Search and Rescue (SAR) Pilot Unit

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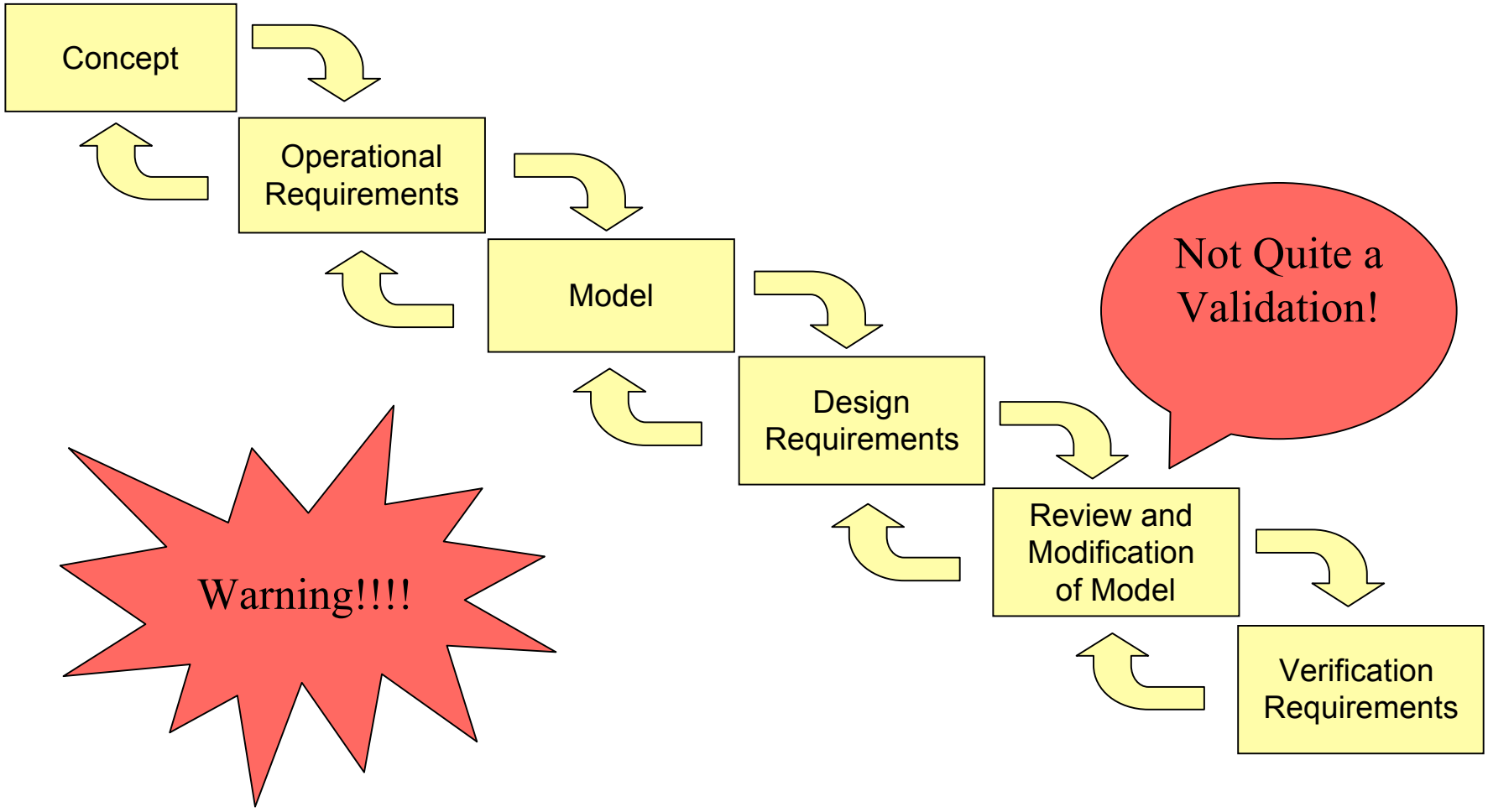
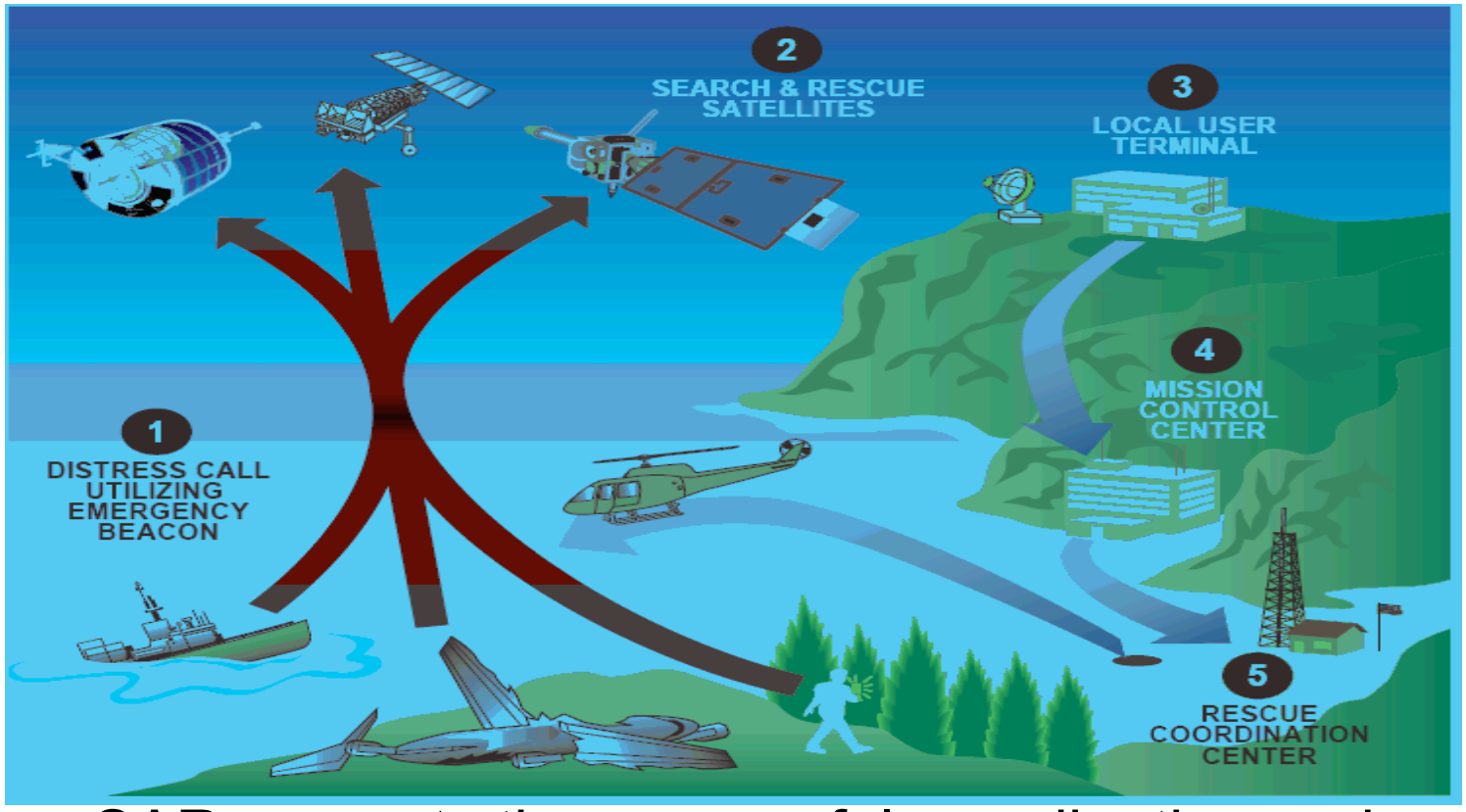
Project Method

