



University of Maryland
ENPM 643: Systems Engineering Design Project

Final Project
Search and Rescue System
Pilot Unit System

Submitted

By:
Anita Brown
Gregorio Vazquez

To
Dr. Mark Austin
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About the Project

The idea behind the project came from an actual Mission Need Statement (MNS) and Operational Requirements Document (ORD) that the Department of Defense published to procure a Search and Rescue Radio Unit for downed pilots.

The complete Search and Rescue (SAR) System for which these radios was being procured had other elements that needed to be developed in order to come up with a detailed and accurate model of what these radios have to do. However, given that this is a short duration project, we took the liberty of keeping the scope of the project to the Pilot Unit and model portions of the other elements as necessary, although not presented in the final report. A combination of UML and non-UML modeling methods were used for the model.

We have a Subject Matter Expert (SME) in our team, providing insights that allow coming up with a Pilot Unit model that is operationally accurate. Maj. Anita Brown, AF, is part of the team putting the project effort and we use her personal network of colleagues to validate some of our assumptions.

Our project did not lend itself to apply model validation techniques as learned in class. However, we use a non-UML set of modeling techniques to validate our model and we are assuming that a high-level of validation has been achieved against our original system. We have applied requirements and traceability techniques to our project and verification requirements have been provided. Once the modeling aspect of the project was completed, we took upon the task of trying to find actual solutions and apply the optimization techniques learned in class. In our case, we resorted to an alternative method not discussed in our lectures and included in our report.

Introduction

Need

Search and rescue operations are extremely complex and risky. Challenges include hostile territory, challenging terrain, limited supplies, short times, and possibly injuries to the downed crewman. In previous military campaigns, low crew rescue signal recognition, long location and rescue timelines, and low location accuracy combined to limit the success rate of search and rescue. Shrinking military forces constrain the resources that are available for these types of missions, making joint cooperative operations more likely necessity. What is needed is a secure, integrated, and dedicated search and rescue system that can be used jointly with other forces. It must provide reliable downed-crew identification, accurate location anywhere on the globe, and timely protected rescue.

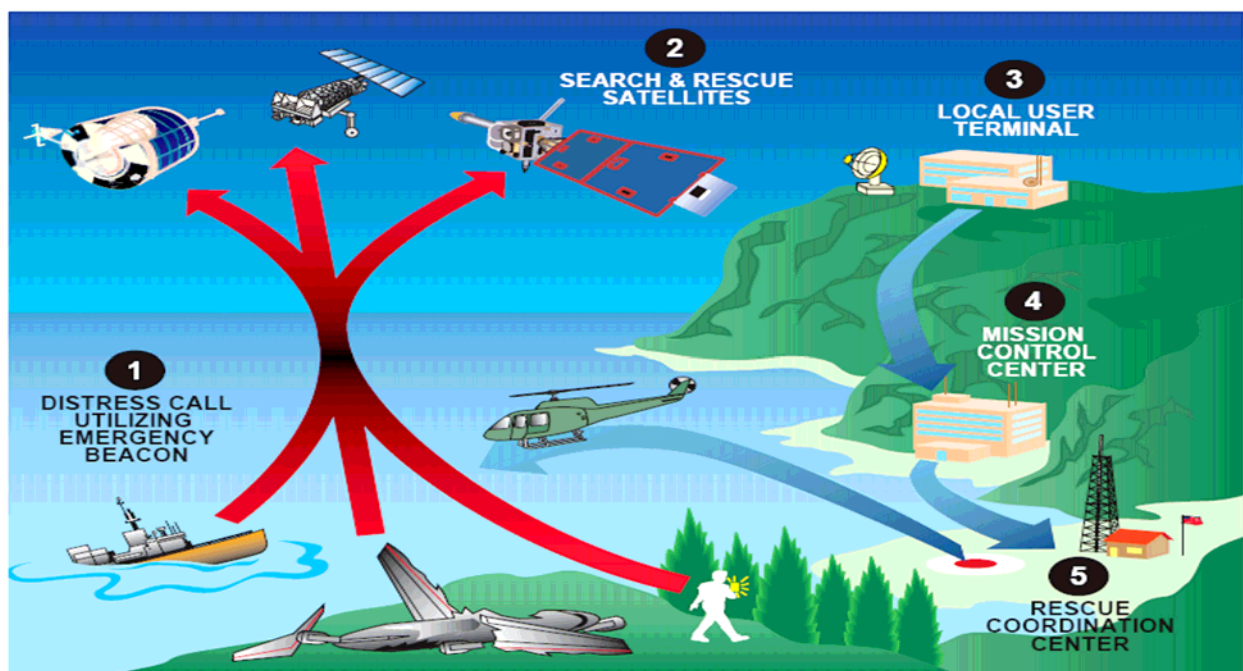
Threat

The threat to US aircraft that could force the need for rescue of downed crewmembers includes enemy fighter aircraft, surface to air missiles, and anti-air gunfire. The threat to a search and rescue system and crewmembers using the system would include enemy electronic interception and jamming of communications and locator elements. Intrusion of the SAR network could be attempted to inject false data or to decode and read messages on the system to obtain crew location for enemy capture. In addition, the enemy could detect the rescue vehicles, either by radar, or by decoding intercepted transmissions, and attack them to disrupt the operation.

System Concept

The Pilot Subsystem will provide the downed crewmembers with the capability to determine their identity and position, and transmit and receive data with the command center and rescue team in both secure and non-secure modes over satellite and Line of Sight radios.

Figure 1 "SAR System Concept"



Unified Modified Language Analysis

Use Case Diagram

Actors

- Automatic Activation Mechanism- Activates Pilot Unit automatically, assumes that Pilot might be disabled. This mechanism will be part of the Seat Ejection System.
- User- Downed crewmember requiring rescue assistance.
- SATCOM - LOS- Actor through which Command and Control Center and Search and Rescue Units perform the monitoring emergency distress calls and coordinate and conduct rescue operations. The difference will be the radio frequencies use (simplified model).

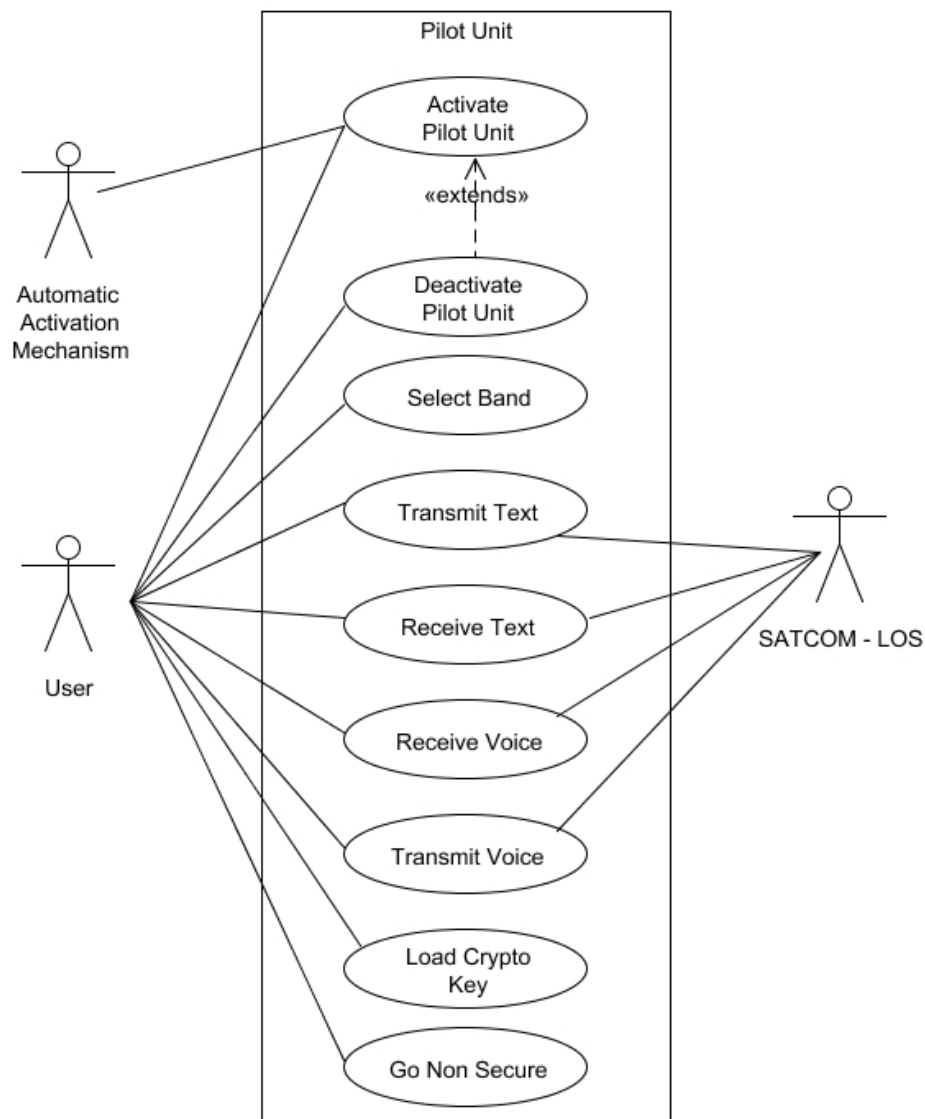


Figure 2 "Use Case Diagram"

