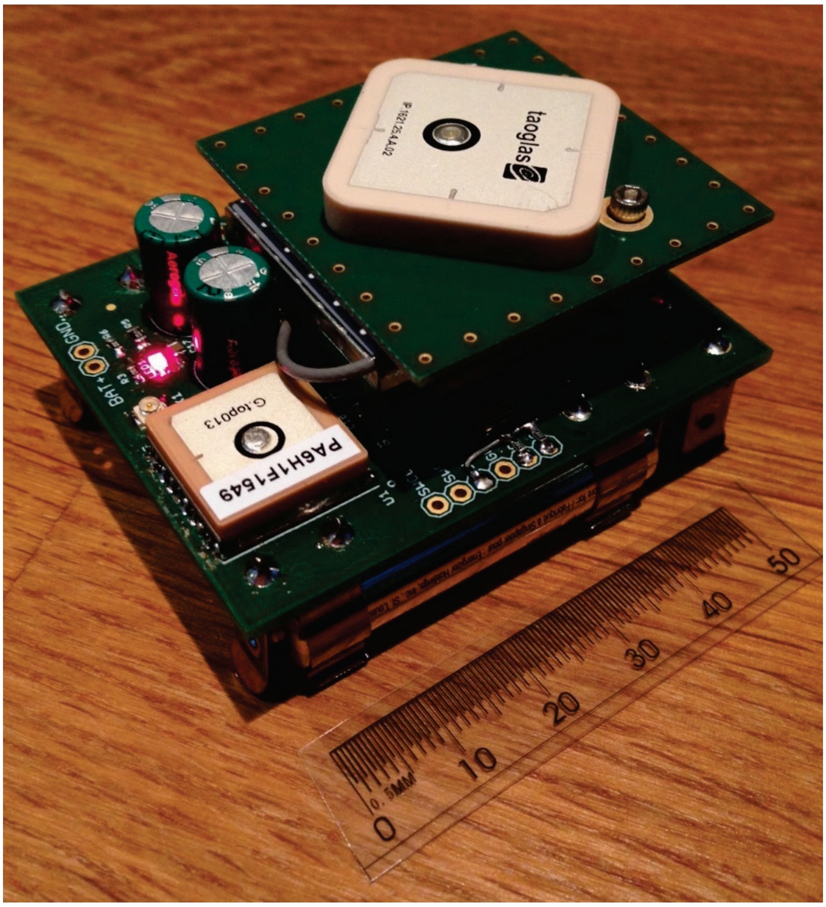
Iridium 9603 Beacon



Background:

One of the more unusual projects I've been involved with is "BIT" – the Balloon-borne Imaging Telescope: a 0.5m telescope flown below a large balloon at an altitude of 30km, above 99% of the Earth's atmosphere. The project is being led by the University of Toronto and Princeton University. You can find out more about the project at:

https://sites.physics.utoronto.ca/bit/

There is a nice time lapse and video montage of the 2016 "SuperBIT" flight from CSBF, Palestine, Texas here:

https://www.youtube.com/watch?v=jsKrfpdGslg

and here is a nice press release about the 2015 BIT flight from Timmins, Canada:

http://www.asc-csa.gc.ca/eng/blog/2016/03/31/university-of-toronto-students-send-a-telescope-soaring-through-the-stratosphere.asp

Now, one of the tricky parts of high altitude balloon missions is that you are not guaranteed to get your balloon payload back again, especially with launches from places like New Zealand where most of the flight takes place over the sea. Wouldn't it be great if you could 'drop off' some of the precious scientific data each time the balloon passes over land? Well, we've been investigating exactly that and working out what it would take for a small, autonomous glider – essentially a flying hard drive – to navigate from 30km to a drop zone somewhere near a major road.

One of the essential components for the glider will be a "come get me" location beacon, so it can tell us where it is and allow us to pick it up once it has landed. The design I have been testing uses an Iridium 9603 Short Burst Data module, which can transmit short (email) messages from anywhere on Earth via the Iridium satellite network. I included a GPS receiver so the beacon can transmit its location, an altitude/pressure and temperature sensor, and powered the beacon from AAA Energiser Ultimate Lithium batteries which should be able to withstand the -56°C temperatures encountered during the flight.

The design I've ended up with weighs in at 72.6g and is light enough to fly on a much smaller balloon should you want to.

