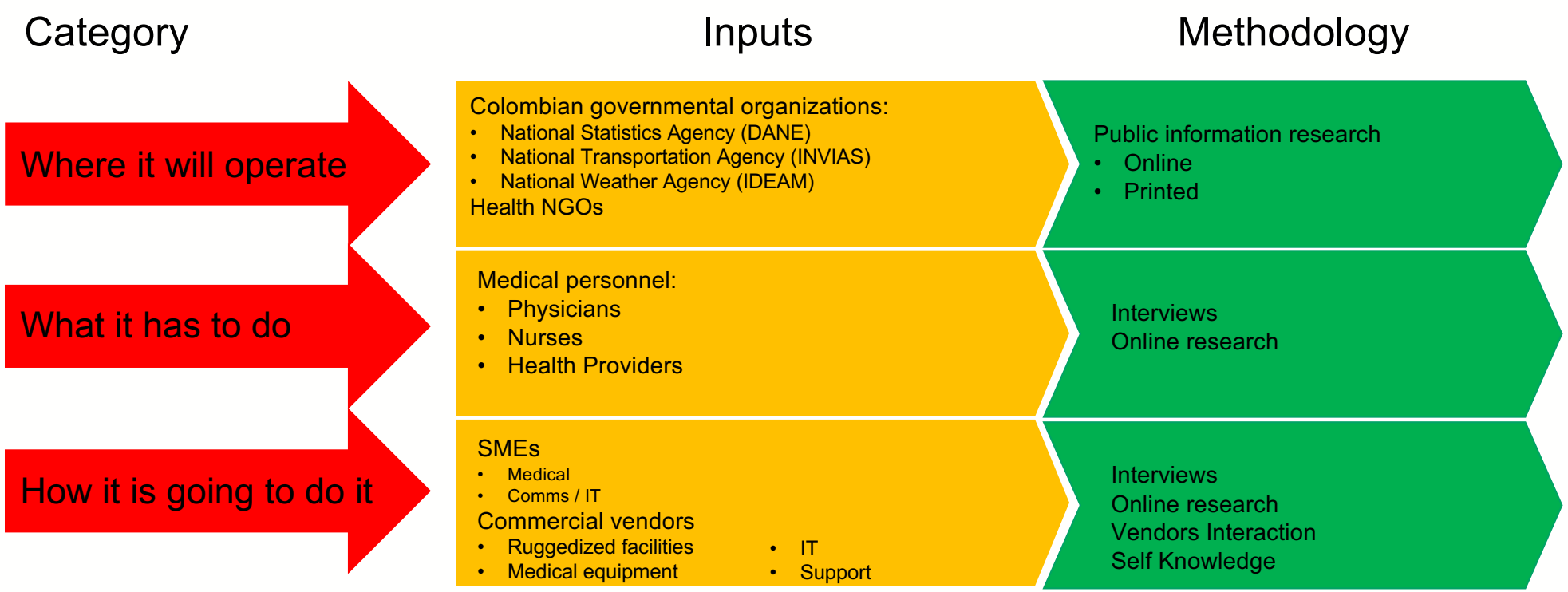


Scenario 3. Laboratory Sample Recollection and Analysis.



Requirements

Requirements Analysis

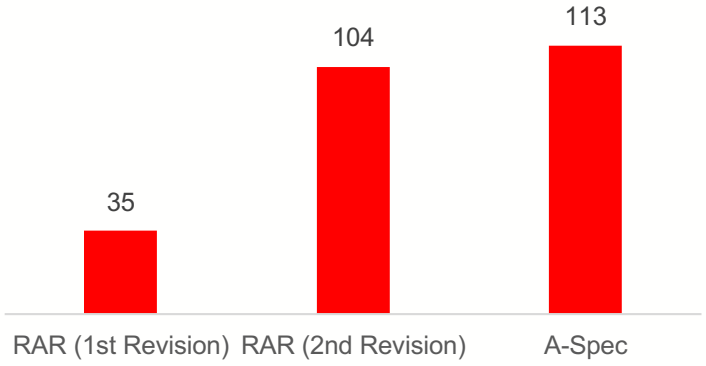


Mission Needs

ID	Statement
MN01	To provide remote medical access to rural population in Colombia
MN02	To provide means of real time communication between patients and physicians
MN03	To be able to transport medical equipment to remote locations
MN04	To be able to operate in a wide range of environmental temperatures and humidity
MN05	To be able to provide its operational status
MN06	To provide connectivity to users and operators
MN07	To be able to gather medical information from patients and transmit it in real time or asymmetrically
MN08	To be able to collect biological samples from patients and analyze, store and transport them
MN09	To be able to securely store digital data
MN10	To be able to securely transmit digital data (such pure data, voice and video)

Requirements

Requirements Evolution

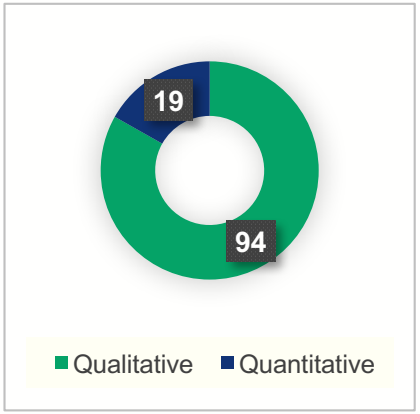


Requirements Codification

#	ID	Requirement	Level	Type
1	T-O-1	The MoTeU shall provide audio and video capabilities to communicate with physicians	Top	Operational
2	T-O-2	The MoTeU shall be able to perform medical imagery procedures	Top	Operational
3	T-O-3	The MoTeU shall collect and analyze biological	Top	Operational

"Level"-"Type"-"Number"

Row Labels	Count
System	90
Functional	71
Performance	19
Top	23
Capability	11
Operational	12
Grand Total	113



Operational Requirements

Number	ID	Requirement	Level	Type
1	T-O-1	The MoTeU shall provide audio and video capabilities to communicate with physicians	Top	Operational
2	T-O-2	The MoTeU shall be able to perform medical imagery procedures	Top	Operational
3	T-O-3	The MoTeU shall collect and analyze biological samples (such blood or tissue) onsite	Top	Operational
4	T-O-4	The MoTeU shall be able to store and transport biological samples	Top	Operational
5	T-O-5	The MoTeU shall be self-sufficient in power source	Top	Operational
6	T-O-6	The MoTeU shall be cyber resilient to data exfiltration, manipulation, and pivot attacks	Top	Operational
7	T-O-7	The MoTeU shall allow operators to write and document digitally the information of the patients	Top	Operational
8	T-O-8	The MoTeU shall allow operators to access the stored information from patients at any time	Top	Operational
9	T-O-9	The MoTeU shall be able to acquire vital signs from patients and send the data	Top	Operational
10	T-O-10	The MoTeU shall be able to acquire diagnose imagery	Top	Operational
11	T-O-11	The MoTeU shall be deployed and operated by at least one operator	Top	Operational
12	T-O-12	The MoTeU shall be able to provide enough power resources for internal active equipment to operate	Top	Operational

KPP (Sample)

ID	Requirement
S-P-113	The MoTeU shall provide protection against elements such water and dust (IP58MW) when transporting the active elements of the system
S-P-112	The MoTeU shall provide protection to extreme windy conditions up to number 7 in the Beaufort scale (50–61 km/h)
S-P-107	The MoTeU shall ensure percent packet loss ≤ 1
S-P-106	The MoTeU shall ensure a jitter ≤ 30 ms
S-P-105	The MoTeU shall ensure a one-way latency ≤ 150 ms
S-P-73	The MoTeU shall be able to capture audio frequencies from 20 Hz to 20 KHz
S-P-72	The MoTeU shall be able to capture high definition video of at least 30 fps
S-P-53	The MoTeU shall be able to acquire high definition imagery of at least 20 Mpixels (photography) to document the condition of the patient
S-P-52	The MoTeU shall provide data storage capabilities of at least 40 TB to store digital data
S-P-42	The MoTeU shall encrypt all outgoing traffic using AES of 128-bit, 192-bit, and 256-bit keys
S-P-41	The MoTeU shall be able to isolate and report malicious activity in the data network
S-P-40	The MoTeU shall apply Quality of Service (QoS) policies to Voice and Video traffic, ensuring at least 2.5 Mbps (Receive) and 3.0 Mbps (Send) for High Definition video traffic and at least 320 Kbps for audio traffic
S-P-37	The MoTeU shall provide a primary data link of at least 100mbps bidirectional
S-P-34	The MoTeU shall be able to maintain a constant and controlled humidity level between 40% and 50% while operating
S-P-33	The MoTeU shall be able to maintain a constant and controlled temperature of 18 degrees celcius at all times while operating
S-P-32	The MoTeU must provide light levels between 20 foot candles and 150 foot candles
S-P-24	The MoTeU shall be able to operate under heavy rainy conditions (above 9000mm of precipitation)
S-P-23	The MoTeU shall be able to operate in humidity range from 60% to 100%
S-P-22	The MoTeU shall be able to operate in ranges of temperature between -10º and 50º Celsius

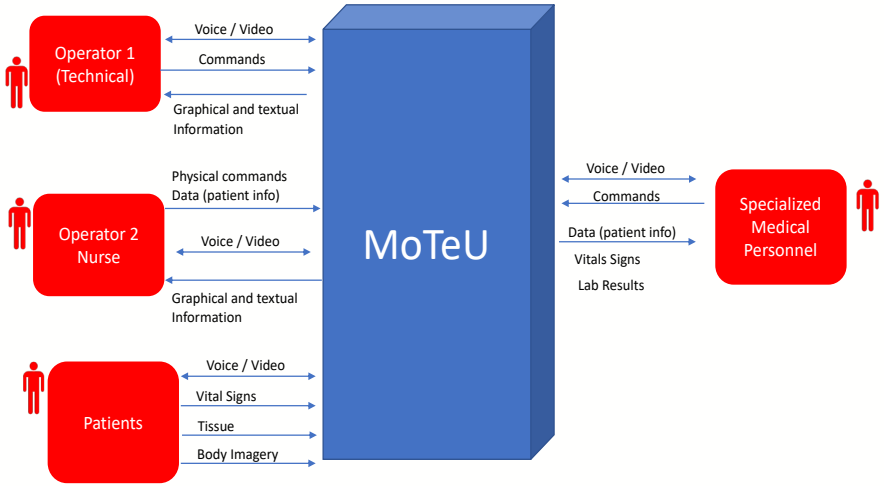
Functional Analysis

Functional Analysis Methodology

The functional analysis of MoTeU will be approached by using Model Based Systems Engineering (MBSE), where several graphical representations are used to depict the different functions of the systems itself. The following models are presented during this analysis:

- Functional Context Diagram
- Functional Hierarchy Model
- Functional Block Diagram
- Functional Flow Diagram
- Requirements traceability
- N^2 Diagrams