Use Cases for Pilot Unit

Activate Pilot Unit

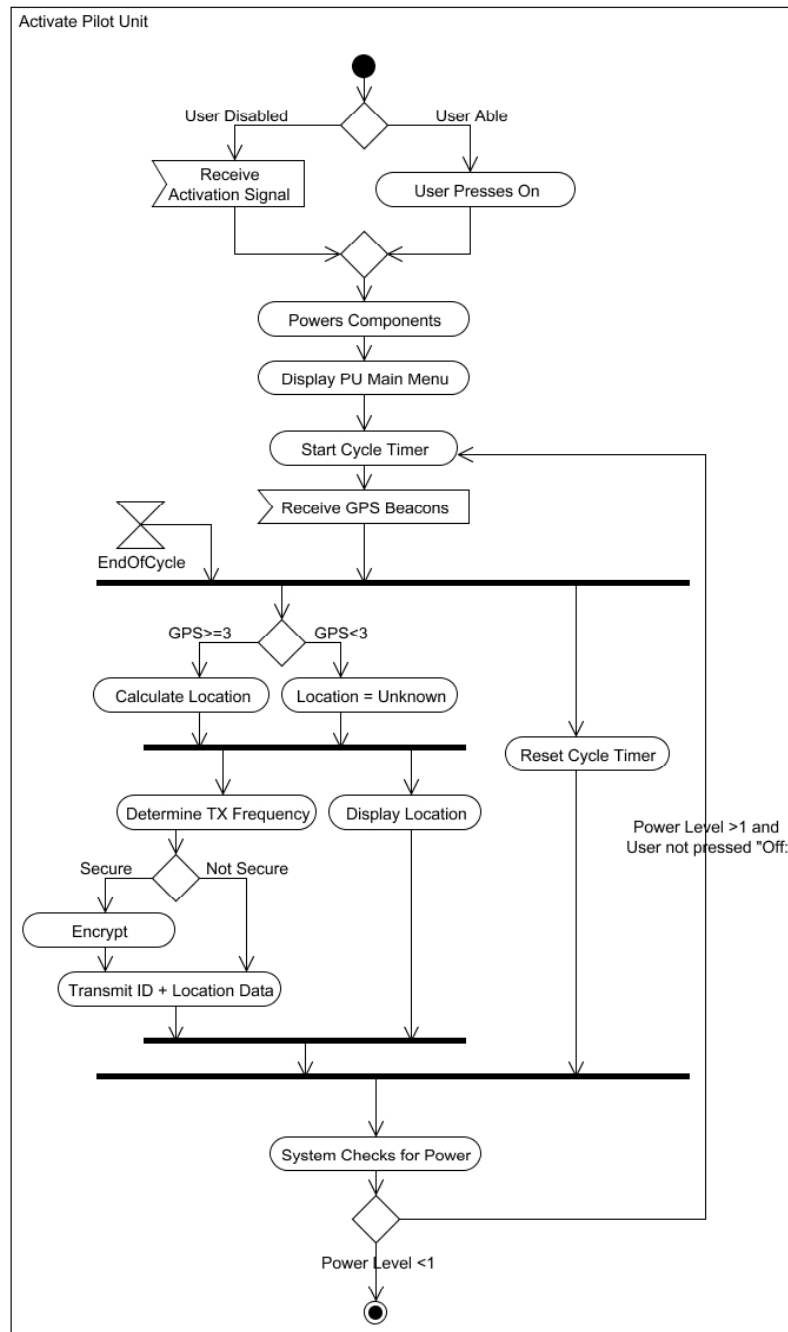


Figure 3 "Activate Pilot Unit Activity Diagram"

Description: The Pilot Unit can be activated manually or by an automatic device. Either way, the unit will power up, the GPS function s will be activated and the Calling or Text messaging functions will be enabled (ready, but waiting for additional actor interactions). We modeled the

Location algorithm as a loop. Once a cycle starts, the Unit must lock on three (3) Geo Position System Satellite Beacons in order to calculate its position. The position will then be detected and transmitted. If the position is not detected, the ID will be sent with a message indicating that the position is unknown. This cycle will be repeated automatically until the Pilot Unit is deactivated.

Send Voice

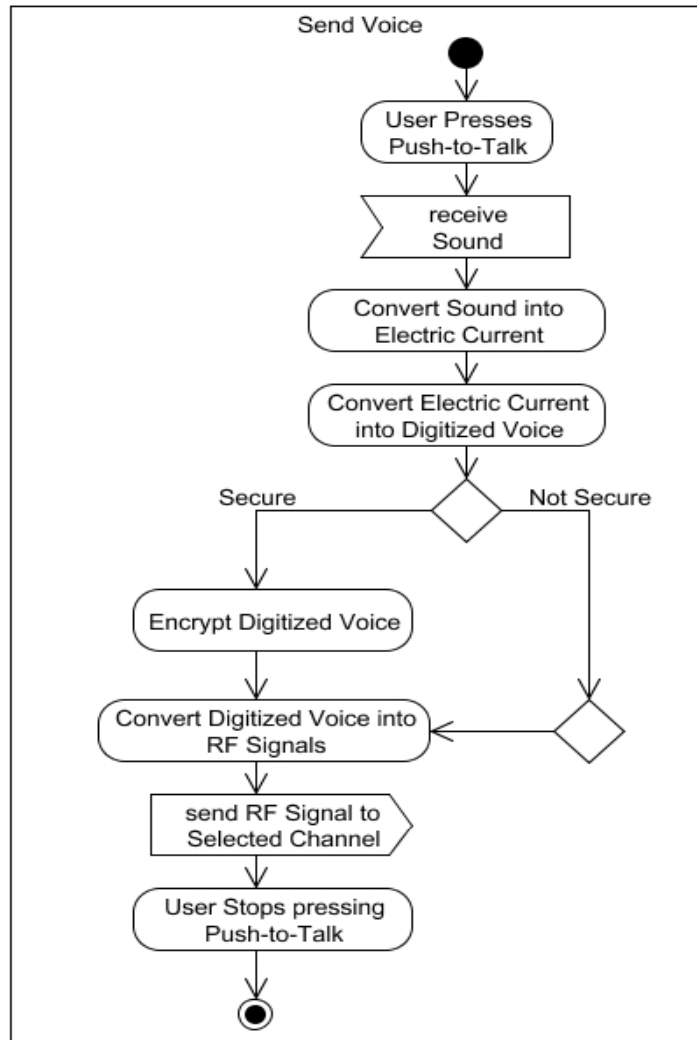


Figure 4 "Send Voice Activity Diagram"

Description: The User will be able to send voice through the Pilot Unit System. We are assuming this will be a Push-To-Talk System. The voice could be encrypted to comply with the secure transmissions requirements. An RF link will be established through a communications satellite or through a Line of Sight Radio (Joint Force Compatible). The method of transmission will depend on the frequency, which will be selected through the Select Band function.

Receive Voice

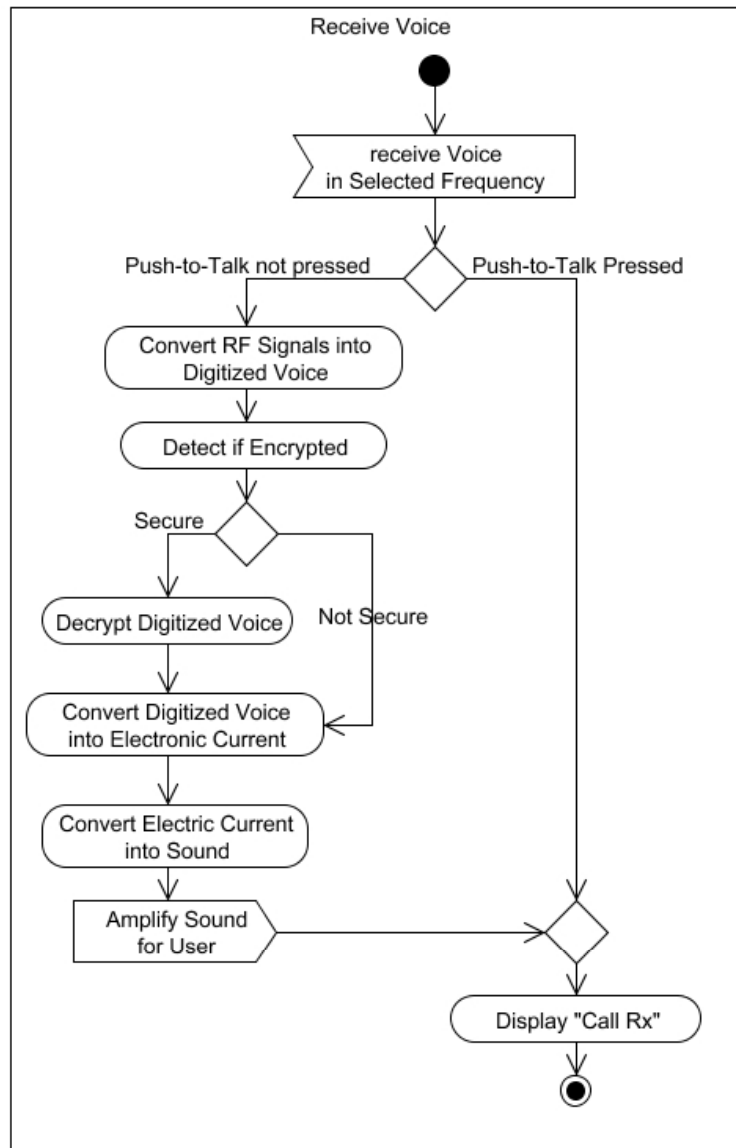


Figure 5 "Receive Voice Activity Diagram"

The Command Control Center or Rescue Unit will be able to send voice to the pilot unit using the same link (Satcom or LOS). Again, a pre-established frequency schema will have to be selected and used to be able to get the transmissions. An additional exception will be to have the Push-to-talk button pressed at the Pilot Unit, which will prevent the sound from being heard. An indication that an incoming call has reached the system has been added to mitigate for that.