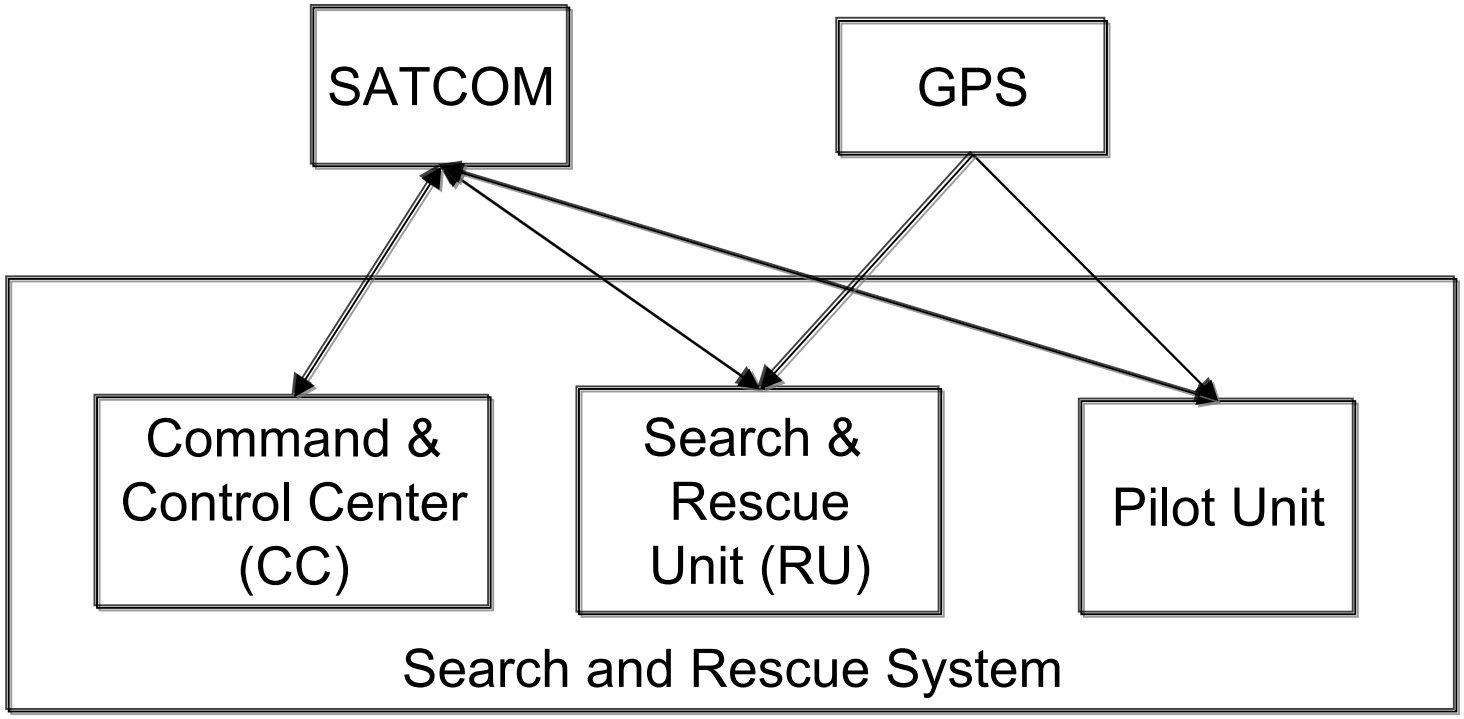


SAR System Concept

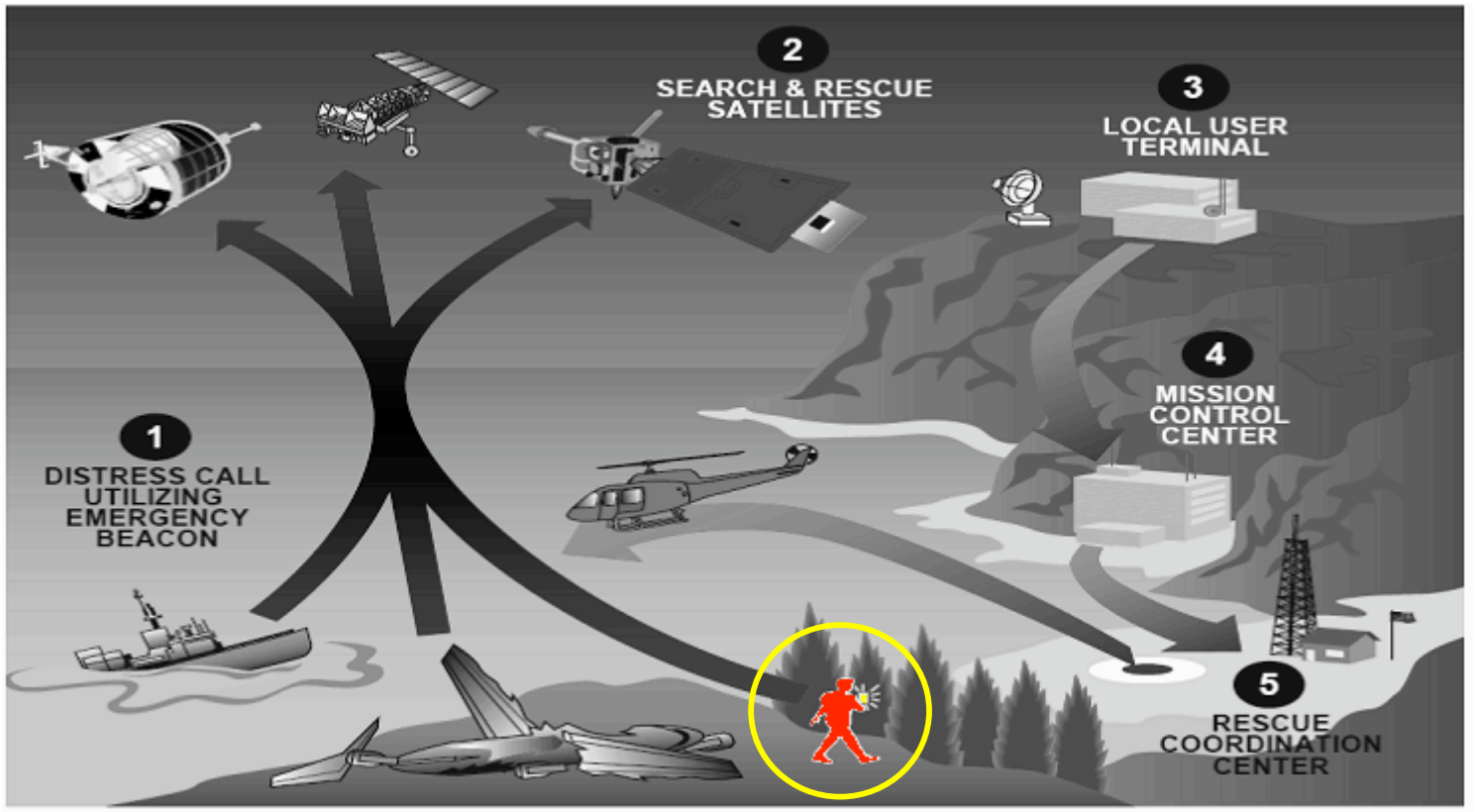


SAR supports the successful coordination and implementation of search and rescue missions using the latest position detection and communications technologies

Preliminary System Architecture



Downed Pilot Support Concept



Downed pilots require the capability to have their positions determined, and transmit and receive voice and data with the command center and rescue teams

SAR Threat – Pilot Unit

- Enemy Forces can:
  - Electronically intercept and/or jam communication and locator elements
  - Inject false data into SAR system
  - Decode and read messages to obtain downed crew or rescue team location

SAR Functional Requirements – Considerations for Pilot Unit

- Operable with Crewmember incapacitated (Alive but unable to assist)
- Pilot Unit must be contained within crewmember's ejection package
- Secure Operation (not easily compromised)
- Positive Identification of downed Aircraft and crewmember
- Interoperability allowing other forces to receive SAR information
- All weather, day/night operation
- Global Capability
- Support continuous operation for at least three weeks after pilot is first downed
- Pilot Unit must be lightweight and mobile

Pilot Unit Top Level Operational Functional Requirements

- Activate on “Pilot Downed” event
- Provide Pilot Unit ID
  - (Aircraft and Crew member ID can be derived from this)
- Provide Unit Position
- Pilot Unit provides data to SAR CC
- Pilot Unit provides data to SAR RU
- SAR CC provides data to Pilot Unit
- SAR RU provides data to Pilot Unit

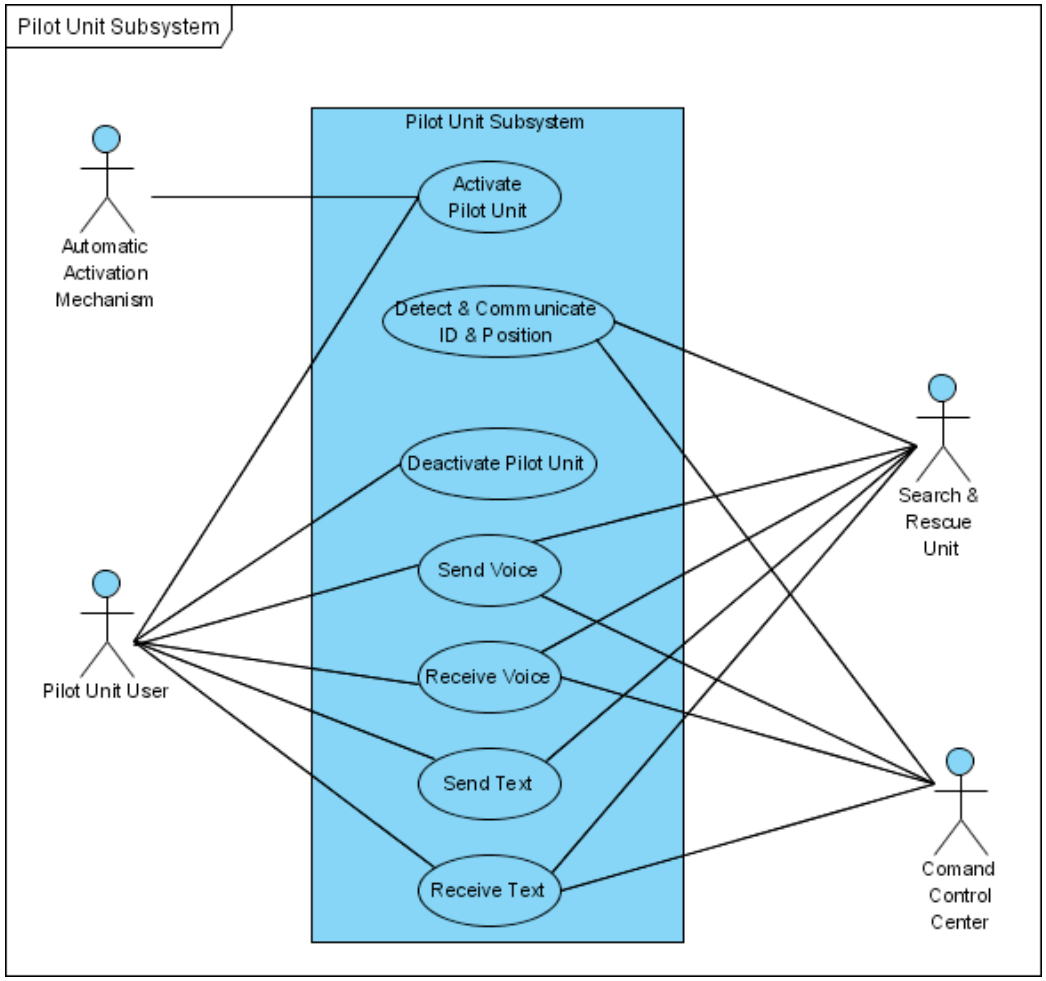
Pilot Unit Operational Associated Requirements

- Automatic activation and operation
  - Operable with Crew Member incapacitated
- Portable
  - Crew Member Unit must be contained within crew member's ejection package
  - Crew member's Unit must be lightweight and mobile
- Secure Communications (not easily compromised)
- Interoperability with Joint Forces
  - Communications
- Resistant to weather conditions
  - Watertight
  - Temperature
- Capable of Day/Night operations
- Operational from any point of the planet

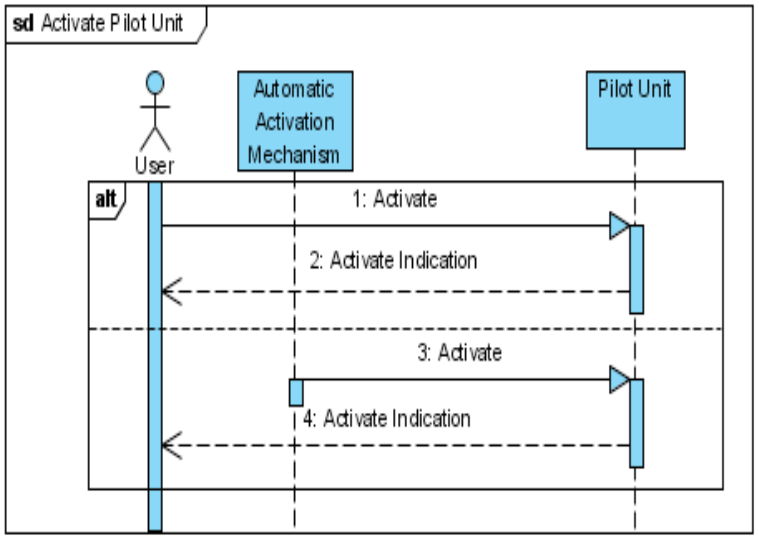
Pilot Unit Operational Performance Requirements

