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# Work in Progress: FieldFi as a Case Study in Interdisciplinary Prototyping and Field-Based Engineering Education

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I am a computer scientist at Earlham College, a small liberal arts college in Indiana, US. Together with Emmett Smith (biology), Rannveig Thorhallsdottir (archaeology), Porter Libby (computer science), Whitney Blackburn-Lynch (engineering), and Seth Hopper (physics) I lead a multidisciplinary student and faculty research group that applies low-cost consumer drone technology and open source software to archaeology and environmental science. Our goal is to make it easier and cheaper for archaeologists to locate subterranean points of interest within a known or suspected cultural activity area and for environmental scientists to map and analyze topography, ground cover, species census, etc.

Our approach combines recent advances in drone, sensor, and machine learning technologies. Working with colleagues in Iceland we use this gear to help identify and describe early Norse settlement activities in the Eastern fjords, map topography, monitor invasive species, and perform avian census at Skalanes, a research center outside of Seydisfjordur.

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## Abstract

For the last 9 years, Earlham College has been flying drone surveys of an Icelandic fjord and river valley to measure surface movement and coastline changes. While determining the location and elevation of the ground control points (GCPs) it was discovered that the satellite locations from the real-time kinematic (RTK) connection was only accurate to within 10 cm in X and Y, and 30 cm in Z. A small team of students and faculty reconfigured the handset receiving RTK data so that it could be augmented by the ICECORE correction service. This improved the accuracy to within 1-3 cm in X, Y and Z. Due to a lack of cellular service in the area to communicate with the correction servers, the research team developed a solution known as FieldFi—a low-cost Wi-Fi system which supports a local area network (LAN) and an uplink designed to extend Wi-Fi support from the base station to out in to the field where the control points are placed.

The first device enhanced connectivity between the field station and the RTK unit but proved to be bulky and somewhat fragile in the field. Building on that qualified success, the team adjusted the design and developed FieldFi v2 in spring 2025, with the hope of improving range, stability, and portability. During a summer 2025 research trip to Iceland, the system was field-tested while ground truthing the previously flown coastline using standard total station surveying methods. Testing revealed new challenges, including terrain-related signal loss and broadcast range, which now inform the design of FieldFi v3 for deployment in 2026.

Led by computer science faculty with support from engineering faculty, staff and student collaborators, this evolving project highlights how rapid prototyping, interdisciplinary collaboration, and field-based problem solving create authentic, high-impact learning experiences.


## Introduction

Remote field research increasingly relies on high-resolution spatial data to support environmental monitoring, geomorphological analysis, and long-term landscape change studies. In many of these contexts, unmanned aerial systems (UAS) and ground-based surveying tools are used in combination to generate georeferenced models of terrain and surface features. The accuracy of such models depends heavily on the quality of ground control point (GCP) placement and positioning, which in turn is influenced by the availability of reliable real-time differential GPS (DGPS) correction data [1] [2].

For the past several years, Earlham College has conducted recurring drone-based surveys of an Icelandic fjord and adjacent river valley to measure erosion and landscape change. These field campaigns have highlighted a persistent challenge common to many remote research environments: while RTK-enabled survey equipment is capable of centimeter-scale accuracy under ideal conditions [1], access to correction services is often constrained by limited or nonexistent cellular connectivity. In initial deployments, satellite-based positioning alone yielded

GCP accuracy on the order of several decimeters, insufficient for the resolution goals of the project. When RTK correction data could be reliably received, positioning accuracy improved substantially; however, maintaining connectivity in the field proved difficult due to terrain, line-of-sight limitations, and infrastructure constraints.

Commercial solutions for extending connectivity in remote environments are often cost-prohibitive, power-intensive, or poorly suited to mobile, student-supported field research [3]. These limitations are particularly acute for small research programs and institutions with limited technical infrastructure, as well as for engineering educators seeking to integrate authentic field-based problem solving into undergraduate curricula.

In response to these challenges, a small interdisciplinary team of faculty and students developed FieldFi, a low-cost, portable Wi-Fi extension system designed to relay DGPS data from a fixed base station to RTK surveying equipment deployed in the field. FieldFi was conceived not only as a technical solution to a recurring research need, but also as a platform for iterative design, testing, and learning within a real-world field environment.