I've tried to keep the beacon 'general purpose' and so you could use it for many other remote monitoring applications, perhaps relaying environmental data from remote locations using sensors connected to the I2C or SPI pins.

The Design:

You can find background information about the prototype for the beacon at:

https://github.com/PaulZC/Iridium_9603_Beacon_Prototype

The key components of the finished beacon are:

- Iridium 9603 Module
    - Available (in the UK) from e.g.:
    - http://www.ast-systems.co.uk/Product-Pages/Iridium-9603-SBD—Satellite-Tracking-Transceiver.aspx
    - http://www.rock7mobile.com/products-iridium-sbd
- Taoglas IP.1621.25.4.A.021 Iridium Patch Antenna
    - Available from e.g. Mouser (960-IP1621254A02)

- Atmel ATSAMD21G18 Processor
  - As used on the Adafruit Feather M0:
  - https://www.adafruit.com/products/2772
  - Available from e.g. Farnell / Element14 (2460544)
- GlobalTop FGPMMOPA6H GPS module
  - As used on the Adafruit Ultimate GPS:
  - https://www.adafruit.com/products/790
- MPL3115A2 Altitude/Pressure sensor:
  - As used on the Sparkfun SEN-11084
  - https://www.sparkfun.com/products/11084
  - Available as a bare chip from e.g. Farnell / Element14 (2009084)
- Linear Technology LTC3225EDDB SuperCapacitor Charger
  - http://www.linear.com/product/LTC3225
  - Available as a bare chip from e.g. Farnell / Element14 (1715231)
  - Charges two e.g. Bussmann HV0810-2R7105-R 1F 2.7V capacitors (Farnell / Element14 2148482)

You can find the full schematics, overlays and bill of materials in: Iridium_9603_Beacon_V1.pdf

The Arduino code can be found in Arduino\Iridium9603Beacon

The Eagle files can be found in Eagle\V1

Before you rush out and build one, V1 of the PCB has the following gremlins which will be corrected in V2:

- I forgot to include 1K pull-up resistors for the I2C SCL and SDA pins; you can add them manually to the SCL/SDA pads; the MPL3115A2 doesn't work without them
- C13 is a 0.1µF capacitor in an 0402 package which is really small; in V2 this will be 0603

Have you flown one of these beacons?

Not yet. I flew all of the components for the beacon on the July 2016 "SuperBIT" flight from CSBF, so I'm confident the beacon will work, but the design presented here is currently untested at altitude.

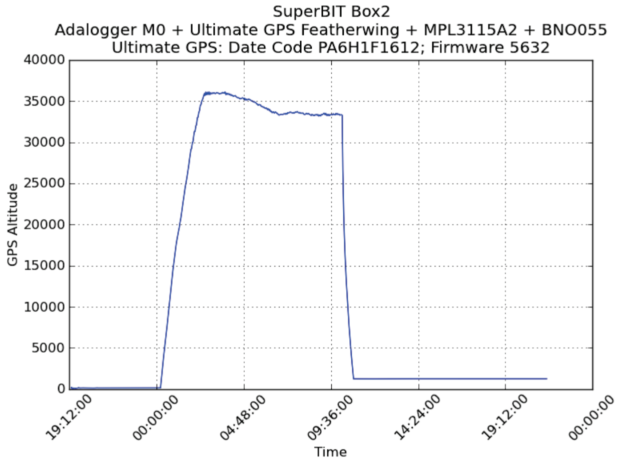
We plan to test the beacon soon, on a small super-pressure balloon flight by the UBSEDS (University of Bristol Students for the Exploration and Development of Space):

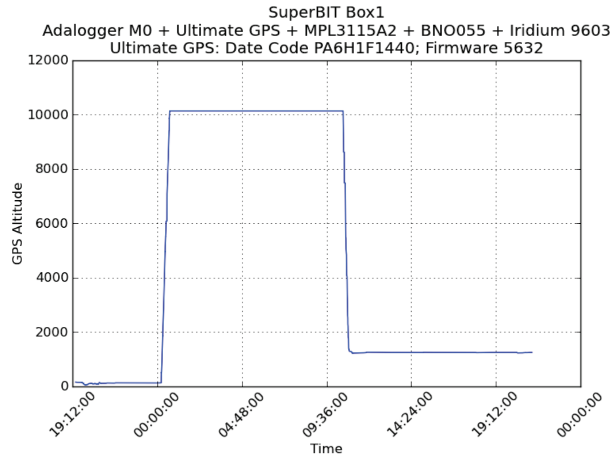
http://www.bristol-seds.co.uk/

I'll report back once the flight has taken place.

