Emergency, Need Backup!

Design Document

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Executive Summary

Development Standards & Practices Used

- ED-23C – Minimum Operational Performance Specification for Airborne VHF Receivers
- RTCA/DO-160G – Environmental Conditions and Test Procedures for Airborne Equipment
- MIL-STD-188-243A – Tactical Single Channel Ultra High Frequency (UHF) Radio Communications
- RTCA/DO-254 – Design Assurance Guidance for Airborne Electronic Hardware
- IEEE 802.3 – Ethernet Working Group
- Assorted Simple Networking Management Protocol (SNMP) standards:
    - RFC 3410 – Applicability Statements for the Simple Networking Management Protocol (SNMP)
    - RFC 3411 – An architecture for Describing Simple Networking Management Protocol (SNMP) Management Frameworks
    - RFC 3412 – Message Processing and Dispatching for the Simple Networking Management Protocol (SNMP)
    - RFC 3413 – Simple Networking Management Protocol (SNMP) Applications
    - RFC 3414 – User-Based Security Model (USM) for version 3 of the Simple Networking Management Protocol (SNMPv3)
    - RFC 3415 – View-based Access Control Model (VACM) for the Simple Networking Management Protocol (SNMP)
    - RFC 3417 – Transport mappings for the Simple Networking Management Protocol (SNMP)
    - RFC 3418 – Management Information Base (MIB) for the Simple Networking Management Protocol (SNMP)

Summary of Requirements

This project aims to produce the foundations of a simple emergency backup radio capable of transmitting and receiving signals from 117.975 to 137.000 MHz as well as from 225.000 to 400.000 MHz using amplitude modulation (AM). The radio will receive status and control signals over Ethernet using Simple Networking Management Protocol (SNMP). Future engineering teams will be able to use the prototype produced by this project as the foundation for a future product that will be able to pass civil certification.

Applicable Courses from Iowa State University Curriculum

- EE 201
- EE 224
- EE 230
- EE 321
- CprE 281
- CprE 288

New Skills/Knowledge acquired that was not taught in courses

- Expanded knowledge of radio transmitter and receiver architectures
- Increased understanding of digital communications, particularly via Ethernet
- Experience writing embedded software to control external circuitry
- Practice writing test PC software to inferface with a microcontroller
- Ability to research and select adequate parts to implement a design
- Practical experience testing and debugging a project on the unit and system levels

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1 Introduction

1.1 Acknowledgement

The design team would like to specially thank Dr. Andrew Bolstad for his technical expertise and practical advice, Brendan Getz for his oversight and support, and Collins Aerospace as a whole for the generous funding it provided for this project.

1.2 Problem and Project Statement

Pilots rely on an airplane radio for communication, so if it breaks, they can no longer communicate with air traffic control (ATC) or other aircraft. This causes many problems since ATC is no longer able to communicate with the aircraft to coordinate airspace deconfliction. It also means that the airplane pilots cannot communicate any ongoing problems to ATC.

To solve the myriad complications that can result from a radio malfunction, this project aims to create a backup radio for use as an alternate communication device in the event that an airplane's main radio fails. Designing a backup radio in its entirety is outside the scope of a two semester design class, so this project's goal is to design and implement a prototype capable of basic amplitude modulation (AM) signal transmission and reception as well as sending status updates and receiving commands via ethernet. This prototype will then be used by future engineering teams as the foundation for a full design capable of passing civil certification.

1.3 Operational Environment

The expected operating environment for this project's end product will be an airplane. As such, our product will need to be able to survive a wide range of extreme conditions specified by civilian and military aeronautic standards such as the DO-178, ED-23C, etc.

A civil-certified backup radio will need to be fully operational under the mandated temperature range (-40 to 71 degrees Celsius), and it should be able to survive for short periods of time under even more extreme temperatures without permanent damage (typically -55 to 85 degrees Celsius). The civil-certified version of this radio will also need to pass various other environmental benchmarks including vibration testing, electromagnetic radiation and susceptibility, dust/mold tolerance, and others.

The goal is that this project's final deliverable will be the foundation for a civil-certified radio, not necessarily a certifiable radio in and of itself. As such, this project's final deliverables will be designed with the rugged environment of an airplane in mind, but compliance with the associated aerospace standards is not a strict necessity.

