

# Reach for the skies: Extreme QRP at 35,000 feet

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Virtual FDIM 2021

QRP Labs

<http://qrp-labs.com>

# Why QRP?

- We're putting a radio on a balloon to track it.
- Light weight payload
  - No boatanchors!
  - No 1kW Linear!
  - No car battery!
- Hence: QRP!

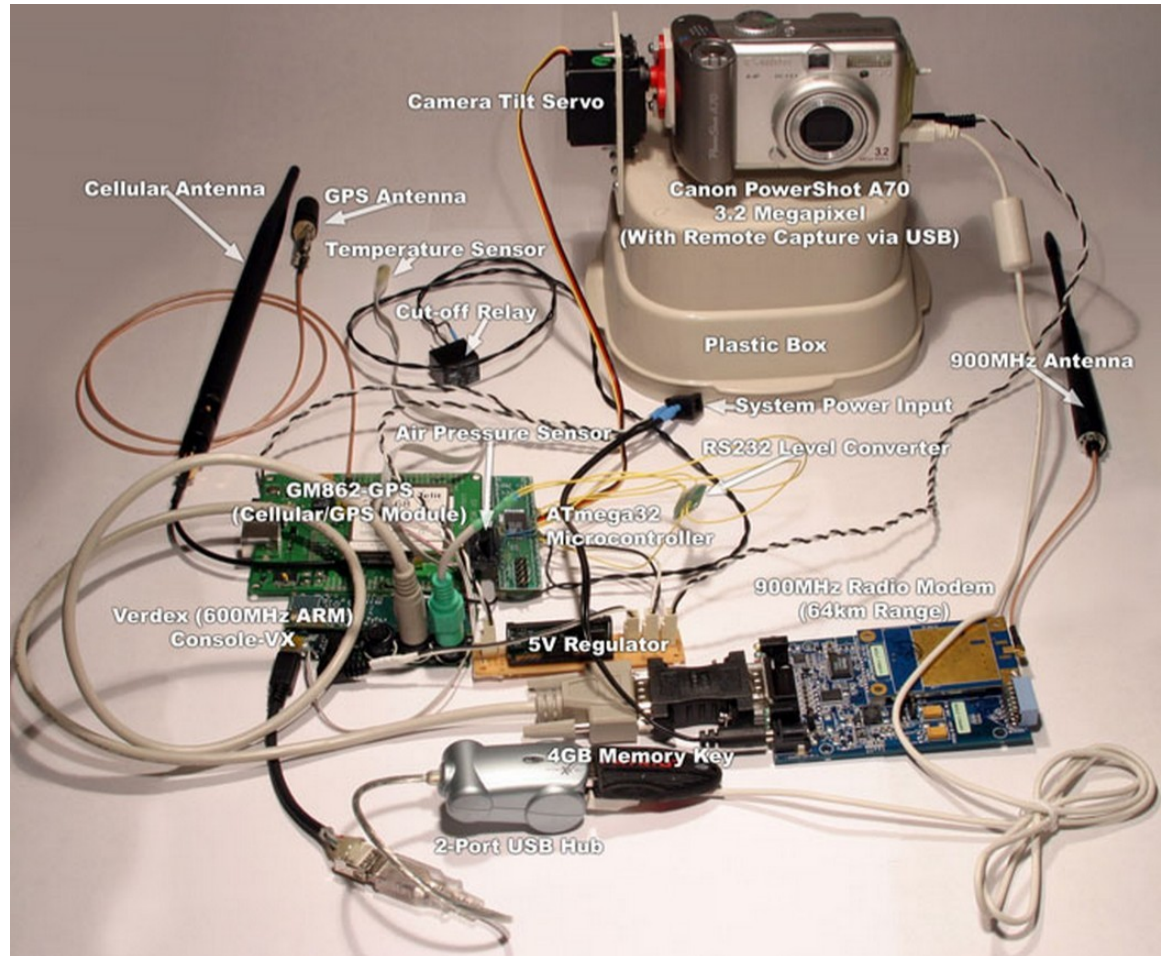


# High Altitude balloon types

- Firstly, “weather balloons”
- 2 – 5m diameter, latex
- Can carry perhaps a kg or few payload
- Flies up, as high as 100,000 feet, bursts, comes down
- Chase teams try to recover the balloon and any videos, photos etc. it captured
- Tracking uses short range VHF/UHF (APRS, data)
- Expensive, BIG projects



# WX balloons: Several kg payload



# High Altitude balloon types

- Floater balloons
- A.k.a. “Super-pressure”, pico-balloons
- Small 1m diameter plastic film
- Inelastic, reaches floating altitude and carried by the wind
- Long distance, long duration
- Very low payload capability
- Communications challenges!