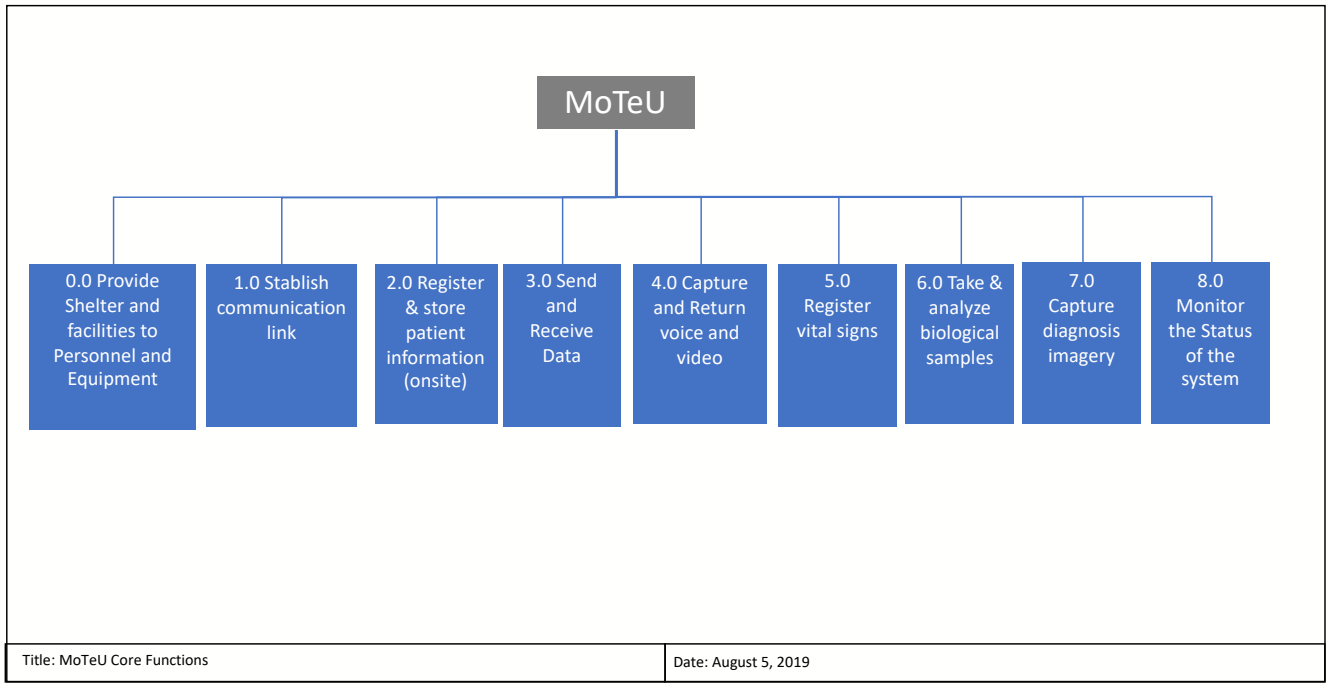
Functional Context Diagram



1) Operator 1 (technician): is responsible to activate and operate the system, may provide commands and actions of certain type to accomplish such task and may receive information from the system related with its operation.
2) Operator 2 (nurse): will interact mainly with patients and medical related elements of MoTeU, receive and provide audio and video communications
3) Patient: Interacts with MoTeU providing voice and video to communicate with remote users of the system. Also, will provide vital signs information and biological samples such blod or tissue to be analyzed locally or remotely.
4) Specialized Medical Personnel: receive information remotely about the patients and interacts with the other users and patient located remotely.