Send Text

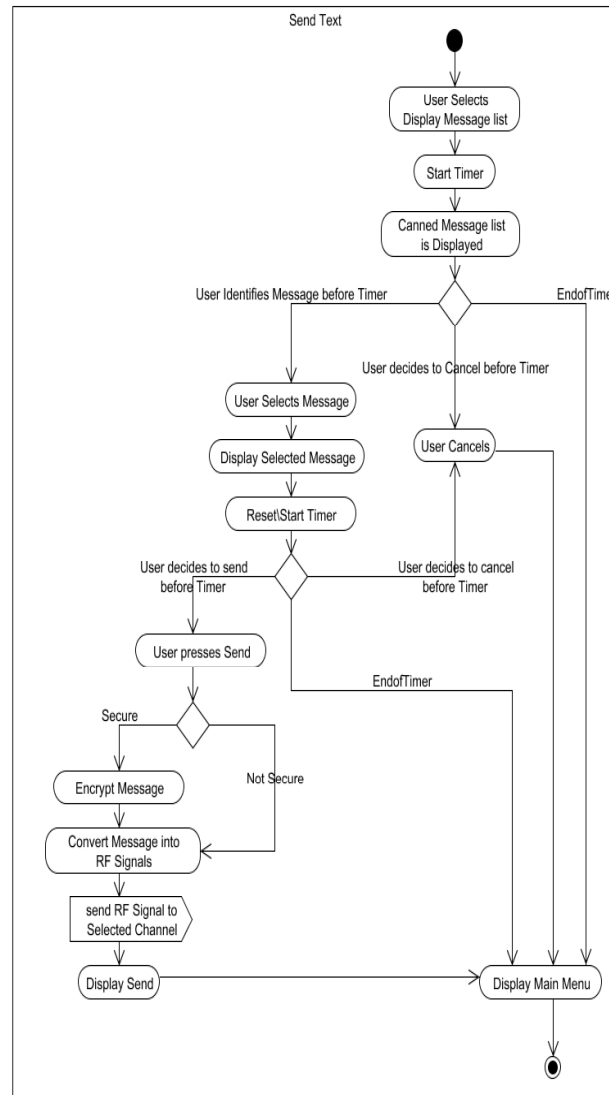


Figure 6 "Send Text Activity Diagram"

Description: The send text function will allow a user to send messages from a limited selection of canned texts previously stored in Pilot Unit. The Pilot Unit will accept the User's Input via a Keypad and send it via Satcom or LOS (using a different frequency from voice links). There will be an option to go secure (encrypted) or non-secure (not encrypted).

Receive Text

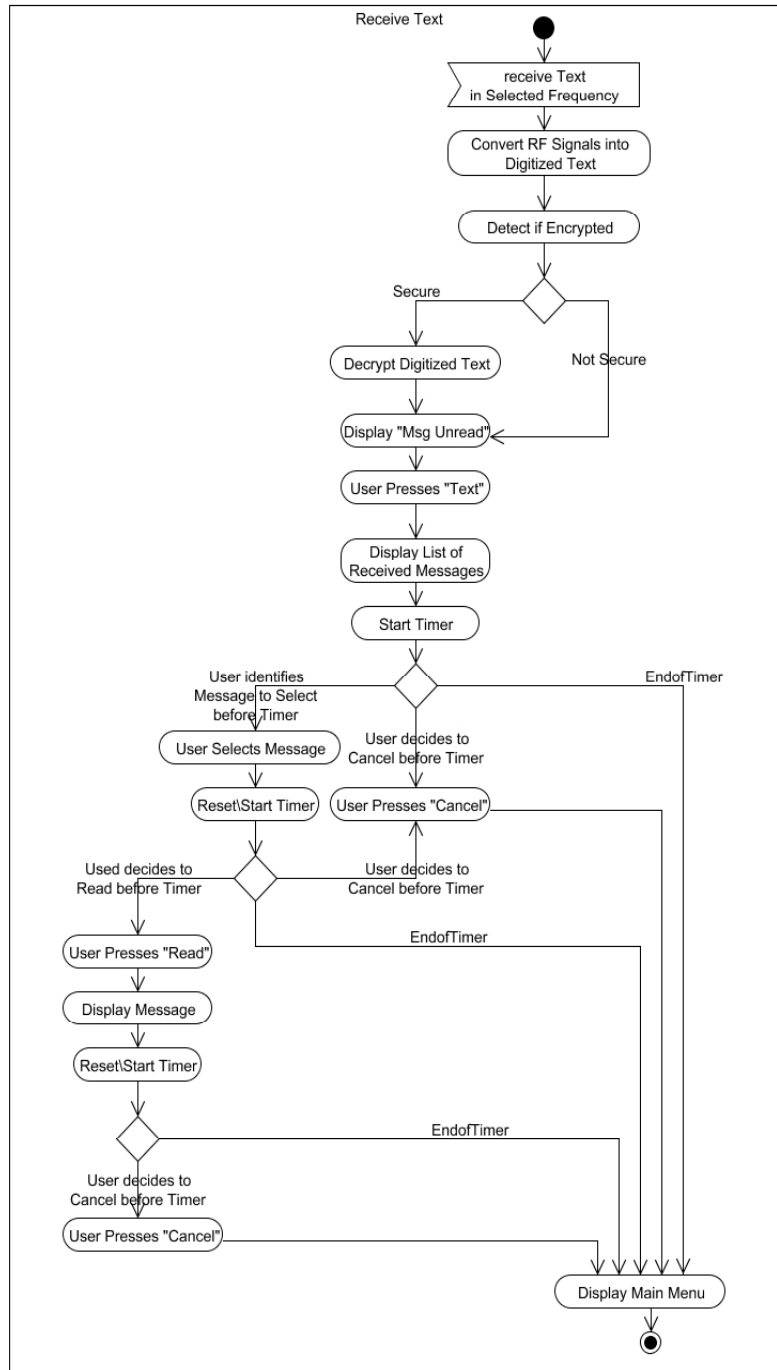


Figure 7 "Receive Text"

Description: The Receive Text function will allow a user to receive both encrypted and/or decrypted messages from Joint Forces Satcom and LOS radios. These messages will be displayed on an LCD screen on the Pilot Unit. Messages that cannot be decoded or decrypted will still be displayed but as errors. Text and Voice functionalities will require different frequencies of operations.

Select Band

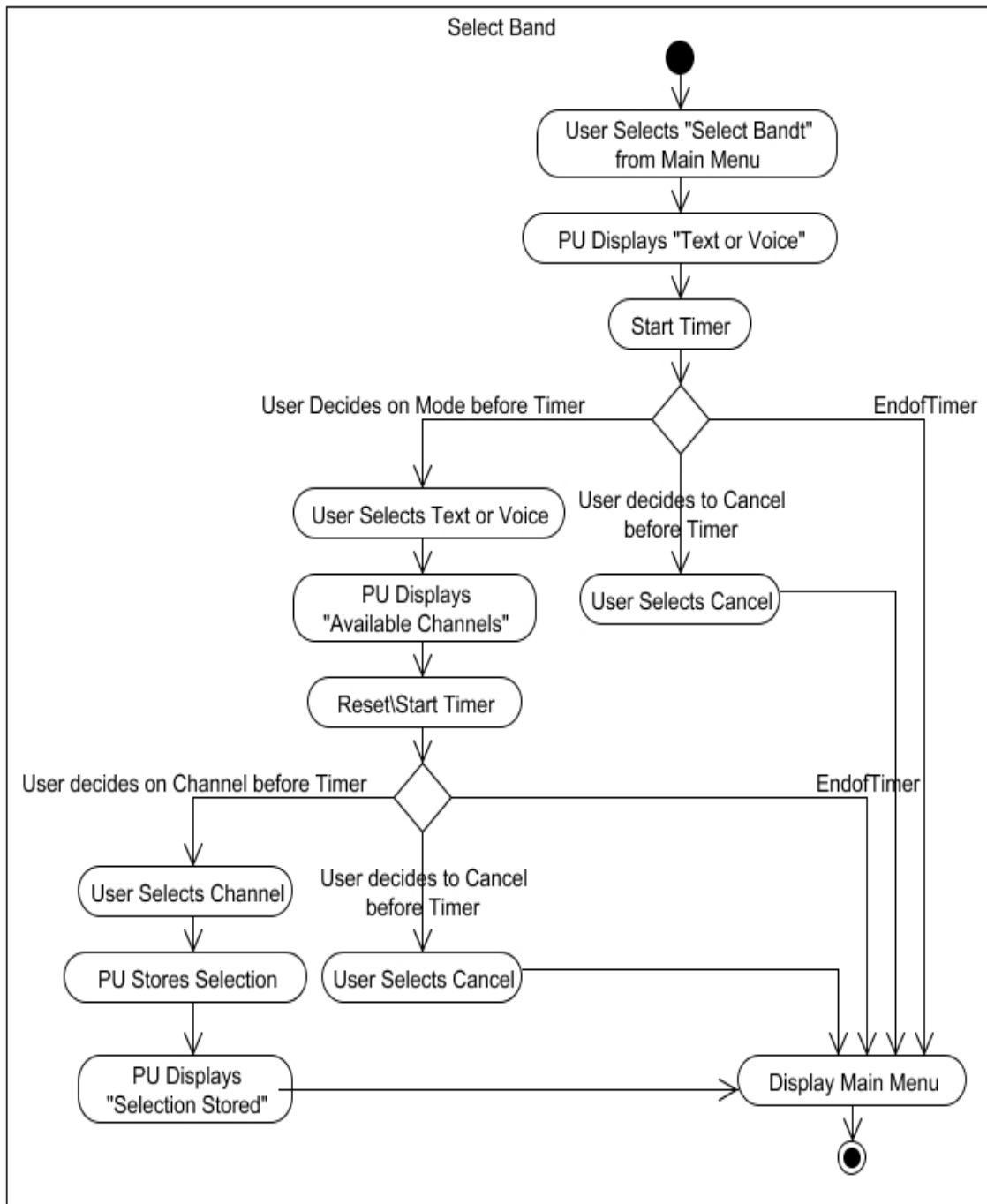
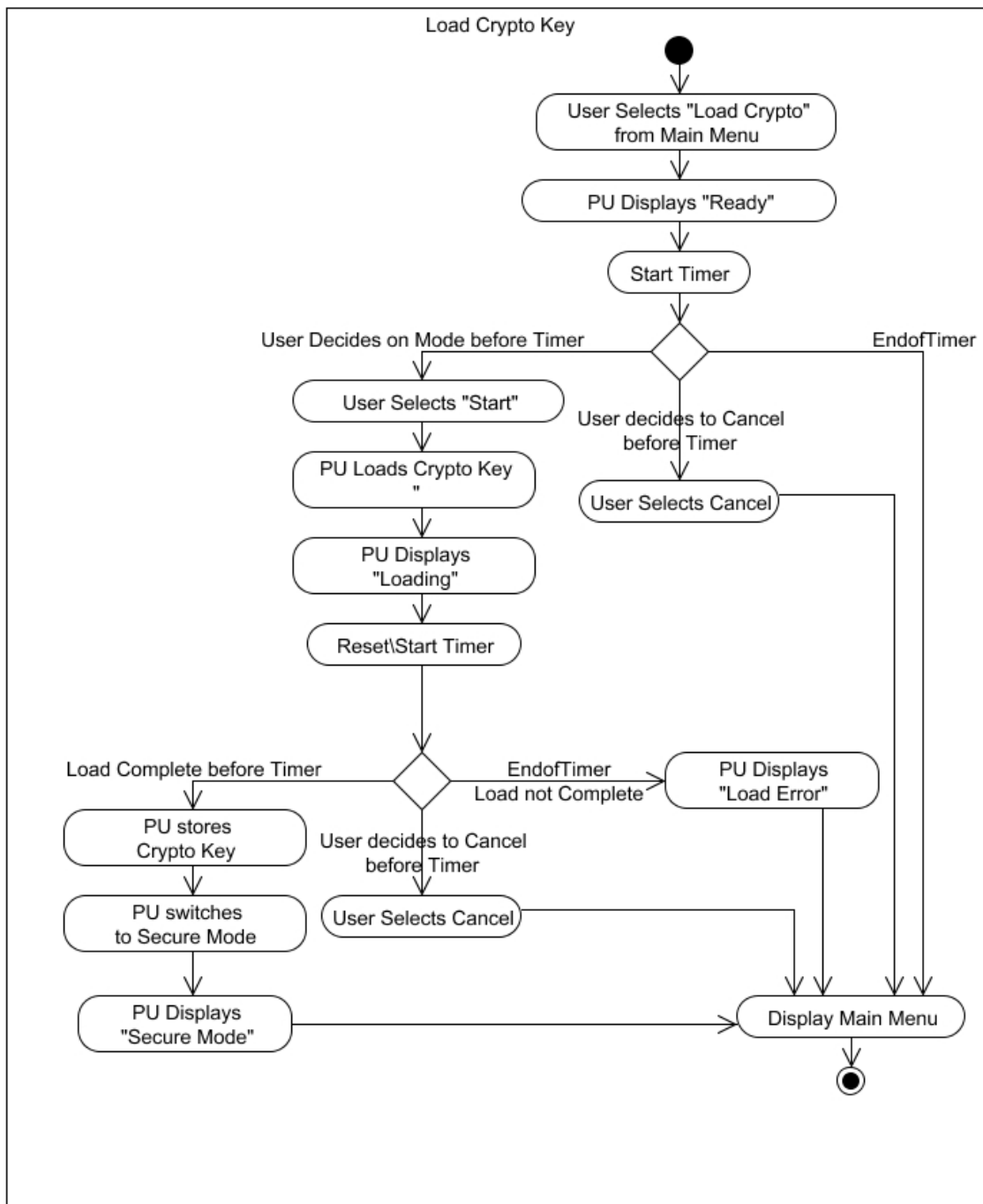