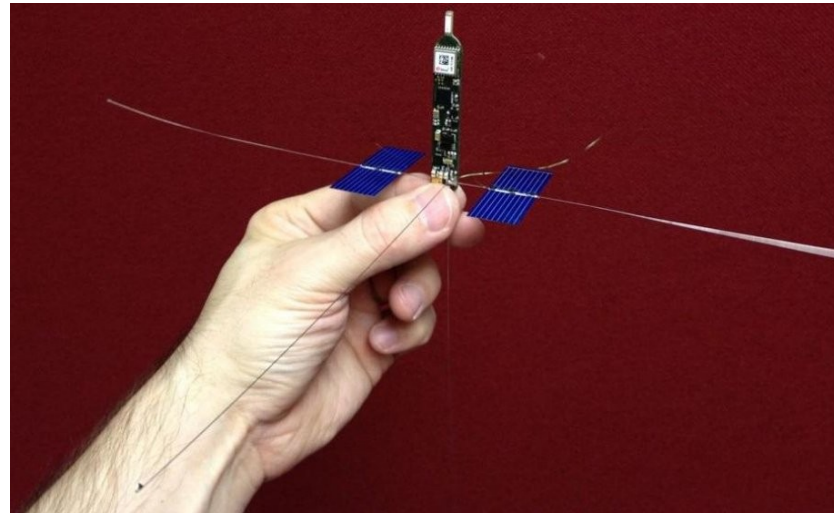
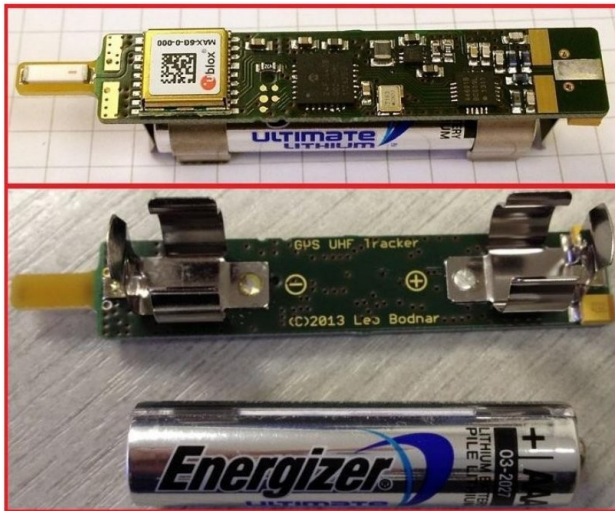


# Floater balloons: extreme QRP

- Very low weight, tiny transmitter
- GPS, power source, antenna
- Thousands of miles of ocean (VHF is no good!)
- HF communications e.g. 30m, 20m band
- Extreme low power: ~ 20mW
- Weak signal techniques: WSPR

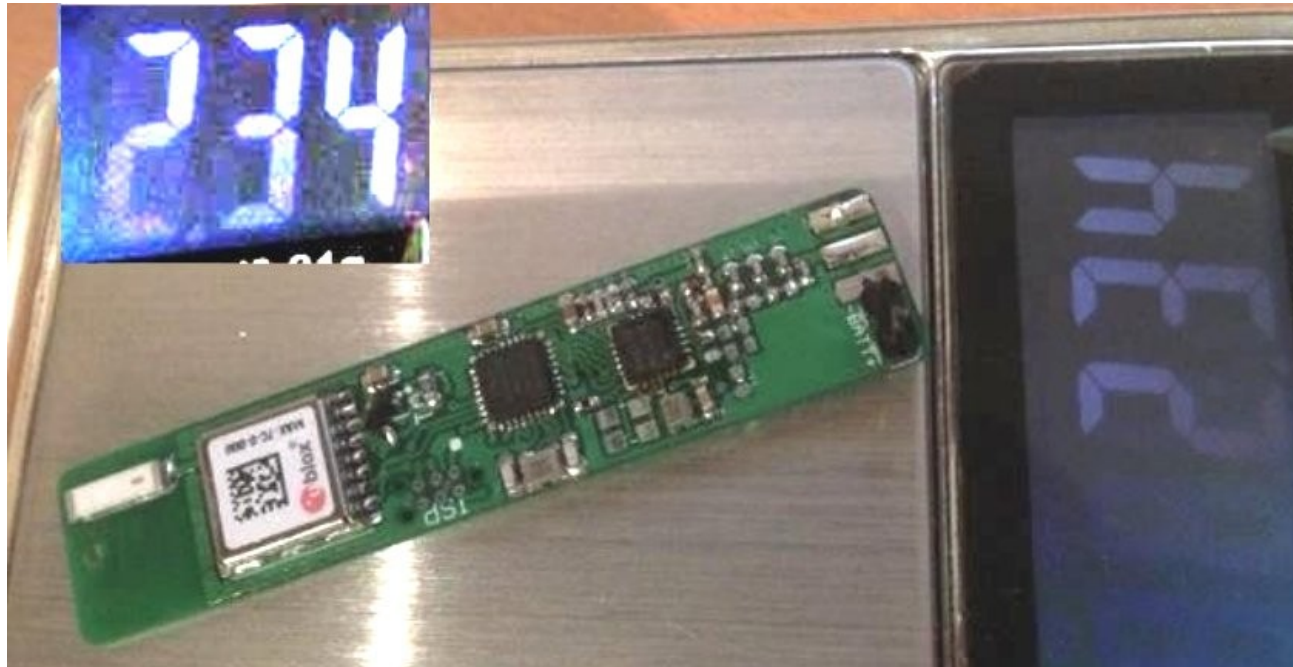
# Giants: Leo MOXER

- 64 flights until July 2014, <http://leobodnar.com/balloons>
- 10mW UHF transmitter, about 10-15g payload weight
- 3 circumnavigating flights, one 6 times
- Mostly used 10mW UHF transmitter