1.4 Requirements

This specification establishes performance requirements for the Receiver/Transmitter (hereby referred to as the RT) Airborne Emergency Back Up communication system.

Project Requirements:

1. The RT shall provide unencrypted voice communications.
2. The RT shall transmit and receive over the following frequency ranges:
    - 117.975 to 137.000 MHz
    - 225 to 400 MHz
3. The RT shall provide the following tuning increments over the defined frequency ranges:

Frequency Range	Tuning Resolution
117.975 to 137.000 MHz	8.33 kHz, 25 kHz
225 to 400 MHz	25 kHz

Table 1: Frequency Range & Tuning Resolution

4. The RT shall support Amplitude Modulation (AM) only.
5. The RT shall adhere to ED-23C (European Air Traffic Control) and shall be classified as a Class H2 receiver and a dual class transmitter (3 and 5)
6. The RT shall provide an Ethernet port in accordance with IEEE 802.3 (10/100 Base-T) for control and status operations.
7. The RT shall provide an Ethernet Simple Network Management Protocol (SNMP) interface for control and status operations.

Command	Options
Frequency	Tunable frequency from 117.975 to 400 MHz
Status	**Options**
Frequency	Report currently tuned frequency from 117.975 to 400 MHz

Tx/Rx Mode	Report currently operational mode
CBIT Results	Report current CBIT results (Optional, see Design Goals)
POST Results	Report POST results (Optional, see Design Goals)

Table 2: Ethernet Command & Status Operations

8. The RT shall provide a discrete input, Push-To-Talk (PTT) that is used to enable/disable transmit operations.
9. The RT shall not exceed 6.0 pounds in total weight
10. The RT shall not exceed 6.0 inches x 6.0 inches x 6.0 inches
11. The RT shall provide an input capable of accepting baseband analog voice signals.
12. The RT shall provide a balanced 150 ohm +/- 10% narrowband audio input interface.
13. The RT shall provide a balanced 600 ohm +/- 10% narrowband audio output interface.
14. The RT electronics piece part cost shall not exceed $1500

In addition to its hard requirements, this project also has some optional design goals that the client desires. These design goals are not absolutely necessary to meet but should be considerations for the designers. If they can be achieved with little project impact, their inclusion is desirable. Considerations should be made to provision for them in a future stage, even if they are not fully completed as part of this project.

<u>Optional Design Goals:</u>

1. The RT should have a path to DO-178C compliance and should incorporate DO-178C design principles.
2. The RT should have a path to DO-254 compliance and should incorporate DO-254 design principles.
3. The RT should provide an interface to operate from a nominal +28V DC power source.
4. The RT should operate in a temperature range from -40 to +71^{o} Celsius.
5. The RT should implement 121.5/243 MHz Guard Monitor capabilities.

(NOTE: Guard Monitor is defined as the simultaneous reception of the main tuned frequency along with either a signal on 243 MHz or 121.5 MHz, selectable by tuned frequency band).

6. The RT should incorporate a modular design allowing for future expansion of capabilities (FM, etc.)
7. The RT should incorporate Power On Self Test (POST) that will complete in no more than 10 seconds.
8. The RT should incorporate Continuous Built In Test (CBIT) which can be executed autonomously without affecting normal system operations.
9. BIT results should be stored in non-volatile memory
10. BIT results should be able to be queried via the Ethernet Command and Control interface.
11. The RT should incorporate a capability to the user to configure an IPv4 address.
12. The RT should allow for top level reprogramming/reloading of firmware and software.

1.5 Intended Users and Uses

The end use for this project's deliverables will be as a foundational design that can eventually be improved to include most or all of its optional design goals and successfully complete civil certification. As such, the anticipated end users for our product will include both engineers at Collins Aerospace and, following the design's completion and certification, airplane pilots.

The fact that this design will be passed to other project teams for further development means that modularity will be a key focus in this project's development to make the final design easily modifiable by future teams. Consequently, concise and perspicuous project documentation will also be critically important.

1.6 Assumptions and Limitations

Assumption:	Justification:
The final product will eventually be used outside the United States.	The project's client wants the design to conform to European standards (ED-23C).
The final product will not be used unless an aircraft's primary radio fails.	This is the definition of a backup radio.
The final product is not intended for use in small engine aircraft.	This project's certification standards apply primarily to commercial aircraft.
The final product will be used by one person at a time.	Aircraft instrumentation is typically designed for a single active user.

