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ARISS
Prototype: Automation and Remote Control (ARC) of the IORS

1 Introduction

The Interoperable Radio System (IORS) aboard the International Space Station (ISS) plays a vital role in fostering communication between astronauts and educational organizations worldwide, allowing for real-time interactions that inspire students and promote STEM education.

Currently, the operation of the IORS on the ISS relies heavily on manual intervention by astronauts. For example, to change radio settings or initiate a Slow Scan Television (SSTV) event ground teams must arrange for a member of the ISS Crew to make the adjustments. This process can take days or weeks, depending on astronaut availability and mission priorities. The reliance on manual operation not only introduces delays but also limits the flexibility and responsiveness of the system.

An in-flight project to develop a Student Virtual Mission Control (SVMC), using a set of sensors on the ISS called the Student On-Orbit Sensor System (SOOSS), requires control over the IORS and it is unrealistic for the ISS Crew to continually switch this off and on.

The need for a more efficient solution is therefore clear, as interest in STEM programs like SVMC continues to grow. By automating and remotely controlling the IORS, ARC can potentially address these issues, offering a solution for scheduling and executing radio events without placing additional demands on the crew.

ARISS Engineering has created a prototype of the Automation and Remote Control (ARC) system, a software and hardware solution, designed to automate and remotely manage the IORS from the ground. This system reduces the dependency on astronaut involvement. It allows the scheduling and execution of tasks, such as the Cross Band Repeater, APRS Digipeater, SOOSS telemetry or SSTV transmissions, all while maintaining the ability for crew members to take manual control at any time. The ARC system uses COTS technologies and custom-built software to provide a flexible and reliable remote-control solution, tailored to the unique environment of the ISS.

1.1 Acronyms

ARISS	Amateur Radio on the International Space Station
COTS	Commercial off the Shelf
FTL0	File Transfer Level Zero. The PACSAT File Upload protocol and Service.
IORS	Inter-Operable Radio System
MVPS	Multi Voltage Power Supply
PB	PACSAT Broadcast Service
PM	The Program Mode on the IORS Radio. e.g., PM-2 is the cross-band repeater
SOOSS	Student On-Orbit Sensor System

STEM	Science, Technology, Engineering, Math
SVMC	Student Virtual Mission Control
TNC	Terminal Node Controller (a modem for AX25, usually in software)

2 The ARC System Prototype

2.1 Overview

The Automation and Remote Control (ARC) system is developed to integrate with the Interoperable Radio System (IORS) and enable ground stations to manage operations remotely. ARC utilizes a Raspberry Pi as its central controller, connected to the radio system via a DigiRig Audio interface, which handles audio and data transmission. Separately there are two serial connections to adjust the radio settings. This setup provides remote control over key functions, such as mode changes and the scheduling of events.