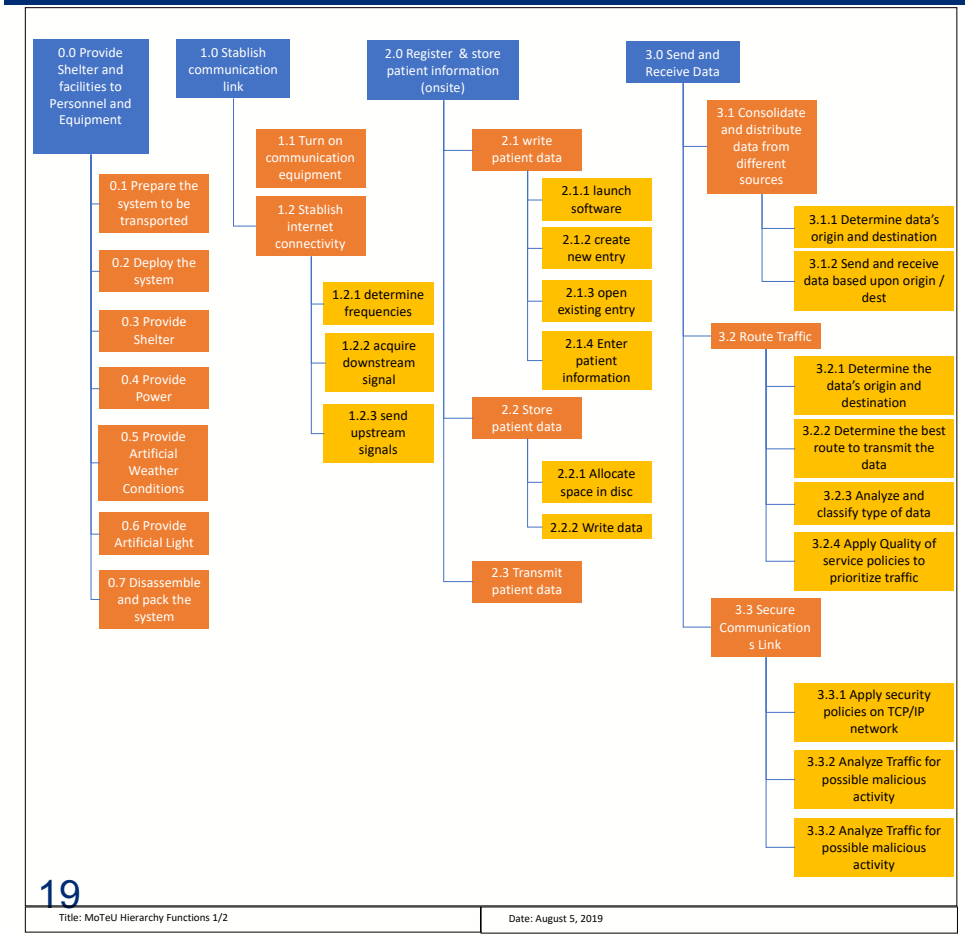
Functional Hierarchy Model

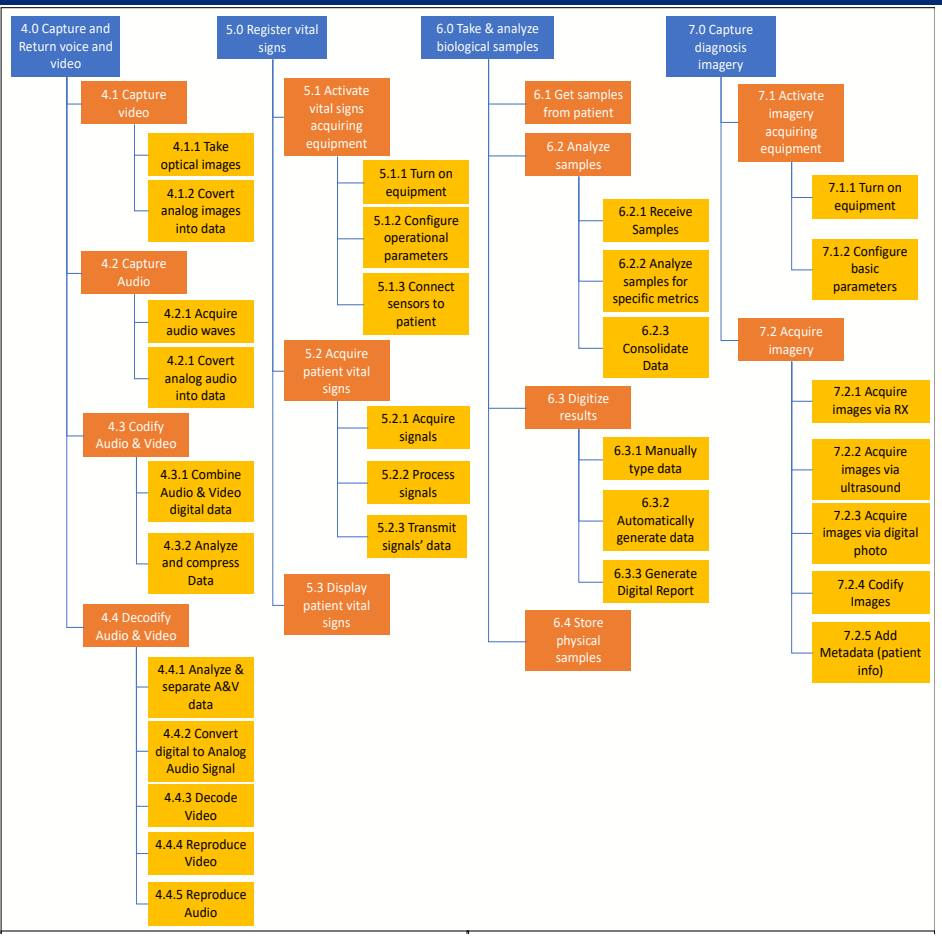
MoTeU Core Functions



Functional Hierarchy Model

MoTeU Functions Hierarchy Detailed



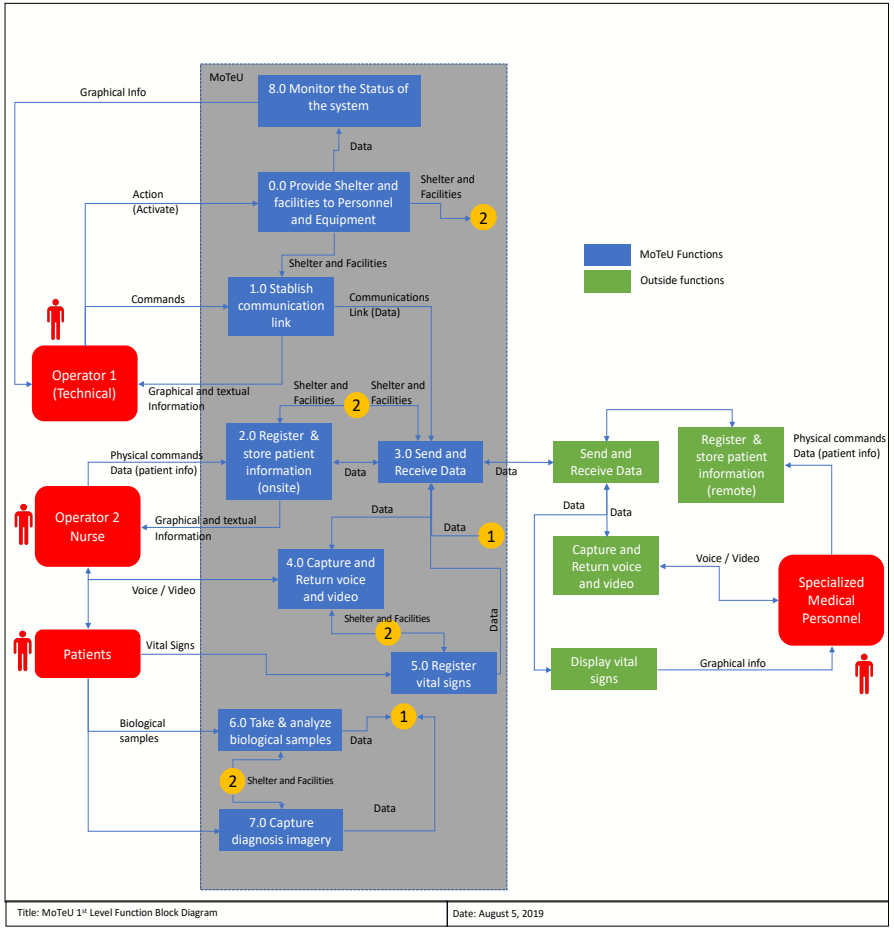


Title: MoTeU Hierarchy Functions 1/2

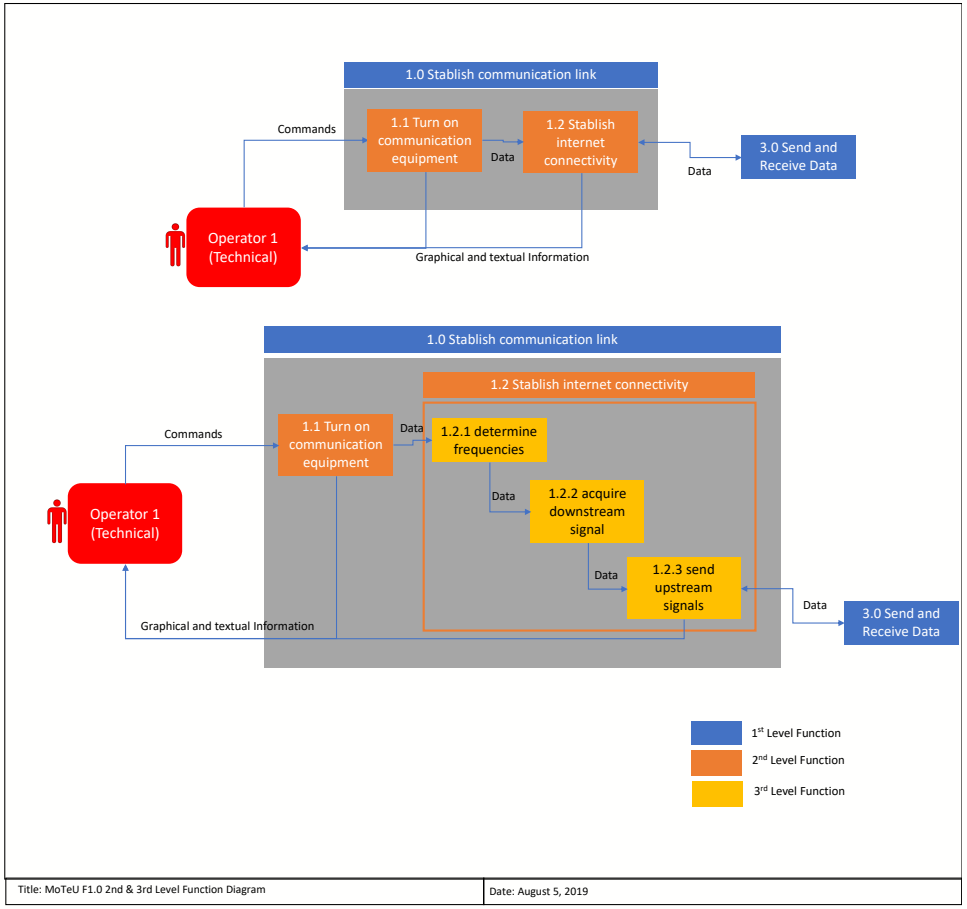
Date: August 5, 2019

Functional Flow Diagram

MoTeU 1st Level Block Diagram



MoTeU 2nd and 3rd Level Function Block Diagram



Requirements Traceability

Unique Function Identifier

Unique Requirement Identifier

Function ID	Function Name	ID	Requirement
0.0	Provide Shelter and facilities to Personnel and Equipment	T-O-5	The MoTeU shall be self-sufficient in power source
		T-O-11	The MoTeU shall be deployed and operated by at least one operator
		T-O-12	The MoTeU shall be able to provide enough power resources for internal active equipment to operate
		T-C-13	The MoTeU shall be able to be transported and deployed to any rural area in Colombia
		T-C-14	The MoTeU shall be able to be transported over water, ground or air
		T-C-15	The MoTeU shall be able to provide shelter and work spaces to the users and operators
		T-C-16	The MoTeU shall be able to operate regardless its external environmental conditions

Function name

Requirement Description

N^2 Diagram

	Operator 1 (Technical)	Operator 2 Nurse	Patients	0.0 Provide Shelter and facilities to Personnel and Equipment	1.0 Stablish communication link	2.0 Register & store patient information	3.0 Send and Receive Data	4.0 Capture and Return voice and video	5.0 Register vital signs	6.0 Take & analyze biological samples	7.0 Capture diagnosis imagery	Send and Receive Data	Capture and Return voice and video	Display vital signs	Register & store patient information	Specialized Medical Personnel	Counter
Operator 1 (Technical)				X	X												2
Operator 2 Nurse			X			X		X	X	X	X						6
Patients		X						X	X	X	X						5
0.0 Provide Shelter and facilities to Personnel and Equipment					X	X	X	X	X	X	X						7
1.0 Stablish communication link	X						X										2
2.0 Register & store patient information		X					X										2
3.0 Send and Receive Data								X	X	X	X	X					5
4.0 Capture and Return voice and video		X	X				X										3
5.0 Register vital signs							X										1
6.0 Take & analyze biological samples							X										1
7.0 Capture diagnosis imagery							X										1
Send and Receive Data							X						X	X	X		4
Capture and Return voice and video																X	1
Display vital signs																X	1
Register & store patient information (remote)												X					1
Specialized Medical Personnel								X						X			2
Counter	1	3	2	1	2	2	8	5	4	4	4	2	1	2	1	2	

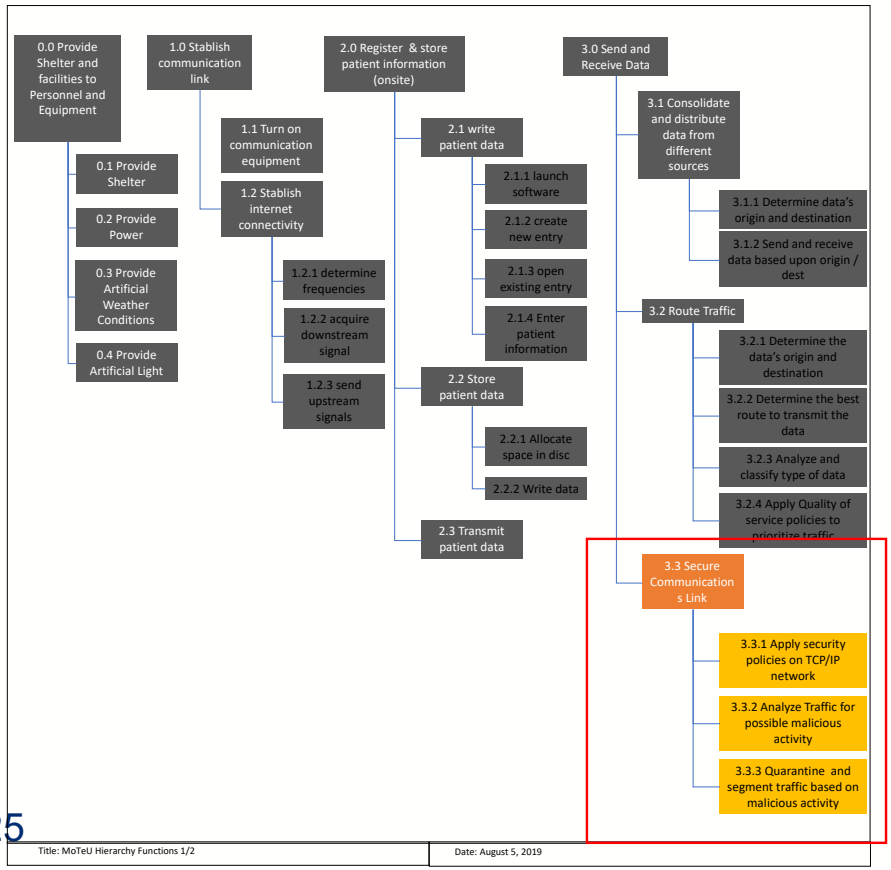
Red: Users
Blue: Internal Functions
Green: External Functions

Trade Study

Trade Study

Function to Evaluate / COTS Alternatives

Function 3.3 “Secure Communications Link” and its subfunctions



COTS Alternatives

Cisco ASA 5500 Series Firewalls

Fortinet Fortigate 80E

Check Point 770 UTM

Meraki MX86

Trade Study

Evaluation Factors, Products, N^{th} Root Value and Normalization

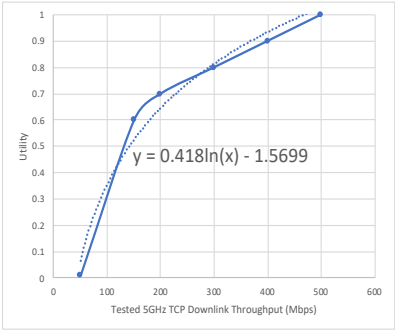
1. Operational Throughput with Security Features Activated
2. GbE ports
3. Weight and Power Consumption
4. Multiple WAN Options

CRITERIA	Throughput: FW + AVC + IPS	1GbE Ports (qty)	Weight (kg)	Power Consumption (W)	WAN Options	Row Value Products	Nth root of value products	Normalized Weighting Factor
Throughput: FW + AVC + IPS	1	6	9	2	0.333	36	2.05	0.25
1GbE Ports (qty)	0.167	1	0.5	0.25	0.125	0	0.3	0.04
Weight (kg)	0.111	2	1	0.5	0.143	0.02	0.44	0.05
Power Consumption (W)	0.5	4	7	1	0.125	1.75	1.12	0.14
WAN Options	3	8	8	8	1	1536	4.34	0.53
						Sum of the Nth Roots >	8.24	1

Utility Functions

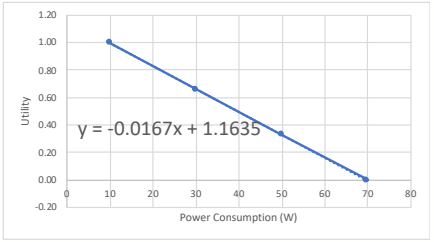
Throughput: FW + AVC + IPS (Mbps)

Throughput: FW + AVC + IPS (Mbps)	Utility	Rationale
50	0.01	This parameter refers to the effective throughput of the UTM with all the security options activated. The highest the value expressed in data transfer units (Mbps) the better because the appliance allows more effective data traffic rates. Most commercially available UTMs in the market in this price range have effective throughputs below 600Mbps
150	0.6	
200	0.7	
300	0.8	
400	0.9	
500	1	



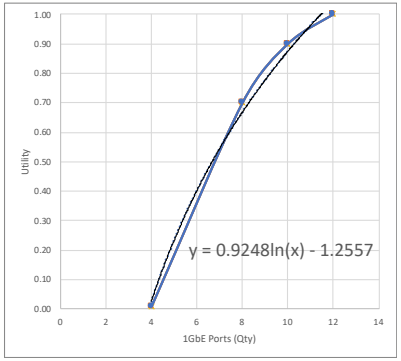
Power Consumption (W)

Power Consumption (W)	Utility	Rationale
70	0.00	The less power consumption the better due to the effectiveness of the use of pwer resources when MoTeU is deployed
50	0.33	
30	0.66	
10	1.00	



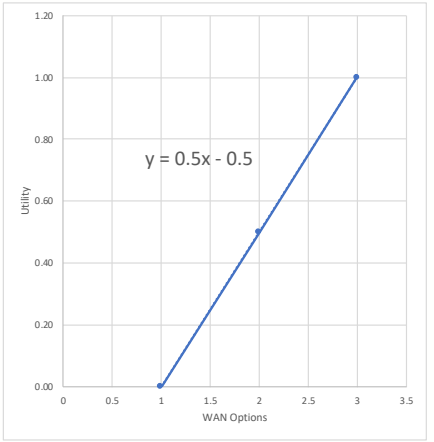
1 GbE Ports (Quantity)

1GbE Ports (Qty)	Utility	Rationale
4	0.01	Most of available UTMs in this range of features and price offer an option of multiple gigabit ethernet ports (GbE) which allow to connect multiple IP devices via wire (UTP) to the UTM. This option simplifies the connectivity in some cases by reducing the need of an external switch to consolidate connections. These small business / small branch options range from 4 up to 16 ports.
8	0.70	
10	0.90	
12	1.00	



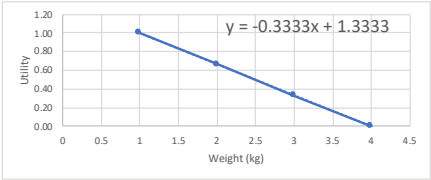
WAN Options (#)

WAN Options	Utility	Rationale
1	0.00	This devices are capable to have more than one interface to connect to the Wide Area Network (WAN). The score criteria are defined like this: **One GbE WAN Port: 1** **Two GbE WAN Port: 2** **GbE + LTE WAN options: 3** Since the MoTeU will be located remotely, the more connectivity options it has to connect with the network, the better.
2	0.50	
3	1.00	



Weight (kg)

Weight (kg)	Utility	Rationale
4	0.00	Lower weight is better due to transportability. MoTeU is conceived as a mobile unite, so the lower the weight of the appliance the easiest to transport.
3	0.33	
2	0.67	
1	1.00	