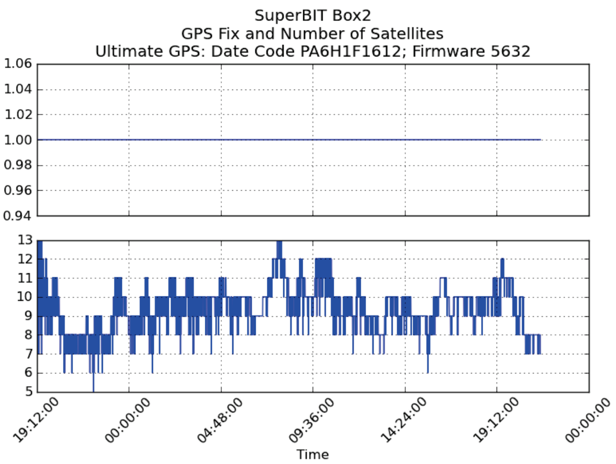
Will the GPS work at 10km – 35km?

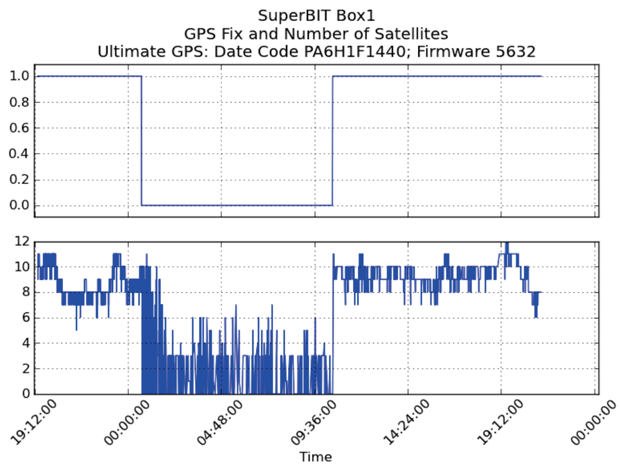
Well, hand on heart, I can't guarantee it. We flew two GlobalTop FGPMMOPA6H GPS modules to 35km on the SuperBIT flight: one worked correctly and one didn't (it lost its fix and thought it was at 10,139m for most of the flight):





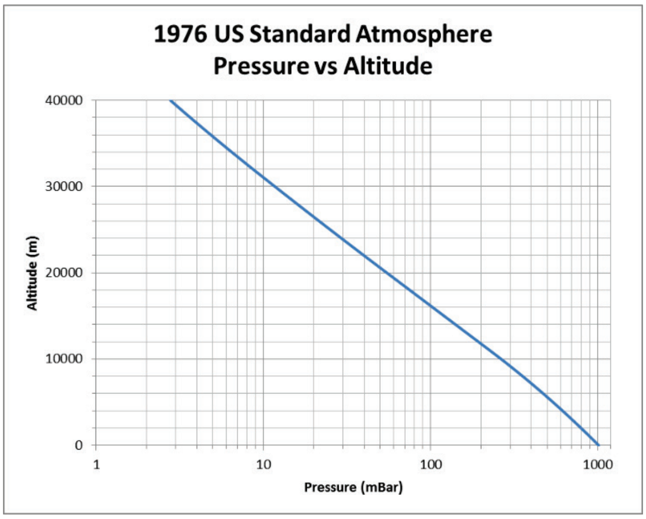
The two GPS modules were mounted on different parts of the balloon gondola, with different antennas and very different views of the sky. It is possible that the one that misbehaved simply wasn't able to lock onto sufficient satellites during the flight and the failure was nothing to do with the module firmware.