Table 3: Design Assumptions

Limitation:	Justification:
The final product must be smaller than 6" x 6" x 6".	This is one of the client's requirements.
The final product must cost less than $1,500 per unit.	This is one of the client's requirements.
The final product must weigh less than 6 lbs.	This is one of the client's requirements.
The final product must be delivered by May 4th, 2021.	This is a class requirement.
The final product should ideally operate off of a 28 Volt DC power supply if possible.	This is one of the client's requirements and is representative of the operational environment in an airplane.
This design's end users will not be blind, deaf, or have other sensory impairments.	The end users, airplane pilots, must possess basic levels of sight and hearing to fly an aircraft.

The environmental tests necessary for civil certification will not be performed during this project's schedule.	This project lacks the necessary facilities to verify full compliance with civil certification requirements.

Table 4: Design Limitations

1.7 Expected End Product and Deliverables

The first deliverable, a paper design, should be finished by November 25th, 2020. This design will be created in accordance with the requirements outlined in section 1.4 of this report and the limitations listed in section 1.6. The first deliverable will be sufficient to theoretically implement all project requirements and as many optional design goals as possible.

The second deliverable, a functional prototype of the radio, should be finished by May 4th, 2021. This prototype will be based on the paper design listed as the first deliverable. The second deliverable should accordingly implement all project requirements and as many of the optional design goals as deemed feasible by the design team.

The third and final deliverable is a completed design document that will include all of the relevant technical information and design specifications pertaining to this project. It will also include results from testing the second deliverable, the radio prototype. This third deliverable is also due May 4th, 2021.

The end product for this project is due May 4th, 2021 and is a combination of the second and third deliverables. As such, it will include an assembled radio prototype along with a design document detailing its specifications and testing results.

2 Project Plan

2.1 Task Decomposition

The task breakdown for this project is given in the following table:

Task No.	Description	Dependent On:
1	Initial Research • Subtask 1: Define the problem • Subtask 2: Determine project requirements • Subtask 3: Define each task and subtask	This is the first task and does not depend on other tasks.

2	Transmitter Design • Subtask 1: Research transmitter architecture • Subtask 2: Design an oscillator that will generate a carrier wave at the desired frequency. • Subtask 3: Design an amplitude modulator that will transmit a message through the carrier wave. • Subtask 4: Design a tuner that will be used to choose which frequency the user wants to transmit at. • Subtask 5: Combine each component and simulate the final transmitter design	This task is dependent on task 1, the initial research of the overall design and the project requirements. Each subtask will depend its predecessor.
3	Receiver Design • Subtask 1: Research receiver architecture. • Subtask 2: Design a modulated signal amplifier that will amplify the transmitted signal from the antenna. • Subtask 3: Design a demodulator that will be used to recover the message from the modulated signal. • Subtask 4: Design an audio amplifier that will amplify that final demodulated message so it can be heard. • Subtask 5: Design a guard monitor that will allow the user to tune into two separate channels. • Subtask 6: Combine each component and simulate the final receiver design.	This task is dependent on task 1, the initial project research. Each subtask will depend on its predecessor.
4	An ethernet Simple Network Management Protocol (SNMP) interface is needed for control and status operations. • Subtask 1: Research ethernet hardware architectures and SNMP. • Subtask 2: Write test PC software that allows the user to send commands • Subtask 3: Design a circuit to implement SNMP control.	This task will rely on task 1, the initial project research. Subtasks 2-4 depend on subtask 1. Subtasks 5-7 are

	• Subtask 4: Write software for the control circuit's microcontroller. • Subtask 5: Implement POST (Power On Self Test). • Subtask 6: Implement CBIT (Continuous Built-in Self Test). • Subtask 7: Implement configurable IPv4 address. • Subtask 8: Integrate each unit and test.	extensions of subtask 4. Subtask 8 depends on subtasks 1-7.
5	Integrate the final design's components together • Subtask 1: Perform unit testing to verify each component's individual operation. • Subtask 2: Integrate the components together. • Subtask 3: Test the integrated design. • Subtask 4: Diagnose problems and make design changes if necessary.	This task is dependent on the completion of tasks 1-4. Each subtask depends on its predecessor.
6	Prototype Implementation • Subtask 1: Select and purchase necessary parts. • Subtask 2: Build the prototype • Subtask 3: Test the prototype	This task depends on the completion of task 5.