Trade Study
Evaluations of Alternatives

Trade Study Analysis result MoTeU UTM Options

Criteria	Wt.	Cisco ASA 5516			Fortigate 80E			CheckPoint 770UTM			Cisco Meraki MX68		
		Raw Score	Utility Value	Weighted Utility Value	Raw Score	Utility Value	Weighted Utility Value	Raw Score	Utility Value	Weighted Utility Value	Raw Score	Utility Value	Weighted Utility Value
Throughput: FW + AVC + IPS (Mbps)	0.248	450	0.98	0.244	400	0.93	0.232	325	0.85	0.211	450	0.98	0.244
1GbE Ports (qty)	0.037	8	0.67	0.025	12	1.04	0.038	12	1.04	0.038	10	0.87	0.032
Weight (kg)	0.053	3	0.33	0.018	1.2	0.93	0.049	1.6	0.80	0.042	1.12	0.96	0.051
Power Consumption (W)	0.136	30	0.66	0.090	18	0.86	0.117	55	0.25	0.033	19	0.85	0.115
WAN Options (Quality)	0.526	2	0.50	0.263	2	0.50	0.263	1	0.00	0.000	3	1.00	0.526
Operational Utility Function (Weighted Sum)		0.640			0.700			0.325			0.968		
Cost ($) (expressed in USD)		6000			4000			1300			1150		
Cost-Effectiveness Selection Function (weighted Sum / Cost)		0.000107			0.000175			0.000250			0.000842		

Trade Study

Sensitivity Analysis

Sensitivity Analysis 1 Weight of Criteria 1 to Zero

Criteria	Wt.	Cisco ASA 5516			Fortigate 80E			CheckPoint 770UTM			Cisco Meraki MX68		
		Raw Score	Utility Value	Weighted Utility Value	Raw Score	Utility Value	Weighted Utility Value	Raw Score	Utility Value	Weighted Utility Value	Raw Score	Utility Value	Weighted Utility Value
Throughput: FW + AVC + IPS (Mbps)		450	0.98	0.000	400	0.93	0.000	325	0.85	0.000	450	0.98	0.000
1GbE Ports (qty)	0.037	8	0.67	0.025	12	1.04	0.038	12	1.04	0.038	10	0.87	0.032
Weight (kg)	0.053	3	0.33	0.018	1.2	0.93	0.049	1.6	0.80	0.042	1.12	0.96	0.051
Power Consumption (W)	0.136	30	0.66	0.090	18	0.86	0.117	55	0.25	0.033	19	0.85	0.115
WAN Options (Quality)	0.526	2	0.50	0.263	2	0.50	0.263	1	0.00	0.000	3	1.00	0.526
Operational Utility Function (Weighted Sum)			0.395			0.468			0.114			0.724	
Cost ($) (expressed in USD)			6000			4000			1300			1150	
Cost-Effectiveness Selection Function (weighted Sum / Cost)			0.000066			0.000117			0.000088			0.000630	

Sensitivity Analysis 2 Weight of Criteria 2 to Zero

Criteria	Wt.	Cisco ASA 5516			Fortigate 80E			CheckPoint 770UTM			Cisco Meraki MX68		
		Raw Score	Utility Value	Weighted Utility Value	Raw Score	Utility Value	Weighted Utility Value	Raw Score	Utility Value	Weighted Utility Value	Raw Score	Utility Value	Weighted Utility Value
Throughput: FW + AVC + IPS (Mbps)	0.248	450	0.98	0.244	400	0.93	0.232	325	0.85	0.211	450	0.98	0.244
1GbE Ports (qty)	0.000	8	0.67	0.000	12	1.04	0.000	12	1.04	0.000	10	0.87	0.000
Weight (kg)	0.053	3	0.33	0.018	1.2	0.93	0.049	1.6	0.80	0.042	1.12	0.96	0.051
Power Consumption (W)	0.136	30	0.66	0.090	18	0.86	0.117	55	0.25	0.033	19	0.85	0.115
WAN Options (Quality)	0.526	2	0.50	0.263	2	0.50	0.263	1	0.00	0.000	3	1.00	0.526
Operational Utility Function (Weighted Sum)			0.615			0.662			0.286			0.936	
Cost ($) (expressed in USD)			6000			4000			1300			1150	
Cost-Effectiveness Selection Function (weighted Sum / Cost)			0.000102			0.000165			0.000220			0.000814	

Sensitivity Analysis 3 Weight of Criteria 3 to Zero

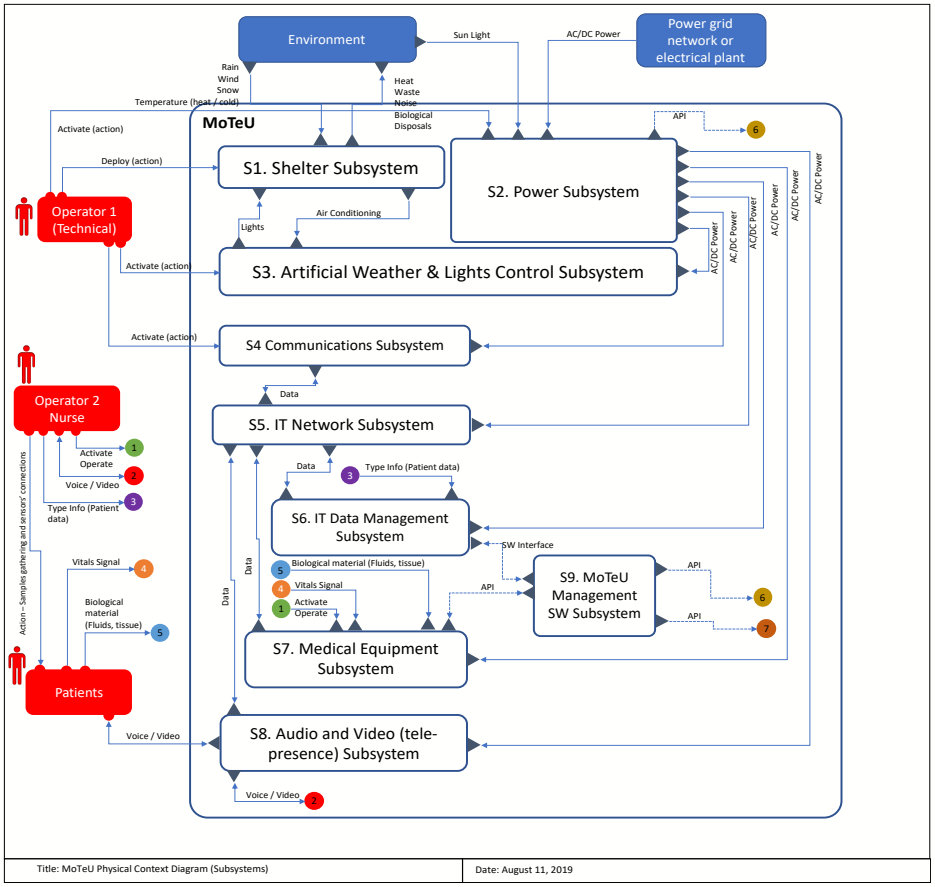
Criteria	Wt.	Cisco ASA 5516			Fortigate 80E			CheckPoint 770UTM			Cisco Meraki MX68		
		Raw Score	Utility Value	Weighted Utility Value	Raw Score	Utility Value	Weighted Utility Value	Raw Score	Utility Value	Weighted Utility Value	Raw Score	Utility Value	Weighted Utility Value
Throughput: FW + AVC + IPS (Mbps)	0.248	450	0.98	0.244	400	0.93	0.232	325	0.85	0.211	450	0.98	0.244
1GbE Ports (qty)	0.037	8	0.67	0.025	12	1.04	0.038	12	1.04	0.038	10	0.87	0.032
Weight (kg)	0.000	3	0.33	0.000	1.2	0.93	0.000	1.6	0.80	0.000	1.12	0.96	0.000
Power Consumption (W)	0.136	30	0.66	0.090	18	0.86	0.117	55	0.25	0.033	19	0.85	0.115
WAN Options (Quality)	0.526	2	0.50	0.263	2	0.50	0.263	1	0.00	0.000	3	1.00	0.526
Operational Utility Function (Weighted Sum)			0.622			0.651			0.282			0.917	
Cost ($) (expressed in USD)			6000			4000			1300			1150	
Cost-Effectiveness Selection Function (weighted Sum / Cost)			0.000104			0.000163			0.000217			0.000798	

Conceptual Design

Conceptual Design

Physical Context Diagram

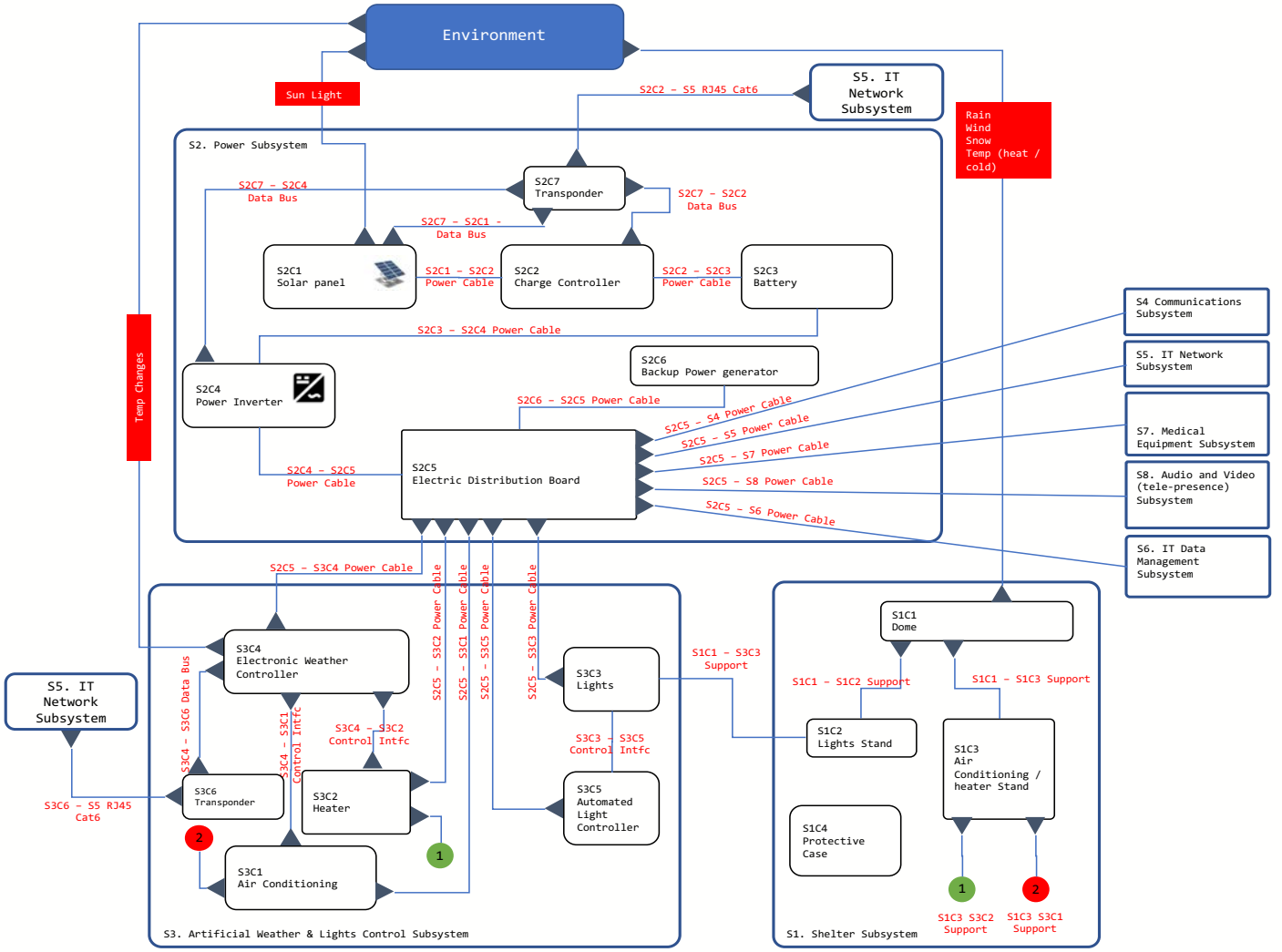
The Physical Context Diagram (PCD) shows the proposed distribution of subsystems among with their interactions between them and external entities