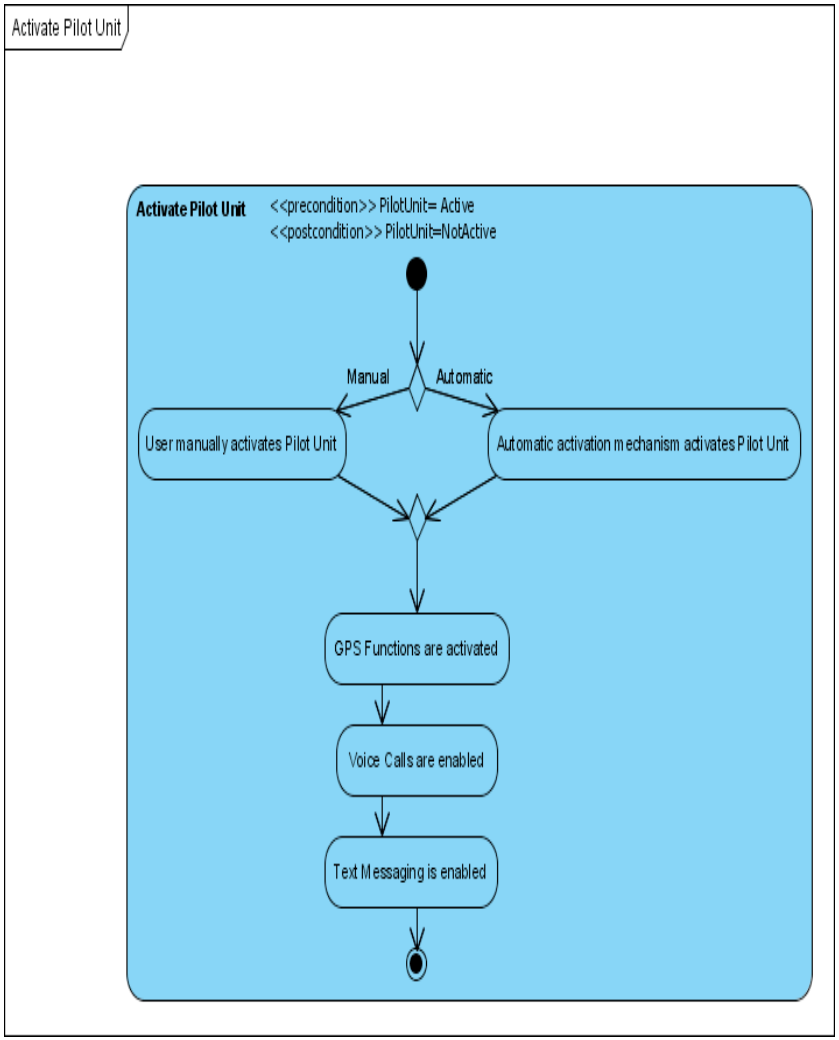
- Operational for three weeks without refurbishing
  - Power
  - Reliability
  - Maintainability
- Timed to downed crew member recognition < 10 minutes
- Location accuracy < 10 meters
- Covert range for enemy to achieve location fix < 5 Nautical Miles
- Anti-jam (communications and position) 2W @ 200 Nautical Miles
- Operational Availability