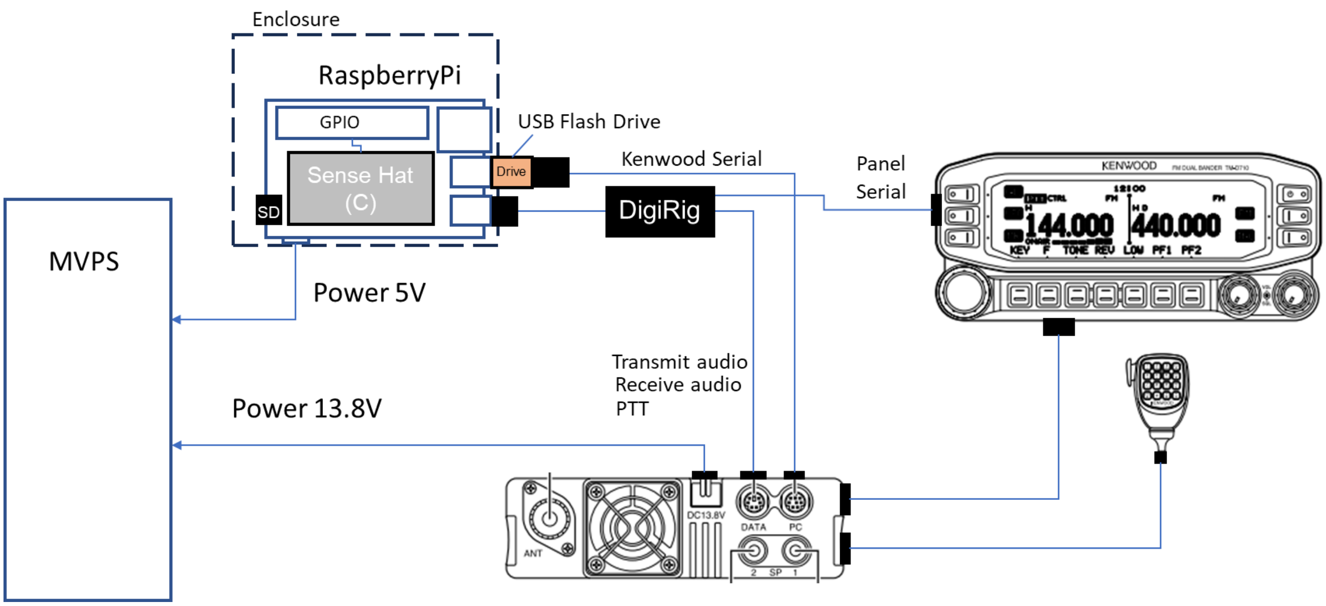

Diagram 1: ARC System Components

2.2 Key Features

2.2.1 Protocols

The ARC system utilizes the AX.25 and FX.25 protocols, using Reed-Solomon forward error correction to improve data integrity during communication. This enhances reliability in transmitting commands and data. While there are theoretically better choices for earth to spacecraft communication, AX.25/FX.25 was chosen because the Kenwood TM-D710 radio used in the IORS only support Frequency Modulation (FM). Using AX.25 also allows us to seamlessly support existing ARISS ISS operations, such as the APRS Digipeater, alongside the remote-control capabilities.

2.2.2 File System

ARC supports an in-orbit file system that uses the PACSAT protocols. This will store results from the SOOSS telemetry, logs or other system data. It will also allow the upload of files. These can be configuration files or data files for transmission, such as images. This allows ground stations to prepare content in advance of scheduled events, such as the broadcast of SSTV.

2.2.3 Telemetry

Telemetry, such as data from the Student On-Orbit Sensor System (SOOSS), can be transmitted in real-time or stored in files in the PACSAT File System for later retrieval, depending on the mission's needs.

