# SpaceScope: A Satellite-Connected Digital Stethoscope for Remote Health Monitoring

Ayush Pradhan
*Software Developer*
*ReOrbit Space*
*Helsinki, Finland*
ayushpradhan1@gmail.com

Chaitanya Kasambe
*Avionics Systems Engineer*
*ReOrbit Space*
*Helsinki, Finland*
cakasambe@gmail.com

***Abstract* -- The stethoscope has been a fundamental tool in clinical diagnosis for over 200 years, traditionally serving as an analog device operated by healthcare professionals. Despite advancements in telemedicine for monitoring basic health metrics, real-time auscultation remains largely inaccessible, especially in rural or isolated regions with limited connectivity. This work introduces SpaceScope, a cutting-edge satellite-connected digital stethoscope aimed at overcoming these barriers. SpaceScope enables the transmission of critical health data—including heart sounds, blood oxygen levels, and body temperature—to healthcare providers in real-time, even in areas with minimal or no mobile internet infrastructure. Specifically designed for use in remote and extreme conditions such as offshore rigs, polar expeditions, conflict zones, and rural outlands, SpaceScope supports accurate and timely medical assessments. By facilitating remote auscultation and reducing the reliance on high-risk emergency evacuations, it significantly enhances healthcare access and informed decision-making in underserved regions. This innovative solution promises to transform healthcare delivery in areas where conventional systems fail to reach.**

***Keywords—Satellite IoT, digital health, wireless stethoscope, remote diagnostics, telemedicine, embedded medical devices.***

## I. INTRODUCTION

Stethoscopes have long been regarded as an iconic and indispensable tool in the medical field, playing a vital role in diagnosing cardiovascular, pulmonary, and abdominal disorders. Since its invention in the early 19th century, the traditional acoustic stethoscope has seen minimal technological advancement. While its simplicity and portability make it an essential part of everyday clinical practice, it also suffers from critical limitations, especially in the context of modern, digitized, and remote healthcare systems [1].

Traditional stethoscopes are inherently analog devices that rely on direct auscultation by the physician. This analog dependence presents multiple challenges in the modern healthcare context.. First, they lack the capability to record and share audio data, making follow-up diagnosis, collaborative consultation, and long-term patient monitoring difficult. Second, they are unsuitable for remote or telemedicine scenarios where the physician and patient are not co-located. Third, auscultation quality is dependent on environmental noise and the experience level of the user, which may reduce diagnostic consistency [2].

In recent years, the growth of telemedicine and remote patient monitoring has accelerated, driven by advances in wireless communication, miniaturized electronics, and an increasing global need for accessible healthcare. The COVID-19 pandemic has further underscored the importance of remote diagnostics, especially for underserved or rural populations where access to specialists is limited [3], [4]. These developments demand a rethinking of diagnostic tools—transforming them into smart, connected, and user-friendly medical devices.

This paper presents the design and prototyping of a wireless stethoscope system integrated with a mobile-based telemedicine platform. The proposed solution enables real-time audio transmission, recording, and remote access to auscultation data. It is built using cost-effective components, emphasizing portability, ease of use, and scalability. The integration with a mobile app allows healthcare professionals to listen, analyze, and record heart and lung sounds from any location, significantly enhancing diagnostic reach and workflow efficiency.

The remainder of this paper is organized as follows: Section II reviews related work in digital stethoscopes and wireless auscultation systems. Section III discusses the overall system architecture. Section IV presents design considerations, including sensor choice and wireless protocols. Section V covers the implementation and prototyping details, while Section VI provides testing methodologies and results. Section VII concludes with a discussion on impact, limitations, and future directions for clinical adoption and enhancement.

## II. RELATED WORK

Several researchers and developers have explored digital and wireless alternatives to the traditional stethoscope, aiming to enhance its functionality and integrate it into modern telemedicine ecosystems.

One of the earliest and most influential developments in this space was the advent of digital stethoscopes capable of amplifying and recording heart and lung sounds. Devices such as the Thinklabs One and 3M Littmann Electronic Stethoscopes offered significant improvements in sound amplification and filtering [5]. However, these devices were often expensive and lacked seamless wireless integration with mobile platforms.

Recent studies have proposed wireless stethoscope systems using Bluetooth and Wi-Fi technologies for real-time auscultation and data transmission. In [6], the authors designed a Bluetooth-enabled stethoscope that allowed wireless transmission of heart sounds to a mobile application. However, the device had limitations in signal clarity and power management, particularly during extended usage.