This work-in-progress paper describes the development and field testing of FieldFi through its second design iteration (v2), including observations from successful and unsuccessful deployments during a summer 2025 field campaign in Iceland. Rather than presenting finalized performance metrics, the paper focuses on how terrain, cost, and setup constraints shaped system behavior and informed subsequent design decisions. These findings are currently guiding the development of FieldFi v3, which is planned for further testing and validation during a Spring 2026 course-based field project.

## Problem Definition and Design Constraints

The primary technical challenge motivating this work is the reliable delivery of DGPS data over the NTRIP (Networked Transport of RTCM via Internet Protocol) to survey equipment operating in remote field environments. While the base station used for the Icelandic field work had consistent access to correction services, survey teams placing ground control points were frequently required to operate hundreds of meters away from the base location, often without direct line-of-sight. In these conditions, conventional assumptions about network availability and signal propagation no longer held.

Four constraints emerged repeatedly during field operations and directly shaped the design of the FieldFi system:

1) Lack of cellular connectivity

The field sites used in this research are characterized by minimal or nonexistent cellular coverage. As a result, RTK correction data could not be reliably transmitted to survey equipment through standard cellular-based workflows. This constraint eliminated many commercial solutions that rely on mobile broadband connectivity and necessitated a local, infrastructure-independent approach to data transmission.

2) Terrain and line-of-sight limitations

The Icelandic fjord and river valley terrain includes steep elevation changes, irregular coastlines, and natural obstructions that frequently interrupt direct line-of-sight between the base station and field-deployed equipment. These terrain features resulted in signal attenuation, multipath effects, and intermittent connectivity, even at relatively short distances. Terrain-driven signal loss proved to be a dominant factor distinguishing successful from unsuccessful deployments and became a central consideration in subsequent design iterations.

3) Cost constraints

As a small research program, the project operated under a limited equipment budget. High-end networking and surveying solutions designed for commercial or industrial use were not financially viable. Consequently, FieldFi was designed to use commercially available, relatively low-cost components, prioritizing affordability and replaceability over maximum performance.

4) Setup complexity and portability

Field deployments were conducted by small teams, often including undergraduate students, under time and weather constraints. Systems requiring extensive calibration, specialized tools, or prolonged setup were impractical. The FieldFi system therefore needed to be portable, quick to deploy, and tolerant of non-ideal installation conditions. Ease of setup was treated as a functional requirement rather than a secondary consideration.

Together, these constraints framed the problem space for FieldFi as one of sufficient, rather than optimal, connectivity: the goal was not to maximize range or throughput, but to provide reliable, field-deployable transmission of RTK correction data under realistic environmental and logistical limitations. These constraints informed the architectural decisions described in the following section.

**Field Deployment and Observed Performance (v2)**

FieldFi v2 (see Figure 1 & Figure 2) was deployed and evaluated during a summer 2025 field research campaign in Iceland. The primary objective of this deployment was not formal performance benchmarking, but rather to observe system behavior under authentic field conditions while supporting ongoing placement and verification of ground control points. Testing occurred across multiple sites within a fjord and adjacent river valley, exposing the system to varied terrain, elevation changes, and line-of-sight conditions.