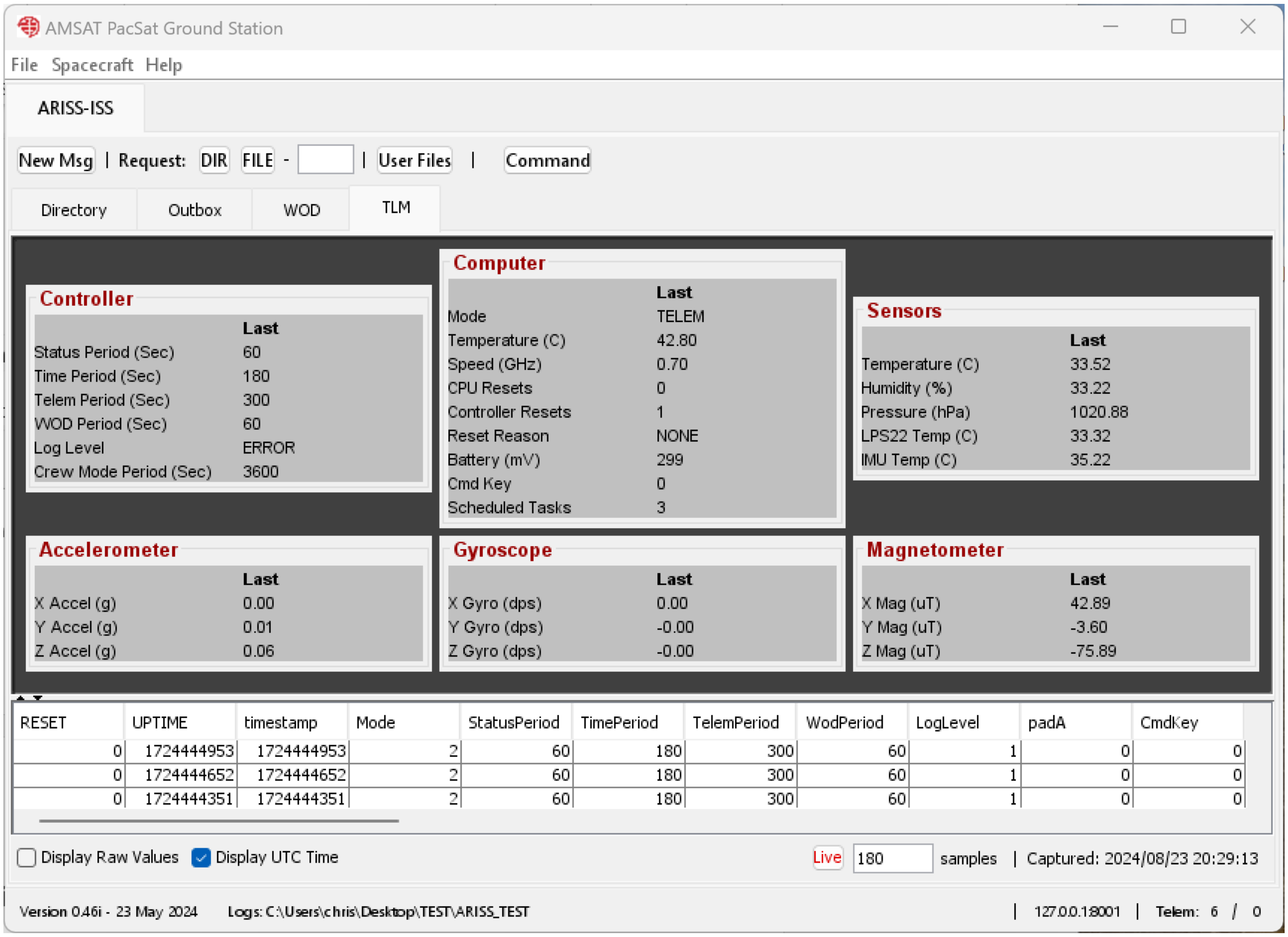

Diagram 2: Telemetry

2.2.4 Crew Interface

ARC features a crew interface, allowing astronauts to manually take control of the radio when needed. By pressing a button, the crew can override the ARC system for a specified period, preventing automated changes during that time. This approach ensures the crew retains the flexibility to use the radio without being interrupted by automated operations.

Diagram 3: Crew Interface Diagram

While the Crew are in control of the radio the Green LED shuts off and two amber LEDs light. A timer counts down with a default of 60 mins. When half of the timer is left (default 30 mins) one of the amber LEDs goes out. When 30 seconds remain the last amber LED flashes on and off. At any time during the count down the crew can re-press the button to reset the timer to 60 mins or long press the button to immediately return control to ARC.

When the ARC reasserts control over the radio any modifications or changes to the radio made by the crew are reset. Any pending scheduled events are executed.

2.3 Software

The Raspberry Pi runs a custom software program called IORS Control (iors_control). This interfaces with the radio, the Software TNC (Direwolf) and any other programs that are launched.