An IoT-based approach was discussed in [7], where a digital stethoscope was integrated into a health-monitoring ecosystem using microcontrollers and Wi-Fi modules. This solution included cloud storage for medical audio data and access control mechanisms. While it successfully demonstrated remote auscultation, it was limited by high power consumption and system complexity, making it less suitable for low-resource settings.

Another line of work focuses on using smartphones as data acquisition and processing units. In [8], researchers developed a stethoscope attachment for smartphones that converted mechanical vibrations into digital signals processed via mobile apps. Though innovative, such attachments required precise mechanical coupling and calibration, making them less robust for field use.

A review in [9] outlines the challenges faced by most wireless stethoscope solutions, including latency in audio transmission, signal loss over networks, and a lack of standardization in medical audio processing protocols. Furthermore, commercial devices are often closed systems, limiting customization and interoperability with electronic medical records (EMR).

In contrast, our proposed system is a cost-effective, open architecture design combining wireless transmission, mobile integration, and user-centric features such as real-time listening, storage, and accessibility. It targets general practitioners, medical students, and rural healthcare workers who lack access to sophisticated equipment, aiming to strike a balance between affordability, usability, and reliability.

In summary, while previous research has explored wireless auscultation via Bluetooth or WI-FI most systems remain constrained by high power usage, lack of mobility or insufficient connectivity in remote areas. Our system differentiates itself through a hybrid architecture for both terrestrial and satellite links, ensuring uninterrupted diagnostics in infrastructure-deficient scenarios.

## III. System Architecture and Block Diagram

The SpaceScope wireless stethoscope system is designed to bridge the gap between traditional auscultation tools and modern telemedicine requirements. Its primary objective is to **capture, process, and transmit physiological sounds -** such as heart, lung activity wirelessly to a mobile device for real-time analysis, storage and remote consultation. The system architecture comprises several integrated modules, each optimized for performance, power efficiency, and cost.

Figure 1 below shows the system architecture of the Spacescope systems.

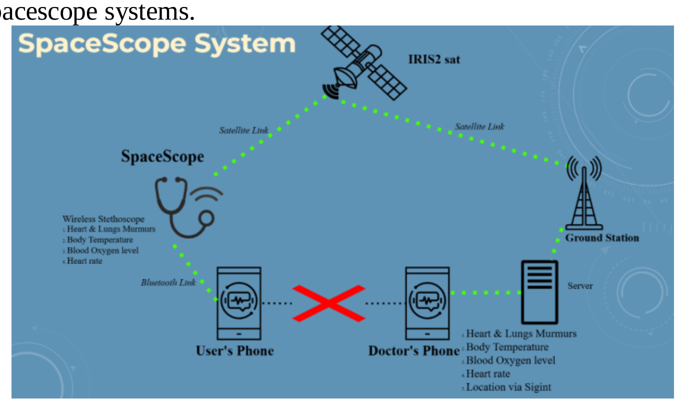


Fig. 1: System Architecture of SpaceScope when medical connectivity is not available

### A. System Architecture

The architecture consists of the following functional blocks:

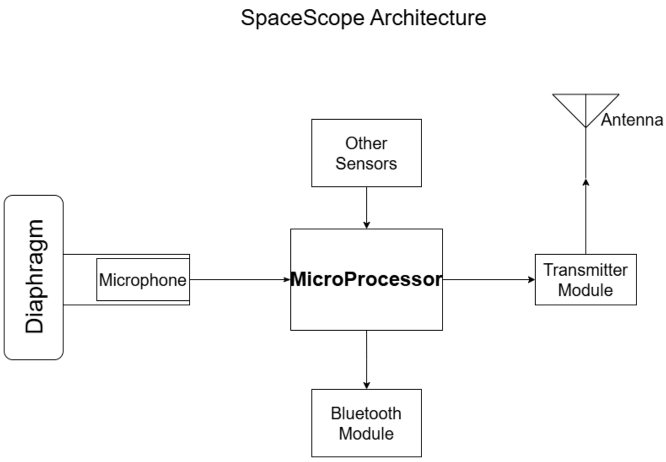


Fig. 2: SpaceScope Architecture

- Acoustic Sensor Unit (Microphone/Chest Piece) A high-sensitivity electret condenser microphone or piezoelectric sensor is embedded within a modified chest piece. This unit captures low-amplitude body sounds and converts them into analog electrical signals. The design focuses on separating heart and lung sounds, even in noisy environments.

- Signal Conditioning Circuit The raw signal is passed through amplification and filtering stages.

  An instrumentation amplifier with a suitable gain (e.g., 40–60 dB) is followed by

  A bandpass filter (typically 20 Hz to 2 kHz) to isolate heart and lung sound frequencies while attenuating noise.