# Giants: VK3YT

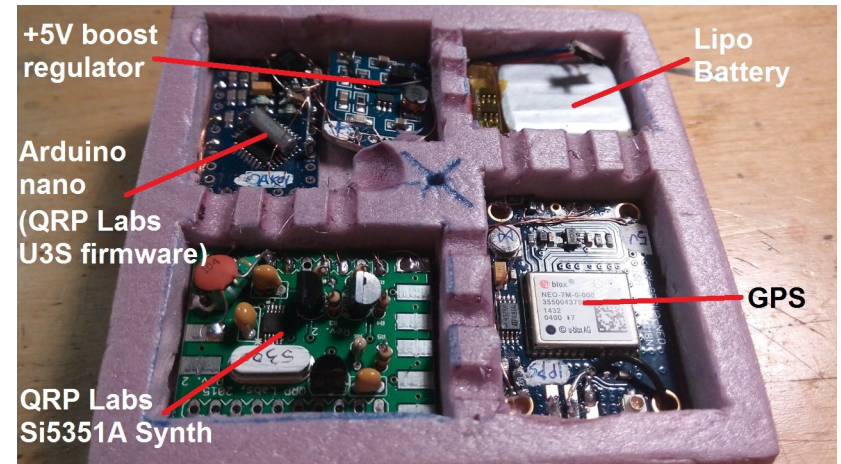
- Many flights, see <http://picospace.net>
- Various radios used; HF 25mW 20/30m WSPR and JT9
- Standard “party balloons”