Pilot Unit : Use Case Diagram

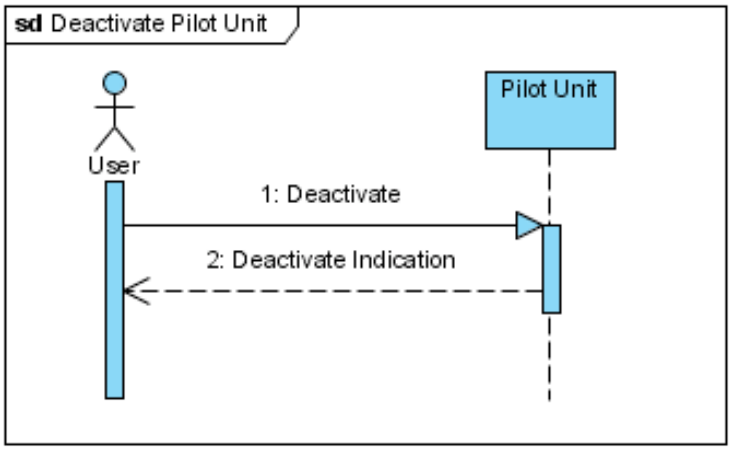


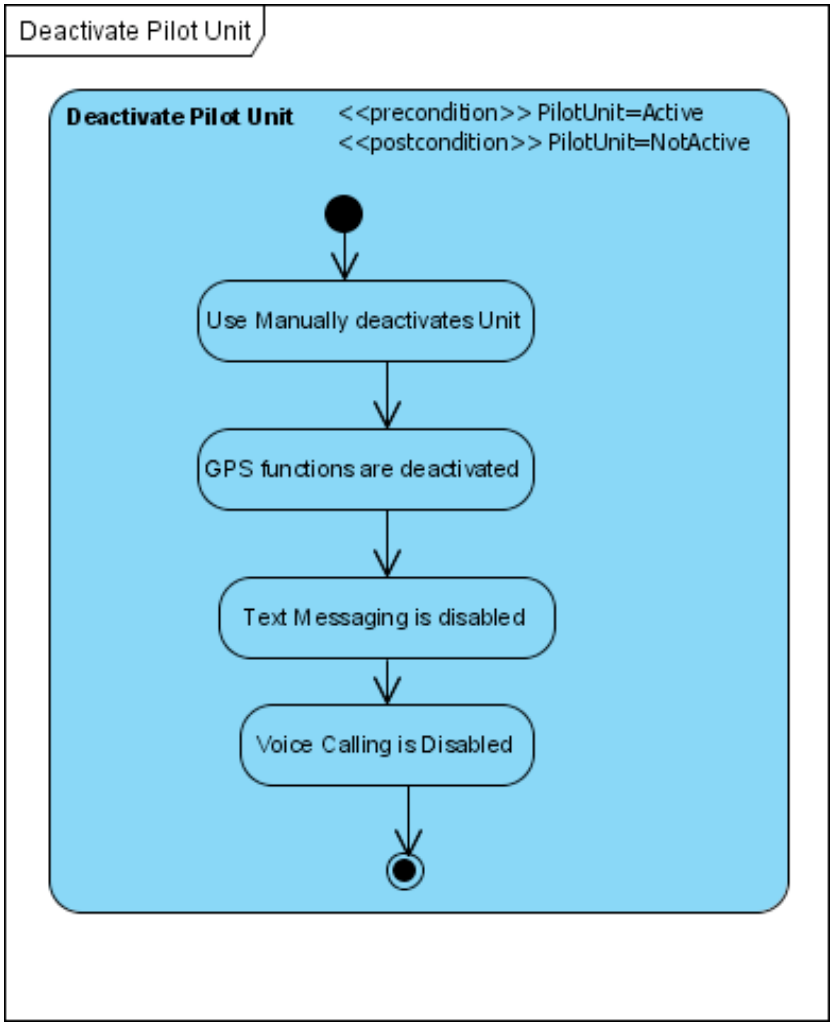
Activate Pilot Unit



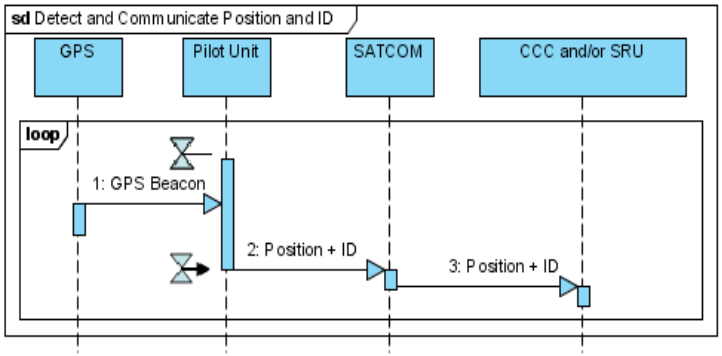


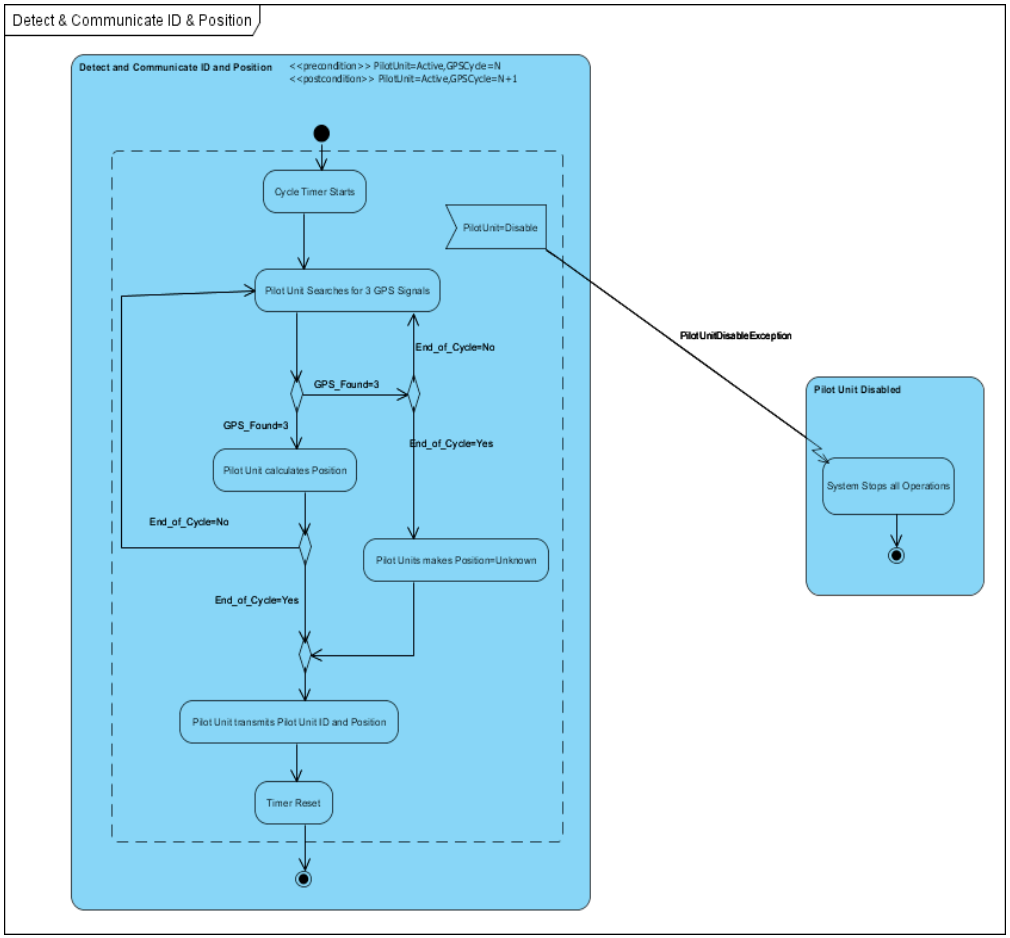
Deactivate Pilot Unit



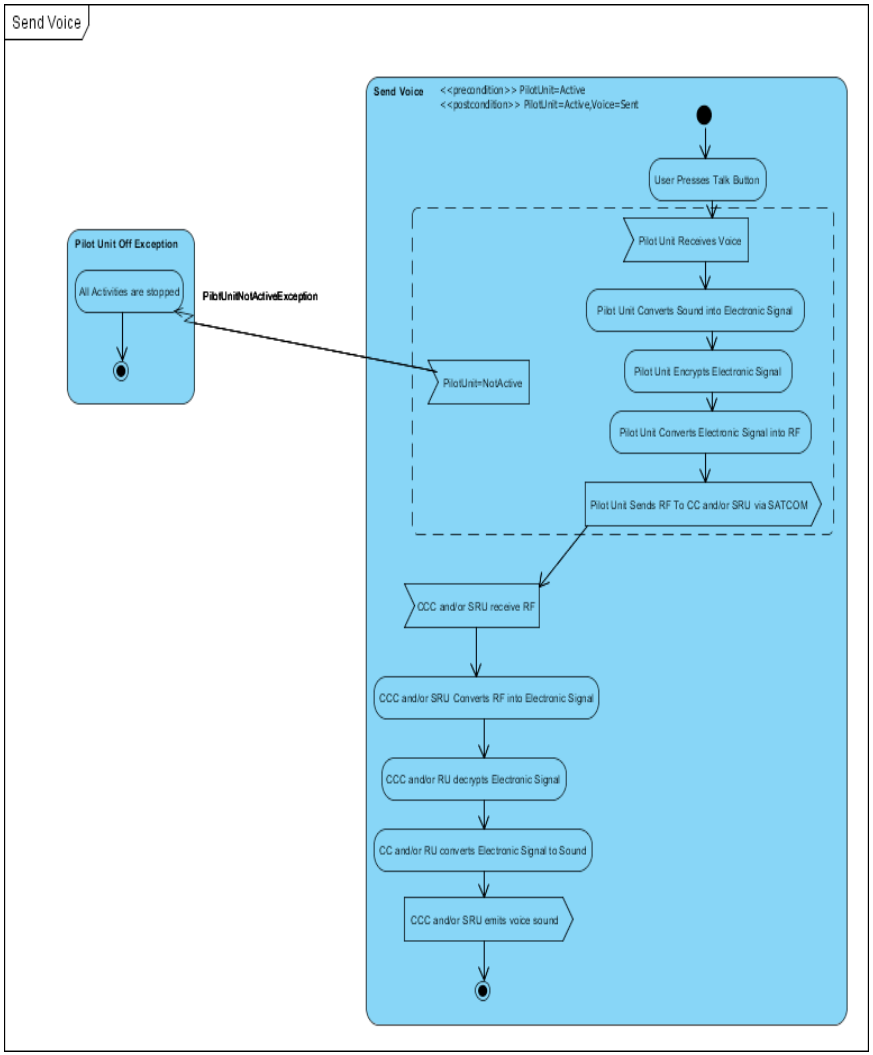


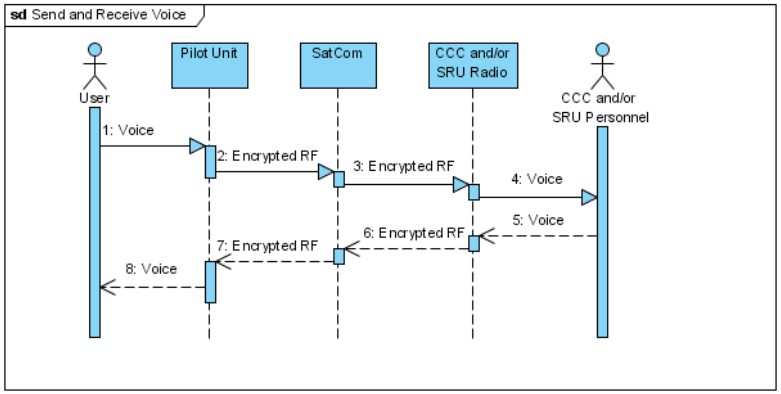
Detect and Communicate ID & Position



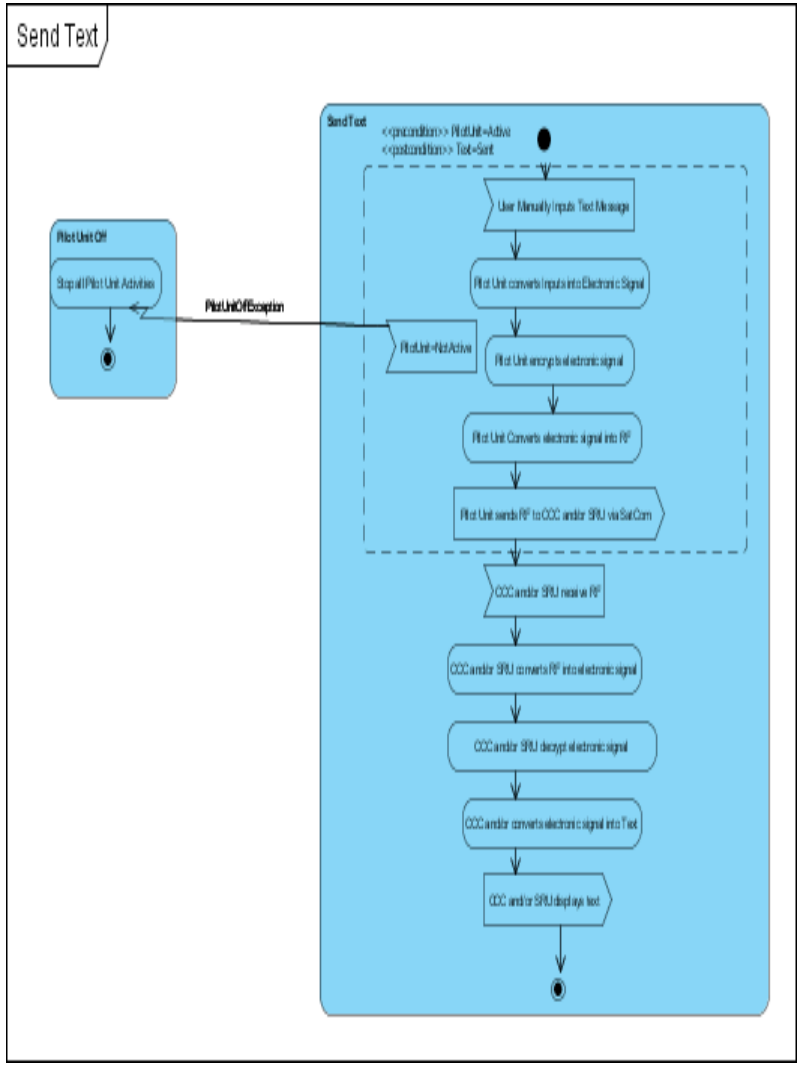


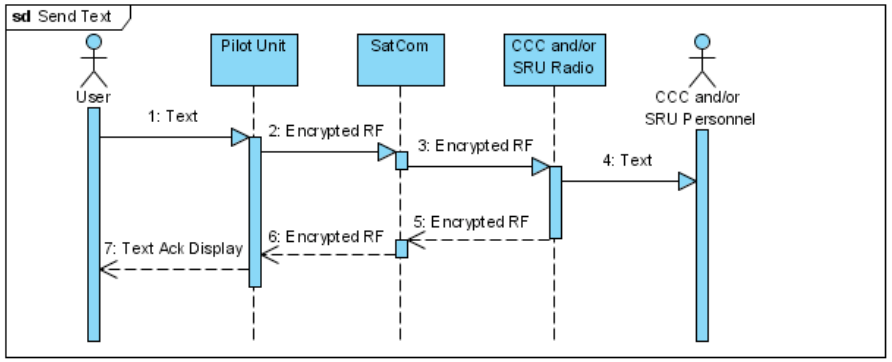
Send Voice


Send Voice
Send Voice
<<precondition>> PilotUnit=Active
<<postcondition>> PilotUnit=Active,Voice=Sent
User Presses Talk Button
Pilot Unit Receives Voice
Pilot Unit Converts Sound into Electronic Signal
Pilot Unit Encrypts Electronic Signal
Pilot Unit Converts Electronic Signal into RF
Pilot Unit Sends RF To CC and/or SRU via SATCOM
CCC and/or SRU receive RF
CCC and/or SRU Converts RF into Electronic Signal
CCC and/or RU decrypts Electronic Signal
CC and/or RU converts Electronic Signal to Sound
CCC and/or SRU emits voice sound
Pilot Unit Off Exception
All Activities are stopped
PilotUnitNotActiveException
PilotUnit=NotActive


sd Send and Receive Voice
User
Pilot Unit
SatCom
CCC and/or SRU Radio
CCC and/or SRU Personnel
1: Voice
2: Encrypted RF
3: Encrypted RF
4: Voice
5: Voice
6: Encrypted RF
7: Encrypted RF
8: Voice

Send Text


Send Text
Send Text
<<precondition>> PilotUnit=Active
<<postcondition>> Text=Sent
User Manually inputs Text Message
Pilot Unit converts inputs into Electronic Signal
Pilot Unit encrypts electronic signal
Pilot Unit Converts electronic signal into RF
Pilot Unit sends RF to CCC and/or SRU via SatCom
CCC and/or SRU receive RF
CCC and/or SRU converts RF into electronic signal
CCC and/or SRU decrypt electronic signal
CCC and/or converts electronic signal into Text
CCC and/or SRU displays text
Pilot Unit Off
Stop all Pilot Unit Activities
PilotUnitOfException
PilotUnit=NotActive


sd Send Text
User
Pilot Unit
SatCom
CCC and/or SRU Radio
CCC and/or SRU Personnel
1: Text
2: Encrypted RF
3: Encrypted RF
4: Text
5: Encrypted RF
6: Encrypted RF
7: Text Ack Display

Primary Design Requirements

Activate Pilot Unit	
FR 1.1	The PU shall be able to automatically power on when the pilot is ejected from the aircraft.
FR 1.2	The PU shall allow the user to power on the unit.
FR 1.3	The PU shall display battery life indication to the user.
Deactivate Pilot Unit	
FR 2.1	The PU shall allow the user to power off the unit.
FR 2.2	The PU shall automatically shut off after 20 minutes of not activity.
Detect and Communicate ID and Position	
FR 3.1	The PU shall be capable of monitoring its own PU location.
FR 3.2	The PU shall be capable of determining its own PU location.
FR 3.3	The PU shall be capable of transmitting PU ID and location without user intervention.
FR 3.4	The PU shall format its own location terms of latitude, longitude, and altitude above sea level.
FR 3.5	The PU shall display its location to the user.