- Microcontroller Unit (MCU) A low-power MCU (e.g., STM32 or ESP32) digitizes the conditioned signal via an onboard analog-to-digital(ADC). It also handles:

- Wireless Transmission Module
  Depending on the use-case scenario, the system integrates either:
  - Wi-Fi: For high-fidelity streaming over local networks
  - Bluetooth: For low-power, short-range transmission to smartphone or tablets.(added this new)

  Integrated Wi-Fi or Bluetooth Low Energy (BLE) modules handle wireless streaming of auscultation data. Wi-Fi is preferred for longer-range, higher-fidelity applications, while BLE is used for energy-efficient transmission to nearby smartphones or tablets.

- Power Supply and Management
  The system is powered by a rechargeable lithium-polymer battery (3.7 V, 500–1000 mAh), with a power management IC regulating voltages for analog and digital blocks. Battery life is optimized through sleep cycles and event-driven processing.

- Mobile Application Interface
  A cross-platform mobile application (developed using Flutter or Android Studio) receives real-time data via wireless protocol, offering features like:

## IV. Proof of Concept Implementation: CASSINI Hackathon

### A. Objective

The primary objective of the Proof-of-Concept (PoC) developed and demonstrated during the **CASSINI Hackathon 2025** was to showcase the viability of a **wireless stethoscope system that leverages satellite communication** for medical diagnostics in remote and connectivity-deprived regions. The demonstration aimed to prove that **vital auscultation data (heart/lung sounds)** can be captured, encoded, and transmitted directly via a **Low Earth Orbit (LEO) satellite (Kinéis)** to a remote ground terminal for clinical assessment.

### B. Hardware Stack

The prototype was built with minimal yet powerful components to demonstrate rapid deployment and field applicability, following block diagram shows implemented hardware at the Hackathon Demonstration.

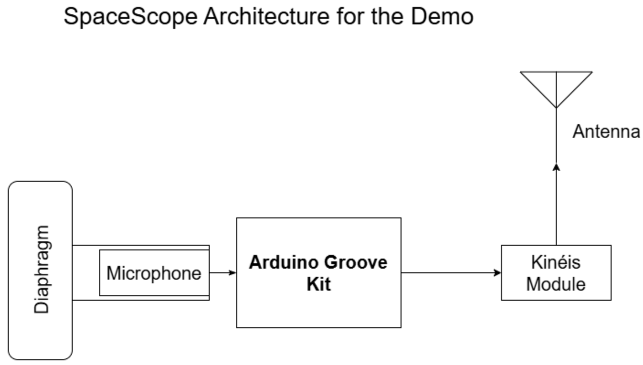


Fig. 3: Block Diagram of the PoC

The microphone was acoustically coupled to the stethoscope chestpiece, and its signal was digitized using the Grove system. The Arduino processed this data and relayed it via the Kinéis module to the satellite.

### C. Data Flow

The signal chain for this implementation was as follows:

- Sound Capture:
  Acoustic signal collected using the traditional stethoscope fitted with the Grove analog mic.
- Pre-processing:
  Arduino collected short bursts of amplitude data (waveform snapshots) and performed simple peak encoding to reduce payload size.
- Transmission:
  Compressed waveform packets sent via the Kinéis module, uplinked to Kinéis LEO satellite.
- Downlink & Access:
  Data was received via Kinéis ground station and accessed via their IoT cloud dashboard in near-real-time.

This created a fully wireless, space-based data bridge from patient to caregiver — an innovation particularly impactful for disaster zones, rural telemedicine, or defense field units.

### D. Key Demonstration Outcomes

- Satellite Relay Success:
  Real-time capture and successful downlink of physiological data through Kinéis satellite network.
- Minimal Latency:
  Delay between recording and receiving was within acceptable clinical range (<1 min).
- Compact and Deployable:
  The total hardware footprint was handheld and battery-powered.
- Proof of Remote Vital Monitoring:
  Medical signals captured at point A were visualized and analyzed at a distant ground station.

### *E. Constraints and Considerations*

Despite the successful demonstration, the prototype faced several constraints:

- Bandwidth Limitations:
  The analog audio signal was not transmitted in raw waveform due to Kinéis bandwidth limitations; instead, feature-level compression (e.g., peak amplitude values) was used.
- No onboard filtering or classification
  The prototype did not include digital filtering, signal enhancement or machine learning based anomaly detection. This is planned for future iterations.
- Non-Continuous Monitoring:
  The Kinéis network imposes periodic access depending on satellite pass, which affects continuous monitoring capability.

