Bidirectional Communications via Argos Satellite Radio

Forrest Milner, University of Maryland

Mentor: Thom Maughan

Summer 2024

Keywords: Satellite Radio, STM32, Arduino, Printed Circuit Board, Argos, Kinéis

ABSTRACT

Argos satellite network has long been a satellite network of choice for low power low bandwidth applications. Messages sent from the devices are localized within a kilometer by receiving satellites so there is no need for a GPS in low accuracy tracking applications. In 2018, the company Kinéis was created by ARGOS organizers to take over the operation of the ARGOS system and deploy a fourth generation of satellites targeted at IOT applications. The 25 fourth generation satellites will operate in the same frequency band but will facilitate downlink. The biggest advantage of downlink is that the device can stop transmitting once received, reducing power consumption. Additionally, the device can receive commands to perform actions. This paper investigates the hardware and software needed for downlink with Kineis satellites, with the eventual recommendation for further devices to use the KIM2 module offered by Kineis.

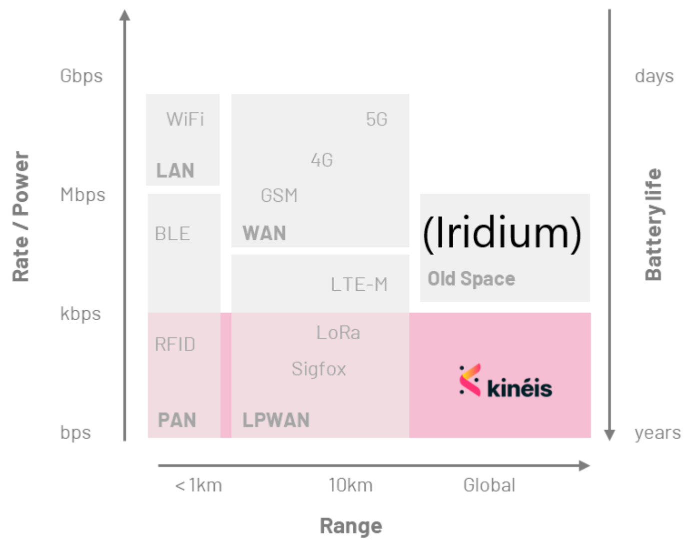

Figure 1: Kineis positioning of services. Modified by Forrest Milner.

INTRODUCTION

In summer 2024, the French Space Agency, CNES, began deploying a constellation of 25 nanosatellites, managed by a company called Kinéis.[3] These fourth generation nanosats are capable of data downlink to devices. They were deployed with the goal to transform the traditionally science / research focussed Argos network into a IOT network.[3] This summer a board was developed and fabricated to determine the applicability of this new satellite network to MBARI operations. The board utilized the STM32WL55, a microcontroller with embedded transceiver similar to the SX1261/SX1262[1] This microcontroller/transceiver combination can transmit continuously from 150MHz to 960MHz [2] and combined with proper configuration on the board is capable of transmission on the frequencies used by Kinéis for uplink.

One element of this internship was communicating with the new company Kineis. During the summer the Kineis team modified the documentation and removed support for the STM32WL55 chip for downlink, something the team discovered during a call with Kineis near the end of the internship. They recommended using the KIM2 module.

As per applications to MBARI, autonomous vehicles often have a primary Iridium satellite radio for communications. In case the primary radio is disabled a backup radio is needed to recover the vehicle. This backup radio should ideally have an independent power scheme, transmit its location when it comes to the surface, and as an added bonus be capable of sending simple “rescue” commands to the main AUV computer. Historically the previous generations of Argos satellites have been used for this purpose but have not been capable of downlink. To support the new generation of Argos satellite capable of downlink and the other requirements of a backup radio a low power battery powered satellite radio board was created, capable of transmitting and receiving on the 400 and 433 Mhz band.