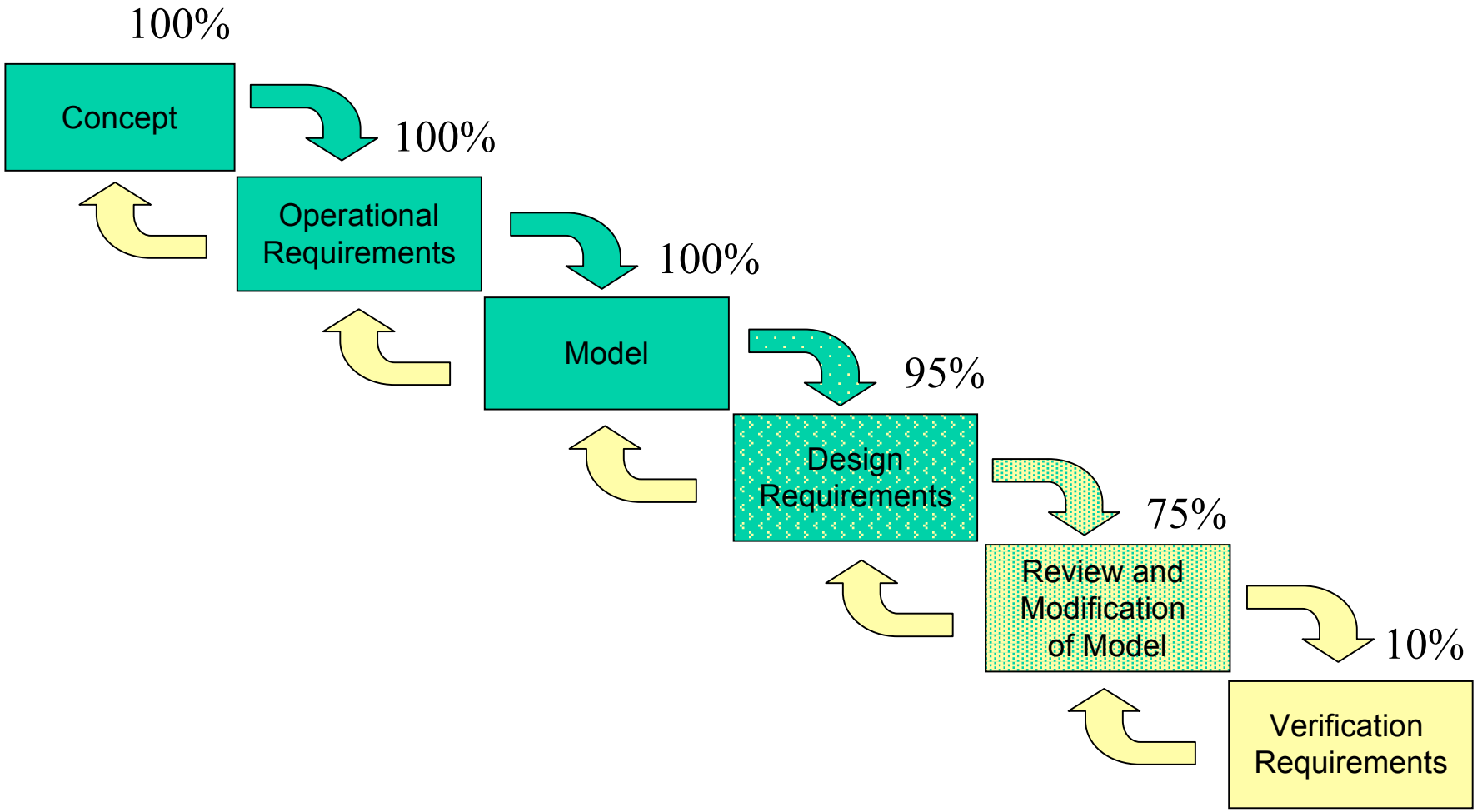
Performance Requirements

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 72 hours 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.

Design to Validation\Verification

Design Requirements	V&V Methods				V&V Requirements
	Test	Analysis	Demo	Inspect	
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	???

Project Status



Left to Complete

- Complete Derived Requirements
- Complete Requirements Traceability Table
- Adjust\Revalidate Model Based on Derived Requirements if necessary
- Complete Verification Requirements
- Regroup Verification Requirements in logical Test Cases
- Done!!!

QUESTIONS

Back Up Slides

Project Scope and Methodology

- Model the Pilot Unit Subsystem
- Aspects of other SAR Subsystems will be modeled with the purpose of helping in the modeling to the Pilot Unit Subsystem
- A combination of UML and other modeling methods will be used for the model
- Use of real SAR Mission Need Statement (MNS) to start project
- Subject Matter Expert (SME)
- Analyze potential solutions to show design optimization alternative methods

SAR Needs – Pilot Unit

- Operational Deficiencies and Technological Opportunities are:
  - Current SAR Operations do not meet new requirements
    - New solution needed to address increase number of aircraft missions, larger areas of operation and increased risk to rescuing force
  - Take Advantage of New Technology
    - Use existing Satellite Technology to detect and locate downed crew member
  - Important: Cost Effectiveness

SAR Performance Requirements– Considerations for Pilot Unit from SME

- Anti-jam (communications and position location)
  - 2W @ 100 Nautical Miles threshold
  - 5W @ 200 Nautical Miles objective
- Operational Availability
  - 95% threshold, 99% objective
- Measures of Performance
  - Total Time from crewmember down to rescue for downing 200 NM behind enemy lines is 2 hour objective/4 hour threshold
  - Probability of Identification of downed crewmember 99% objective and 95% threshold

SAR Performance Requirements– Considerations for Pilot Unit from SME

- Timed to downed crewmember recognition
  - < 10 minutes threshold, < 5 minutes objective
- Location accuracy
  - < 10 meters threshold, < 5 meters objective
- Covert range for enemy to achieve location fix
  - < 5 Nautical Miles threshold
  - < 3 Nautical Miles objective

SAR Constraints – Considerations for Pilot Unit

- Commercial-off-the-shelf (COTS) that shall be considered:
  - Commercial Satellite Constellation for the Crewmember Up and Downlink communications
  - Commercial Receivers for GPS

Operational Analysis

- Subsystem Activation
  - The event of the Pilot being downed triggers the activation of the subsystem
  - Downed crewmember might not be able to activate the system, therefore automatic activation is required
  - The location detection of the subsystem and the Pilot Unit ID are the only features that need to be activated automatically – if the pilot is not able, he/she can not exchange data at will
  - Downing of the Aircraft has to be somehow detected automatically as well
  - If the crewmember is able, he/she might activate the system

Operational Analysis

- Provide Pilot Unit ID
  - Once the System is activated the Pilot Unit ID shall be provided to the CC and later to the RU
  - Provisions need to be made such that the Pilot Unit ID does not get jammed or interfered with
  - The Pilot Unit ID needs to be activated automatically – if the pilot is not able, he/she can not send data at will
  - If the crewmember is able, he/she might activate the subsystem
  - Assuming that SAR CC and SAR RU can derive Crewmember and Plane for Pilot Unit ID

Operational Analysis

- Provide Position Location
  - Unit to receive GPS Signals and use them to calculate Position – Design constraint
  - Unit to send Position Location to SAR CC and/or SAR RU using Commercial Satellite Constellation - Design constraint
  - Provisions need to be made such that the Position Location does not get jammed or interfered with
  - Provisions need to be made such that the Position information does not get compromised
  - The Position Information needs to be provided automatically – if the pilot is not able, he/she can not send data at will
  - If the crewmember is able, he/she might provide the Position of the subsystem

Operational Analysis

- The Pilot sends data to the SAR CC and RU
  - Use Commercial Satellite Constellation for communications - Design constraint
  - Initially, data exchange only with SAR CC, since the RU will be deployed later
  - The SAR CC will require from the crewmember its Pilot Unit ID and position estimates. Verification that a rescue plan is accepted or rejected, abort mission, and information on immediate threats can also be sent
  - Provisions need to be made such that the Pilot Data to be sent does not get jammed or interfered with
  - Provisions need to be made such that the Pilot Data to be sent does not get compromise

Operational Analysis

- The Pilot sends data to the SAR CC and RU
  - If the pilot is not able, he/she will not be able to actively verify identity
    - For positive identification, the Pilot Unit ID will be the only thing available to determine identity
  - SAR CC and RU data has the same content and might use same method of communication
    - Potential choice: Single SAR COMM interface can address both

Operational Analysis

- The Pilot receives data from the SAR CC and/or RU
  - Use Commercial Satellite Constellation for communications - Design constraint
  - Provisions need to be made such that the SAR CC and/or RU can be decrypted if so required
  - According to Subject Matter Expert in order not to compromise the mission, the likelihood is that the crewmember will have its location estimated without receiving a timeframe or location for the rescue
  - Status of Identity of the downed crewmember, casualties or surrounding threat, might be required from the user
  - A rescue plan that includes location and time might be sent, but unlikely given the experts
  - Other Miscellaneous data might need to be sent

Operational Analysis

- The Pilot receives data from the SAR CC and/or RU
  - SAR CC and RU data has the same content and might use same method of communication
    - Potential choice: Single SAR COMM interface can address both
  - A rescue plan that includes location and time might be sent, but unlikely given the experts
  - Other unspecified data might potentially need to be sent
  - SAR CC and RU data has the same content and might use same method of communication
    - Potential choice: Single SAR System interface can address both

Pilot Unit
Top Level Functional Requirements

- **Provide ID**
  - Pilot Unit Determines Pilot Unit ID
  - Pilot Unit Encrypts Pilot Unit ID for Secure transmission
  - Pilot Unit Converts Pilot Unit ID into RF and Sends
- **Determine and Communicate Position**
  - Pilot Unit Receives GPS Information
  - Pilot Unit Calculates Position
  - Pilot Unit Encrypts Position Data for Secure TX
  - Pilot Unit Transmits Position Data to SAR CC and/or RU

Pilot Unit
Top Level Functional Requirements

- **User Sends Voice to CC and/or RU**
  - Pilot Unit Receives Voice from User
  - Pilot Unit Processes Voice message for transmission
    - Coverts Voice into Electronic Signals
    - Encrypts Electronic Signals
    - Converts Electronic Signals into RF
  - Pilot Unit Sends RF to SAR CC and/or RU

- **SAR CC or RU sends Voice to User**
  - Pilot Unit Receives SAR CC or RU RF
  - Pilot Unit Process received SAR CC or RU RF
    - Convert RF into Electronic Signals
    - Decrypt Electronic Signals
    - Convert Electronic Signals to Voice
  - Pilot Unit Send Voice to Pilot

Pilot Unit
Top Level Functional Requirements

- **User sends Text Message to CC and/or RU**
  - Pilot Unit Receives Text Message from User
  - Pilot Unit Process Text message for transmission
    - Coverts Text Message into Electronic Signals
    - Encrypts Text message
    - Converts Text message into RF
  - Pilot Unit Send RF to SAR CC and/or RU

- **SAR CC or RU sends Text messages to User**
  - Pilot Unit Receives SAR CC or RU RF
  - Pilot Unit Process received SAR CC or RU RF
    - Converts RF into Data
    - Decrypt SAR RU Data
    - Route SAR RU message
  - Pilot Unit Displays Text message to Pilot

Outline

- System Concept
- Operational Requirements
- Functional Requirements
- Performance Requirements
- Functional Diagram
- Physical Diagram
- Allocated Diagram
- Tradeoff Analysis of Alternatives

Basic Trade-off Principles

- Define the Objective
- Identification of Alternates
- Comparing the Alternatives
- Sensitivity Analysis
- Select preferred alternatives
- Execute decision

Purpose of Trade Study

The Pilot Unit trade study will include four possible options for meeting the mission needs

- Formal analysis methodology
- Determine the relative merits of the alternatives
- Aid in the selection of the best alternative for meeting the mission objective

Option A

Option A: The Combat Survivor Evader Locator (CSEL) communication system by The Boeing Company

- 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

<u>Option B:</u> Advanced Dual Mode Personal Survival Radio with GPS

- 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**
- **Automatic activation on pilot ejection**
- 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**
- Operational temp -20°C to +55°C

Option C

<u>Option C:</u> GPS CSAR System from General Dynamics and Rockwell Collins.