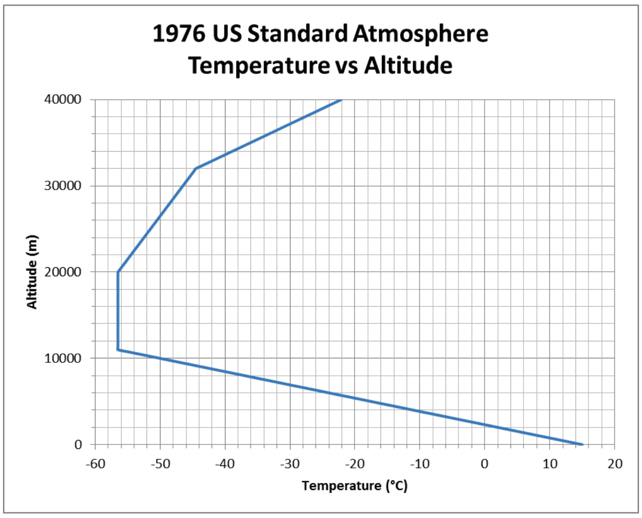




How cold does it get up there?

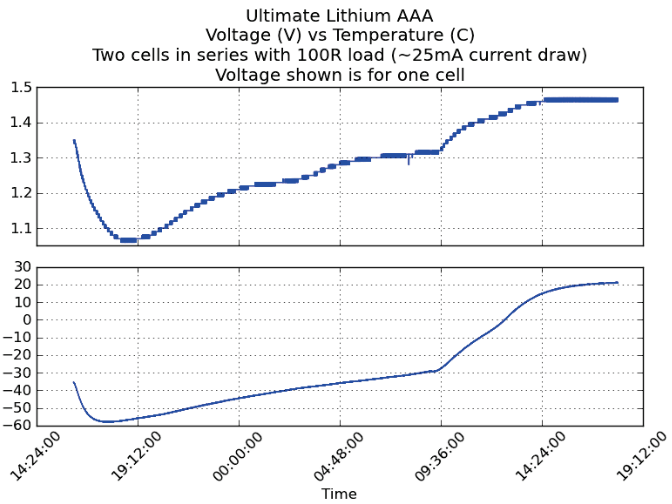
Very. The US Standard Atmosphere (1976) is the standard reference for the temperature and pressure at altitude. A balloon floating at 13km will be at an ambient temperature of -56°C. But, the sunlight at that altitude is very intense so your electronics can easily overheat unless covered in white insulation or reflective film such as Mylar™. Mylar™ is rather good at blocking satellite signals, so white insulation is the way to go.





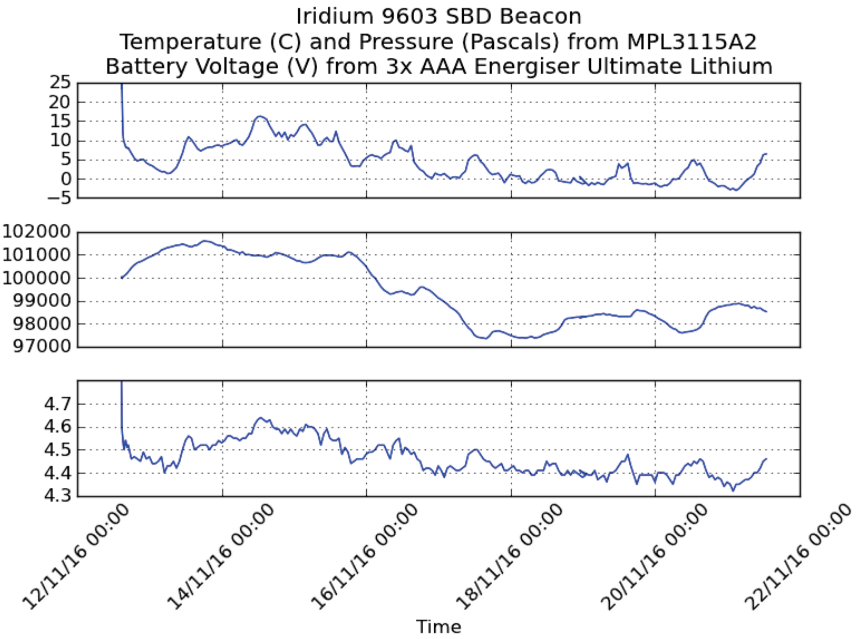
Will the batteries work at altitude?