Table 5: Task Decomposition

2.2 Risks And Risk Management/Mitigation

The following table identifies risks associated with each project steps and identifies a mitigation plan if the probability of a risk's occurrence is 0.5 or higher.

Task	Risk(s)	Probability	Mitigation Plan
Initial Research	Critical information may not be found.	0.1	
Transmitter Design	Initial design ideas may prove unworkable	0.5	Multiple transmitter architectures will be researched, and

			alternate designs will be developed as alternatives.
Receiver Design	Initial design may prove unworkable.	0.5	Multiple receiver architectures will be researched, and alternate designs will be developed.
SNMP control	Different ethernet hardware may need to be selected. Chosen test software may not interface with the unit well.	0.5 0.5	Several different methods for receiving and sending ethernet will receive design attention. Alternative programs will be considered while planning the test environment.
Component Integration	Components may prove incompatible.	0.5	See risk mitigation strategies for individual unit redesigns.
Power (Optional)	The design team may have insufficient time to develop power circuitry.	0.75	Implementing circuitry to power the entire radio from a 28V DC supply is a stretch goal, not a design requirement, and is therefore not critical to include.
Prototype Construction	Chosen parts may prove incompatible.	0.2	

Table 6: Risks & Mitigation Strategies

2.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

Tasks (and Subtasks):	**Completion Criteria:**
Initial Research	
Create a problem definition	Client approval
Determine project requirements	Client verification
Determine tasks and subtasks	Completion of the design document's 2^{nd} chapter.
Transmitter Design	
Research transmitter architectures	Engineers have sufficient knowledge to begin transmitter design.
Design a local oscillator	Selection of local oscillator design and accompanying implementation with CAD software.
Design an AM modulator	Selection of AM modulator design and accompanying implementation with CAD software.
Design a tuner	Selection of tuner design and accompanying implementation with CAD software.
Integration and simulation	Completion of full transmitter schematic accompanied by simulations verifying that it can transmit high-frequency AM carrier waves.

Receiver Design	
Research receiver architectures	Accrual of sufficient knowledge to begin transmitter design.
Design a low-noise signal amplifier	Selection of low-noise signal amplifier design and accompanying implmenetation in CAD software.
Design an AM demodulator	Selection of AM demodulator design and accompanying implementation in CAD software.
Design a demodulated signal amplifier	Selection of message signal amplifier design and accompanying implementation in CAD software.
Design a guard monitor	Selection of guard monitor design and accompanying implementation in CAD software.
Integration and simulation	Completion of full receiver schematic accompanied by simulations verifying that it can receive and demodulate a high-frequency AM signal and convert it into a low-frequency audio signal.
SNMP Control/Status Design	
Research SNMP	Accrual of sufficient knowledge to begin writing test PC and microcontroller software.
Write PC test software	Completion of test software with a user interface that allows transmission of SNMP status/control messages to the radio.