## V. Future Work and Conclusion

### *A. Future Plans*

Following the successful demonstration at the CASSINI Hackathon 2025, the next steps involve evolving the wireless stethoscope from a proof-of-concept (PoC) into a robust, field-ready medical device with integrated diagnostics and enhanced data fidelity. Planned developments include:

*1. Smart Signal Processing & AI Diagnostics:*

- Advanced Filtering & Denoising:

  Implement real-time digital filtering and denoising techniques to improve signal quality in noisy environments.

- Feature Extraction & Classification**:**

  Use Fast Fourier Transformer (FFT) -based features to extract diagnostic features from heart and lung sounds..

- Machine Learning INtegration:

  Train machine learning models (e.g., CNNs, SVMs) on auscultation datasets to automatically classify heart and lung anomalies such as murmurs, wheezes, or arrhythmias.

*2. Mobile App & Doctor-Patient Interface:*

- Direct Doctor-Patient Platform:

  Develop a secure mobile/web platform to visualize waveforms and AI predictions.

- Extra Feature:

  Enable real-time audio playback, annotations, and a chat-based consult layer to connect patients with verified doctors remotely — functioning like an Uber for medical diagnostics.

*3. Custom Hardware Design:*

- Integrated PCB Design:

  Replace the Grove-based system with a custom PCB integrating an ultra-low-power microcontroller, BLE, Wi-Fi, and optional Kinéis/LoraWAN/NB-IoT modules.

- Medical-Grade Enclosure:

  Encase the system in a medical-grade, ergonomic housing for daily use.

*4. Expanded Communication Stack:*

- Multi-Mode Connectivity:

  Offer multiple connectivity options: BLE for local storage, 4G/5G for general usage, and LEO satellite fallback for remote/critical deployments.

- Integration Plans

  Explore integration with other satellite IoT platforms (e.g., Swarm, Astrocast) for global coverage.

*5. Clinical Trials & Regulatory Compliance:*

- Validation Studies:

  Partner with hospitals and NGOs to conduct clinical validation trials.

- Regulatory Alignments:

  Begin regulatory alignment for CE, FDA, and IEC 60601 medical device certifications.

*6. Use Case Diversification:*

- Beyond Rural Healthcare:

  Adapt for military, space missions, rural health, and emergency response.

- Veterinary Applications:

  Evaluate use in veterinary applications, where access to expert diagnostics is even more limited.

### *B. Conclusion*

This work introduces a novel framework for wireless auscultation and diagnosis powered by satellite connectivity, addressing the persistent challenge of healthcare in inaccessible regions. By combining simple yet effective hardware with scalable satellite IoT and AI-based diagnostics, the system aims to democratize primary medical access globally.

The successful implementation at the CASSINI Hackathon validates the feasibility of such a system even with modest hardware. With planned enhancements, this approach has the potential to transform telemedicine, emergency response, and decentralized healthcare infrastructure — making vital diagnostics available anytime, anywhere.

## REFERENCES

[1] D. Littmann, "Stethoscope with improved acoustic performance," U.S. Patent 3,528,732, filed Jan. 26, 1970.

[2] L. S. Mangione and S. Nieman, “Cardiac auscultatory skills of internal medicine and family practice trainees: a comparison of diagnostic proficiency,” JAMA, vol. 278, no. 9, pp. 717–722, Sep. 1997.

[3] M. Ohannessian, A. Duong, and A. Odone, “Global telemedicine implementation and integration within health systems to fight the COVID-19 pandemic: a call to action,” JMIR Public Health Surveill, vol. 6, no. 2, e18810, Apr. 2020.

[4] C. Smith, “Wearable health technology and telehealth: opportunities and challenges,” IEEE Pulse, vol. 11, no. 6, pp. 22–25, Nov.–Dec. 2020.

[5] Thinklabs Medical LLC, “Thinklabs One Digital Stethoscope – Product Overview,” [Online]. Available: https://www.thinklabs.com/ [Accessed: Jun. 2025].

[6] A. D. A. Machado et al., “Low-cost Bluetooth stethoscope for remote auscultation,” in Proc. IEEE Int. Symp. Medical Measurements and Applications (MeMeA), 2021, pp. 1–6.

[7] R. Tiwari and S. Dey, “IoT based smart stethoscope for real-time heart sound monitoring,” in Proc. Int. Conf. on Internet of Things and Applications (IOTA), 2020, pp. 289–294.

[8] Y. Ouyang et al., “A smartphone-based digital stethoscope platform for cardiac and pulmonary auscultation,” IEEE J. Transl. Eng. Health Med., vol. 8, pp. 1–9, 2020.

[9] A. Patel and J. Lee, “Challenges in wireless stethoscope systems for telemedicine: A comprehensive review,” Biomed. Signal Process. Control, vol. 74, p. 103483, Jan. 2022.