Figure 8 "Select Band Activity Diagram"

Description (figure 8): The Select Band feature will allow a user to pick which frequency to operate for voice and text messages. The selection will be done by type of function and it will be stored when the unit is powered down. We envisioned that before any pilot goes flying a mission, these frequencies would be assigned and loaded into the SAR PU.

Load Crypto Key



Description: The Pilot Unit can only be turned into secure mode by loading a crypto key into the system. The activity diagram depicts a fully successful activity. In the event that the load key function is selected but the key is absent or a faulty connection is present, a load error will have to be displayed. We also time out this operation if idle for a period of time.

Go Non Secure and Deactivate Pilot Unit

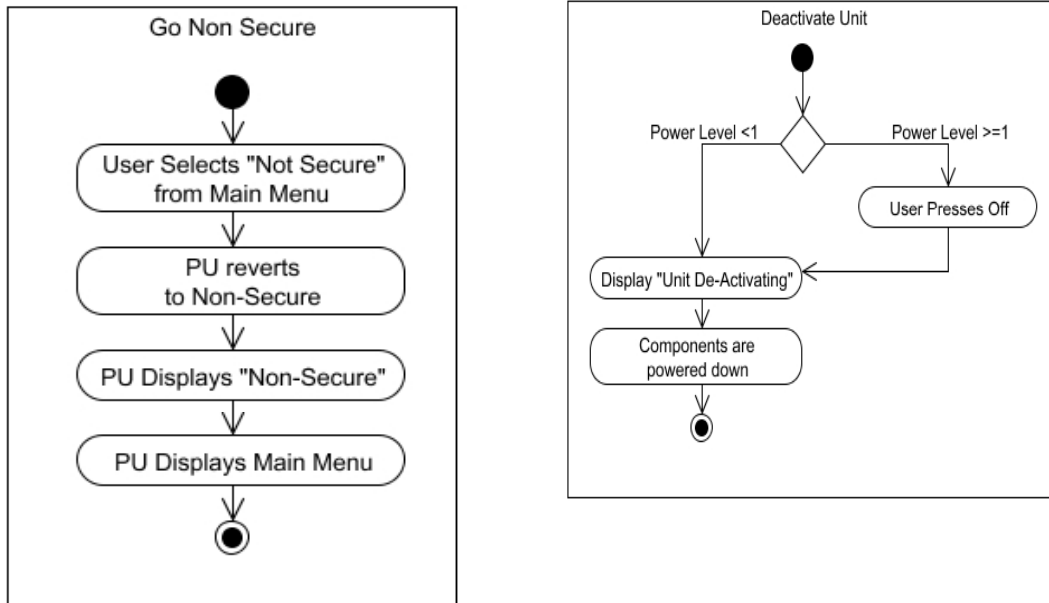


Figure 9 "Go Non Secure and Deactivate Pilot Unit Activity Diagrams"

Description: The Pilot Unit will go on non-secure mode of operations by selecting a menu option to that effect. Once it goes non secure, a crypto key will have to be uploaded again to go on secure mode.

The Pilot Unit will be activated manually or if power runs out. Once deactivated, all functions will be deactivated and/or disabled as well. The user will receive an indication that the system has been deactivated

Non-UML Analysis

Interface Modeling

Description: A context and N² diagrams were developed to discover and validate additional requirements about the Pilot Unit Interfaces. The N² diagram explores the relations between different system elements, and helps discovering and/or validating features (both active and passive) related to the interactions. A Context Diagram helps with the enumeration and clarification of active interactions, helping in the discovery and/or validation of the interfaces (inputs, outputs, cause and effect). Requirements related to "ruggedization" of the unit and power were discovered and/or detailed using these tools.

Figure 10 "Pilot Unit N² Diagram"

Command Center								LEO Sat Com Link Encrypted Voice
	Rescue Unit							LEO Sat Com Link Encrypted Voice
		GPS System						3 GPS Signals
			User (Pilot)					Voice through Microphone Key Pad
				Activation				Activation Button for Pilot Mechanism to Auto activate upon event detection
					Power			DC Electrical Power at TBD Volts.
						Environment		Ruggedized Casing impervious to weather Human/Form Factor considerations for usability
							Encryption	Crypto Key port
LEO Sat Com Link Encrypted Voice Encrypted Data	LEO Sat Com Link Encrypted Voice Encrypted Data		Voice through Speaker Display			Heat RF Emissions		Pilot Subsystem