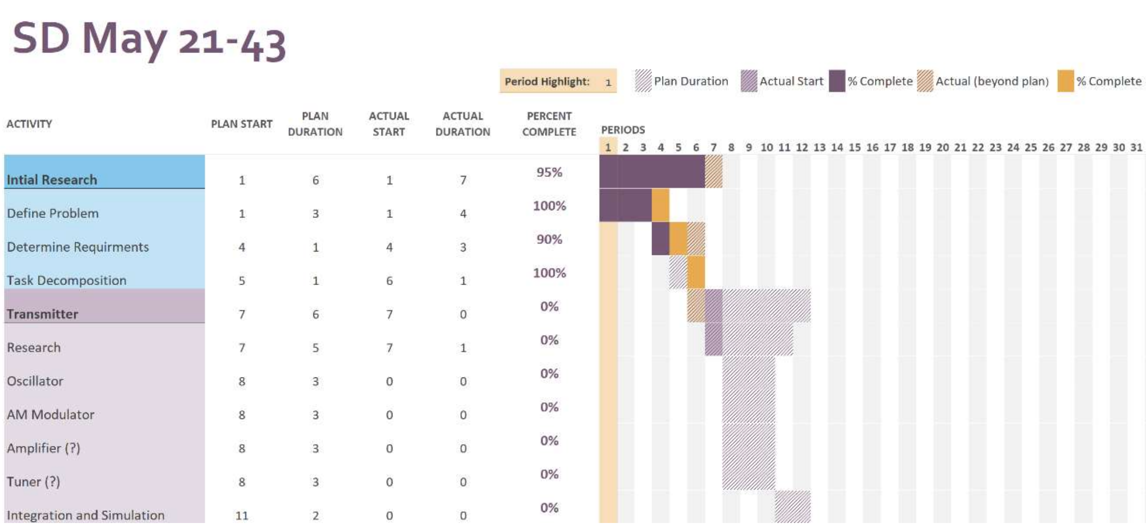
SNMP system design	Selection of an appropriate microcontroller and surrounding circuitry to achieve SNMP control of the radio
Write microcontroller SNMP software	Implementation of SNMP message reception for PC-based SNMP requests that controls the radio's behavior based on each command.
Implement CBIT (Continuous Built-In Test)	Completion of software to implement CBIT functionality.
Implement POST (Power On Self Test)	Completion of software to implement POST functionality.
Implement configurable IPv4 address	Completion of software to implement configurable IPv4 functionality.
Integration and testing	Verification that the microcontroller can receive SNMP messages from a test PC and query/command the radio accordingly.
Component Integration	
Initial component design	Completion of each individual circuit component (outlined in tasks 2-4).
Device integration and simulation	Functioning combination of the transmitter, receiver, and SNMP control circuits into a single design.
System Redesign	Modification of any components that cease functioning after integration to restore correct operation.

Prototype Construction	
List necessary parts	Creation of a complete list of necessary parts complete with specific part numbers, prices, and vendors.
Build the prototype	Construction of a prototype of the integrated RT system that can be powered on.
Test the prototype	Verification that testing demonstrates the final design's compliance with its requirements.

Table 7: Project Proposed Milestones, Metrics, and Evaluation Criteria

2.4 Project Timeline/Schedule

The following Gantt chart shows this project's timeline in terms of each task and subtask:



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Period Highlight: 1 | Plan Duration | Actual Start | % Complete | Actual (beyond plan) | % Complete

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Intial Research	1	6	1	7	95%
Define Problem	1	3	1	4	100%
Determine Requirments	4	1	4	3	90%
Task Decomposition	5	1	6	1	100%
Transmitter	7	6	7	0	0%
Research	7	5	7	1	0%
Oscillator	8	3	0	0	0%
AM Modulator	8	3	0	0	0%
Amplifier (?)	8	3	0	0	0%
Tuner (?)	8	3	0	0	0%
Integration and Simulation	11	2	0	0	0%

Receiver	7	6	7	0	0%
Research	7	5	0	0	0%
Modulated Signal Amplifier	8	3	0	0	0%
Demodulator	8	2	0	0	0%
Message Signal Amplifer	8	3	0	0	0%
Tuner	8	2	0	0	0%
Guard Monitor	10	1	0	0	0%
Simulation	11	2	0	0	0%
SNMP	7	6	7	0	0%
Research	7	5	0	0	0%
Test PC Software	8	3	0	0	0%
Digital Hardware/Control Logic	8	3	0	0	0%
Microcontroller Software	11	1	0	0	0%
CBIT (Continous Built in Test)	11	1	0	0	0%
POST (Power on Self Test)	11	1	0	0	0%
Configurable IPv4 adress	11	1	0	0	0%
Integration and Simulation	11	2	0	0	0%
Microcontroller Software	11	1	0	0	0%
CBIT (Continous Built in Test)	11	1	0	0	0%
POST (Power on Self Test)	11	1	0	0	0%
Configurable IPv4 adress	11	1	0	0	0%
Integration and Simulation	11	2	0	0	0%
Integrating Individual Components	12	5	0	0	0%
Initial Design	12	2	0	0	0%
Integration and Simulation	14	3	0	0	0%
Redesign (if needed)	17	2	0	0	0%
Prototype	17	15	0	0	0%
Determine Parts	17	2	0	0	0%
Build	19	2	0	0	0%
Test	22	10	0	0	0%