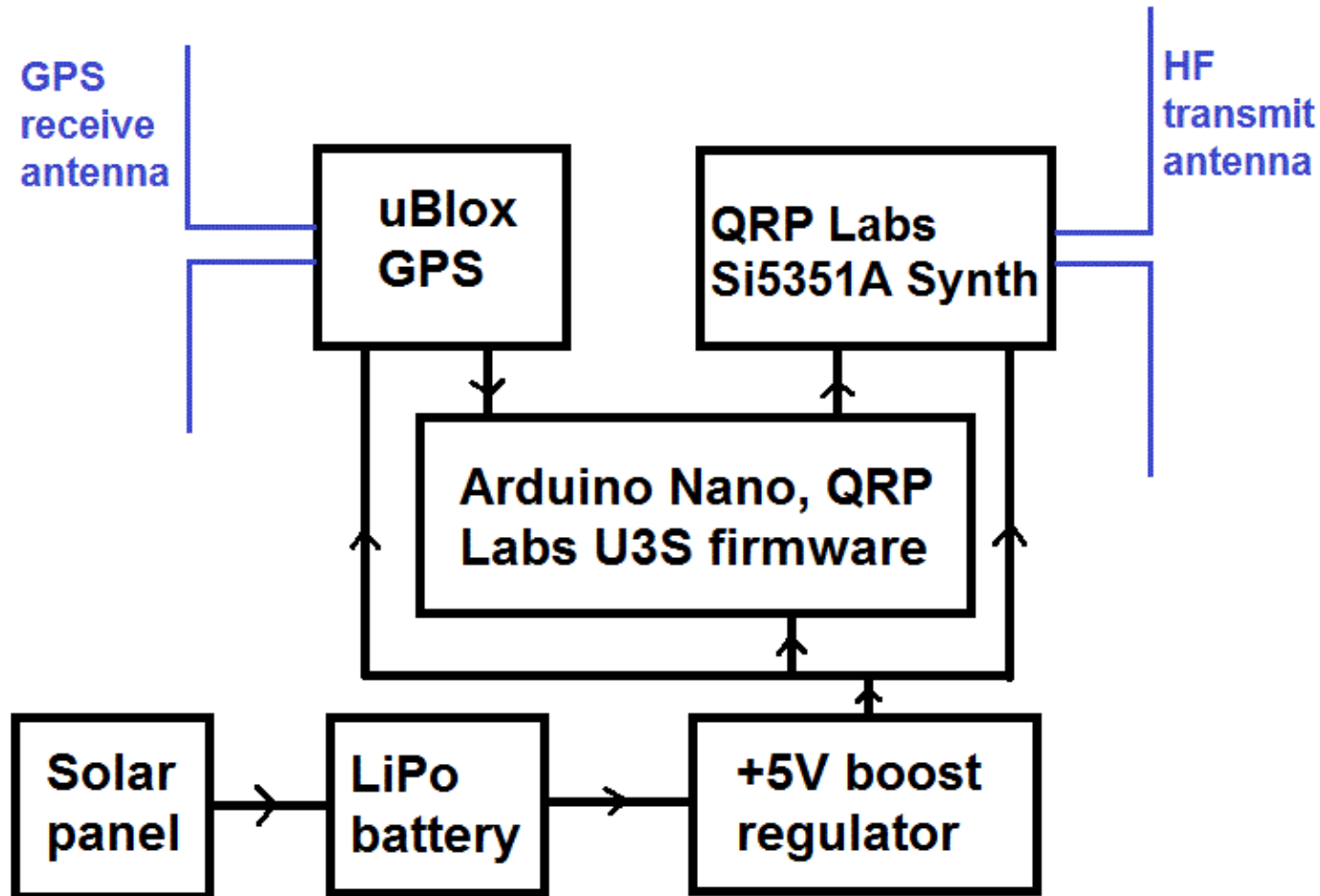


# 2014: Dave VE3KCL

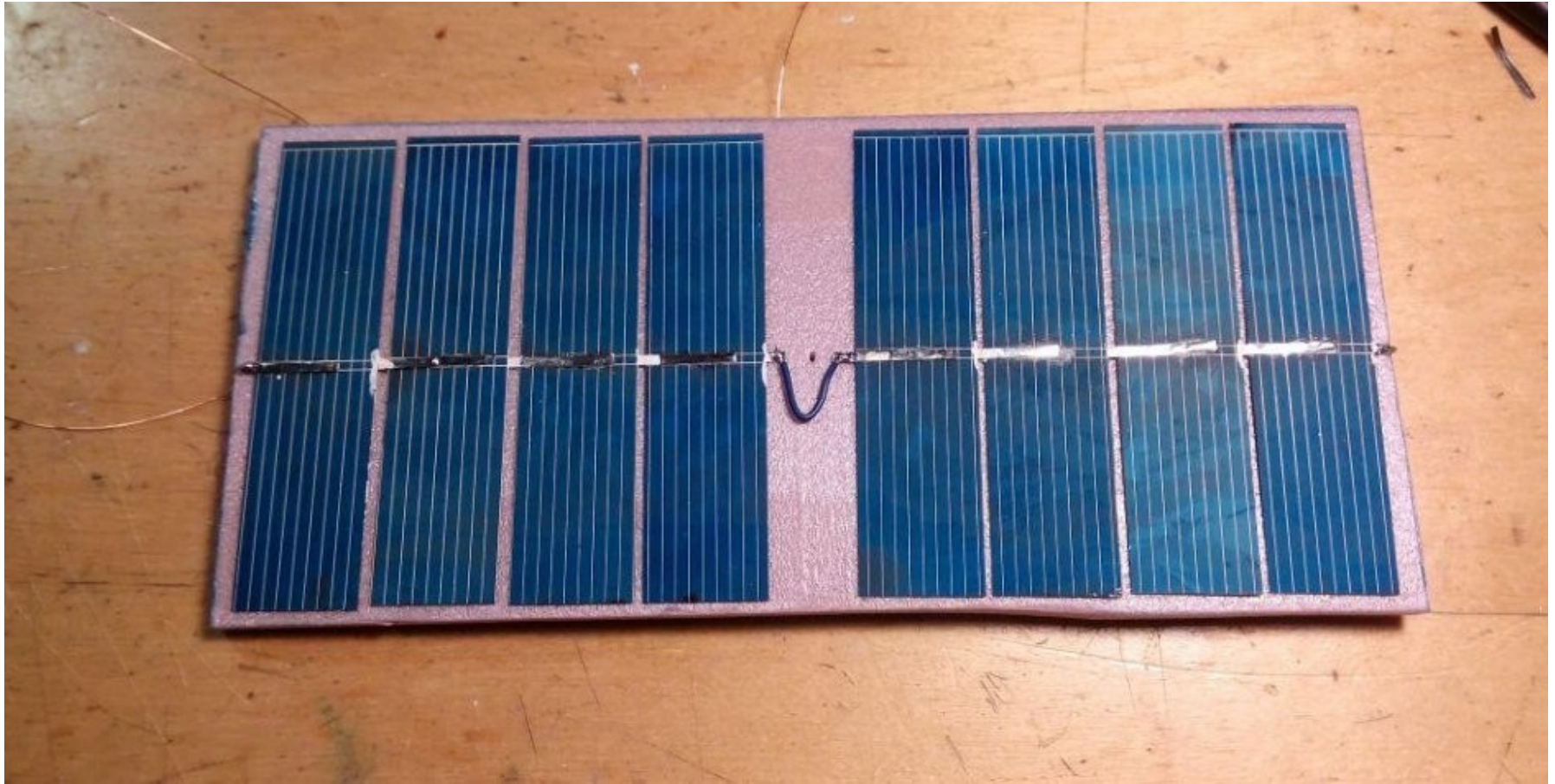
- Ultimate 3S kit on a balloon
- Off the shelf modules, 30-35g
  - Arduino nano as U3S
  - Si5351A Synth kit
  - GPS module
  - LiPo, battery and regulator
  - Antennas (HF, GPS)