- 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

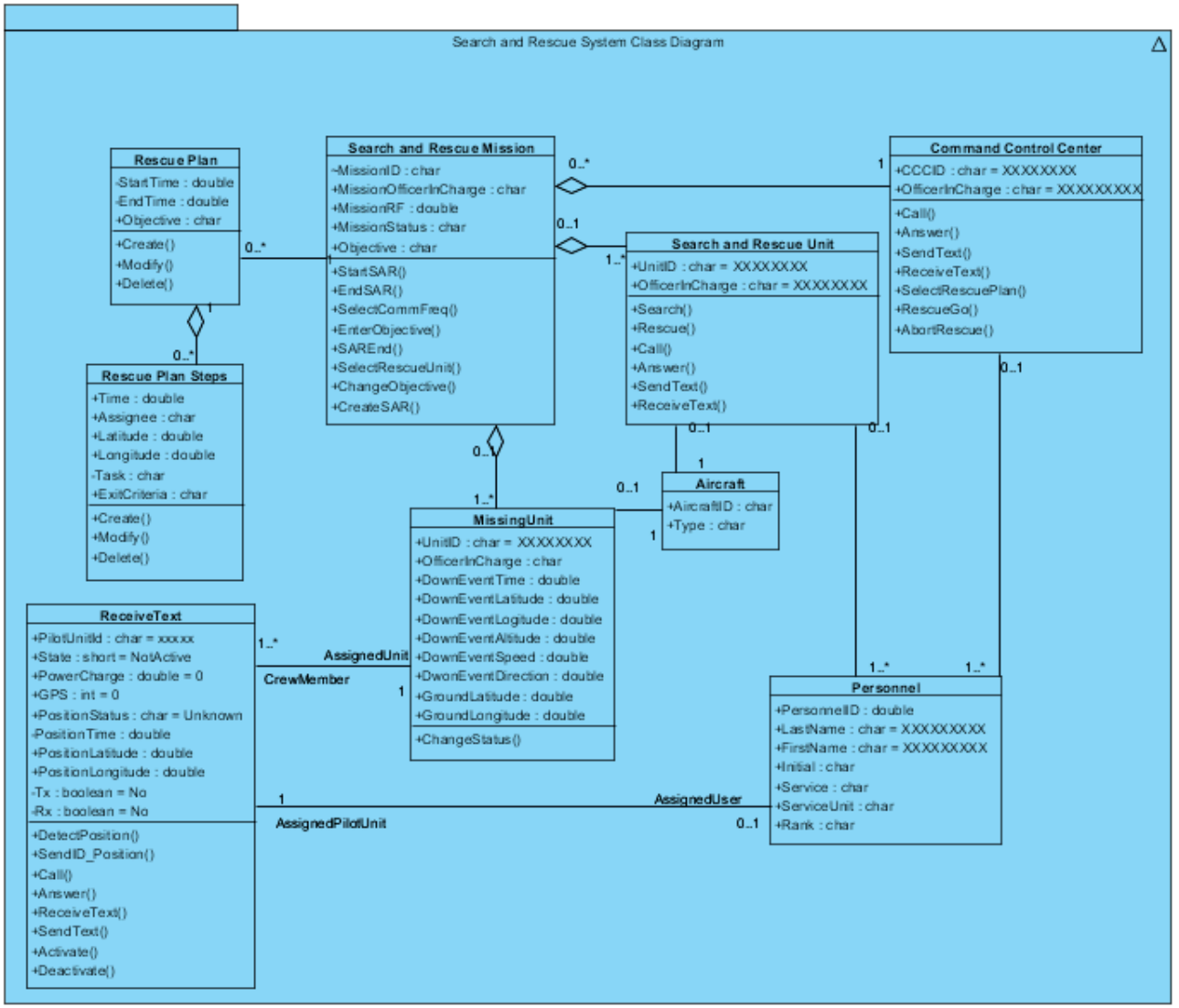
Option D: Iridium Satellite Phone with Encryption equipment and separate handheld GPS Unit

Motorola's Satellite Series 9505 Portable Phone is a communication tool that transcends current communication offerings exclusively for use on the Iridium® System. Now smaller, lighter and more water, dust and shock resistant, this newest addition to the Satellite Series portfolio is ideal for industrial or rugged conditions, yet appealing to the traveling professional.

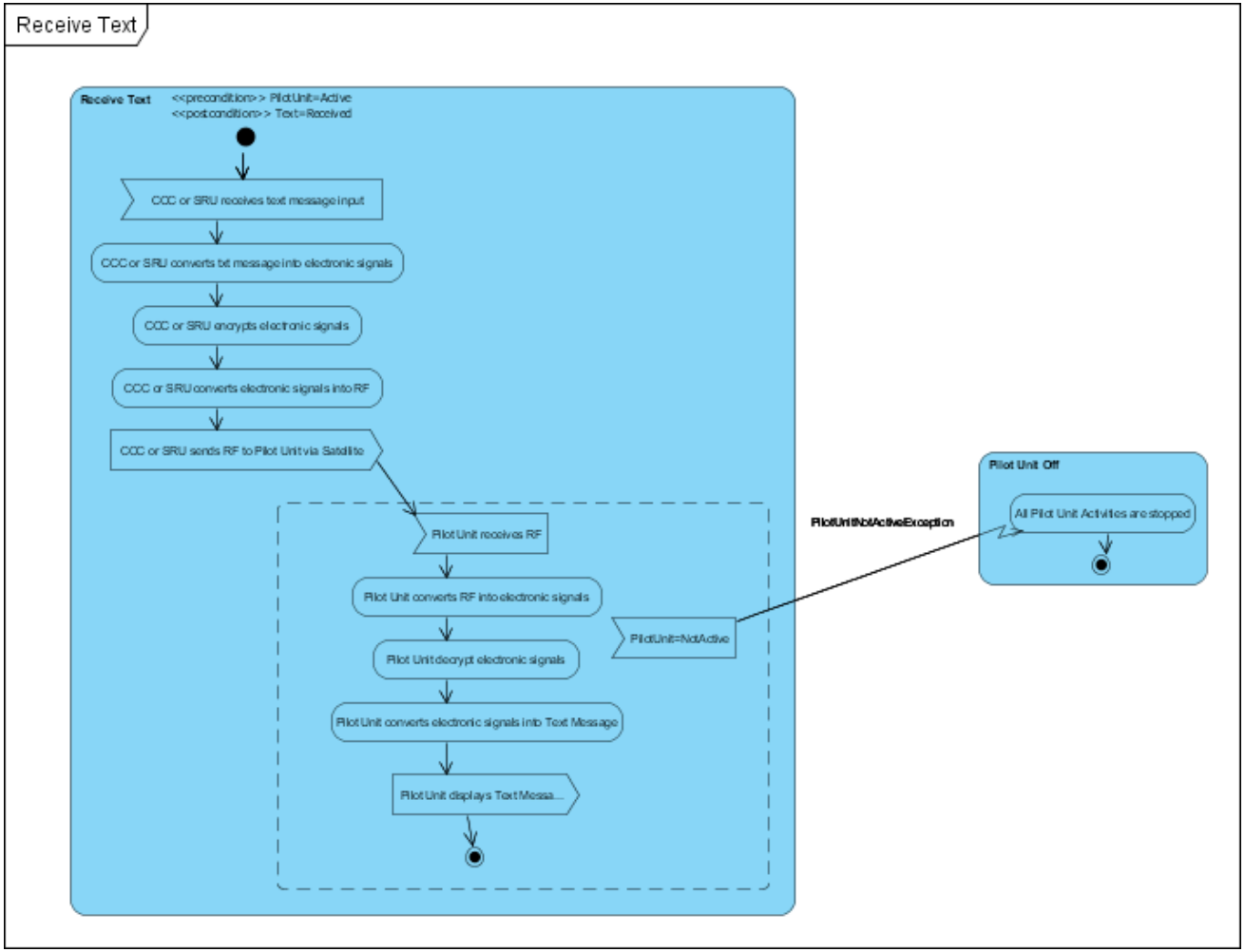
The DCS-1200 supports secure Voice and Data (SVD) during the same secure call. Connect the RS-232 serial port of the DCS-1200 to the serial port of your computer. Secure **point-to-point file transfer** is facilitated by special software (requires Windows). Secure voice communication can resume after files are transferred.