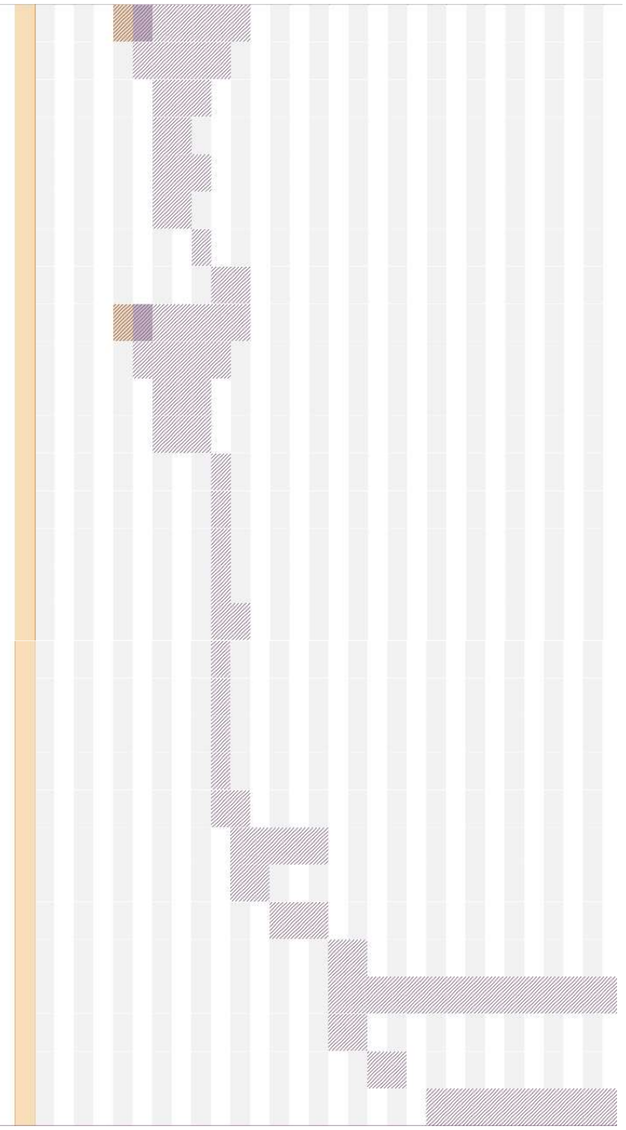

Figure 1: Gantt Chart of Project Timeline

2.5 Project Tracking Procedures

To keep track of work and communication, the design team will use Microsoft Teams. The most significant benefit of MS Teams is that it allows for the creation of collaborative Microsoft Office files that can be modified simultaneously by multiple users. It also allows the design team to track its schedule using built-in features, create separate discussion channels for different topics, and engage in virtual meetings. This amalgamation of critical functions in a single software application will help the design team to make quick, efficient progress.

2.6 Personnel Effort Requirements

The following table displays the estimated time needed for the design team to complete each of its tasks and subtasks:

Task or Subtasks	Estimated Number of Person Hours Required to Complete
Initial Research	
Initial Research: Define Problem	80
Initial Research: Determine Requirements	10
Initial Research: Task Decomposition	10
Initial Research: Total Estimated Time	**100**
Transmitter	
Transmitter: Research	60
Transmitter: Local Oscillator	40
Transmitter: AM Modulator	40
Transmitter: Amplifier	30
Transmitter: Tuner	25
Transmitter: Integration and Simulation	40

Transmitter: Total Estimated Time	**235**
Receiver	
Receiver: Research	60
Receiver: Modulated Signal Amplifier	30
Receiver: Demodulator	30
Receiver: Message Signal Amplifier	20
Receiver: Tuner	25
Receiver: Guard Monitor	20
Receiver: Simulation	30
Receiver: Total Estimated Time	**215**
SNMP	
SNMP: Research	60
SNMP: Test PC Software	40
SNMP: Digital Hardware/Control Logic	60
SNMP: Microcontroller Software	40
SNMP: CBIT (Continuous Built in Test)	30
SNMP: POST (Power on Self-Test)	30
SNMP: Configurable IPv4 address	30
SNMP: Integration and Simulation	20
SNMP: Total Estimated Time	**310**
Component Integration	

Component Integration: Initial Design	60
Component Integration: Testing	60
Component Integration: Redesign - Optional	0 - 150
Component Integration: Total Estimated Time	**120- 270**
Prototype	
Prototype: Determine Parts	40
Prototype: Build	40
Prototype: Test	40
Prototype: Total Estimated Time	**120**

Table 8: Estimated Personnel Effort Requirements

2.7 Other Resource Requirements

The design team will need access to DO-178C, DO-254, ED-23C documents to meet civil certified and European Air Traffic Control requirements. In terms of parts, the designers will need access to basic circuit components such as resistors, capacitors, inductors, diodes, and operational amplifiers in addition to a microcontroller (or possibly an FPGA board) for the SNMP control logic. Standard lab equipment such as variable power supplies, oscilloscopes, voltmeters, and ammeters will be needed to test the final prototype.