# VE3KCL payload block diagram

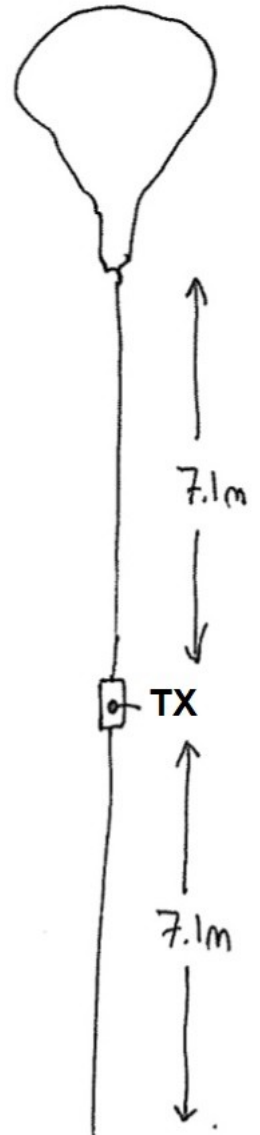
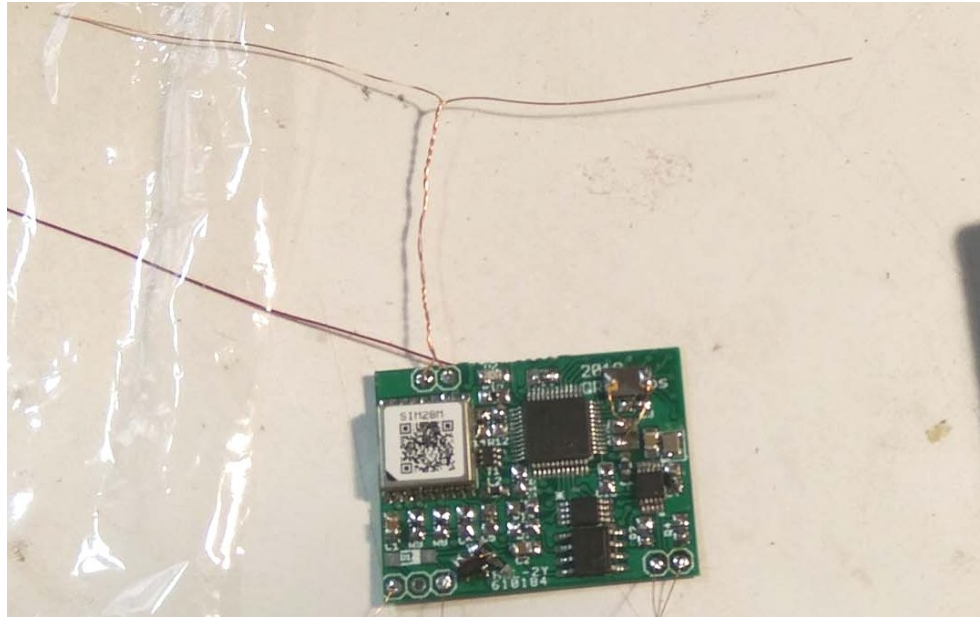
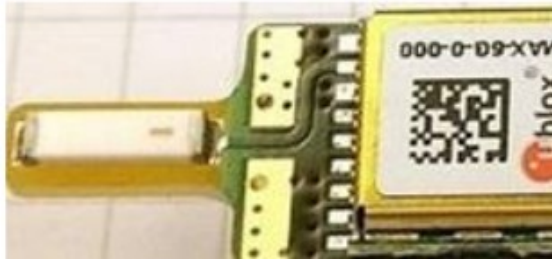
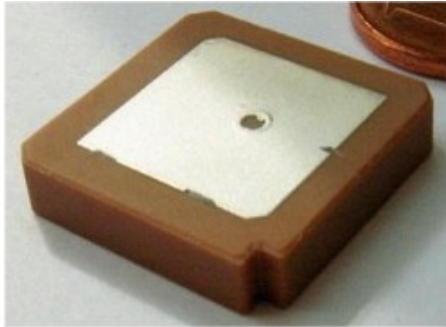


# VE3KCL payload solar panel



# Balloon tracker antennas

- 20m or 30m dipole for HF
- Wire dipole for GPS (1575MHz)





# Communications modes

- VHF and UHF APRS and others
  - Limited VHF and UHF range is fine for WX balloons but no good for global floaters
- JT9 special telemetry by Andy VK3YT
  - Required special software run by volunteers
- WSPR
  - Limited information and 4-character grid square is not very accurate



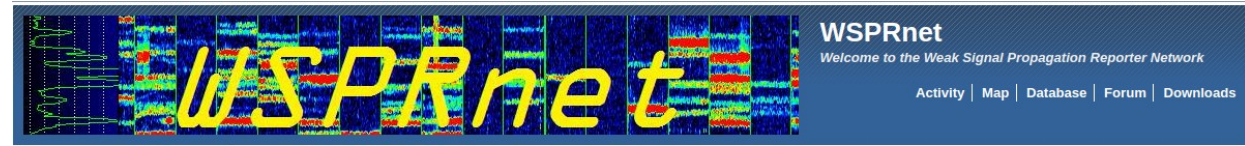
# WSPR: Weak Signal Propagation Reporter

- Created by Joe K1JT
- Very popular worldwide, as a propagation tool!
- Powerful weak signal, narrow bandwidth mode using forward error correction
- Encodes 50 bits of information
  - Callsign (4-6 characters, no prefix/suffix)
  - Maidenhead grid square (4 characters)
  - Transmission power in dBm
- Transmission has 162 symbols, each symbols is one of 4 tones; tone spacing 1.46Hz, message transmission takes almost 2 minutes (1:52)