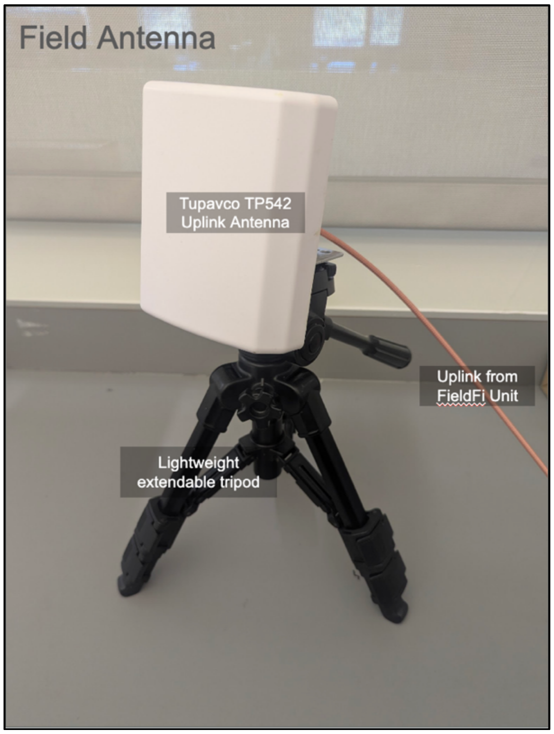


Figure 1: FieldFi Uplink Antenna

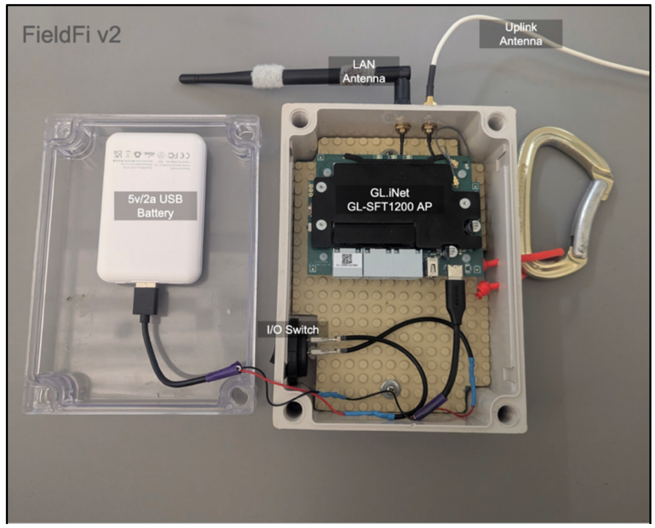


Figure 2: FieldFi v2 design and component parts

*Deployment Context*

FieldFi v2 was designed to extend Wi-Fi connectivity from a fixed base station, where RTK correction data were accessible, to handheld RTK survey equipment used by field teams placing ground control points. Deployments typically required extending connectivity several hundred meters from the base station, often across uneven terrain and around natural obstructions. System setup and relocation were performed by small teams, including undergraduate students, under typical field constraints such as limited time windows, weather variability, and restricted access to power.

*Successful Deployments*

In configurations where a clear or near-clear line of sight existed between the base station and the FieldFi antenna, the system successfully relayed DGPS data to the RTK unit. Under these conditions, users observed stable connectivity sufficient to maintain NTRIP connection during GCP placement. These deployments demonstrated that the core architectural concept of FieldFi—using a portable Wi-Fi extension rather than cellular infrastructure—was viable within certain spatial and terrain limits.

Successful deployments were generally characterized by elevated antenna placement, minimal terrain shadowing, and relatively short transmission distances. These observations informed early confidence that the system could meet its intended purpose under favorable conditions.
Unsuccessful Deployments and Failure Modes

In contrast, deployments involving significant elevation changes, terrain occlusion, or indirect transmission paths frequently resulted in intermittent or unstable connectivity. Fjord walls, riverbanks, and subtle terrain features that were not immediately apparent during setup often produced signal loss or degradation. In some cases, small changes in antenna placement or orientation produced disproportionately large changes in system performance, highlighting sensitivity to installation conditions.

These failures were particularly instructive. Rather than indicating fundamental flaws in the concept, they revealed limitations in range, robustness, and terrain tolerance that were not fully apparent during earlier testing. Importantly, these challenges emerged only during extended field use and would have been difficult to replicate in a laboratory environment.

*Implications for Redesign*

The mixed outcomes of the FieldFi v2 deployments directly informed the design priorities for the next iteration of the system. Observed failure modes emphasized the need to improve terrain resilience, extend effective range, and reduce sensitivity to placement and orientation. These insights are guiding the development of FieldFi v3, which will incorporate revised antenna strategies and deployment configurations aimed at mitigating terrain-driven signal loss. Formal validation of FieldFi v3, including planned ground-truthing comparisons using standard total station surveying methods, is scheduled for Spring 2026 as part of a course-based engineering project. The results presented here should therefore be interpreted as formative observations rather than finalized performance metrics.

**High-Impact Learning Through Iterative Prototyping**

Beyond its technical goals, the FieldFi project was intentionally structured as a high-impact learning experience grounded in the principles of authentic, problem-based learning. The purpose of this kind of high-impact practices is not only to aid students in learning, but also to build confidence in their work [4]. This kind of high-impact learning also increases the chances that our students will remain in the engineering field [5].