They should. The beacon is powered by three AAA Energiser® Ultimate Lithium batteries. These are rated down to -40°C but tests I've done (using dry ice) show that they continue to work much colder than that. At -56°C, the voltage per cell drops to approximately 1.1V. As most of the beacon electronics runs from 3.3V, the batteries should be just about OK but we will probably have to rely on some solar heating.

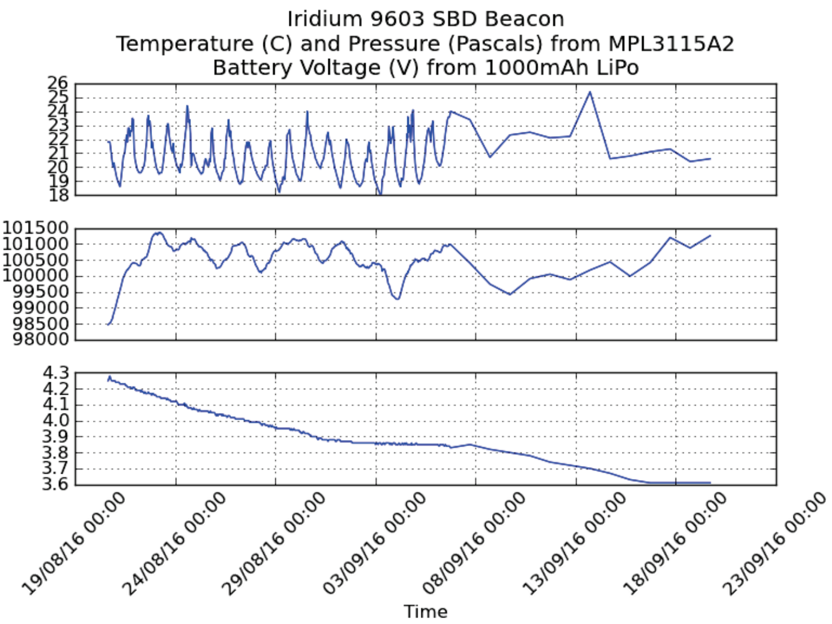


How long will the batteries last?

Hopefully about a month. By default, the beacon transmits its position, temperature and pressure: every 10 minutes for the first two hours; every hour for the next ten days; and then every 6 hours until the batteries run out. Here is data from a 10 day test at sea level:

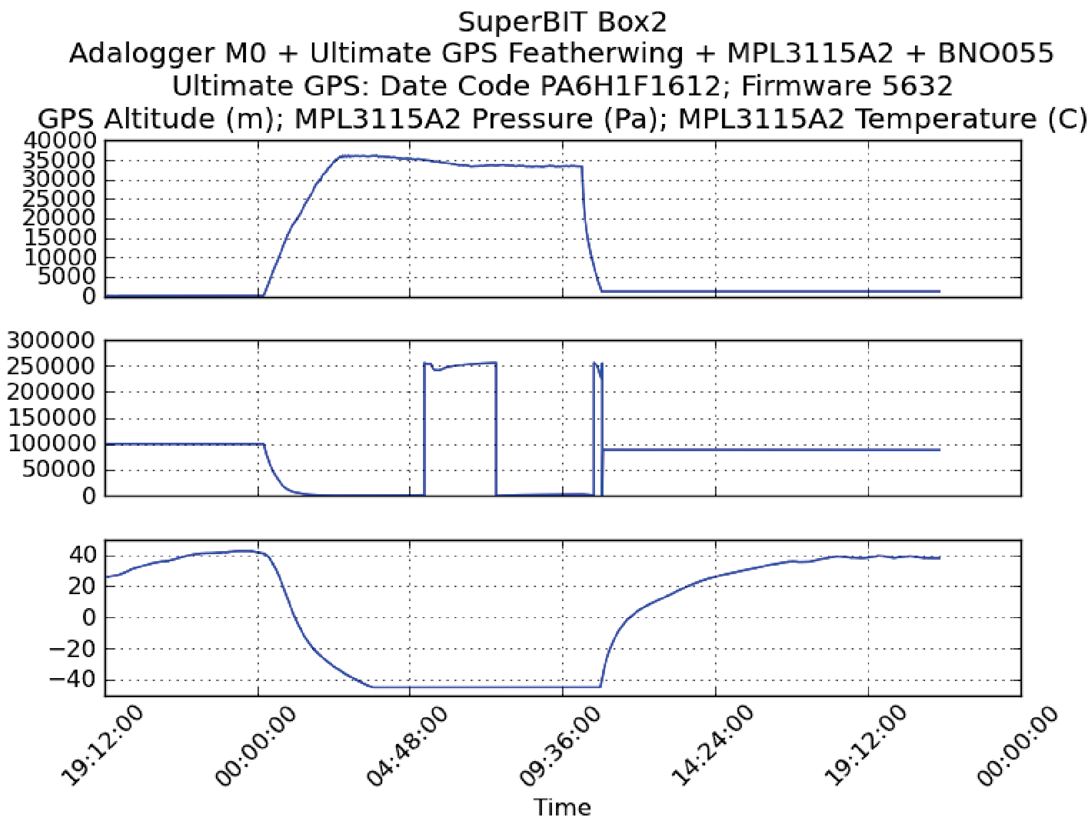


And here is data from a longer test where the beacon was powered by a 1000mAh LiPo battery (the Ultimate Lithium batteries have a capacity of approximately 1200mAh):



The MPL3115A2 is only rated to 20 kPa and -40°C. Will it work above 12km?

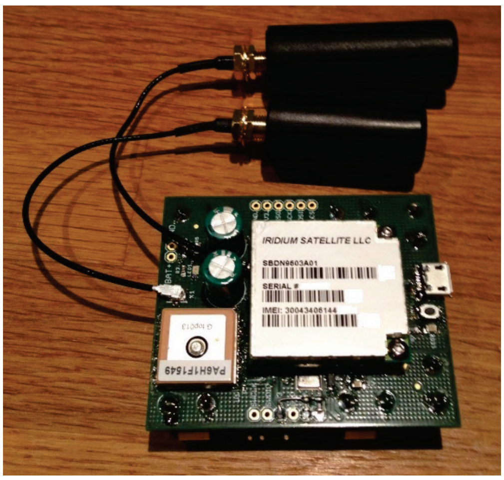
Yes. But: it does exhibit an unusual wrap-around when the pressure drops below about 500 Pa (~35km); and the temperature reading does bottom-out at about -47°C:



Can I use different antennas?

Yes. There are uFL antenna connectors for both the Iridium 9603 and the GPS module and you can attach external antennas using readily-available uFL to SMA adaptors.

If you want to use the 9603 Beacon as a hand-held unit, you could use small helix antennas:



Or, for fixed or vehicle-mounted applications, a larger dual-band Iridium+GPS antenna. E.g.:

https://www.beamcommunications.com/products/70-iridium-beam-whip-dual-mode-antenna

Do you recommend coating the board once it is populated?

Yes. When we were at CSBF, the Texas weather was hot, humid and occasionally very wet. We were working in an air-conditioned high bay but frequently had to open the bay doors, letting in lots of warm, moist air. Just before our first launch window, all of my Adaloggers stopped working. They acted like they had lost their bootloaders and refused to operate at all. After a few hours of head scratching, I eventually figured out that it was moisture that was causing the boards to malfunction. After I dried them with a hot air gun and coated them in silicone (it was all I had available!) they all operated perfectly. I suspect we were working very close to the dew point and letting all that warm moist air into the cool lab was probably the main culprit.

As a minimum, I'd recommend applying a conformal coating to the processor and surrounding components (especially the crystal). But be careful to mask off the connectors, switch and the pressure sensor before you spray the board!

How do I upload the Arduino code?

The 9603 Beacon is based on the Adafruit Feather M0 (Adalogger):

https://www.adafruit.com/products/2796

https://www.adafruit.com/products/2772

You can follow Lady Ada's excellent instructions:

https://cdn-learn.adafruit.com/downloads/pdf/adafruit-feather-m0-adalogger.pdf

What other libraries do I need?

The main one is Mikal Hart's Iridium SBD library. It was written for the Rock7 RockBLOCK, which uses the Iridium 9602 module, but it works just fine on the 9603:

http://arduiniana.org/libraries/iridiumsbd/

https://github.com/mikalhart/IridiumSBD

You will also need:

https://github.com/mikalhart/TinyGPS

http://arduiniana.org/libraries/pstring/

https://github.com/adafruit/Adafruit_MPL3115A2_Library

https://github.com/arduino-libraries/RTCZero

How do I install the ATSAMD21G18 bootloader?