# WSPR reports to internet database

- Database
- Map



User login

Username \*

Password \*

Create new account  
Request new password

Log in

Frequencies

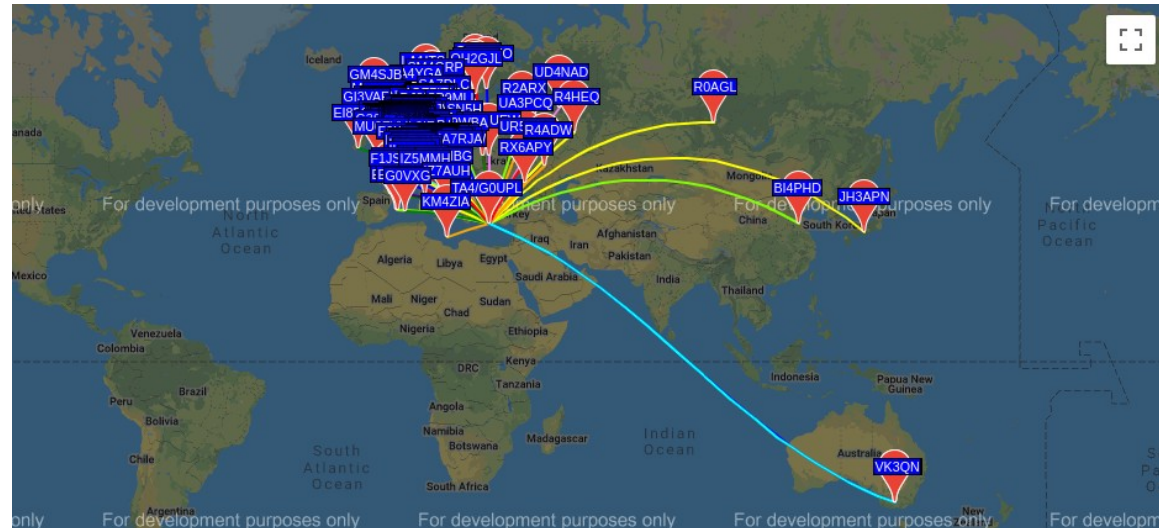
USB dial (MHz): 0.136, 0.4742, 1.8366, 3.5686, 5.2872, 5364.7, 7.2000, 10.1000, 14.0000

## Spot Database

Specify query parameters

50 spots:

Timestamp	Call	MHz	SNR	Drift	Grid	Pwr	Reporter	RGrid	km	az	Mode
2021-03-25 09:30	EA6GK	14.097106	-24	-4	JM19iq	0.1	TA4/GOUP	KM46	2317	90	2
2021-03-25 09:28	DD2RT	14.097087	-22	3	JN58	1	TA4/GOUP	KM46	1981	126	2
2021-03-25 09:22	GOCCL	14.097123	-25	0	J002	5	TA4/GOUP	KM46	2815	118	2
2021-03-25 09:22	PA0MLC	14.097141	-24	0	JO31aw	5	TA4/GOUP	KM46	2488	125	2
2021-03-25 09:22	HAGQL	14.097102	-23	0	JN97xs	5	TA4/GOUP	KM46	1456	146	2
2021-03-25 09:22	IZ7AUH	14.097089	-7	0	JN80pl	1	TA4/GOUP	KM46	1108	110	2
2021-03-25 09:16	DL3TU	14.097113	-22	0	JN48mm	2	TA4/GOUP	KM46	2100	122	2
2021-03-25 09:16	GOCCL	14.097119	-26	0	J002	5	TA4/GOUP	KM46	2815	118	2
2021-03-25 09:14	DL6NL	14.097042	-21	0	JO50cb	0.5	TA4/GOUP	KM46	2130	128	2
2021-03-25 09:12	IZ7AUH	14.097089	-6	0	JN80pl	1	TA4/GOUP	KM46	1108	110	2



# QRP Labs WSPR telemetry protocol

- One normal WSPR message sends Maidenhead grid square – e.g.

G0UPL IO90 23

- Second message of the form:

0x0xxx xxxx xx (where 'x' encode additional data)

- Callsigns with 0, 1 or Q first character are never issued by ITU so we use them to create 30 “channels 0x0xxx to 0x9xxx etc
- WSPR reporting network reports balloon data automatically with no special software

# QRP Labs WSPR telemetry protocol

- The second WSPR message 'x' characters are encoded to contain the following telemetry:
  - 5<sup>th</sup> and 6<sup>th</sup> Maidenhead subsquare characters, giving position accuracy of a few miles
  - Altitude
  - Temperature
  - Battery voltage
  - Groundspeed
  - GPS status

# Telemetry example

13:18 **VE3KCL FN03 13** (normal WSPR)  
13:20 **0C0QQE RG74 43** (telemetry on WSPR)

- Callsign: VE3KCL
- Power: +13dBm
- Locator: FN03IQ
- Altitude: 80m
- Temperature: 36C
- Battery: 3.8V
- Groundspeed: 0 m/s
- GPS: Fix OK,  $\geq$  8 satellites