Student involvement was a central component of the FieldFi project. Students not only collected and analyzed data, but they also functioned as active co-designers and field engineers. They had the opportunity to engage directly with the uncertainties and constraints of a real-world system. This approach allowed students to move beyond the theoretical exercise of classroom-based learning into a cycle of iterative design, field testing, failure analysis, and data-informed decision-making.

*FieldFi v2: Field Testing and Data Collection*

During the summer 2025 field experience, undergraduate students from computer science, engineering and mathematics participated in the deployment and testing of FieldFi v2 as part of ongoing research in Iceland (See Figure 3). Faculty oversight focused primarily on maintaining the fixed base-station infrastructure and monitoring the field antenna connectivity, while students operated as mobile field teams using RTK surveying equipment (See Figure 4).

*Figure 3: FieldFi v2 deployed in the field*

*Figure 4: Students collecting RTK data in Iceland*

Students were responsible for traversing the field site with the RTK handset to pre-identified test locations and determining whether reliable differential correction could be maintained. This task required them to move beyond simply following instructions and engage in active problem solving. When a connection failed it was not a failed lab experiment, but an opportunity to engage with an authentic engineering problem. Students had to consider the terrain, antenna orientation, and distance.

Test points were initially established through reconnaissance field walking and selected to maintain clear line-of-sight to the base station. Students then refined the testing strategy by consulting antenna radiation patter data sheets and implementing a radial testing approach that aligned with predicted signal propagation zones [6]. This process required students to translate manufacturer specifications into a spatial testing plan and to evaluate how those expectations held under actual terrain conditions.

As testing progressed, students exercised judgement in determining when to continue or terminate a radial or distance-based test based on observed connectivity and data quality. Students documented each text point using field notebooks, GPS loggers, and photographic

records.  They recorded location (distance and angle from field antenna), success or failure of correction reception, and RTK-derived X, Y, and Z position data.
As the importance of consistency became apparent, student documentation practices evolved from informal field notes into a more standardized field-testing protocol, reflecting an authentic transition from exploratory investigation to structured experimentation that is important as part of the development as an engineer [7].  They learned firsthand why rigorous documentation is critical to the engineering design process.

*Post-Field Analysis and Transition to FieldFi v3*

Following the field work, students participated in post-field discussions focused on identifying patterns in successful and unsuccessful deployments.  These debriefs emphasized interpretation rather than verification, encouraging students to connect observed failures to terrain effects, antenna placement sensitivity, and range limitations.  Insights from these discussions directly informed the prioritization of design changes for FieldFi v3.

Subsequently, a smaller group of students became more deeply involved in the redesigned process contributing to decisions about revised antenna strategies and deployment configurations.  This work continued into the fall semester as an extracurricular activity, reflecting sustained student ownership of the project.

*Educational Value and Ongoing Integration*

Student involvement in FieldFi was intentionally structured to expose students to the uncertainties and constraints inherent in real-world field research. Rather than following a fixed laboratory protocol, students engaged in iterative problem definition, data-informed decision making, and redesign based on incomplete and sometimes conflicting evidence. These experiences reinforced core engineering practices, including experimental design under constraint, documentation, and the translation of theoretical specifications into operational systems.

Planned Spring 2026 field testing of FieldFi v3 will further integrate student participation through a course-based engineering project, allowing students to validate redesign decisions and compare system performance against independent surveying methods. Together, these phases illustrate how sustained student involvement can simultaneously advance a technical research system and provide high-impact educational experiences grounded in authentic field conditions.

*Planned Redesign: FieldFi v3*

Based on our experiences with FieldFi v1 and v2 we gathered a group of students and faculty who had used those versions and conducted a series of design sessions. The outcome of those sessions was a design for FieldFi v3 which embodies the following:

- Continue using the GL.iNet access point (AP). This unit has proven to be reliable, highly configurable, and easy to embed in an enclosure.

- Reduce the number of external connections by using a patch antenna mounted inside the enclosure for the LAN.
- Integrate the I/O switch into the battery/power supply cable, reducing the part count and the number of external connections.
- Move to a smaller, more rounded enclosure so that it packs more easily.
- Improve operating time and stability by increasing the capacity and available current of the battery.
- Redesign enclosure interior for improved field durability and cable management.
- Add the capability to visualize uplink signal strength to reduce the time to connection.