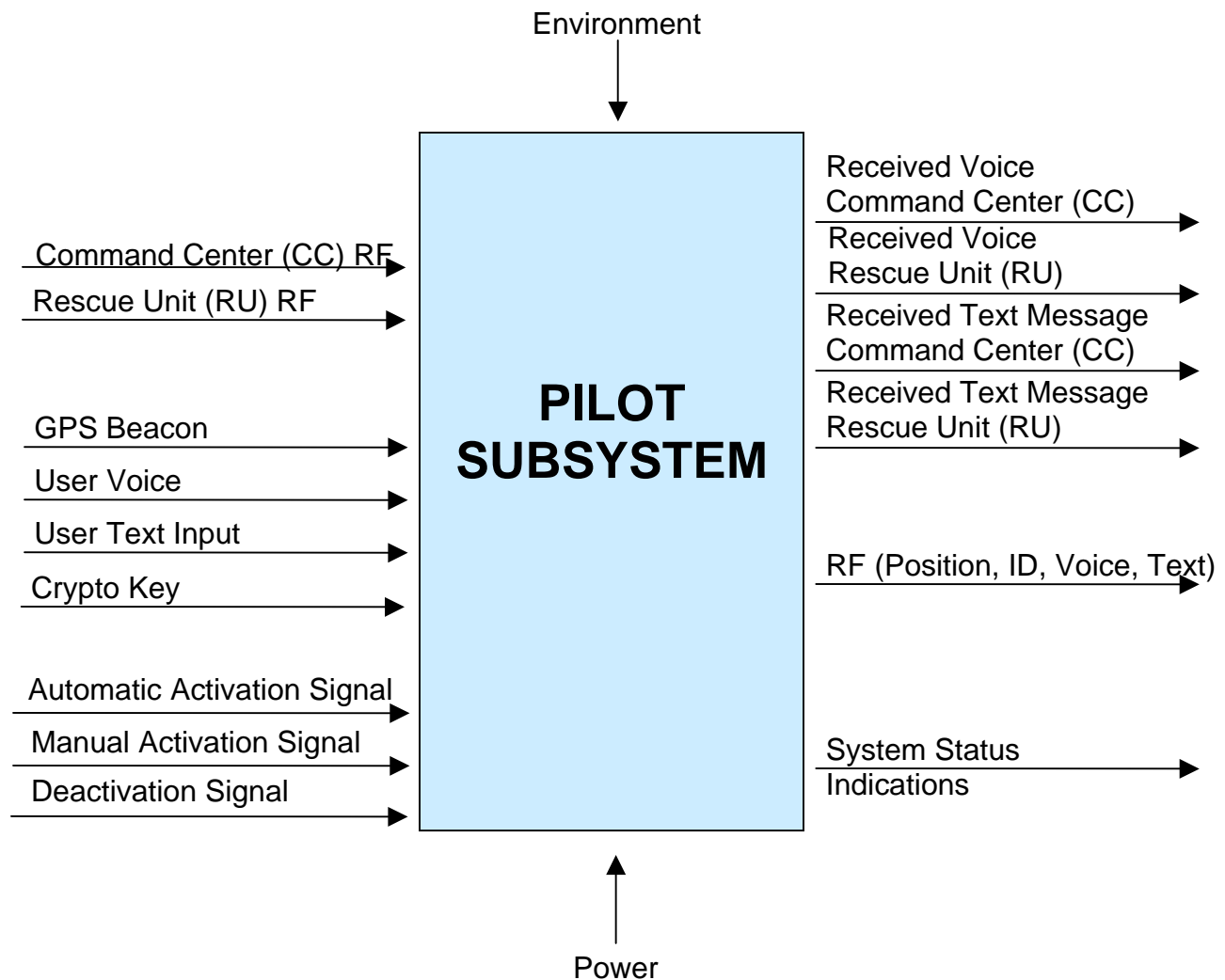


Figure 11 "Pilot Unit Subsystem Context Diagram"

Once the Context Diagram was completed, 3 additional analyses were completed. In the first one, the Functional analysis (using a Functional Diagram, figure 17), the previously functions identified in the use cases were mapped to the inputs and outputs of the Pilot Subsystem. In second analysis, the physical analysis (using a Physical Diagram, figure 18), potential components for the system were identified, mapping also the connections amongst them. A third and last analysis, the Allocation analysis (using an Allocated Diagram, figure 19) we mapped the functions identified in the Functional Analysis and assign them to the components in the Physical Analysis.

Functional, Physical and Allocation Analysis for Modeling

Figure 12 "SAR Pilot Unit Functional Diagram"

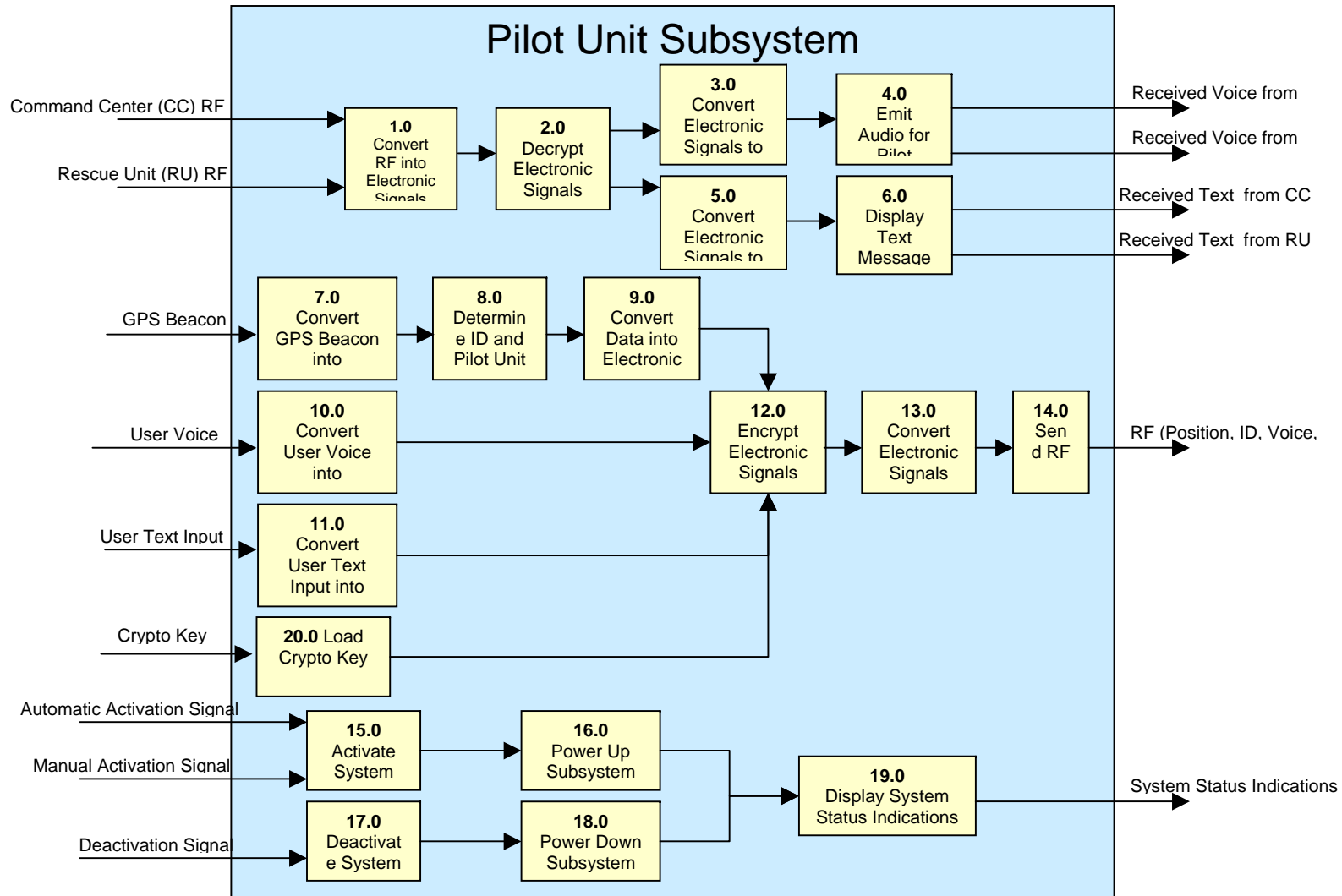


Figure 13 "Pilot Unit Physical Diagram"

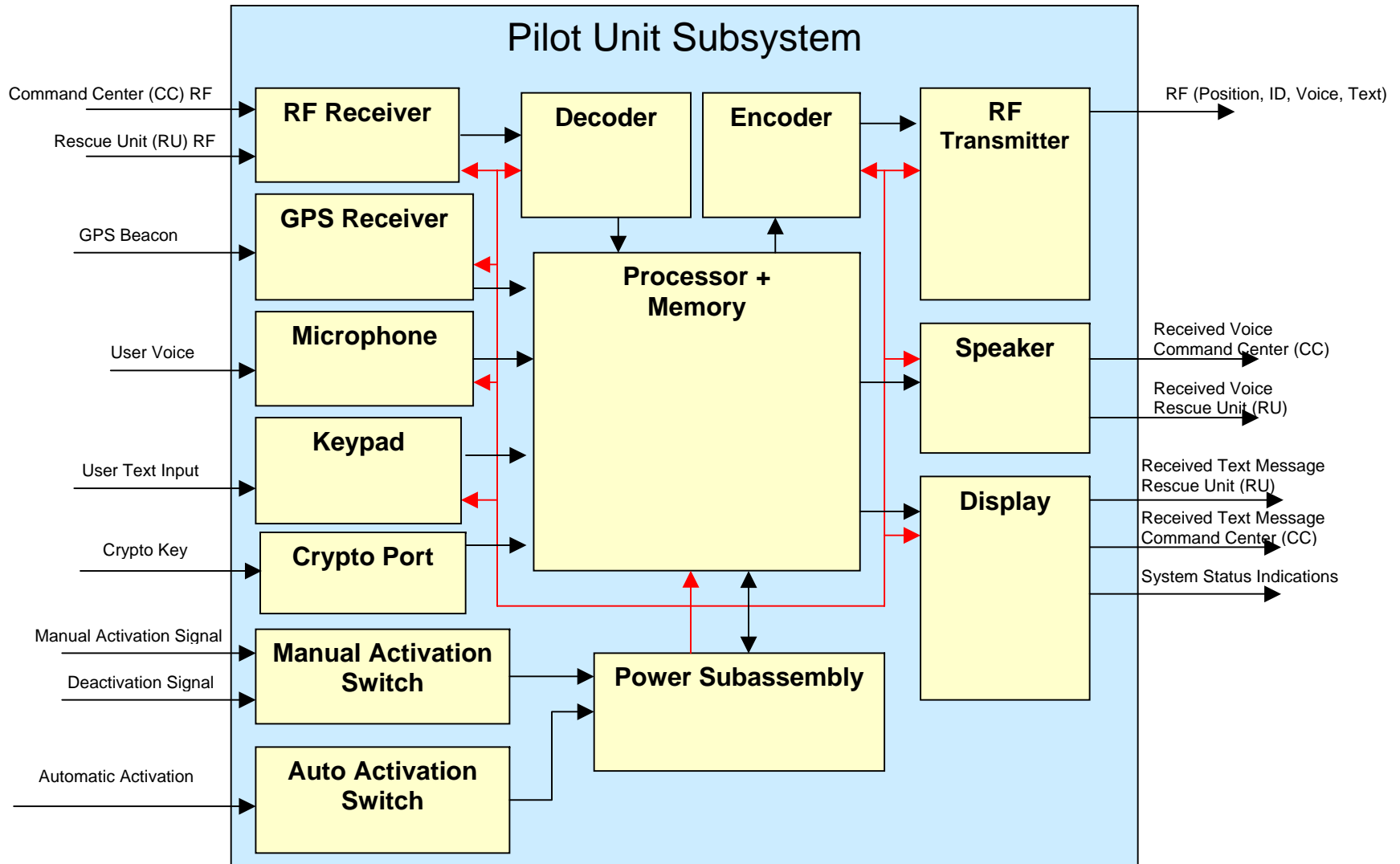
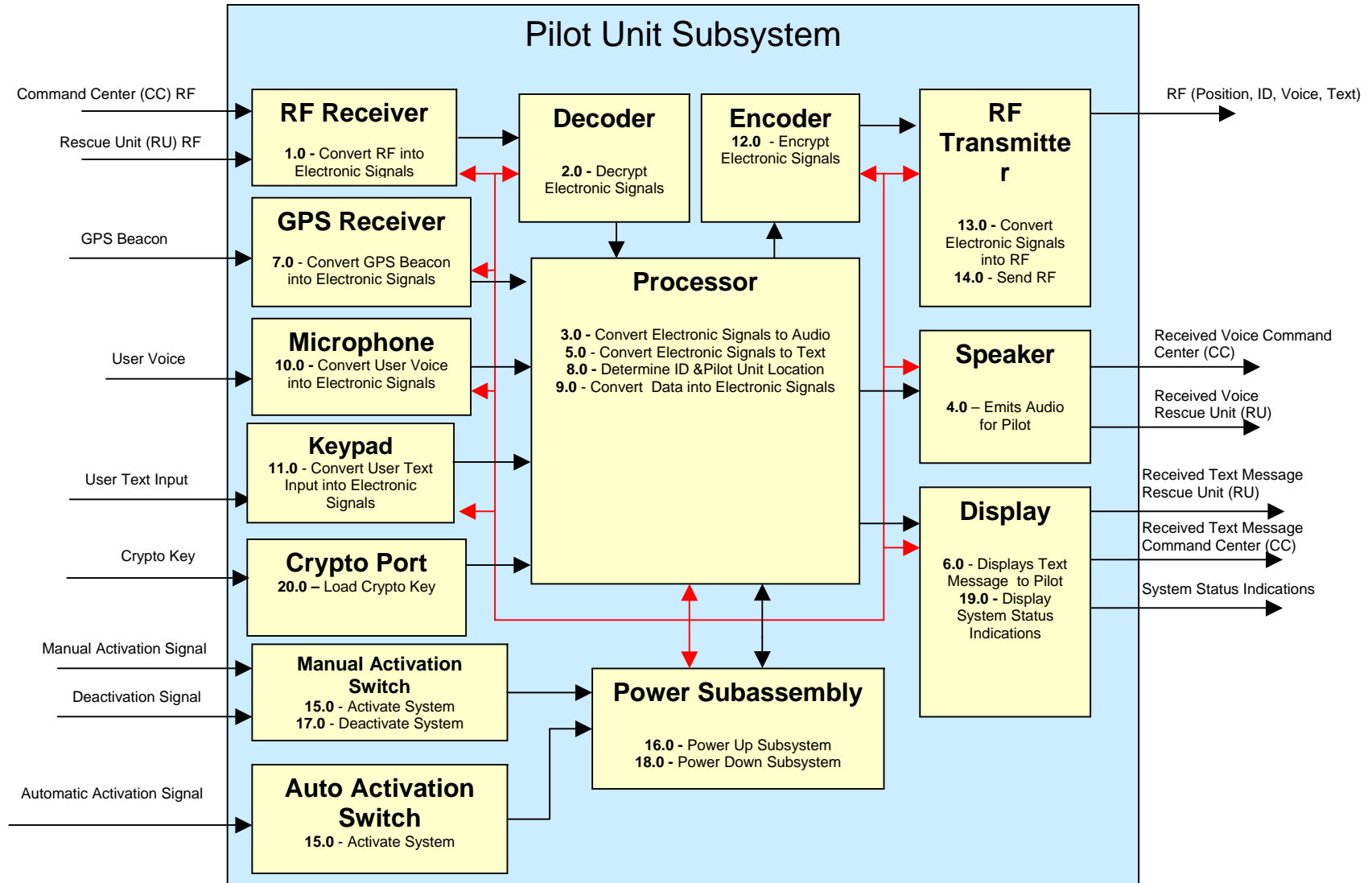