Conceptual Design

Physical Block Diagrams

PBD - MoTeU Physical Block Diagram (Subsystems 1 – 3)



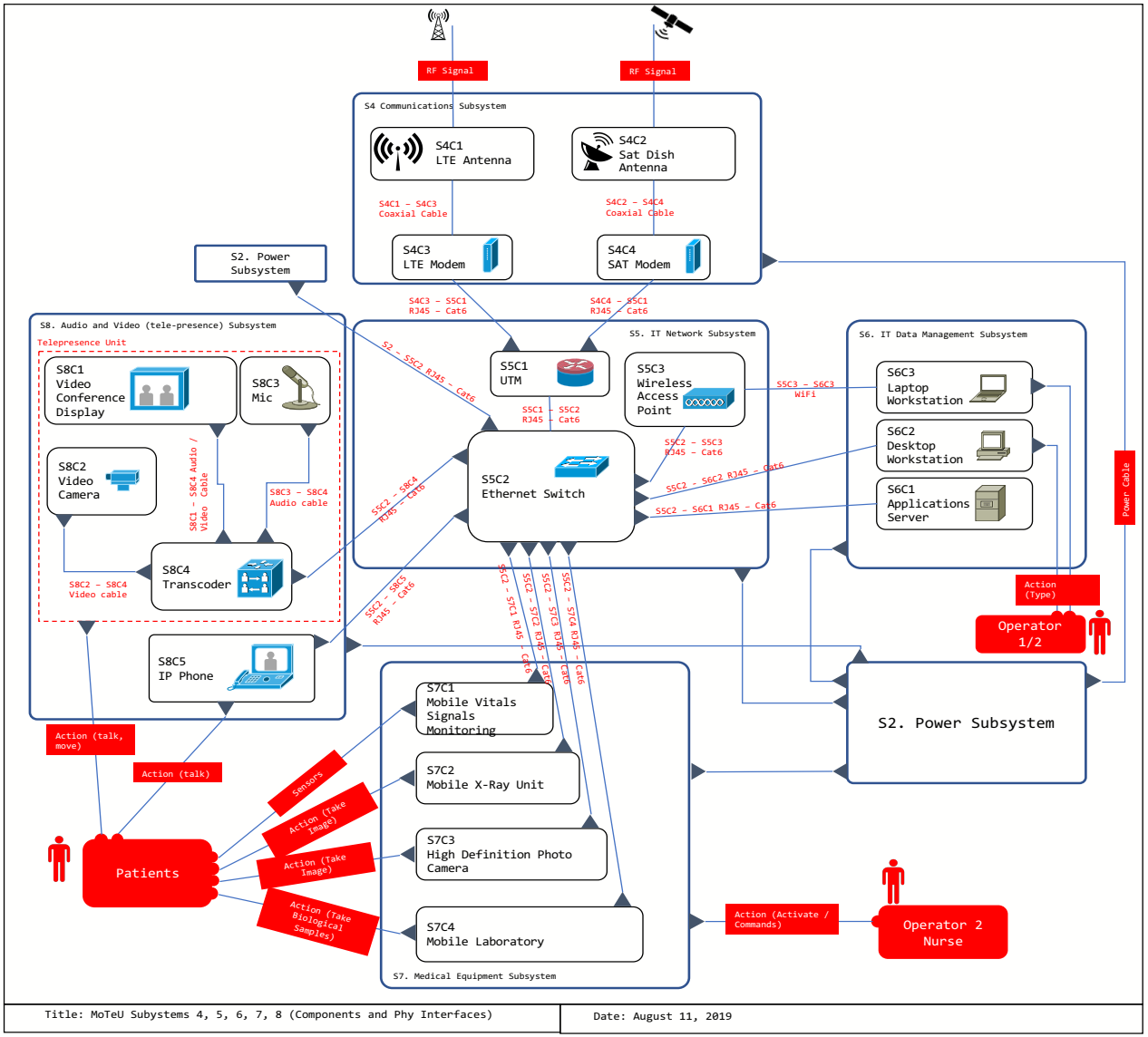
Title: MoTeU Subsystems 1,2,3 (Components and Phy Interfaces)

Date: August 11, 2019

Conceptual Design

Physical Block Diagrams

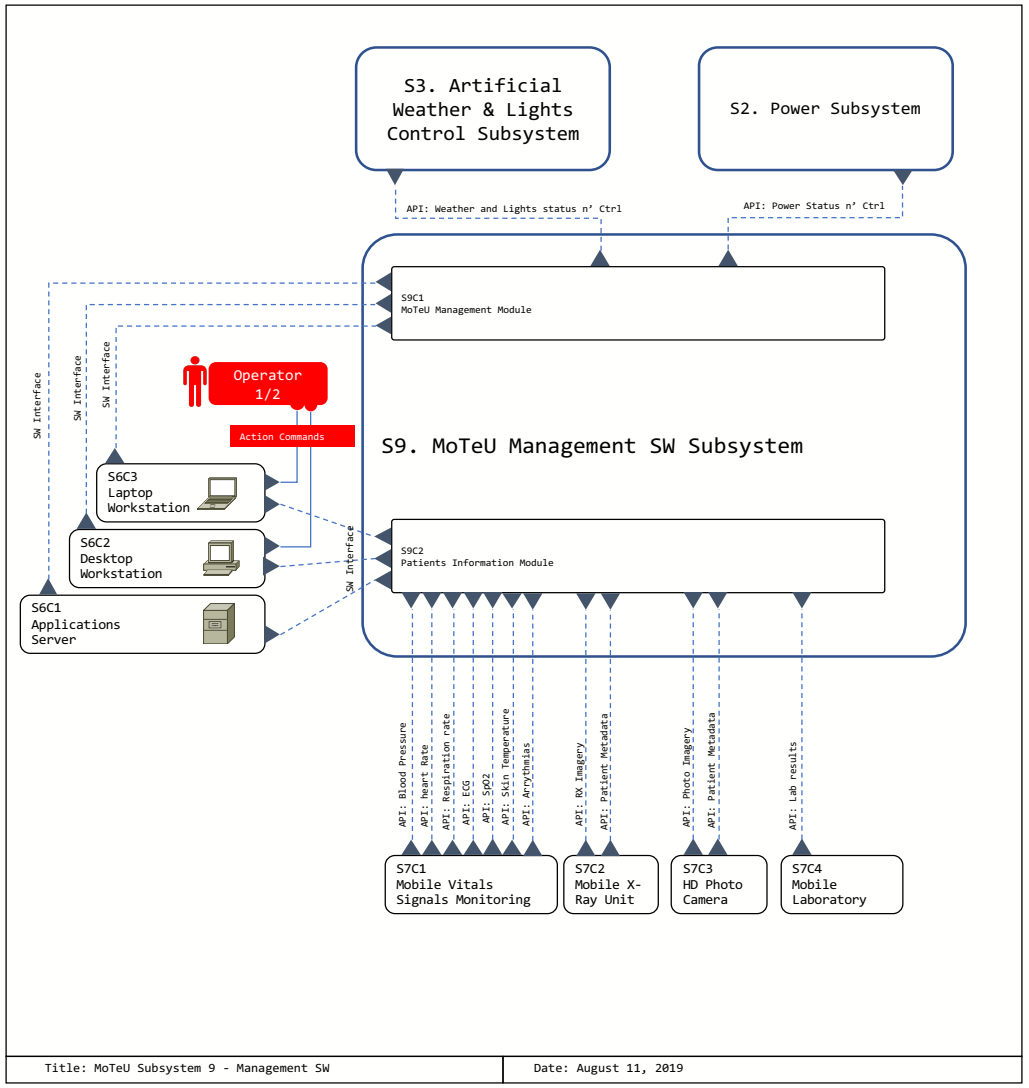
MoTeU Subsystems 4 - 8



Conceptual Design

Physical Block Diagrams

MoTeU Subsystem 9 Management Software



Conceptual Design

Requirements Traceability (Subsystem and Component level) – [Sample]

Subsystem / Component

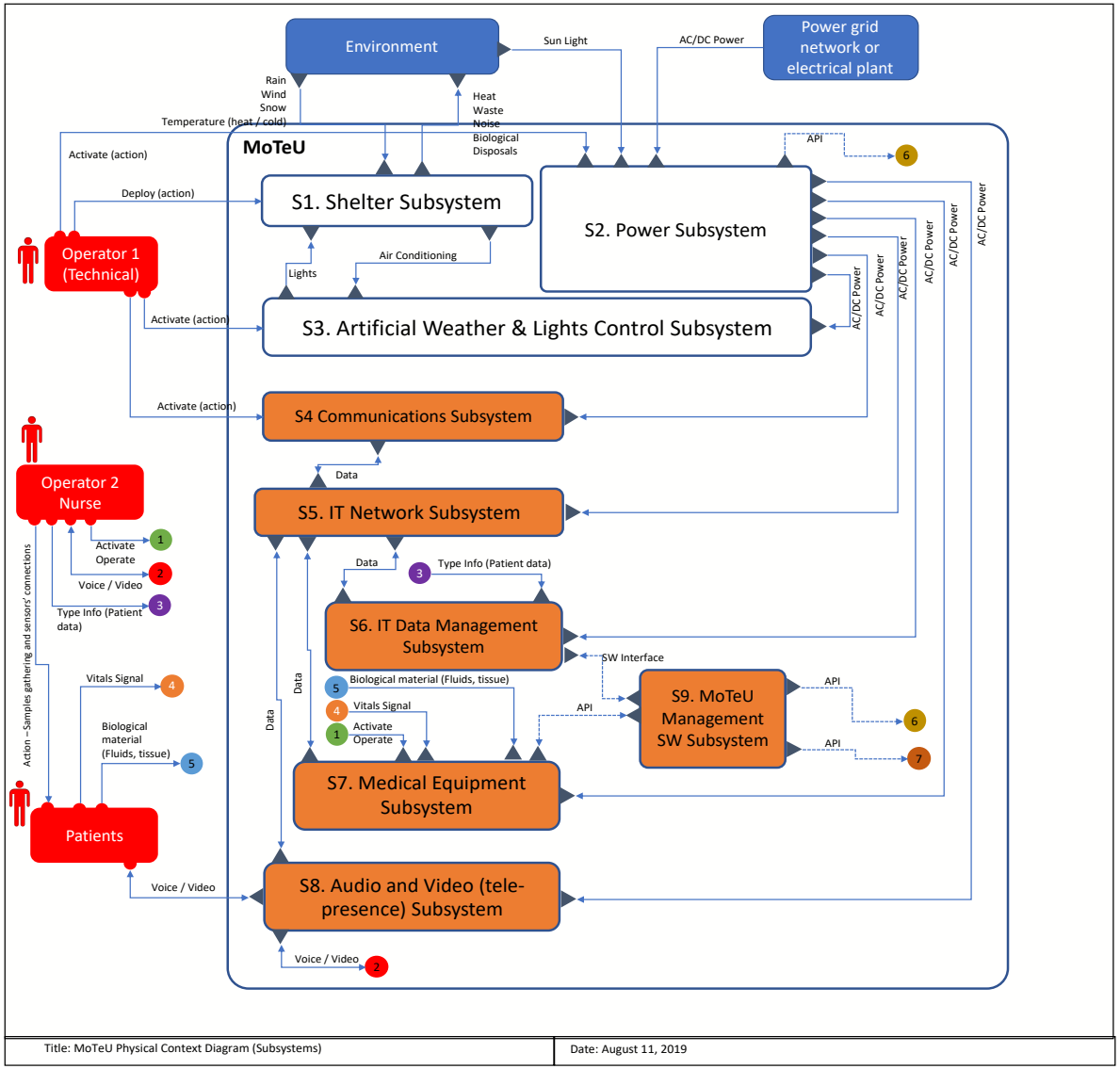
S1. Shelter Subsystem	S-P-22	The MoTeU shall be able to operate in ranges of temperature between -10º and 50º Celsius	S1C1 Dome
	S-P-23	The MoTeU shall be able to operate in humidity range from 60% to 100%	S1C1 Dome
	S-P-24	The MoTeU shall be able to operate under heavy rainy conditions (above 9000mm of precipitation)	S1C1 Dome
	S-F-25	The MoTeU shall be packaged in the smallest format possible to be transported	S1C4 Protective Case
	S-F-26	The MoTeU shall provide enclosures to safely transport its elements and protect them while on movement	S1C4 Protective Case
	S-F-85	The MoTeU shall provide a rigid structure to safely install lights and other support infrastructure	S1C2 Lights Stand
S2. Power Subsystem	S-F-27	The MoTeU shall be capable to switch from at least two sources of electrical power	S2C5 Electric Distribution Board
	S-F-28	The MoTeU shall be able to monitor the status of the electrical power elements	S2C7 Transponder
	S-F-29	The MoTeu shall be able to distribute electrical power to all the active components as needed	S2C5 Electric Distribution Board
	S-F-30	The MoTeU shall be able to store energy to ensure continous supply of electrical power to active elements	S2C3 Battery
	S-F-89	Teh MoTeU shall be able to monitor and control the electrical power elements via APIs	S2C7 Transponder
	S-F-100	The MoTeU shall be able to be feeded by a off-grid power source	S2C1 Solar panel
	S-F-101	The MoTeU shall be able to control the charge of the bateries in the system	S2C2 Charge Controller
	S-F-102	The MoTeU shall convert from DC to AC	S2C4 Power Inverter
	S-F-103	The MoTeU shall provide redundant source of power	S2C6 Backup Power generator