See Figure 5 below for an illustration of the new case and other v3 components.

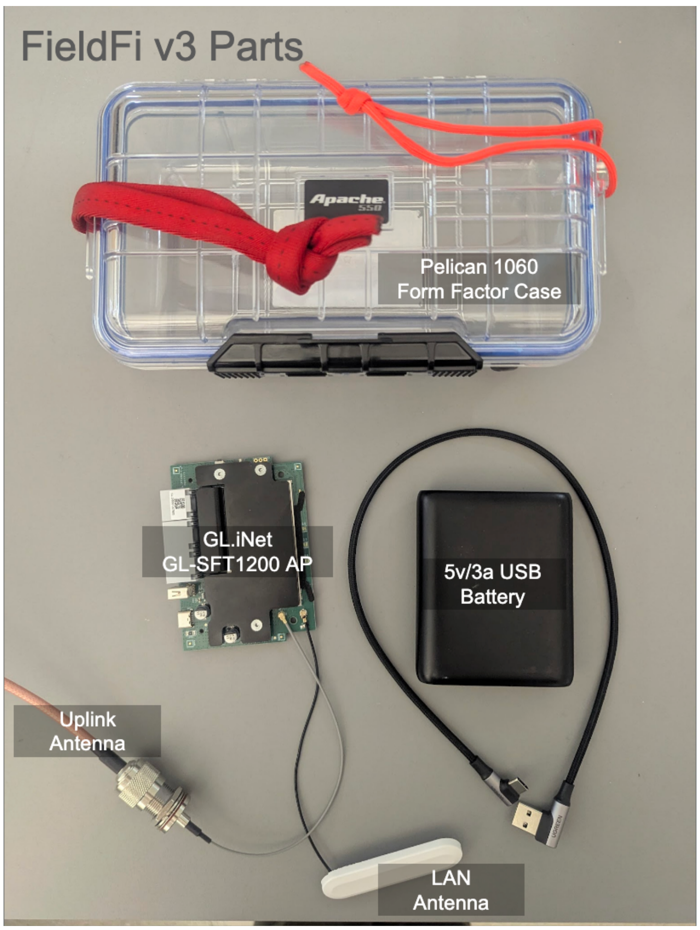


*Figure 5: FieldFi v3 components.*

## Conclusion

This work-in-progress paper has described the development and field deployment of FieldFi, a low-cost, portable Wi-Fi extension system intended to support RTK surveying in remote environments. Field testing of FieldFi v2 during a summer 2025 research campaign in Iceland demonstrated that the underlying system architecture can successfully extend correction data under favorable conditions, while also revealing important limitations related to terrain, range, and deployment sensitivity. These mixed outcomes were intentionally treated as diagnostic rather than evaluative, providing concrete insight into failure modes that are difficult to reproduce in laboratory settings. Observations from v2 directly informed the identification of design priorities for FieldFi v3, which aims to improve robustness to terrain-driven signal loss and reduce sensitivity to placement and orientation.

Student involvement was central to both the technical progress of the project and its educational value. Students played active roles in field testing, documentation, interpretation of results, and subsequent redesign, exercising judgment in uncertain, constraint-driven conditions. This project structure allowed students to:

- Grapple with ambiguity and failure: Unlike curated classroom exercises, field deployments often fail for reasons that are not immediately obvious and require students to dig deeper into understanding not only what we are doing, but the tool we designed to do it.
- Translate theory into practice: Students had to apply theoretical knowledge of antenna patterns and signal propagation to a complex real-world system that gave them experience with seeing the gap between datasheet specifications and field performance.
- Develop professional skills: students had to quickly develop their skills in communication, collaborative problem solving and risk assessment as they were dealing with both technology and field site constraints.
- Experience the full engineering design cycle: As they participated in the testing of v2 and the discussions around the design for v3, students saw how field data and failure analysis directly inform subsequent design iterations, closing the loop between problem, solution, and improvement.

Planned Spring 2026 deployment and ground-truthing of FieldFi v3 through a course-based project will enable further validation of design changes while continuing to integrate authentic field research into undergraduate education. Together, this project illustrates how iterative, low-cost system development in real field environments can advance research infrastructure while simultaneously providing high-impact learning experiences for students in small programs with limited resources.

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