Figure 14 "Pilot Unit Allocated Diagram"



Performance Requirements

Performance Requirement	SAR ORD Traceability	Comments
Transmission Power should not exceed X (TBD) watts	•Covert range for enemy to achieve location fix < 5 Nautical Miles	Determination has been made that this requirement has to be addressed by limiting the transmission power. Additional calculations will have to be performed to determine actual value.
Transmission Window should not exceed 5 minutes	•Covert range for enemy to achieve location fix < 5 Nautical Miles	Determination has been made that this requirement has to be addressed by limiting the transmission power. Additional calculations will have to be performed to determine actual value.
Transmission Power should not be less than Y (TBD) watts	•Anti-jam (communications and position) 5W @ 100 Nautical Miles	Proposing a systems level SAR ORD Requirement: Anti-Jam 5W @100 NM. Requirement as stated is conflicting (not clear which one is more restrictive, the threshold or the objective values). Additional calculations will have to be performed to determine actual value.
Estimate Pilot Position Location in less than 5 minutes after CC ID acknowledgement.	•Timed to downed crew member recognition < 10 minutes	
Send Pilot Estimated Location 5 minutes after CC ID acknowledgement.	•Timed to downed crew member recognition < 10 minutes	

Performance Requirement	SAR ORD Traceability	Comments
Power available for 3 weeks	•Operational for three weeks	Battery life – 3 weeks – operational addressable
Mean Time Between Failures: 1000 hours	•Operational for three weeks	Operationally speaking we only need 504 Hours. To meet assigned Availability number we are using 1000 hours.
Mean Time Between Repairs: 1000 Hours	•Operational for three weeks without refurbishing	Operationally speaking we only need 504 Hours. To meet assigned Availability number we are using 1000 hours
Send Pilot ID within 10 seconds of subsystem activation	<ul style="list-style-type: none"> •Timed to downed crew member recognition < 10 minutes •Probability of Identification of downed crewmember 99% objective and 95% threshold 	To recognize Pilot ID we will need to send ID and CC or RU will have to investigate and confirm. Assigned performance supports System Performance Requirement
Resend Pilot ID every 10 seconds	<ul style="list-style-type: none"> •Timed to downed crew member recognition < 10 minutes •Probability of Identification of downed crewmember 99% objective and 95% threshold 	To recognize Pilot ID we will need to send ID and CC or RU will have to investigate and confirm. Assigned performance supports System Performance Requirement

Performance Requirement	SAR ORD Traceability	Comments
Operational Availability – 99.58 %	•Operational Availability (System) - 95%”	System Requirement on SAR MNS Integration team derived requirements and floated them down to the Subsystems.
Mean Time Between Failures - 1000 hours	•Operational Availability (System) - 95%”	System Requirement on SAR MNS Integration team derived requirements and floated them down to the Subsystems.
Mean Time to Repair – 3 hours	•Operational Availability (System) - 95%”	System Requirement on SAR MNS Integration team derived requirements and floated them down to the Subsystems. We do not see how this contributes to the mission, but we accepted the requirement.
No performance required allocated.	•Total Time from crewmember down to rescue from downing 200 NM behind enemy lines: 2-hour objective/4 hour threshold.	Requirement is unfeasible since mission safety might be jeopardized if we restrict it to 4 hours.
Capable of One hand operation	•Operable with crewmember incapacitated.	
Dimensions: <20 linear inches	•Crew member Unit must be contained within crew’s ejections package	

Performance Requirement	SAR ORD Traceability	Comments
Waterproof	All Weather, Day/Night operation	
Operational within 0 degrees Celsius and 40 degrees Celsius	All Weather, Day/Night operation	
Withstand relative humidity up to 95 percent non-condensing	All Weather, Day/Night operation	
Operational under in dark environments	All Weather, Day/Night operation	
RF Emission should not exceed XX level		Human Factors- Safety: XX levels to be later calculated and proposed
Heat Dissipated should not exceed YY level		Human Factors- Safety: YY levels to be later calculated and proposed

System Functional Requirements

Activate Pilot Unit

- 1.1. The PU shall be able to automatically power on when the pilot is ejected from the aircraft.
- 1.2. The PU shall allow the user to power on the unit.
- 1.3. The PU shall display battery life indication to the user.

Deactivate Pilot Unit

- 2.1. The PU shall allow the user to power off the unit.
- 2.2. The PU shall display to the user that the unit is powering off.

Detect and Communicate Position

- 3.1. The PU shall be capable of determining its own PU location
- 3.2. The PU shall display when location has not been determined.
- 3.2. The PU shall be capable of transmitting PU ID and location without user intervention.
- 3.4. The PU shall format its own location terms of latitude, longitude, and altitude above sea level.
- 3.5. The PU shall display its location to the user.

Transmit Voice

- 4.1. The PU shall be able to transmit voice communications to external joint forces with the same class of radios.
- 4.2. The PU shall be able to transmit voice communications to the CSAR Command Center.
- 4.3. The PU shall be able to transmit voice communications to the CSAR Pilot Rescue Unit.

Receive Voice

- 5.1. The PU shall be able to receive voice communications from external joint forces with the same class of radios.
- 5.2. The PU shall be able to receive voice communications from the CSAR Command Center.
- 5.3. The PU shall be able to receive voice communications from the CSAR Pilot Rescue Unit.

Transmit Text

- 6.1. The PU shall be able to transmit Variable Message Format (VMF) messages to external joint forces with the same class of radios.
- 6.2. The PU shall allow the user to transmit VMF messages to the CSAR Command Center.
- 6.3. The PU shall allow the user to transmit VMF messages to the CSAR Pilot Rescue Unit.
- 6.4. The PU shall allow the user to enter User Identification data.
- 6.5. The PU shall allow the user to transmit User Identification data.
- 6.6. The PU shall allow the user to transmit rescue plan acceptance indications.
- 6.7. The PU shall allow the user to transmit rescue plan rejection indications.
- 6.8. The PU shall allow the user to transmit rescue plan abort indications.

Receive Text

- 7.1. The PU shall be able to receive VMF messages from external joint forces with the same class of radios.
- 7.2. The PU shall be able to receive VMF messages from the CSAR Command Center.
- 7.3. The PU shall be able to receive VMF messages from the CSAR Pilot Rescue Unit.
- 7.4. The PU shall display rescue plan details to the user.