MATERIALS AND METHODS

DESIGN REQUIREMENTS

The core requirements of the project originated from the technology the project was focussed around. Principal among them was the use of the STM32WL55 chip. This chip, developed by STMicroelectronics, combines two Arm cores, the usual smattering of peripherals, and a radio capable of LoRa, (G)FSK, (G)MSK, and BPSK modulations in the 150 - 960 MHz range. The internal radio is comparable to the Semtech SX1261 / SX1262 radios. Although the team was informed that this radio was not compatible with Kineis downlink, this was too late in the summer to impact this intern’s activities.

The board should optionally be able to locate itself with greater precision than the radio location services provide. For this purpose a SAM-M10Q-00B GPS module is included, along with an appropriate power switch to allow the module to be shut down completely. If this is not needed the GPS and switch can be omitted during fabrication. This module includes an integrated antenna which simplified the design. It also has a fast fix time of about a second if the device was recently powered on which is critical when in low power operation modes. Maximum accuracy for this chip is around 2-3 meters.

Another requirement for the board was for it to be battery operated for about 6 months. Ideally the device would be wirelessly charged with a charging time of less than 12 hours to allow for an overnight turnaround of this part. This requirement constrained component selection to either be low power or be switched. Some components like the GPS (many mA) and current sensor (9mA) are switched on and off by the microcontroller. The charger was externally powered and did not factor into the power budget, although the reverse leakage current needed to be low. A TPS73733QDRBRQ1 was selected for the linear regulator because of its low quiescent current of 400 nA. The battery monitor IC, capable of reporting state of charge, uses 3µA.

A self imposed limitation is that the board should be drawn up KiCAD 8 for the benefit of the education of the intern. The parts were entirely purchased in DigiKey. These limitations were imposed to simplify manufacturing.

DESIGN CONCEPTS & PRELIMINARY DESIGN

The STM32WL55 dev board from STMicro was used as a reference for the radio component of this board. Since STMicro publishes the EDA files for these boards, it was simple to convert to KiCAD and then copy and paste these components into my design. There was some effort required to change the part numbers for passive components to the cheapest ones on digikey - some resistors were not the most common.

The battery used was a simple 18650 cell with a measured capacity of 2978 mAh. A MCP73831 was used as the charger. This charger accepts power at 5V and can charge the battery at 500 mA. The design allows the battery to be charged by a 5V wireless charging module for when the design is placed in a waterproof housing, and power supply access is not preferred. A "charging finished" led was included in the design, and is not a power consideration because the LED will only be illuminated when connected to an external power supply.

Three common peripherals were broken out: I^2C, SPI, and a serial port. The serial port is connected to the low power UART (LPUART) on the STM32WL55. This LPUART was used in development to print out debugging messages.

A current sensor (ACS722LLCTR-05AB-T) was included in the design to allow for testing of the radio power draw to detect if we were underwater.

Github was used as a repository for my KiCAD projects. KiCAD stores files in a git friendly way. The KiCAD files can be referenced here. https://github.com/ForrestFire0/radioboard This link includes both the original STM32WL55 Nucleo boards, converted originals, and also my project. There is also some preliminary code used at some point of the project that did not end up being relevant.

FINAL DESIGN AND ASSEMBLY PROCESS

The PCBs were fabricated using PCBWAY (Chinese company) and delivered in about a week. Also purchased was a solder paste stencil. After laying the solder paste with help from Jose Rosal, MBARI's manual pick and place machine was used to place all parts excluding the headers, battery connector, and antenna connector. MBARIs reflow oven was used to bake the boards, which turned the solder paste into liquid and then solid solder connections.