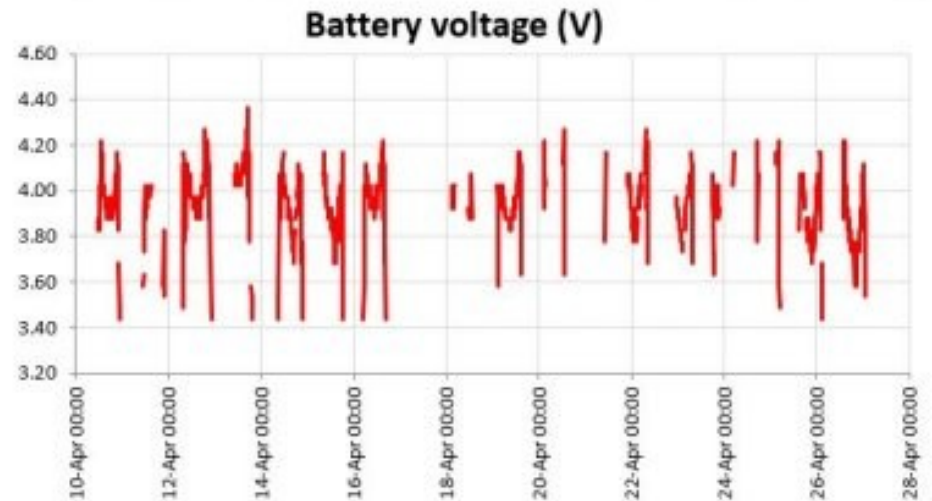
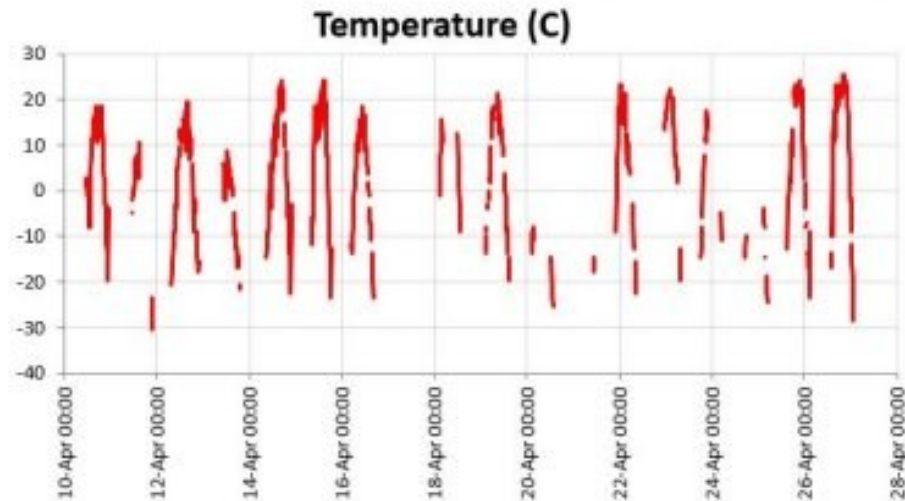
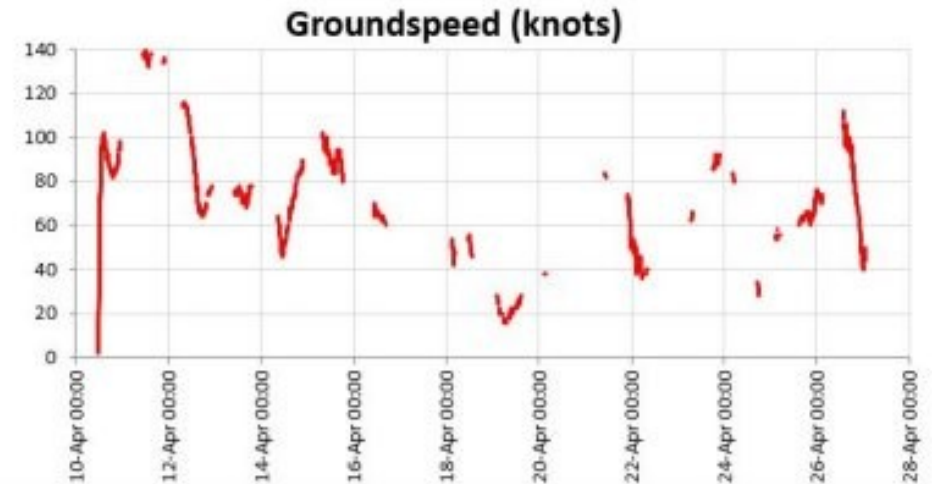
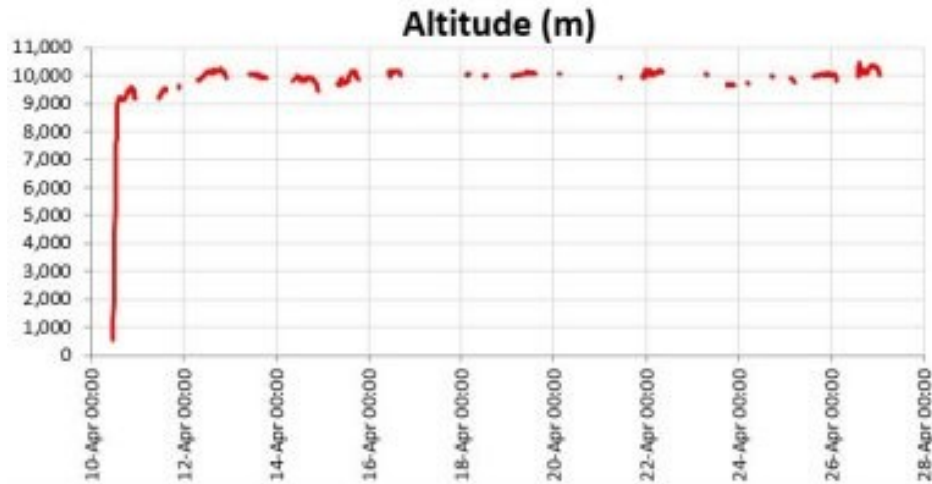


# Tracking: live online map

Updated 2020-12-17 12:12:00 UT, Loc=KO11XQ, Duration=, Distance=  
Alt=11640m, Speed=22knots, Batt=3.85V, Temp=-3C, GPS=3