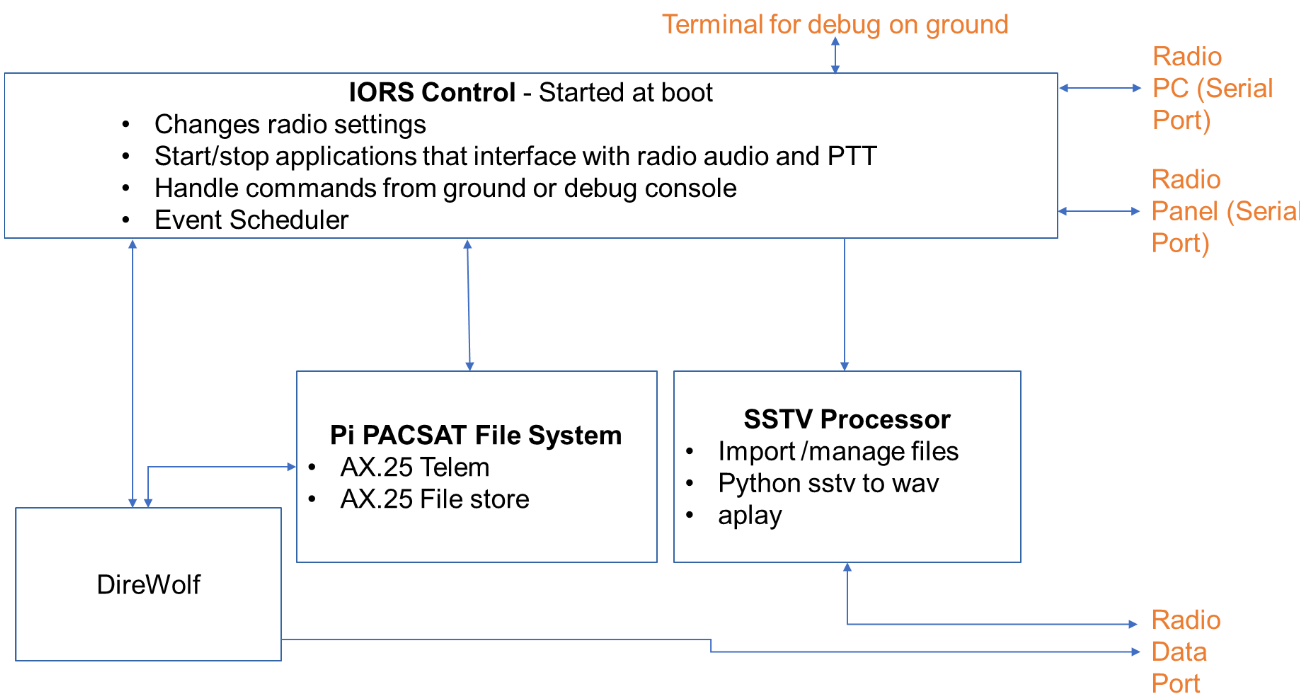

Diagram 4: Software Architecture

2.4 File System Mode

In file system mode ARC will broadcast a list of files stored in the file system. This includes log files, SOOSS telemetry, whole orbit data, configuration, the schedule or any uploaded images

Directory | Outbox | WOD | TLM

File	Pri	State	To	From	Uploaded	Size	Holes	Title	Type	Keywords	Zip
6			ARISS	VE2TCP	24 Aug 24 15...	12218	1/ 0%	3-Tim-Peak	JPG-16		
5			LOG	VE2TCP-12	24 Aug 24 15...	232	1/ 0%	log2408240048	Log-223		
4			WOD	VE2TCP-12	24 Aug 24 15...	7752	1/ 0%	wod2408240048	WOD ...		PKZIP
3		MSG	LOG	VE2TCP-12	23 Aug 24 20...	183	0/1...	log2408232038	Log-223		
2		MSG	WOD	VE2TCP-12	23 Aug 24 20...	1489	0/1...	wod2408232038	WOD ...		PKZIP

Diagram 5: File System Directory Listing

For example, new images for future SSTV events can be prepared in the Pacsat ground station software. These are then automatically uploaded by the command station when the ISS is over their station. This all works seamlessly with the PACSAT protocols