Test Plan

Test Plan

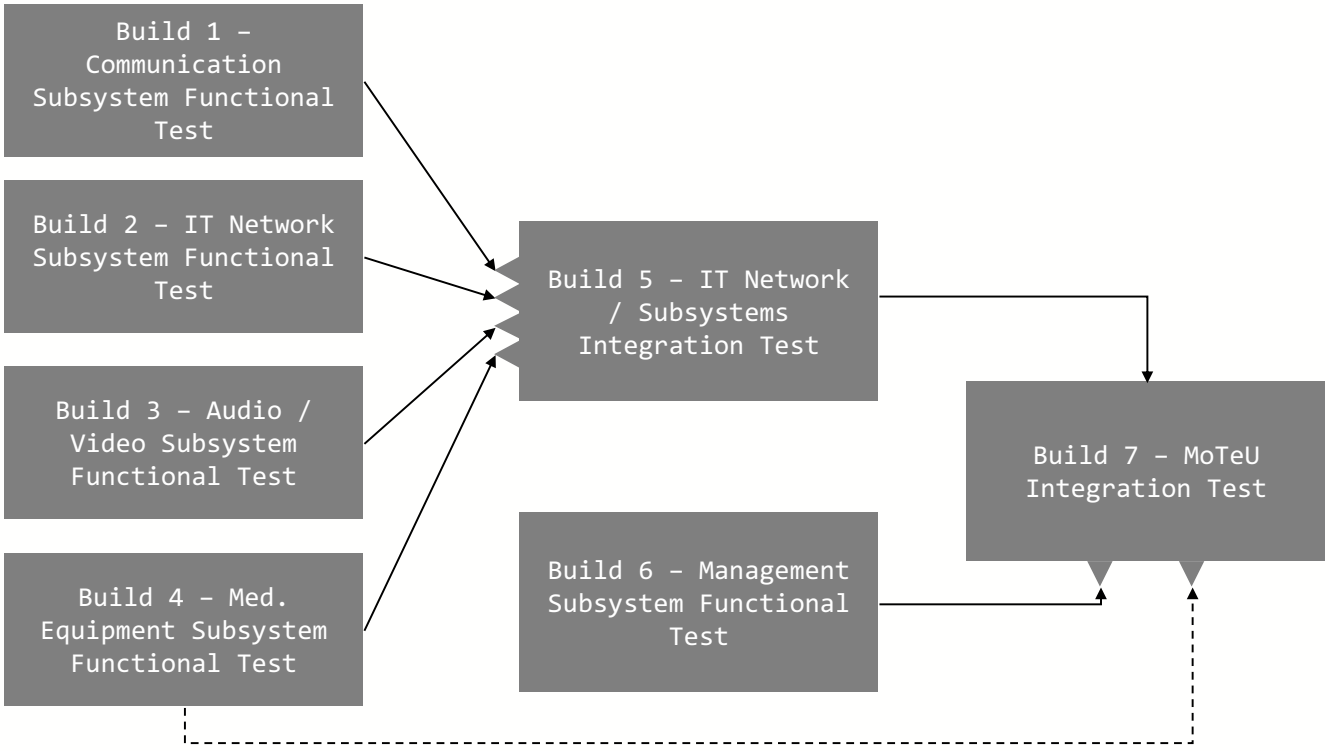
MoTeU Test Integration Test Approach

The scope of this approach will be focused on the subsystems that are related with communication, data integration, medical equipment and audio & video communications. In this process there are not processes related with the infrastructure, power and shelter

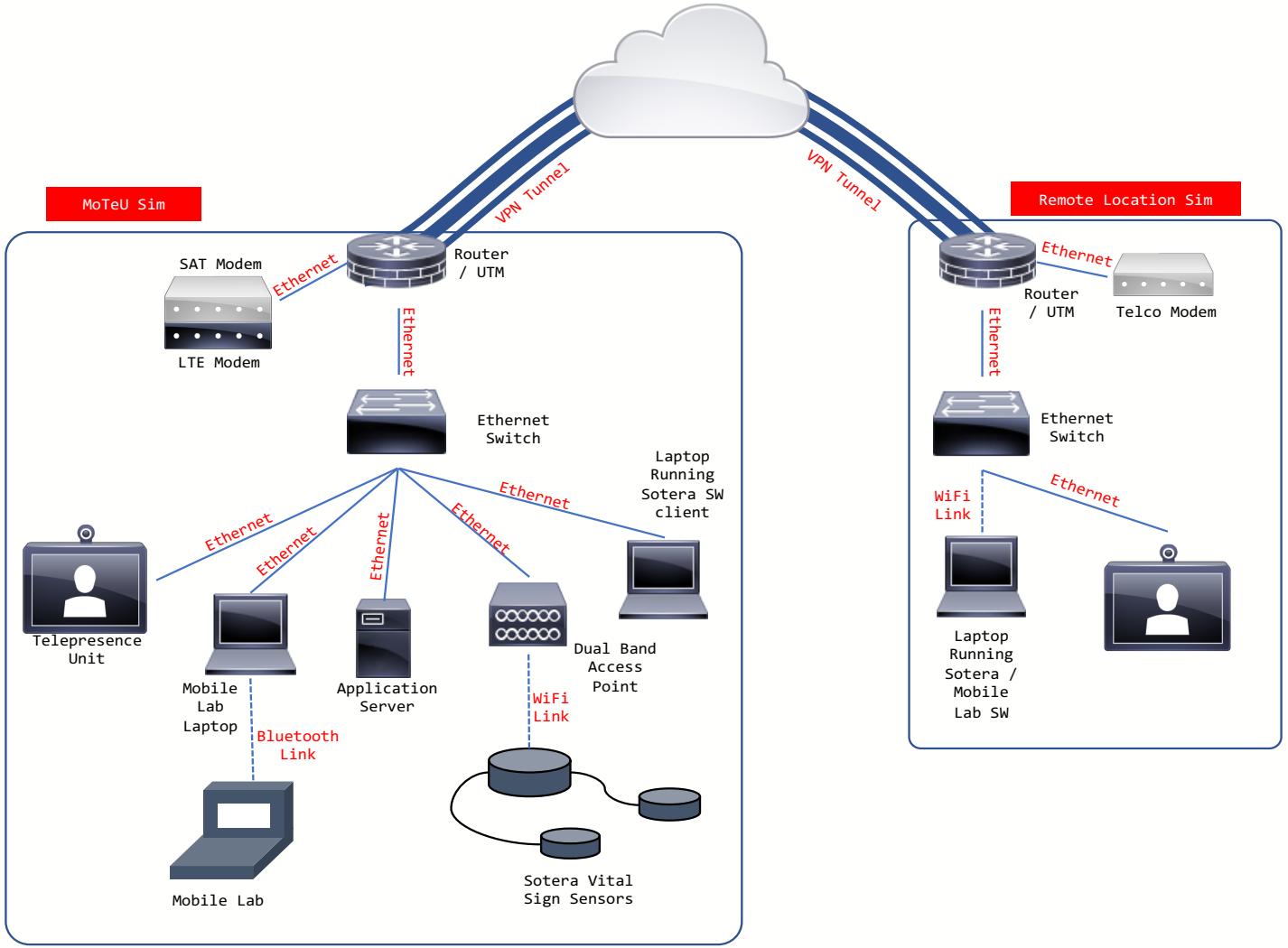


Test Plan

Functional and Integration Testing – Sequence and Description

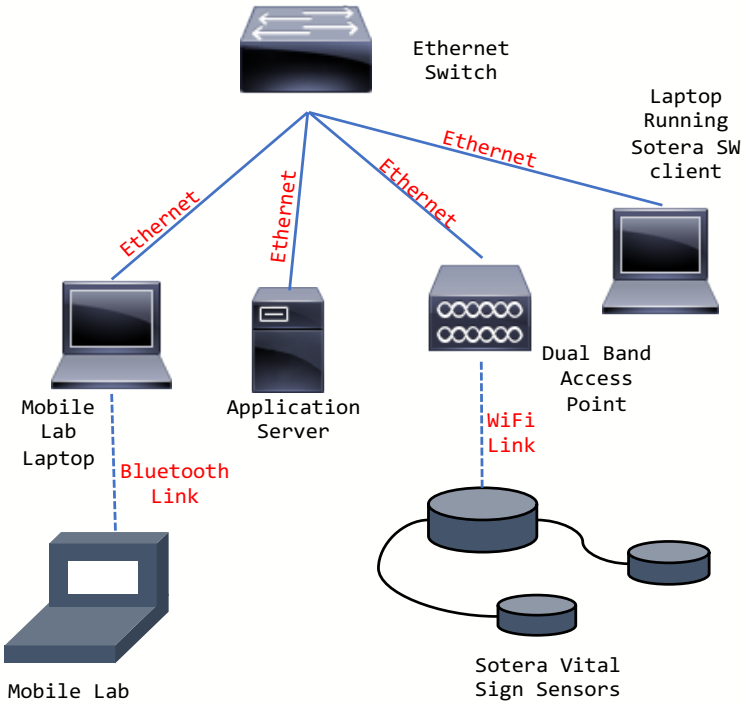


Test Plan
Build 5
IT Network / Subsystems Integration Test

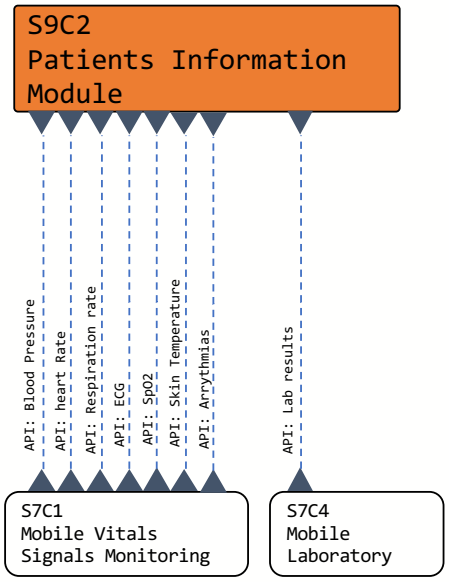


Build 6

Management Subsystem Functional Test



Test Bed Build 6 (Physical)



Test Bed Build 6 (Software)

Verification Cross Reference Matrix (VCRM)

ID	Requirement	Verification Method	Verification Description	Build
T-O-1	The MoTeU shall provide audio and video capabilities to communicate with physicians	Demonstration	Using the entire mock-up of the MoTeU, several audio and video communications will be executed between the simulated MoTeU and remote location	Build 7
T-O-3	The MoTeU shall collect and analyze biological samples (such blood or tissue) onsite	Test	Using the Medical equipment stand-alone equipment and compare it with a reference laboratory result of the same sample	Build 4
T-O-6	The MoTeU shall be cyber resilient to data exfiltration, manipulation, and pivot attacks	Demonstration	A vulnerability assessment of the system would be performed to demonstrate this capability	Build 5
T-O-7	The MoTeU shall allow operators to write and document digitally the information of the patients	Demonstration	A live demonstration of the documentation of patient's data into the GUI of the patient's information management component	Build 6
T-O-8	The MoTeU shall allow operators to access the	Demonstration	A live demonstration of a user accessing	Build 6

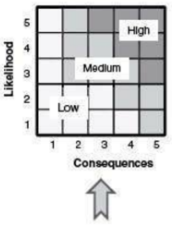
Risk Analysis

Risk Analysis
Methodology

Derived from
Risk Management—A Process Overview by Bob Skalamera

What is the likelihood the risk will happen?