Garmin etrex handheld GPS - waterproof —among the smallest on the market. Measuring roughly 4"x 2"x1" and weighing less than 6 oz.; personal navigator; one-hand operation with buttons located on each side; logical operations, using four information pages; proven 12-channel GPS performance; long battery life (22 hours on two AA batteries); storage for up to 500 waypoints

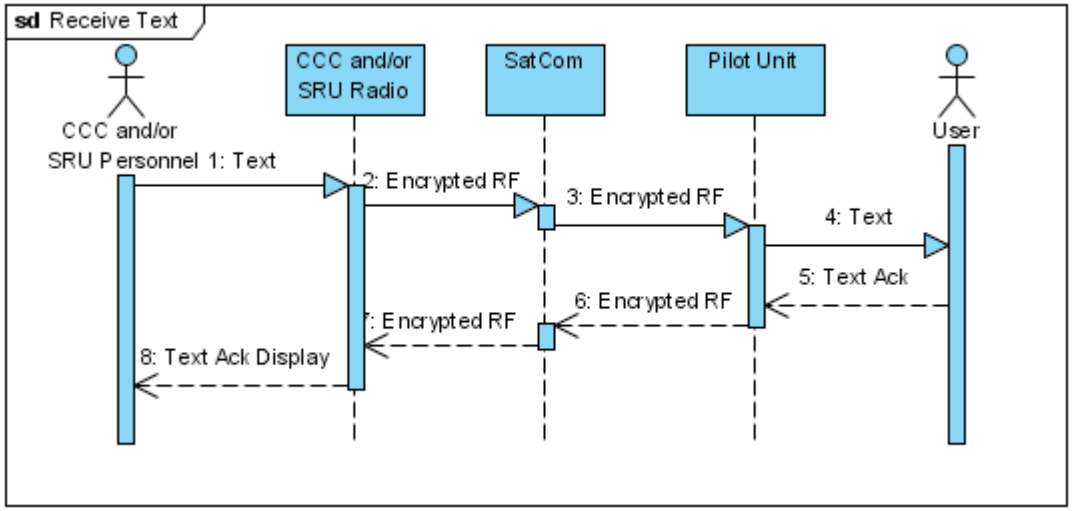
Pilot Unit Subsystem: Class Diagram



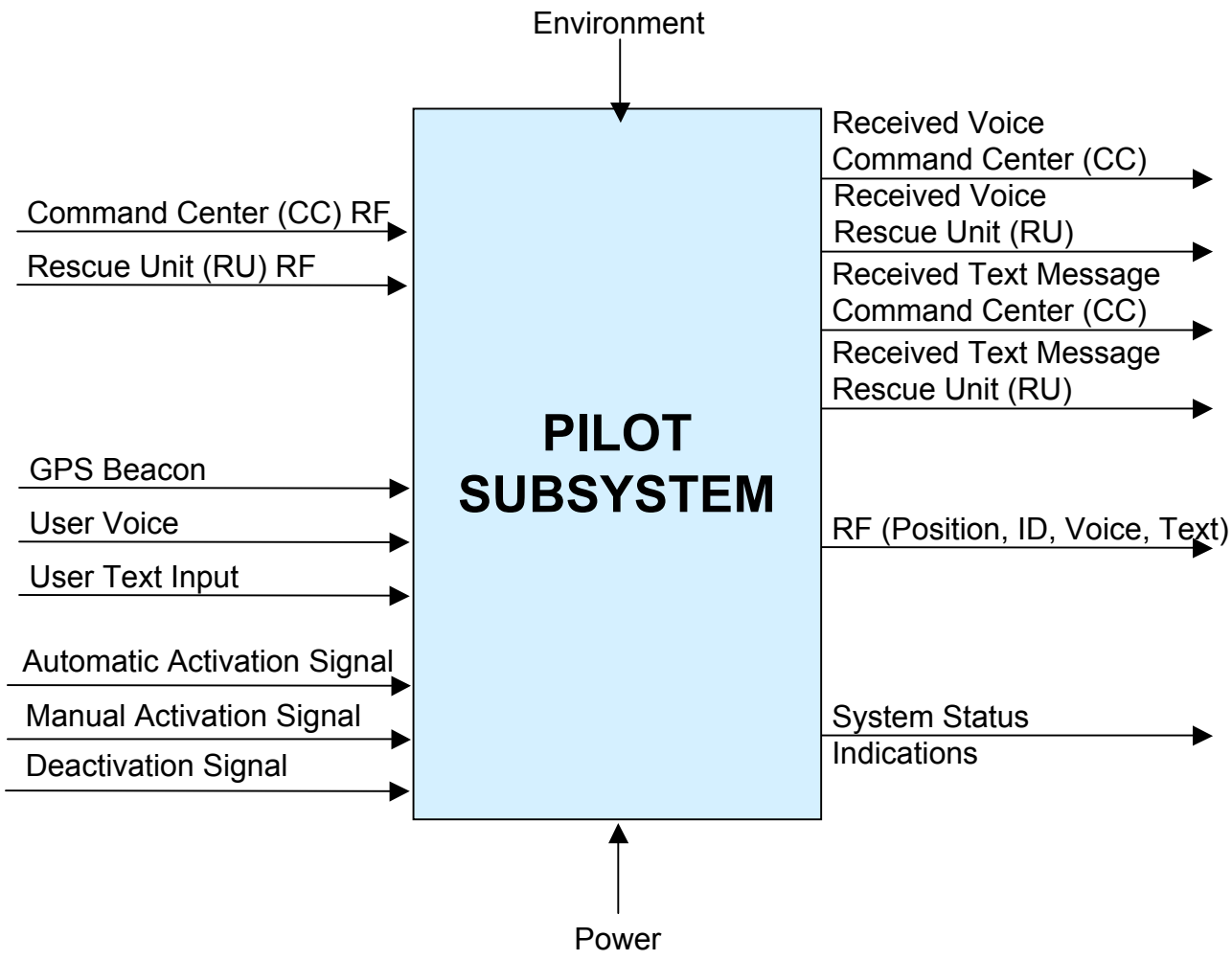
Pilot Unit
Top Level Functional Requirements



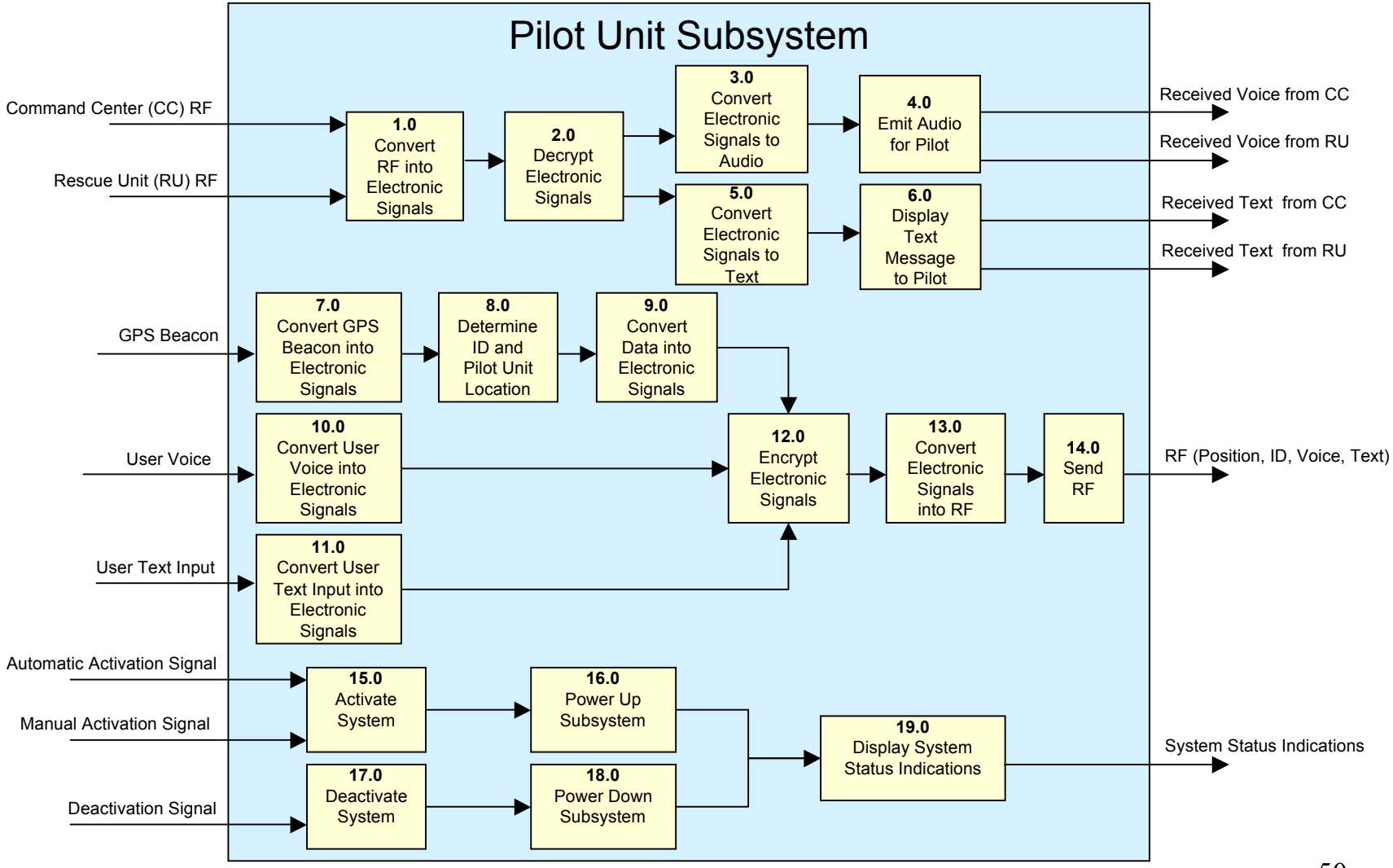
Pilot Unit
Top Level Functional Requirements