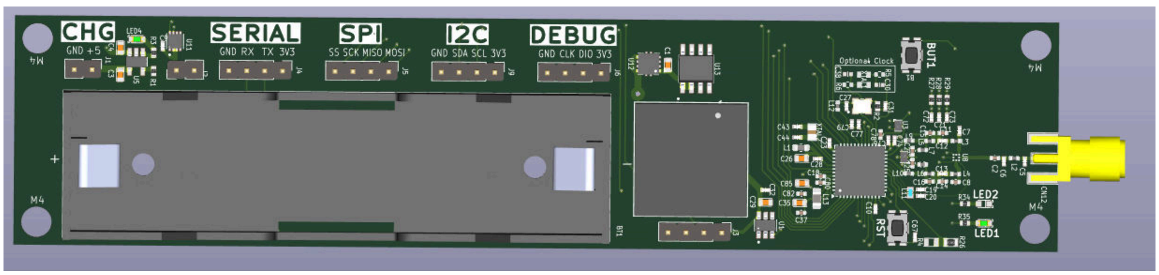

Figure 2: CAD rendering of the top of the board

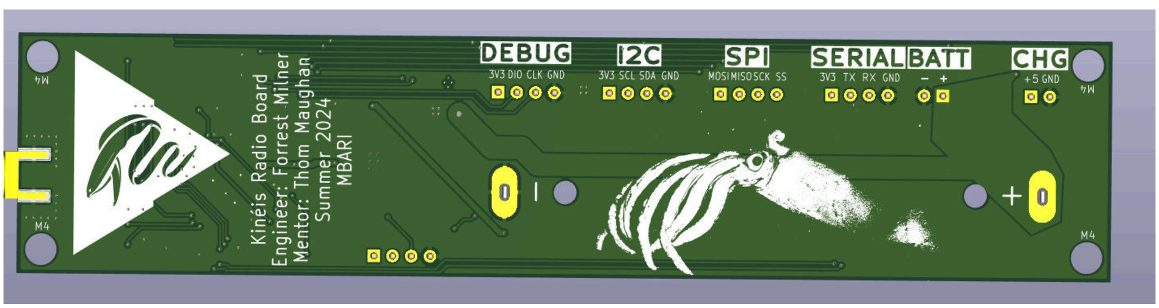

Figure 3: CAD rendering of the bottom of the board.

The stencil, pick and place, and reflow oven was completed in one day. The next day the headers, battery connector, and radio antenna mount were soldered.

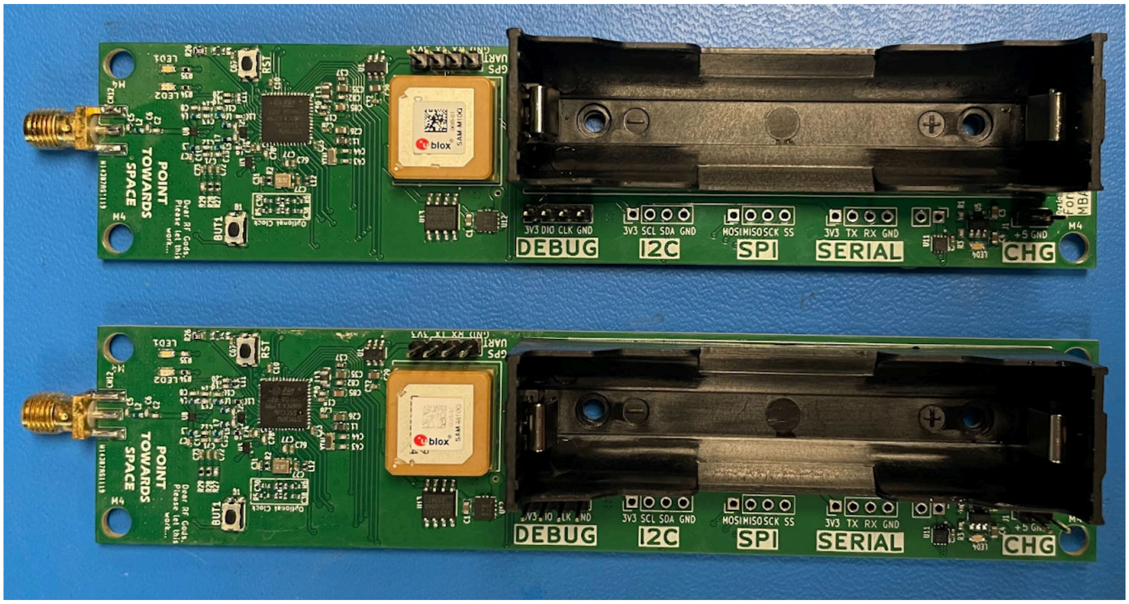

Figure 4: The two boards assembled during summer 2024.