Get yourself a Segger J-Link programmer and connect it according to Atmel_SAMD21_Programming_Cable.pdf

Ignore the RST connection

Connect the 5V-Supply output from the J-Link to VBAT / BAT+ to power the board while you configure it (it doesn't need batteries for this bit)

Follow Lady Ada's excellent instructions:

https://learn.adafruit.com/proper-step-debugging-atsamd21-arduino-zero-m0/restoring-bootloader

Why does the beacon weigh 72.6g?

I've tried to keep the mass as low as possible, this is how it breaks down:

- Batteries: 22.8g
- PCBs (main PCB + antenna PCB + small components): 16.7g
- Iridium 9603 Module: 11.6g
- Iridium Antenna: 9.3g
- GPS Module: 4.0g
- Battery Clips: 3.9g
- Module and Antenna Fixings: 2.6g
- Super Capacitors: 1.7g
- Total: 72.6g

Why do you need the Super Capacitors?

The Iridium 9603 module draws a peak current of 1.3A when transmitting its short data bursts. That's too much for most small batteries, especially at low temperatures. The LTC3225 super capacitor charger draws 150mA from the batteries to charge two 1F 2.7V capacitors, connected in series, to 4.8V. The capacitors then deliver the 1.3A to the module when it sends the data burst.

What data will I get back from the beacon?

The Arduino code included in this repository will send the following (separated by commas):

- GPS Time and Date (year, month, day, hour, minute, second)
- GPS Latitude (degrees)
- GPS Longitude (degrees)
- GPS Altitude (m)
- GPS Speed (knots)
- GPS Heading (degrees)
- Atmospheric pressure (Pa)
- Temperature (C)
- Battery voltage (V)

E.g.:

20160820152446,55.866596,-2.428457,95,0.0,303,98472,21.8,4.25

You will receive the data as an email attachment from the Iridium system. The email itself contains extra useful information:

- Message sequence numbers (so you can identify if any messages have been missed)
- The time and date the message session was processed by the Iridium system
- The status of the message session (was it successful or was the data corrupt)
- The size of the message in bytes
- The approximate latitude and longitude the message was sent from
- The approximate error radius of the transmitter's location

E.g.:

From: sbdservice@sbd.iridium.com

Sent: 20 August 2016 16:25
To:
*Subject: SBD Msg From Unit: 30043406174****
*Attachments: 30043406174****_000029.sbd*

MOMSN: 29
MTMSN: 0
Time of Session (UTC): Sat Aug 20 15:24:57 2016 Session Status: 00 - Transfer OK
Message Size (bytes): 61

Unit Location: Lat = 55.87465 Long = -2.37135 CEPradius = 4

It is quite easy to write scripts or rules for your email software to automatically divert these messages to an email folder and save both the message and attachment to disk. You can then use (e.g.) Python to stitch these messages together and plot (e.g.) pressure and temperature against time (as shown above).

You can adapt the code to send whatever data you like, up to a maximum of 340 bytes. The message is sent as plain text, but you could encrypt it if required.

<u>Thanks!</u>

This project wouldn't have been possible without the open source designs and code kindly provided by:

- **Adafruit**:
  - the Adafruit SAMD Board library
  - the design for the Feather M0 Adalogger
    - For more details, check out the product page at
      - https://www.adafruit.com/product/2772
    - Adafruit invests time and resources providing this open source design, please support Adafruit and open-source hardware by purchasing products from Adafruit!
    - Designed by Adafruit Industries.
    - Creative Commons Attribution, Share-Alike license
  - the MPL3115A2 library
  - sercom examples

        - https://learn.adafruit.com/using-atsamd21-sercom-to-add-more-spi-i2c-serial-ports/creating-a-new-serial
- **Mikal Hart**:
    - the Iridium SBD library (distributed under the terms of the GNU LGPL license)
    - TinyGPS
    - PString
- **Arduino**:
    - the Arduino IDE
    - Arduino SAMD Board library
    - RTCZero library
- **Cave Moa**:
    - the SimpleSleepUSB example
        - https://github.com/cavemoa/Feather-M0-Adalogger/tree/master/SimpleSleepUSB
- **MartinL**:
    - sercom examples
        - https://forum.arduino.cc/index.php?topic=341054.msg2443086#msg2443086

The small print