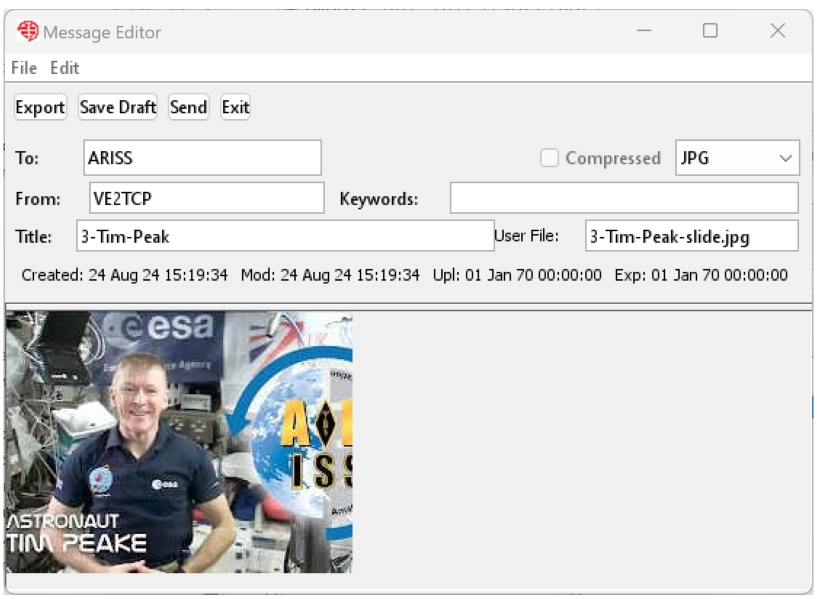

Diagram 6: An image prepared for automatic upload

3 Technical Challenges and Solutions

The development of ARC required addressing several technical challenges specific to operating in the ISS environment.

3.1 Sudden Power Loss

One major challenge is ensuring that the system can handle sudden power interruptions, as astronauts may need to shut down the system at any time for safety reasons, such as during extravehicular activities (EVA) or when spacecraft are docking. To prevent corruption of the Raspberry Pi's file system, ARC uses an Overlay File System, which effectively makes the SD card read-only, thereby protecting it during unexpected power-offs. A USB drive is used to store key configuration data, though this introduces a potential risk of data corruption, which the software mitigates by implementing error detection and recovery measures.

3.2 Heat management in microgravity

Heat management is another significant concern, as the Raspberry Pi can generate heat during prolonged operation. In the microgravity environment of the ISS, traditional convection-based cooling methods are not effective, so the ARC enclosure design includes dual fans to ensure heat dissipation. NASA requires two fans to provide redundancy in case of failure, and the design must also meet noise regulations to avoid introducing additional sound into the already noise-sensitive ISS cabin.

3.3 Prototype Enclosure

[Enclosure designs by Hunter McNamara]
NASA has many requirements to ensure that enclosures have no sharp edges and meet all safety requirements, such as for flammability, outgassing, EMI shielding and many more. The design of the final enclosure is ongoing. Currently we have a simple prototype case that can be 3D printed

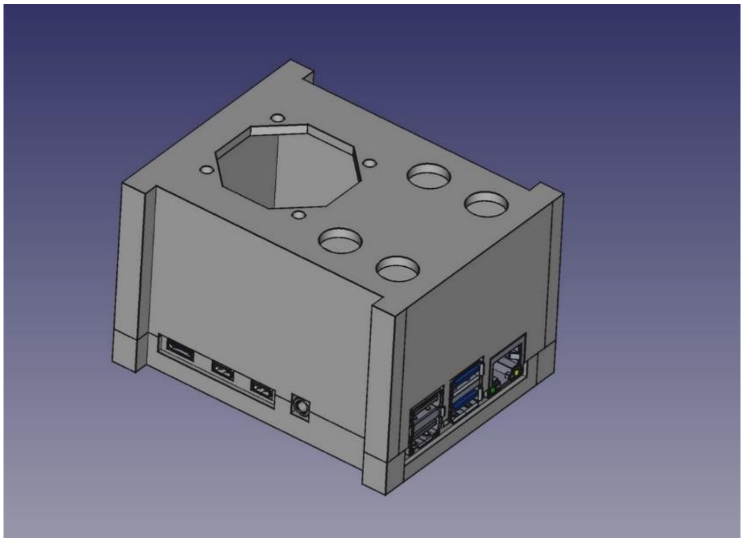

Diagram 7: Prototype Enclosure Design

3.4 Future Enclosure

The future case will likely be anodized aluminum, to enhance shielding. It will support the SOOSS and Raspberry Pi on one side and have room for future expansion on the other side. This case would fit seamlessly underneath the existing MVPS.