Level		Your approach and processes …
1	Not likely	… Will effectively avoid or mitigate this risk based on standard practices
2	Low likelihood	… Have usually mitigated this type of risk with minimal oversight in similar cases
3	Likely	… May mitigate this risk, but work-arounds will be required
4	Highly likely	… Cannot mitigate this risk, but a different approach might
5	Near certainty	… Cannot mitigate this type of risk; no known processes or work-arounds are available



Given the risk is realized, what would be the magnitude of the impact?

Level	Technical	Schedule	Cost
1	Minimal or no impact	Minimal or no impact	Minimal or no impact
2	Minor performance shortfall, same approach retained	Additional activities required, able to meet key dates	Budget increase or unit production cost increase <1%
3	Moderate performance shortfall, but work-arounds available	Minor schedule slip, will miss needed dates	Budget increase or unit production cost increase <5%
4	Unacceptable, but work-arounds available	Project critical path affected	Budget increase or unit production cost increase <10%
5	Unacceptable; no alternatives exist	Cannot achieve key project milestones	Budget increase or unit production cost increase >10%

Consequences

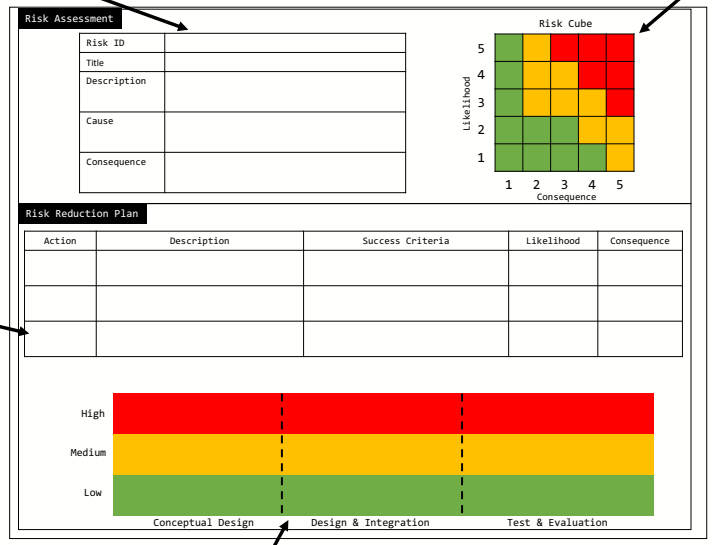
Kossiakoff, Sweet, Seymour, & Bie

Proposed Risk Analysis Worksheet

Risk Details
ID, Title, a Brief Description , cause and consequence

Risk Cube
Depicts the initial assessment and the variances in likelihood and consequence based on the risk reduction plan

List of Actions
Detailed list of actions taken to mitigate the risks described



Risk Mitigation Waterfall chart

Risk Analysis

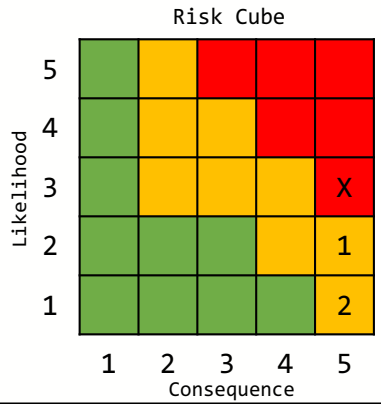
List of Risks

Risk ID	Risk	Classification
1	Inaccurate laboratory results	Development / Technical / Integration
2	Data communication interruption	Development / technical
3	Equipment damaged due to water ingress during transportation	Operational / Environmental
4	System unavailable due to management software failure	Development / technical / technology
5	System undeployable due to high cost	Programmatic / Cost
6	Regulation restrictions	Operational / Organizational
7	Patient information lost in local digital data storage	Operational / Procedural

Risk Analysis Risk 1 – Inaccurate Laboratory Results

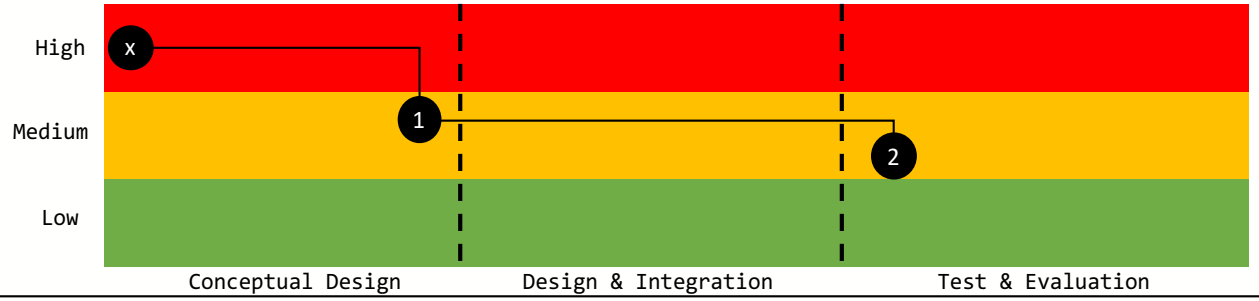
Risk Assessment

Risk ID	1
Title	Inaccurate laboratory results
Description	The laboratory results provided by the mobile laboratory component provide inaccurate data
Cause	It could be due to a misconfiguration or failure of the equipment
Consequence	Physician will receive inaccurate laboratory data result, which can lead to a bad / mistaken diagnosis



Risk Reduction Plan

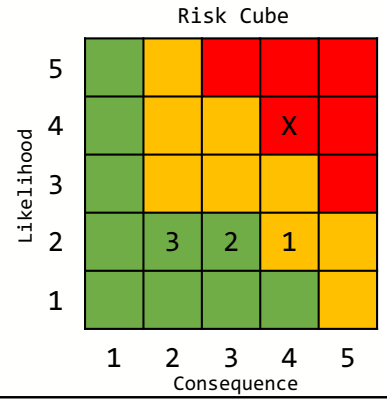
Action	Description	Success Criteria	If successful: Likelihood	If successful: Consequence
1	Evaluate COTS equipment that has been proven in other implementations	Acquire success references on which the selected COTS mobile lab has been proven	2	5
2	Perform test to the COTS lab equipment to compare its results with proven results	Data provided by the mobile lab matches the data obtained by using a known lab equipment	1	5
3				



Risk 2
Data communication Interruption

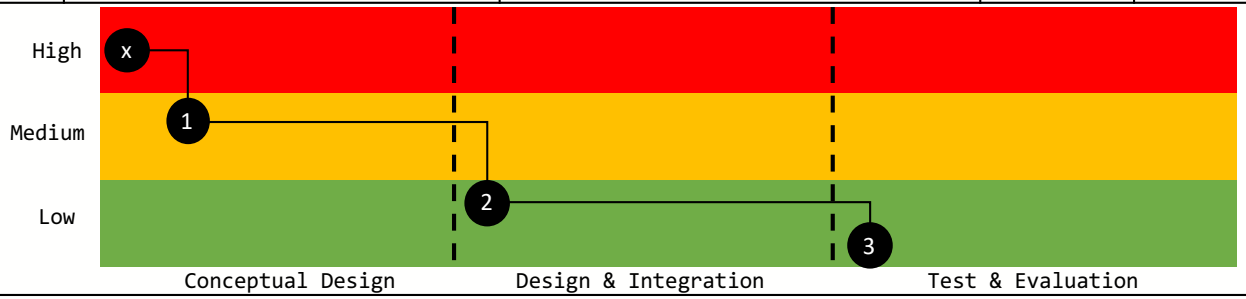
Risk Assessment

Risk ID	2
Title	Data communication interruption
Description	The data communication is interrupted leaving the MoTeU without connectivity
Cause	It could be due to a failure on the communication equipment or an interruption on the service provided
Consequence	The MoTeU won't have communication with physicians remotely



Risk Reduction Plan

Action	Description	Success Criteria	Likelihood	Consequence
1	Consider a redundancy in the data link proposed to have at least 2 communication channels	A proven design that can ensure continual communication despite the failure of one of the communication channels	2	4
2	Consider a technology that can prioritize data traffic based on its characteristics	The system being able to identify the failure on one link and optimize the data transfer over the remaining one	2	3
3	Demonstrate the capability of the system to prioritize traffic	On a real simulation of the communication subsystem, demonstrate the capability of data prioritization	2	2



Conclusion

Next Steps

- Plan to [get resources] to build a prototype of the MoTeU's main Communications and Health components
  - Review the viability with governmental and Non Profit Organizations
- Deeper participation of SMEs to refine requirements and add more capabilities
- Deeper commercial exploration to seek for COTS components that could be integrated with the MoTeU
- Refining the software components and integrate with early prototypes

Lessons Learned

- Knowledge of SE tools could be really helpful
  - Such “CORE”, it may reduce greatly the time spend in traceability and reports
  - It should be included in the program (maybe an elective?)
- Time Management
  - Not only the time invested in the project itself, but the time spend revisiting notes from courses and textbooks!
  - Difficult to manage a self paced progress while working
- SMEs support is key
- There are aspects way beyond the technical / engineering (such regulatory and legal) that may be considered if one wants to move forward
- SE Methodology can be applied to pretty much anything

SE Program Feedback

- Deep understanding of Systems Engineering Meaning, Methodology and its applications
- It provided a whole new professional perspective
  - It reminds me how much I like engineering
- Challenging!
  - Study load
  - Language barrier
  - Time management
- It used to be highly US Gov / Military focused, now it has a wider approach

JOHNS HOPKINS

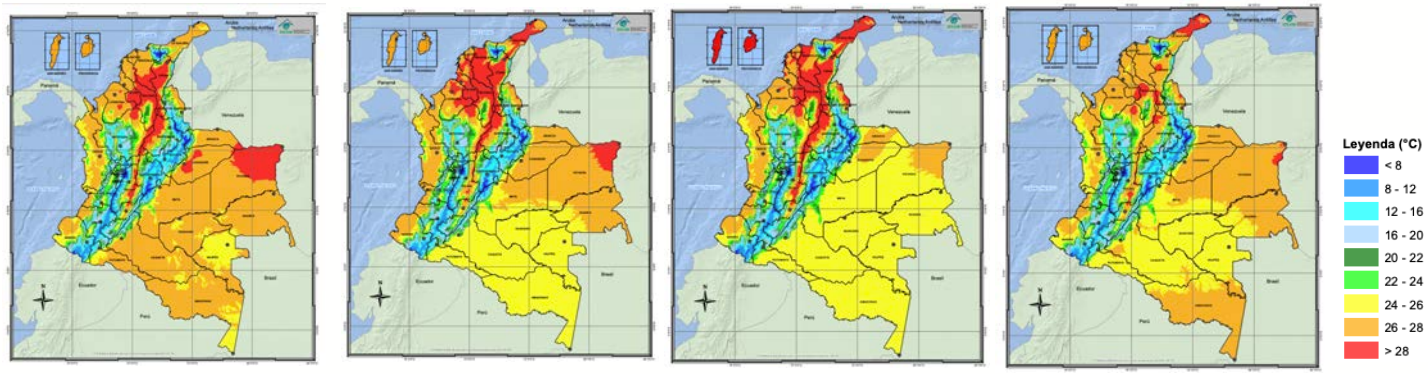
WHITING SCHOOL
of ENGINEERING

BACKUP SLIDES

Need Analysis

Information Collection – Characterization of the Environment on which MoTeU will operate (Temp)