Switch Secure Mode

- 8.1. The PU shall allow the user to switch from non-secure to secure mode.
- 8.2. The PU shall be able to receive voice communications in secure mode.
- 8.3. The PU shall be able to receive VMF messages in secure mode.
- 8.4. The PU shall be able to transmit voice communications in secure mode.
- 8.5. The PU shall be able to transmit VMF messages in secure mode.
- 8.6. The PU shall allow the user to load crypto keys.
- 8.7. The PU shall allow the user to purge crypto keys.

Switch to Non-Secure Mode

- 9.1. The PU shall allow the user to switch from secure to non-secure mode.

- 9.2. The PU shall be able to receive voice communications in non-secure mode.
- 9.3. The PU shall be able to receive VMF messages in non-secure mode.
- 9.4. The PU shall be able to transmit voice communications in non-secure mode.
- 9.5. The PU shall be able to transmit VMF messages in non-secure mode.

Radio Frequency Interfaces

- 10.1. The PU shall be capable of read and process fixed positional data from GPS Satellite.
- 10.2. The PU shall be capable of receiving and process data through Joint Interoperable Force Compatible frequencies.

System Performance Requirements

- PR 1 The PU shall be able to estimate user position location in less than 5 minutes after Command Center acknowledges User ID.
- PR 2 The PU shall be able to send user location 5 minutes after Command Center acknowledges User ID.
- PR 3 The PU shall determine a location accuracy of less than 10 meters.
- PR 4 The PU battery life shall be a minimum of three weeks in activate mode.
- PR 5 The PU shall be able to send User ID within 10 seconds of activation.
- PR 6 The PU shall be able to send User ID every 10 seconds after the initial User ID message.
- PR 7 The PU shall be designed for one hand operation.
- PR 8 The PU shall be lightweight and mobile for user.
- PR 9 The PU must be contained within the user's ejection package.
- PR 10 The PU shall be operational during day and night operations.
- PR 11 The PU display shall be visible to the user during the hours of darkness.
- PR 12 The PU shall be capable of withstanding 0-40 degrees Celsius.
- PR 13 The PU shall be capable of withstanding relative humidity up to 95 percent.
- PR 14 The PU shall be waterproof.
- PR 15 The PU shall have low probability detection/indication (LPD/I) feature.

RTM Table

Requirements	Use Cases								
	Activate PU	Deactivate PU	Select Band	Transmit Voice	Receive Voice	Transmit Text	Receive Text	Load Crypto Key	Go Non Secure
FR 1.1	X								
FR 1.2	X								
FR 1.3	X								
FR 2.1		X							
FR 2.2		X							
FR 3.1	X								
FR 3.2	X								
FR 3.3	X								
FR 3.4	X								
FR 3.5	X								
FR 4.1				X					
FR 4.2			X	X					
FR 4.3			X	X					
FR 5.1			X		X				
FR 5.2			X		X				
FR 5.3			X		X				
FR 6.1			X			X			

Requirements	Use Cases								
	Activate PU	Deactivate PU	Select Band	Transmit Voice	Receive Voice	Transmit Text	Receive Text	Load Crypto Key	Go Non Secure
FR 6.2			X			X			
FR 6.3			X			X			
FR 6.4						X			
FR 6.5						X			
FR 6.6						X			
FR 6.7						X			
FR 6.8						X			
FR 7.1				X			X		
FR 7.2				X			X		
FR 7.3				X			X		
FR 7.4							X		
FR 8.1								X	X
FR 8.2					X			X	
FR 8.3							X	X	
FR 8.4				X				X	
FR 8.5						X		X	
FR 8.6								X	
FR 8.7									X
FR 9.1								X	X
FR 9.2					X				X
FR 9.3							X		X

Requirements	Use Cases								
	Activate PU	Deactivate PU	Select Band	Transmit Voice	Receive Voice	Transmit Text	Receive Text	Load Crypto Key	Go Non Secure
FR 9.4				X					X
FR 9.5						X			X
FR 10.1	X								
FR 10.2							X		
PR 1	X								
PR 2	X					X			
PR 3	X								
PR 4	X	X							
PR 5	X								
PR 6	X								
PR 7	X	X		X	X	X	X		
PR 8	X	X		X	X	X	X		
PR 9	X								
PR 10	X		X	X		X	X	X	X
PR 11	X			X		X	X		
PR 12	X								
PR 13	X								
PR 14	X								
PR 15			X	X	X	X	X	X	X

FR – Functional Requirement : PR – Performance Requirement

System Tradeoff Analysis

Many features of the Pilot Unit system influence the performance of the system. All features must be examined and a tradeoff must be done prior to selecting the system that illustrates high performance and cost effectiveness. The tradeoff analysis will be of the communication unit, which consists of the radio with internal GPS device. Four devices were selected for analysis. A fifth concept was discussed and discarded.

Option A: The Combat Survivor Evader Locator (CSEL) Communication System by The Boeing Company

Figure 15 "BOEING CSEL"



Features:

- Secure digital message communications
- Global Positioning System (GPS)
- Line-of-Sight (LOS) voice
- Full spectrum of radio and ground equipment interfaces required to work with your existing search and rescue systems
- Specially designed for easy, intuitive use
- Unique communication and message encryption prevents signals from being intercepted
- 21-day battery life provides crucial contact for extended periods
- Based on a flexible, modular communication architecture providing multiple satellite links for dependable, secure (LPI/LPD) Over-the-Horizon (OTH) communications global navigation, and beacon functions
- Flexibility for future growth, and enhancements, including migration to a commercial satellite solution

Option B: Advanced Dual Mode Personal Survival Radio with GPS Tadiran Spectralink's advanced PRC-434G Transceiver is a small but powerful long-endurance Personal Survival Radio (PSR)

Figure 16 "Tadiran Advanced Dual Mode Personal Survival Radio"



Features:

- Automatic activation on pilot ejection
- Embedded GPS receiver, assures precise global positioning
- Large LCD display, and state-of-the-art electronics, the PRC-434G/SV
- Easy navigation and extensive interrogatable two-way messaging
- Fully back-compatible with all previous ASARS versions and interoperable with airborne systems like ARS-700, ARS-700G and other NATO CSAR systems
- Operate effectively under severe conditions
- One-handed operation make the Personal Survival Radio unit effective even if the survivor is injured or unconscious
- Automatic response to airborne unit interrogation
- Exceptionally long battery life
- A text communication selected out of 40 canned messages
- Very short burst transmissions
- Intrinsic LPI/LPD
- Battery Life: > 96hrs in Sleep Mode; > 30 hrs @ 1:10 Transmit/Receive Ratio; >15 hrs in Beacon Mode

Option C: GPS CSAR System from General Dynamics and Rockwell Collins

Figure 17 "General Dynamics/Rockwell Collins GPS CSAR"



Features:

- B1 radio responds to either a specific identification code or to an "all call" interrogation for operational flexibility
- Short burst to the SAR aircraft,
- Communicate with a General Dynamics Quickdraw2 handheld interrogator or the RSC-125G and the AN/ARS-6 airborne radios
- Combining GPS technology with Distance Measuring Equipment (DME) Standard latitude, longitude, UTM or MGRS coordinates
- Position accuracy to 25 meters
- Detects GPS Interference
- Provides GPS position interrogation on VHF or UHF frequencies
- Sends and receives pre-formatted and free text encrypted messages
- Accuracy < 25 meters
- Weight 35 ounces with battery
- Size 7.7" x 3.87" x 2.1"
- Operational temp -30°C to +55°C
- Storage temp -40°C to +80°C
- Immersible to 50 feet
- Predicted MTBF 3133 hours
- Battery life >4 days, predicted

Option D: Satellite Mobile Phone with encryption device and separate GPS unit.

Figure 18 "Satellite Mobile Phone with separate GPS unit"



Features:

- Satellite Mobile Phone
- Quick access interface
- Data capable
- Subscriber identity module PIN availability (security code)
- Small and light weight
- More resistive to water
- Newest addition to Satellite Series portfolio
- Withstand rugged conditions
- Crisis Calling
- Provides up to 38 hours of standby time/ 3 hours of talk time
- Operating Temperature: -30/+60 degrees Celsius
- Multiplexing method: TDMA/FDMA
- Battery meter and signal strength meter

GPS Receiver

- Position of accuracy 15 meters
- Lightweight
- Waterproof
- One-hand operation
- 12 channel GPS performance
- Battery life: 20 hours

Option E – New Development*

- Full Compliance
- GPS
- Commercial Satellite Communications Capable
- Secure Communications
- High Cost \$\$\$\$\$ - All new development
- High Risk
- Schedule: 3 year development very aggressive
- Interfaces with Joint Forces might prove technically unfeasible

Option E was discarded due to the high risk associated with its implementation.

Selection Criteria

The selection criteria are based on objectives and level of importance.

1. Activation
2. Operational Modes
3. Positive Identification of downed aircraft and crewmember
4. Battery Life
5. GPS Location Accuracy
6. Operational Availability
7. Anti-Jam/ Protection of data

A comparison of these objectives against the four options will be based on the following criteria:

Figure 19 "Pilot Unit Tradeoff Criteria"

Rating	Evaluation Criteria	Criteria		Reason for Priority
		Threshold	Goal	
1	Activation	Manual	Automatic upon ejection	If pilot incapacitated SAR many never initiate
2	Operational Modes	UHF/VHF, GPS, AM Beacon	SARSAT, UHF/VHF, GPS, AM Beacon	Global communications is dependent on the system ability to communicate over SARSAT or SATCOM
3	Positive ID of downed aircraft and crewmember		Interrogation	Avoiding false positives will protect both the rescue crew and the pilot
4	Battery Life	10 days	21 days	Extended battery life with the potential of rescue taking longer in high threat areas
5	GPS Location Accuracy	<10m	<5m	Location determination day and night
6	Operational Availability	95%	99%	High operational availability is essential
7	Anti-Jam (comms and position location)	2W @ 100 NM Threshold	5W @ 200 NM Objective	Compromising the downed pilot would be worst than not knowing the pilot needs rescuing

The Pair wise comparison is used to determine the weighting of criteria.