2.8 Financial Requirements

Currently the design team is allotted $1,500.00 in funding to meet its goals. The entirety of the project must comply with this budget.

3 Design

3.1 Previous Work And Literature

Include relevant background/literature review for the project

– *If similar products exist in the market, describe what has already been done*

– *If you are following previous work, cite that and discuss the* ***advantages/shortcomings***

– *Note that while you are not expected to "compete" with other existing products / research groups, you should be able to differentiate your project from what is available*

Detail any similar products or research done on this topic previously. Please cite your sources and include them in your references. All figures must be captioned and referenced in your text.

3.2 Design Thinking

Detail any design thinking driven design "define" aspects that shape your design. Enumerate some of the other design choices that came up in your design thinking "ideate" phase.

3.3 Proposed Design

Include any/all possible methods of approach to solving the problem:

Discuss what you have done so far – what have you tried/implemented/tested?

Some discussion of how this design satisfies the ***functional and non-functional requirements*** *of the project.*

If any ***standards*** *are relevant to your project (e.g. IEEE standards, NIST standards) discuss the applicability of those standards here*

This design description should be in ***sufficient detail*** *that another team of engineers can look through it and implement it.*

3.4 Technology Considerations

Highlight the strengths, weakness, and trade-offs made in technology available.

Discuss possible solutions and design alternatives

3.5 Design Analysis

– *Did your proposed design from 3.3 work? Why or why not?*

– *What are your observations, thoughts, and ideas to modify or iterate over the design?*

3.6 Development Process

Discuss what development process you are following with a rationale for it – Waterfall, TDD, Agile. Note that this is not necessarily only for software projects. Development processes are applicable for all design projects.

3.7 Design Plan

Describe a design plan with respect to use-cases within the context of requirements, modules in your design (dependency/concurrency of modules through a module diagram, interfaces, architectural overview), module constraints tied to requirements.

4 Testing

Testing is an ***extremely*** *important component of most projects, whether it involves a circuit, a process, or software.*

1. Define the needed types of tests (unit testing for modules, integrity testing for interfaces, user-study or acceptance testing for functional and non-functional requirements).
2. Define/identify the individual items/units and interfaces to be tested.
3. Define, design, and develop the actual test cases.
4. Determine the anticipated test results for each test case

5. Perform the actual tests.
6. Evaluate the actual test results.
7. Make the necessary changes to the product being tested

8. Perform any necessary retesting
9. Document the entire testing process and its results

Include Functional and Non-Functional Testing, Modeling and Simulations, challenges you have determined.

4.1 Unit Testing

– Discuss any hardware/software units being tested in isolation

4.2 Interface Testing

– Discuss how the composition of two or more units (interfaces) are to be tested. Enumerate all the relevant interfaces in your design.

4.3 Acceptance Testing

How will you demonstrate that the design requirements, both functional and non-functional are being met? How would you involve your client in the acceptance testing?

4.4 Results

– List and explain any and all results obtained so far during the testing phase

Include failures and successes

Explain what you learned and how you are planning to change the design iteratively as you progress with your project

If you are including figures, please include captions and cite it in the text

5 Implementation

Describe any (preliminary) implementation plan for the next semester for your proposed design in 3.3.

6 Closing Material

6.1 Conclusion

Summarize the work you have done so far. Briefly re-iterate your goals. Then, re-iterate the best plan of action (or solution) to achieving your goals and indicate why this surpasses all other possible solutions tested.

6.2 References

List technical references and related work / market survey references. Do professional citation style (ex. IEEE).

6.3 Appendix A: Abbreviations & Acronyms

Abbreviation/Acronym	Definition
ATC	Air Traffic Control
AM	Amplitude Modulation
RT	Receiver/Transmitter
SNMP	Simple Networking Management Protocol
CBIT	Continuous Built-in Test
POST	Power On Self Test
PTT	Push to Talk

6.4 <additional appendices TBD>