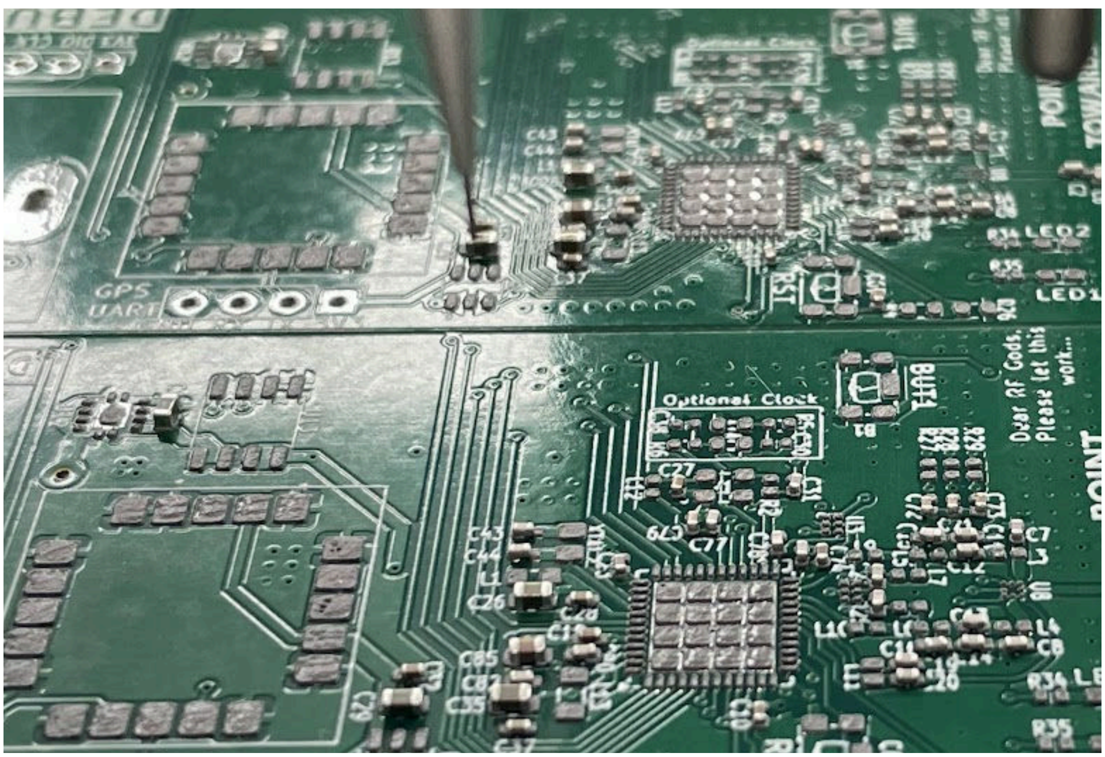

Figure 5: Placing the components using the manual pick and place into the solder paste.

RESULTS

The two boards were a moderate success. The project was severely time limited in debugging the boards, so the team focused on aspects of the board most likely to get working.

GPS FUNCTIONALITY

The GPS did not work on either board. It became apparent that the GPS pads had connected during the soldering process, leaving the power and ground pins shorted. It is probable that other pins were shorted as well. In future revisions of this board one would manually remove solder paste for this part. Mentor Thom noted that this part has been difficult like this before for other engineers.

BATTERY AND POWER

The board features a TPS73733QDRBRQ1, a 3.3V regulator. This functionality worked. Testing the output of the regulator for voltage ranges from 4.2 to 3 volts and saw perfect regulation from 4.2-3.3V, and then output voltages matching input voltages for inputs below 3.3V. A serious current increase was noted when powering the system from the battery input as compared to the 3.3V input (bypassing the regulator) which is suspected to be from different chips other than the regulator.

The board has a MCP73831 lithium battery charger. This charger also worked fine. When testing charging current into the battery, there was 503mA going into the battery when at about 50% state of charge, fully within specifications. This current was delivered consistently regardless of the 5V source, either when using a power supply or when using a wireless charger generating the same five volts to power the charger.