The topography in Colombia is very diverse due to its geographical location. The country is located at the north of South America, just above the equator, meaning that the variances in weather are not determined by the northern or southern hemispheres' seasons, but on height and seasonal period (such rain or dry) of the year, that means that average temperatures in an specific region are more or less constant during the year



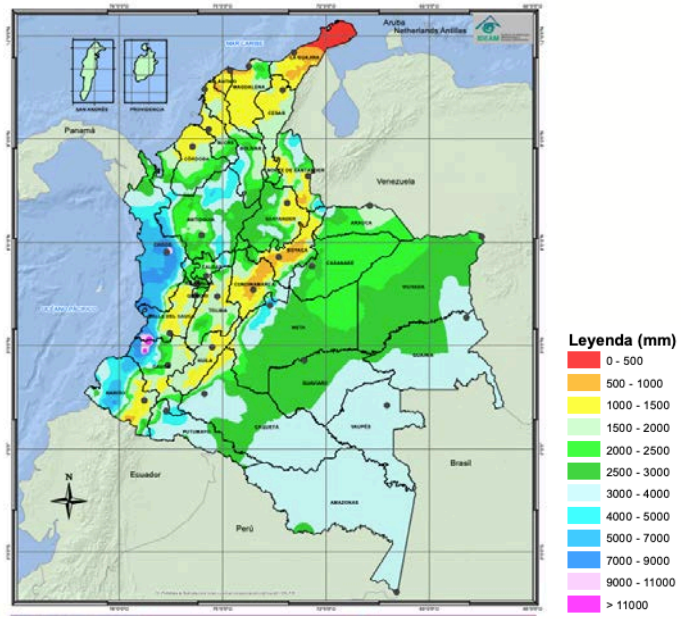
January April July October

Hence, the variances in temperature in a specific region never goes over 4 degrees Celsius, nonetheless, all year long there are temperatures ranging from subzero degrees Celsius to over 40+ degrees Celsius

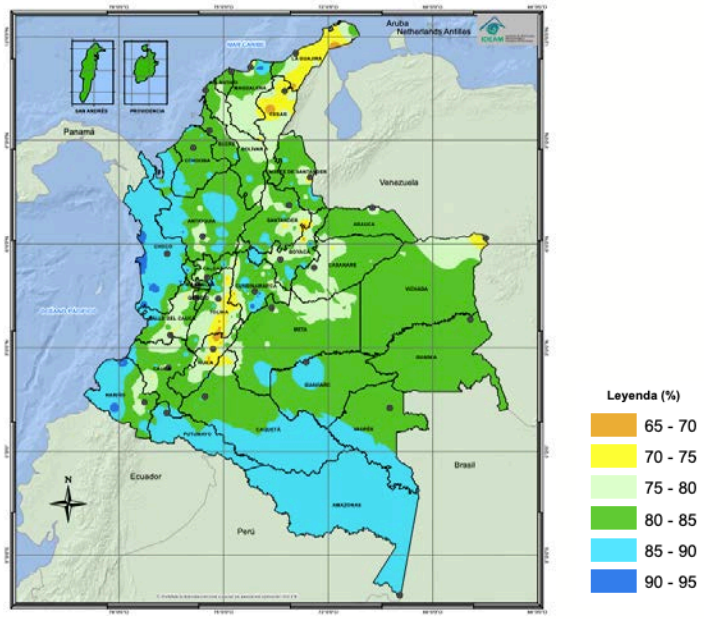
Need Analysis

Information Collection – Characterization of the Environment on which MoTeU will operate (Precipitation & Humidity)

In terms of rain, there are also a highly contrasting variances among the regions, with very dry areas such the north of the country (La Guajira) and extremely rainy regions such the west (pacific) coast. A similar situation occurs with humidity levels, however, is worth to notice that most of the country presents humidity percentages of above 80 %



Precipitation Levels per region (mm)



Humidity of the Air (%)

Need Analysis

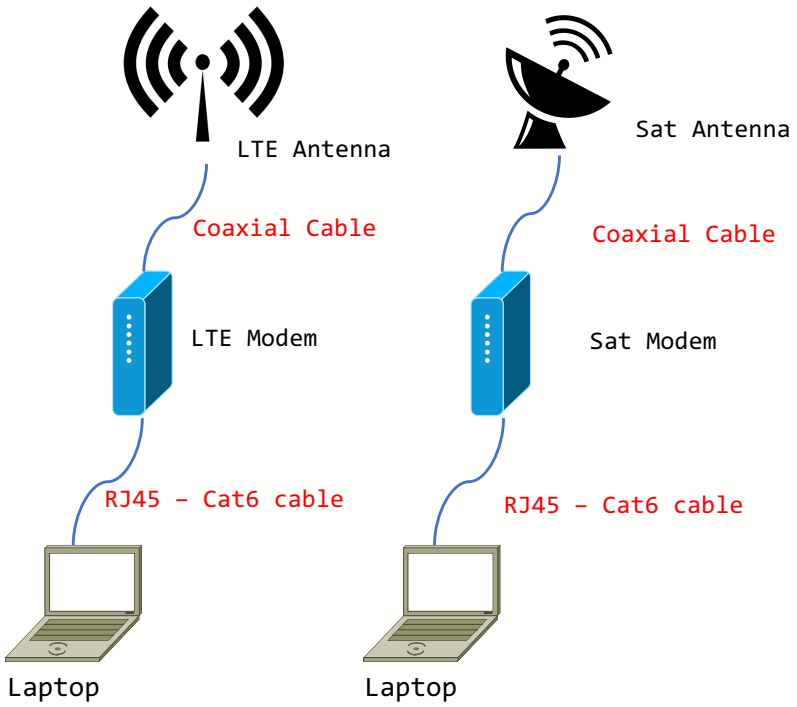
Information Collection – Characterization of the Transport Infrastructure on which MoTeU will mobilize

The transport infrastructure capability varies from region to region. Whereas in the central west and north territories is well developed and there's road access to most of the subregions, the south and east (in fact almost half of the national territory) lacks of any types of roads at all, is these regions the transportation is mainly done through rivers which cover the entire territory. The following maps depicts the road infrastructure coverage and the Colombian river basins respectively:

Colombian Main Road Infrastructure

Colombian river basins

Test Plan
Build 1 - Communication Subsystem Functional Test

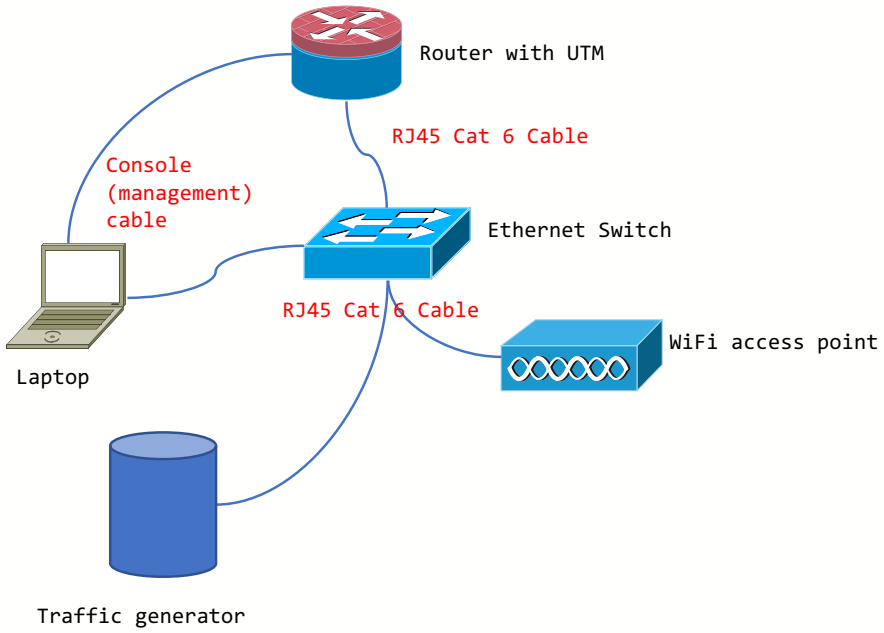


The test will require access to the communication equipment provided by the ISP, typically a modulator-demodulator (modem), an antenna for each type of service (LTE and Satellite) and the corresponding cabling (coaxial). From each one of the modems, a laptop connected through a Catt6 RJ45 cable and running any commercially available operative system such Apple's macOS, Windows or Linux will run the following tests as follows:

- Latency
- Jitter
- Packet Loss

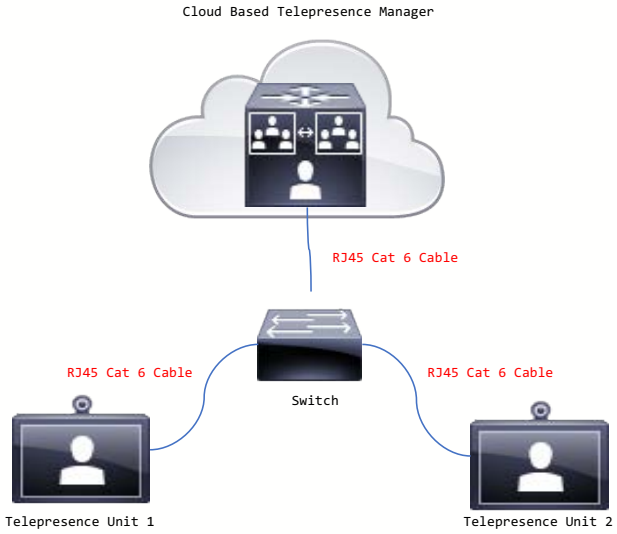
It's is expected that this test will run under a controlled laboratory environment, although it's important to ensure that the area on which it will take place has coverage from the ISP that's offering the service. Several test will be taking under the course of a determined time lapse, it is proposed one week, at different times during the day. Results will be stored and documented for further review.

Test Plan
Build 2 – It Network Subsystem Functional Test



Build 2 is focused on test the performance of the IT Network as an independent subsystem. During this test the components of the IT Network Subsystem will be assembled and proven in its optimal operational conditions based upon manufacturer recommendations. Figure 5.4 depicts the test bed for Build 2. On it, the Router with UTM (Unified Threat Manager) is connected via a RJ45 Category 6 cable to an ethernet switch. A single access point will be connected via RJ45 Category 6 to the switch as well. A computer will be connected using the management (console) to the switch and the access point.

Test Plan
Build 3 – Audio / Video Subsystem Functional Test



This build will focus on testing the components responsible for capture and reproduce audio and video for remote communication, often known as “telepresence unit”. These commercially available (COTS) units typically are assembled from the manufacturer and came as one unit with all the peripherals included. In this test, the claimed specification of the equipment with will be demonstrated by simulating a point to point connection between two telepresence endpoints.

Test Plan
Build 4 – Med. Equipment Subsystem Functional Test

The medical equipment subsystem groups all the components aimed to gather medical information from patients accessing MoTeU for diagnosis and treatment. These components are capable to register vital signals, imagery and provide laboratory analysis based on biological samples such blood or tissue. During this test, it is proposed that two COTS products will be evaluated in order to determine its performance:

Sotera Wireless: This product offers a series of sensors that can provide information regarding the vital sign of a patient, including the following:

- SpO_2 / Pulse Rate
- ECG / Heart Rate
- Respiration Rate
- Skin Temperature
- Non-invasive Blood Pressure (NIBP)
- Continuous Non-Invasive Blood Pressure (cNIBP)

Accuster – Mobile Lab: This product offers a mobile laboratory option capable to take a large range of test analysis and convert the information in digital format to be analyzed, stored and transmitted. Figure 5.5 shows a list of the available tests available by Accuster's solution