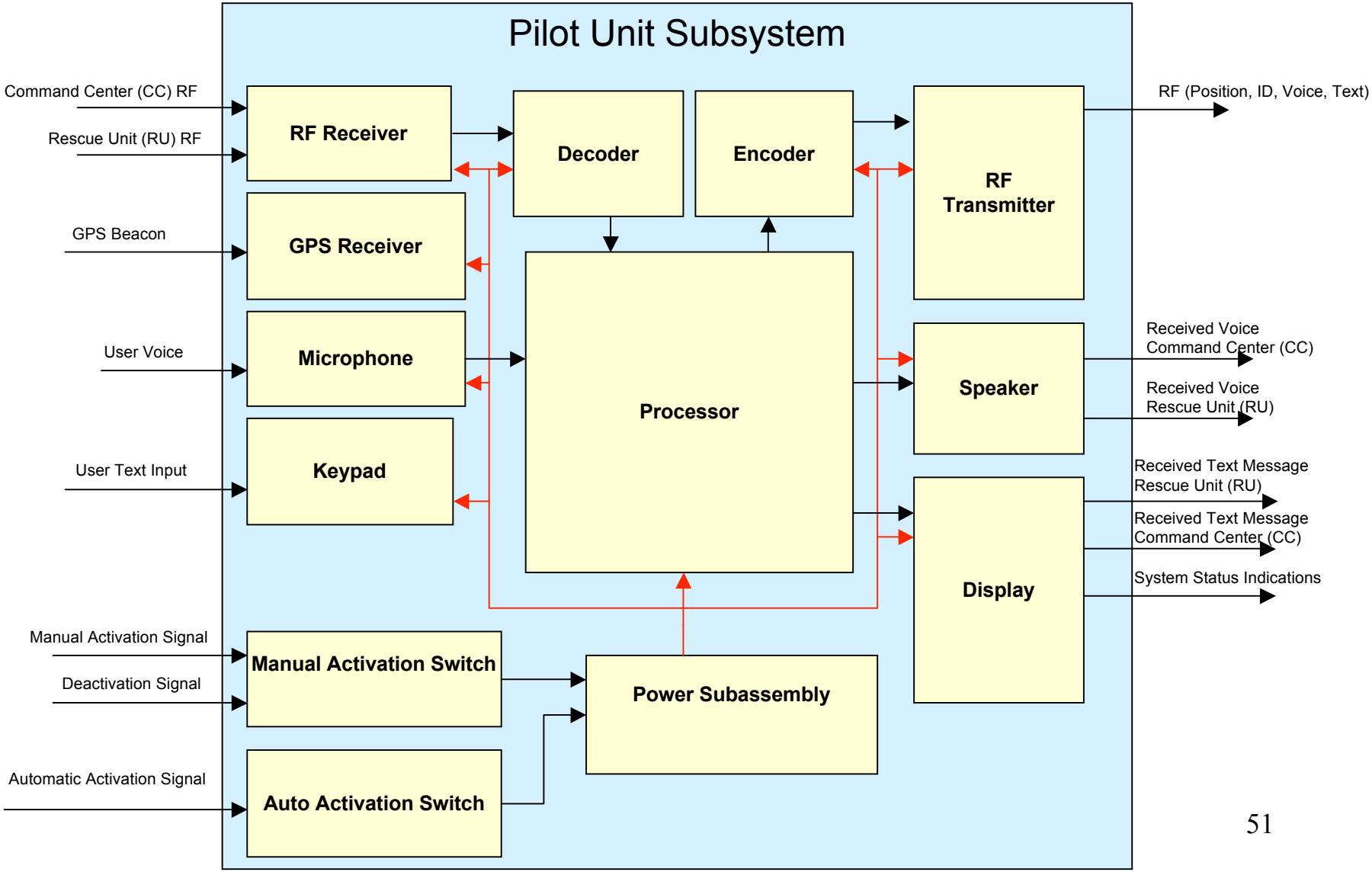
Pilot Unit Context Diagram



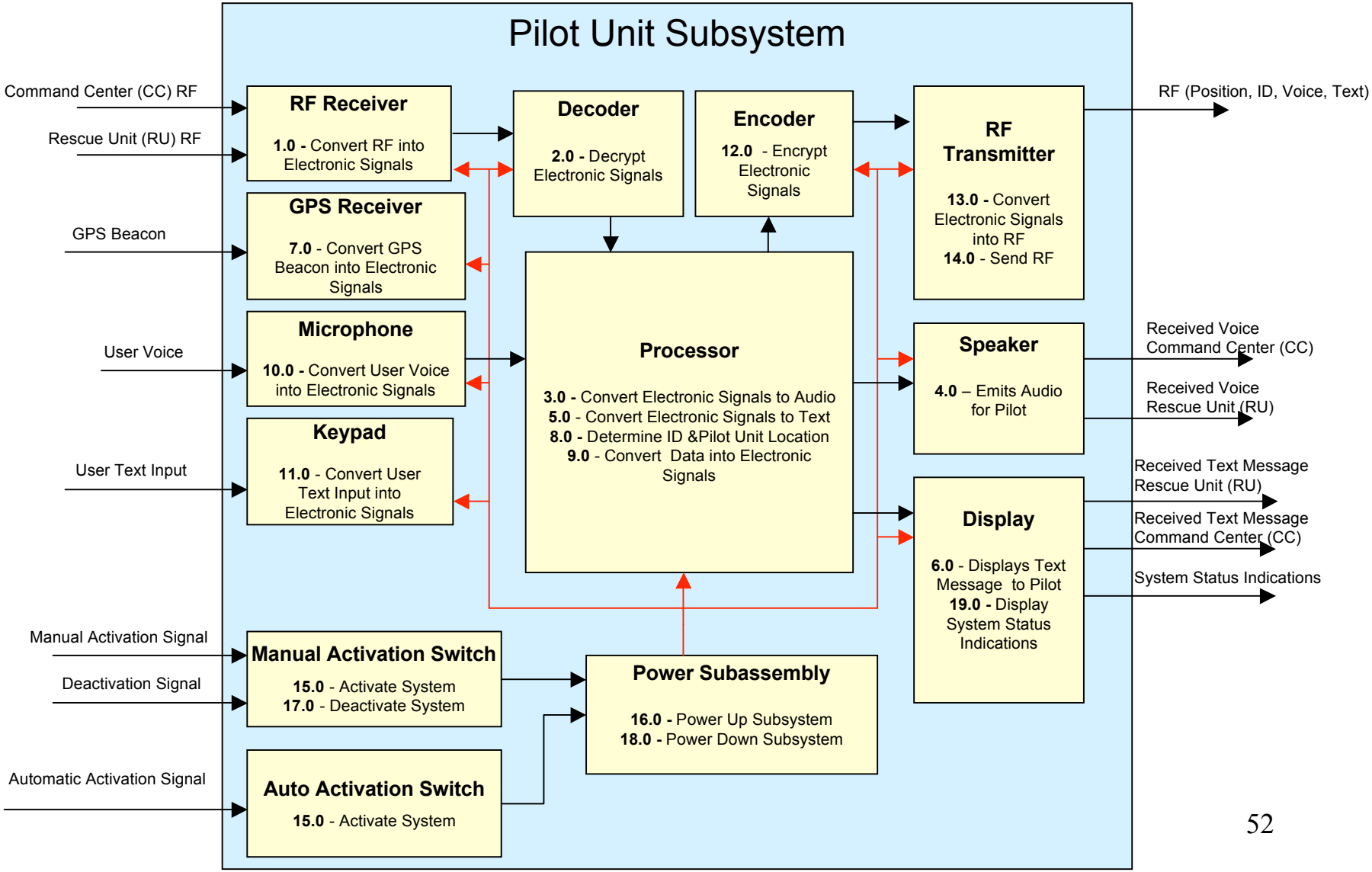
Pilot Unit Functional Diagram



Pilot Unit Physical Diagram



Pilot Unit Allocated Diagram



Alternatives

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

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)

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

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

Selecting Criteria

- Selected criteria based on objectives
- Level of importance
- Collected and organized available data

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**

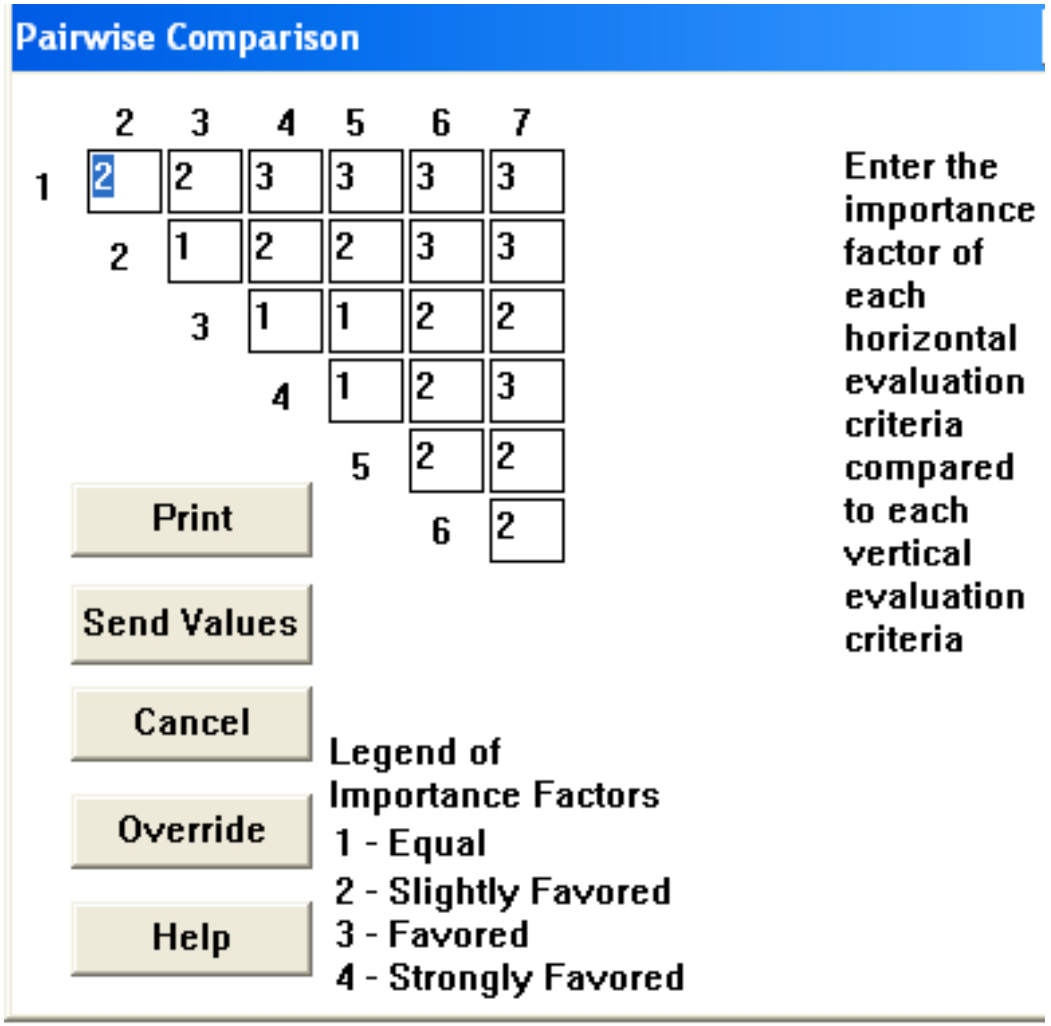
Compare the Alternatives

Priority by rating / Criteria (goal/threshold) / Reason for Priority

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

Compare the Alternatives

Determine Weighting for Criteria



Compare the Alternatives

Priority by rating / Criteria (goal/threshold) / Reason for rating

- Option A superior based on the selected criteria.

DECISION MATRIX Pilot Unit

Weight	4.88	3.20	2.31	2.11	1.98	1.28	1.00	Total
Criteria / COA	Activation	Operational Modes	Positive ID	Battery Life	GPS Loc Accuracy	Ao	Anti-Jam	
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
	Min / Max	Min / Max	Min / Max	Min / Max	Min / Max	Min / Max	Min / Max	

Multiplication Matrix
Less is better
All values times 10^{-12}
Consistency Ratio = 97.74

Sensitivity Analysis

Sensitivity Analysis

Activation: Not Sensitive
Operational Modes: Not Sensitive
Positive ID: Not Sensitive
Battery Life: Not Sensitive
GPS Loc Accuracy: Not Sensitive
Ao: Not Sensitive
Anti-Jam: Not Sensitive

Results of Trade Study

Decision Matrix with Pairwise Comparison

Option A scored higher

The Combat Survivor Evader Locator (CSEL)