The team used a µCurrent clone to test power consumption of the board. The board in theory should have a nominal power consumption of 8 uA if all parts are sleeping properly. When tested through the 3.3V input, which bypasses the regulator and doesn't power the charger output or battery monitor IC, the board drew 43.9 uA, which was a success. When powered through the battery input at 3.5V, the board drew 382 uA, which is significantly more than expected. The project was too time constrained to determine the cause of this excess power usage.

Sleep Power Consumption	Power Via 3.3V		Power Via Battery	
Theory	7 uA	(48 Years)	8 uA	(42 Years)
Test	**43.9 uA**	**(8 Years)**	**382 uA***	**(1 Year)**

Figure 6: Power consumption and runtime assuming a 3Ah battery.

The numbers in Figure 6 show power consumption when the processor is in deep sleep. While the processor is in deep sleep it can wake up after a defined amount of milliseconds, which would be applicable for a period broadcasting of data. While running the STM32WL55 used approximately 5 milliamps when not running the radio. Although not tested, the radio should consume about 300mA for 1 second to transmit a message, which if transmitted every hour is an added 83 uA of equivalent current draw. A sleep current of 43.9uA is reasonable for this application although not optimal. The measured battery draw of 382uA combined with a 1 hour transmission period would result in a total of 462uA draw, or 270 days. This is within the requirements of 6 months runtime. If future developers are able to achieve a similar current consumption measurement to the 3.3V scenario, the total current draw would be ~120uA or a runtime of 2.7 years.

CURRENT SENSOR

The current sensor was tested and worked. It could detect the increased draw of turning on LEDs. The sensor will be able to detect the increased current from the radio being underwater.

CONCLUSIONS/RECOMMENDATIONS

During an introductory meeting with a Kinéis, the team learned that the STM32WL55 is not supported for bidirectional communication with the new network. Instead, the easiest and Kinéis suggested solution seems to be to use the KIM2 module[5]. The KIM2 module is an enclosed RF solution that uses a serial port to send and receive data. It can be turned off to not use power when sleeping, and does not use significantly more power than a custom radio front end would. The module is not small, measuring

36.6 mm by 25 mm. (1.5”x1”) but is reasonable for a backup radio on an LRAUV. This module can be purchased on an Arduino style shield and attached to supported Arduino and STM32 Nucleo boards. This is recommended for development.

All other parts on this board are recommended. Although the GPS did not work it has existing code from SparkFun and a fast acquisition time. The battery charger and regulator all are low power and work. The battery holder was new to me and a great buy; highly recommended.

ACKNOWLEDGEMENTS

Thom Maughan was my fabulous mentor who encouraged me to use new tools, get results, and meet people. My summer at MBARI would have been completely different without him and for this I am extremely grateful. He found time for me almost daily. I would like to thank Chris Beebe, Jim Montgomery, Jose Rosal for assisting with the fabrication of the PCB and instruction with the Manual Pick and Place tool, the oven, and some of the re-work tools. I could not have used these tools as seamlessly with my project without them. I frequently bothered Chris and Jim who were always willing to brainstorm and set me up for success. George Matsumoto, the (celebrity) intern coordinator, made all of this possible. I found him steadfast, extremely competent, and always willing to lend an ear to my ramblings.

REFERENCES

1) Adding support for STM32WL integrated transceivers · Issue #588 · jgromes/RadioLib. (n.d.). GitHub. https://github.com/jgromes/RadioLib/issues/588

2) Communication. (2024, August 14). *Success of the first launch no time Toulouse*. KINEIS. https://www.kineis.com/en/success-of-the-first-launch-no-time-toulouse/

3) The future of Argos. (2022, October 21). CLS Telemetry.

https://telemetry.groupcls.com/argos-solutions/the-future-of-argos-argos4ng/

4) Kim2. (n.d.). Kinéis. https://connect.kineis.com/kim2/kim2

5) Sx1261. (n.d.). Semtech Semiconductor, IoT Systems and Cloud Connectivity |

Semtech. https://www.semtech.com/products/wireless-rf/lora-connect/sx1261

6) ForrestFire0/radioboard. (n.d.). GitHub. https://github.com/ForrestFire0/radioboard