Enclosure will be a modified COTS enclosure

- Takachi HY70-28-23 aluminum electronics enclosure
- Almost identical model as MVPS enclosure (different height)

Major modifications:

- Remove heat sink fins on one side panel
- Add holes for drawers, fans, vents, connectors, and fasteners
- Several additional newly manufactured parts

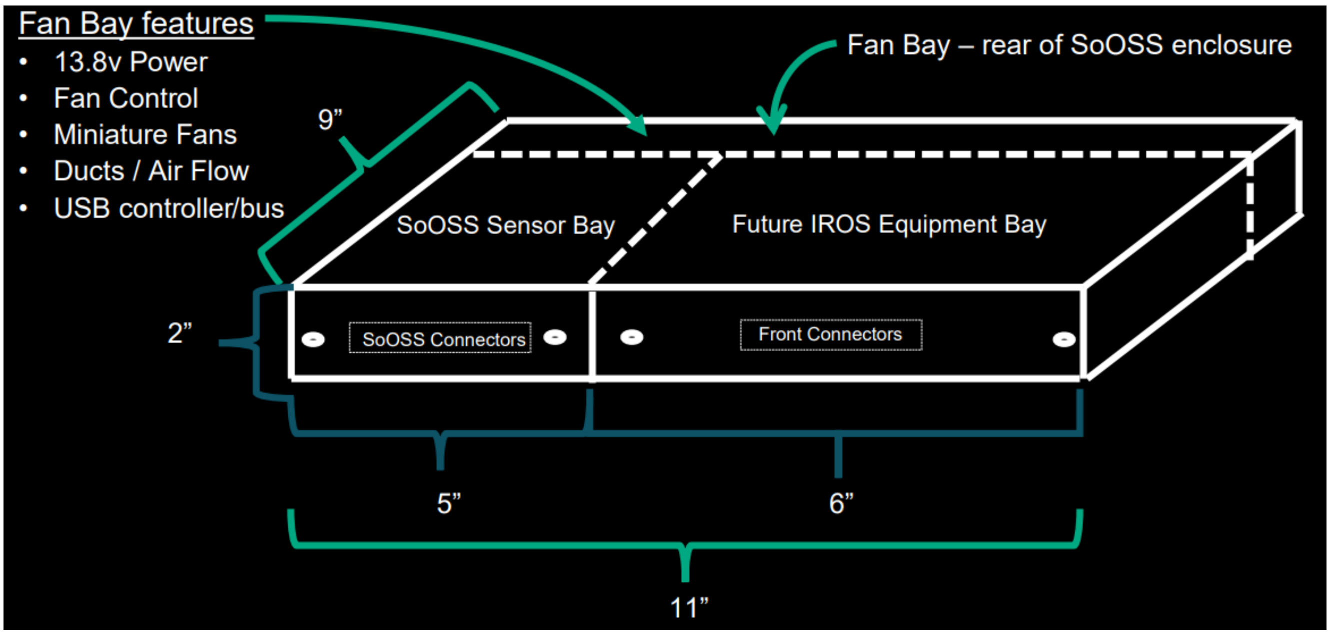

Diagram 8: Future Concept for Final Enclosure Design

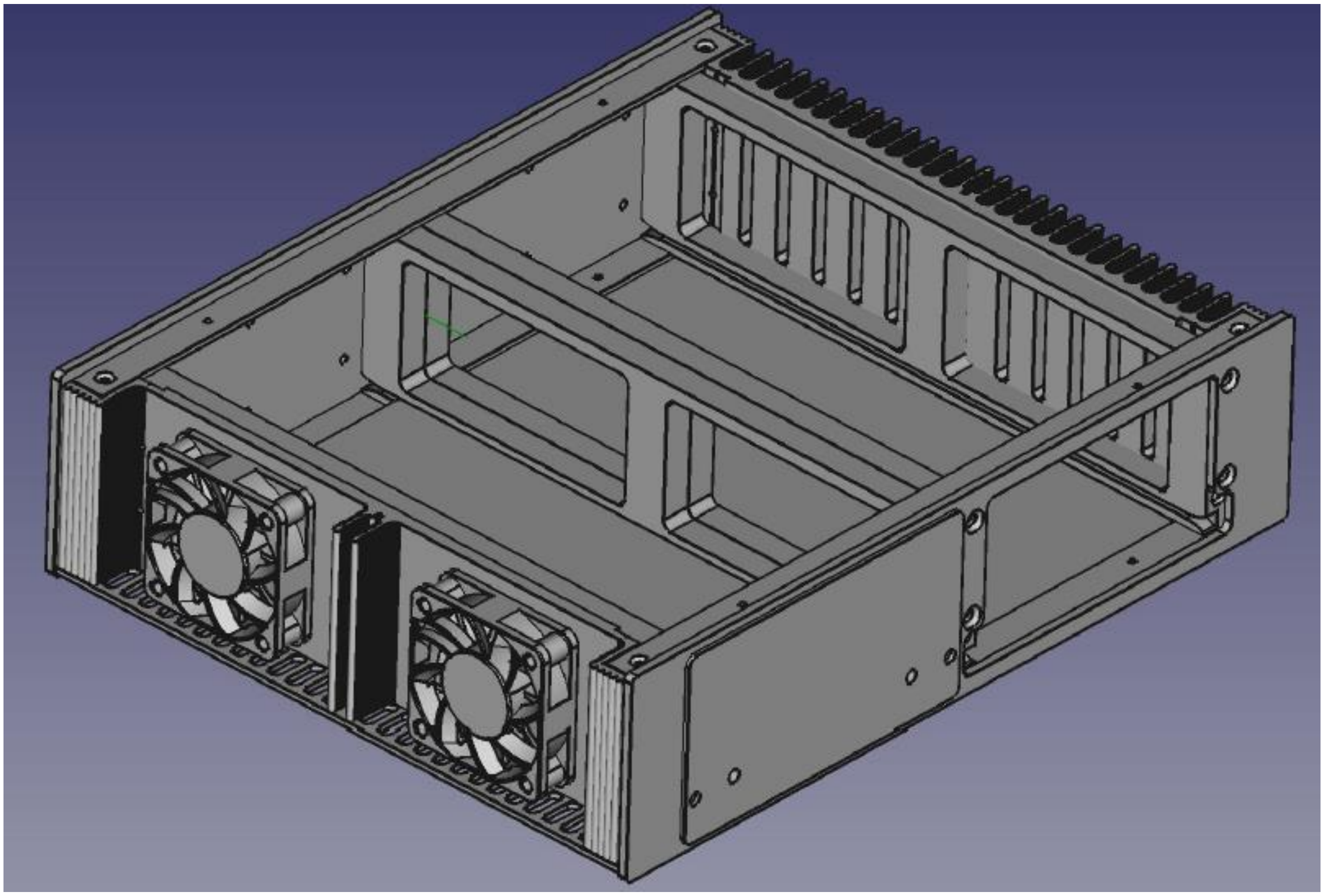

Diagram 9: Design for Target Enclosure Design

4 Testing and Future applications

The ARC system has undergone extensive testing in its development phase, including prototype tests in a lab environment to simulate the functionality required for ISS operations. These initial tests have verified the system's ability to control the IORS remotely, schedule SSTV events, and handle telemetry transmission. The next phase of testing will involve building flight units in the target enclosure and acting as ground stations, further validating ARC's performance in more rigorous conditions.

Looking ahead, ARC has the potential to greatly enhance the operational flexibility of the IORS on the ISS. By reducing the reliance on astronaut intervention, the system enables more frequent and efficient communication events, benefiting both crew members and educational outreach programs. Additionally, the inclusion of the Student On-Orbit Sensor System (SOOSS) provides unique opportunities for schools to engage in the Student Virtual Mission Control (SVMC) with real-time space data, expanding ARC's educational impact.

5 Conclusions

The Automation and Remote Control (ARC) system could be a key enhancement to the operation of the Interoperable Radio System (IORS) on the ISS. By enabling remote control of the IORS and automating critical functions such as SSTV event scheduling, ARC reduces the need for astronaut involvement and provides greater flexibility for communication and educational outreach. The system's integration of easily understood Amateur Radio communication protocols, including forward error correction and telemetry capabilities, make it a robust learning and teaching solution for understanding the challenges of space communication.

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