Figure 20 "Pilot Unit Trade Off Pair wise Comparison"

Pairwise Comparison

	2	3	4	5	6	7
1	<input type="text" value="2"/>	<input type="text" value="2"/>	<input type="text" value="3"/>	<input type="text" value="3"/>	<input type="text" value="3"/>	<input type="text" value="3"/>
2	<input type="text" value="1"/>	<input type="text" value="2"/>	<input type="text" value="2"/>	<input type="text" value="3"/>	<input type="text" value="3"/>	
3	<input type="text" value="1"/>	<input type="text" value="1"/>	<input type="text" value="2"/>	<input type="text" value="2"/>		
4	<input type="text" value="1"/>	<input type="text" value="2"/>	<input type="text" value="3"/>			
5	<input type="text" value="2"/>	<input type="text" value="2"/>				
6	<input type="text" value="2"/>					

Legend of Importance Factors
 1 - Equal
 2 - Slightly Favored
 3 - Favored
 4 - Strongly Favored

Enter the importance factor of each horizontal evaluation criteria compared to each vertical evaluation criteria

The Decision Matrix is used to determine the best option.

Figure 21 "Pilot Unit Decision Matrix"

DECISION MATRIX		Pilot Unit						
Weight	4.88	3.20	2.31	2.11	1.98	1.28	1.00	Total
Criteria	Activation	Operational Modes	Positive ID	Battery Life	GPS Loc Accuracy	Ao	Anti-Jam	
COA								
Option A	1/4	1/5	1/5	1/5	1/5	1/4	1/5	7.697
Option B	1/5	1/5	1/4	1/3	1/3	1/4	1/5	35.095
Option C	1/4	1/5	1/4	1/3	1/3	1/4	1/5	104.168
Option D	1/2	1/3	1/2	1/3	1/4	1/4	1/2	110140.342

Multiplication Matrix
 Less is better
 All values times 10⁻¹²
 Consistency Ratio = 97.74

Option A scored significantly higher. The Combat Survivor Evader Locator is the best device to enhance the SAR capability in rescue operations in a joint and global environment.

System Validation and Verification

Referring to Figure 26, the V-Model of systems development, the process of requirements flow-down involves decomposition of the high-level stakeholder requirements into detailed subsystem and component specifications, which are used by component and subsystem designers to produce integral parts of a system from the bottom up. The task of system verification is to prove the system functionality concurrently as the design is transformed into functional component, module, subsystem, and system level objects and assemblies. At the highest level of verification, the system is tested against the stakeholder requirements, which is called validation. Once validation is complete, the system can be fully commissioned and turned over to its users.

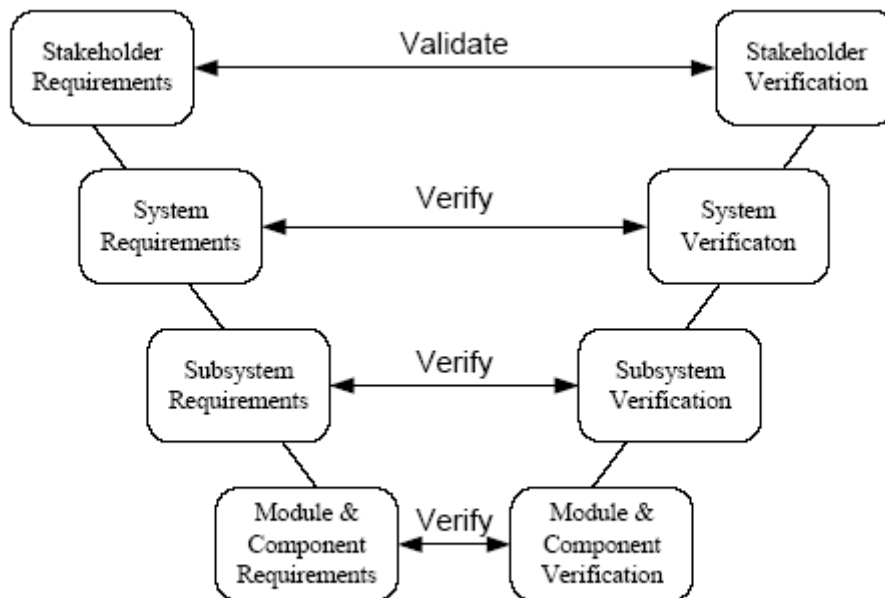


Figure 25: V-Model of Systems Development

Verification of Design Requirements

A verification plan for the pilot unit subsystem will insure that the requirements listed in the RTM Table are verified, and the Pilot unit is properly designed for use within the search and rescue system. Each requirement listed in RTM must have at least one verification requirement that can be traced to it. In some cases several verification requirements are needed to properly verify one requirement. The verification requirements are listed below. A verification traceability matrix is used to document the

traceability between the various design and verification requirements. The verification requirements are then organized into tasks based on the type of verification (test, analysis, demonstration, and inspection).

Verification Requirements

- VR 1 Verify that the PU is capable of secure two-way over-the-horizon messaging, line-of-sight voice, near-real time geo-positioning, authentication of evader identity and condition, and low probability of intercept/low probability of detection communications.
- VR 2 Verify that the PU incorporates approved communications security techniques to protect the unit against extraction of crypto keys.
- VR 3 Verify that the PU allows the user to "zeroize" crypto keys. There will be two levels of "zeroization" available to the user.
 - a. If the PU is "zeroized" once, the user may continue to use the PU, however, the user will be alerted that the PU may be in hostile hands and must re-authenticate the user's identification.
 - b. If the PU is "zeroized" a second time, the PU will provide AM voice communications on factory-set frequencies and course acquisition code GPS capabilities.
- VR 4 Verify that the PU battery, when new, will provide a maximum life of 21 calendar days (at 25 degrees Celsius) with a duty cycle of one GPS fix and one data burst transmission per hour, plus 15 minutes of voice communications at the end of the 21st day.
- VR 5 Verify that the PU consists of speaker-microphone, keypad, volume control, push-to-talk button, Light Emitting Diode, Liquid Crystal Display, alarms, and three power modes: User Mode for normal operation, Sleep Mode for battery conservation, and Extended Mission Mode for low power storage.
- VR 6 Verify that the PU can be operated using for one-hand (right or left) with flight gloves or modified winter gloves, and storable in pilot ejection suit.
- VR 7 Verify that the PU can activate and deactivate automatically, allow the user to manually activate and deactivate system.

Verification Table Matrix

Design Requirements	Verification Methods				Verification Requirements
	Test	Analysis	Demo	Inspect	
FR 1.1			X		VR 7
FR 1.2			X		VR 7
FR 1.3				X	VR 7
FR 2.1			X		VR 7
FR 2.2			X		VR 7
FR 3.1		X			VR 1, VR 4, VR5
FR 3.2		X			VR 1, VR 4, VR 5
FR 3.3			X		VR 1, VR 7
FR 3.4		X			VR 1
FR 3.5				X	VR 5
FR 4.1	X		X		VR 1, VR 3, VR 4, VR 7
FR 4.2	X		X		VR 1, VR 3, VR 4, VR 7
FR 4.3	X		X		VR 1, VR 3, VR 4, VR 7
FR 5.1	X		X		VR 1, VR 3, VR 4, VR 7
FR 5.2	X		X		VR 1, VR 3, VR 4, VR 7
FR 5.3	X		X		VR 1, VR 3, VR 4, VR 7
FR 6.1	X		X		VR 1, VR 5
FR 6.2	X		X		VR 1, VR 5
FR 6.3	X		X		VR 1, VR 5
FR 6.4				X	VR 6
FR 6.5	X		X		VR 1, VR 5
FR 6.6	X		X		VR 1, VR 5
FR 6.7	X		X		VR 1, VR 5
FR 6.8	X		X		VR 1, VR 5
FR 7.1			X	X	VR 1, VR 5
FR 7.2			X	X	VR 1, VR 5
FR 7.3			X	X	VR 1, VR 5
FR 7.4				X	VR 5
FR 8.1		X		X	VR 1, VR 2, VR 5
FR 8.2			X		VR 1, VR 2
FR 8.3			X		VR 1, VR 2

FR 8.4			X		VR 1, VR 2
FR 8.5			X		VR 1, VR 2
FR 8.6	X	X			VR 2
FR 8.7	X	X			VR 3
FR 9.1		X		X	VR 5
FR 9.2			X		VR 1, VR 3
FR 9.3			X		VR 1, VR 3
FR 9.4			X		VR 1, VR 3
FR 9.5			X		VR 1, VR 3
FR 10.1		X			VR 1
FR 10.2		X		X	VR 1
PR 1		X			VR 1
PR 2		X			VR 1, VR 5
PR 3		X			VR 1
PR 4	X				VR 4
PR 5		X			VR 1
PR 6		X			VR 1
PR 7			X		VR 6
PR 8				X	VR 6
PR 9				X	VR 6
PR 10			X		VR 5
PR 11			X		VR 5
PR 12	X				VR 5
PR 13	X				VR 5
PR 14			X		VR 5
PR 15		X			VR 2, VR 3

FR: Functional Requirements
PR: Performance Requirements
VR: Verification Requirements

Conclusion

After spending a number hours on this project, it is safe to conclude that UML is a very good tool for system modeling, but it needs the support of non-UML tools to complete the tasks at hand since it is difficult to achieve a complete system perspective with it. In addition, the team members found that there is more than one way to model something, and that no matter how impartial and how objective a view is, there will always be preferences amongst the members of a team on how to achieve the desired results. On optimization, it became obvious that linear programming was not a good choice to come up with a preferred design, but a pair wise comparison was.

The next step would be to develop actual test cases and test the pilot unit subsystem in a tactical environment under real-world scenario drive conditions.