# Tracking: data charts

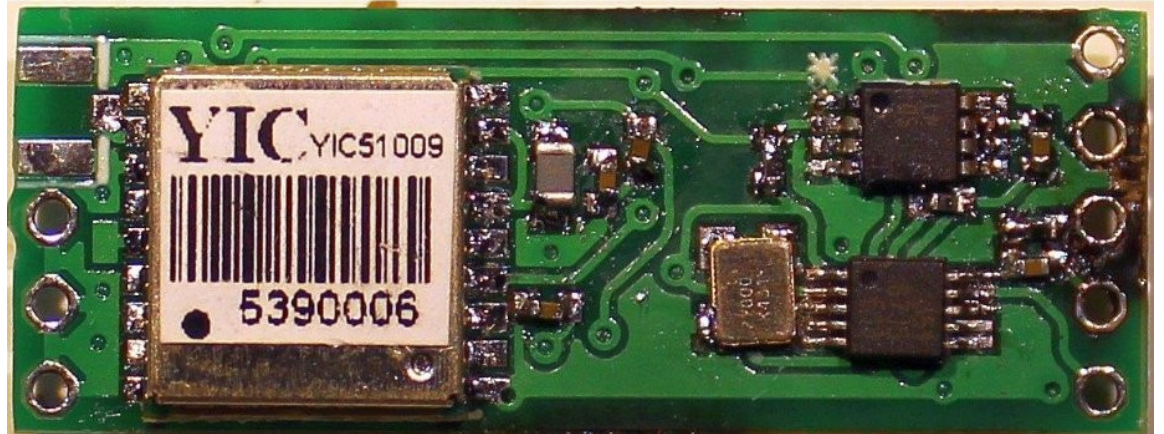
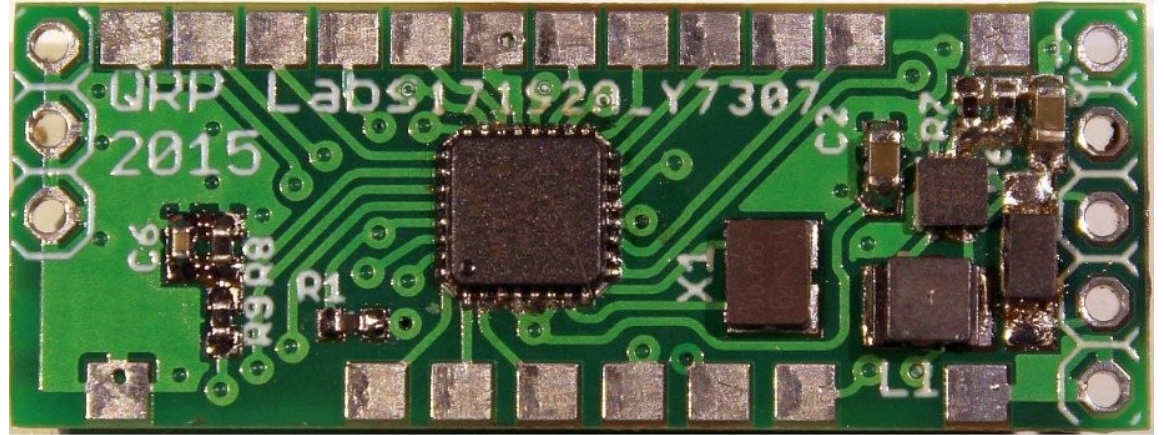


# Hardware

- “Off-the-shelf” version of Ultimate3S, running special U3S firmware (26 flights)
- U3B product development – tiny board also using the ATmega328 processor, running a BASIC interpreter (28 flights)
- U4B product development – STM32 processor, and much more advanced operating system (19 flights to date)

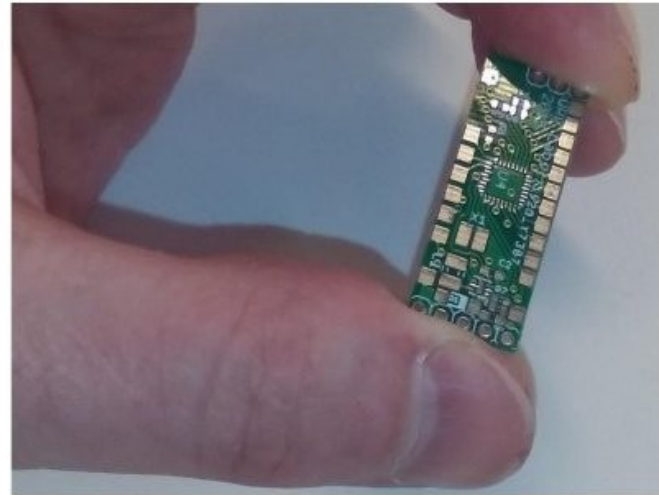
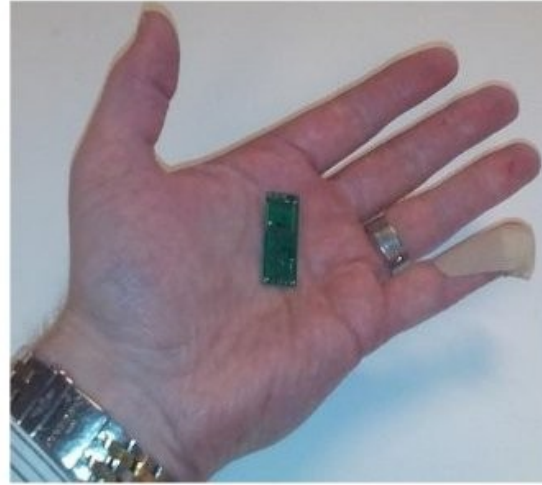
# Ultimate3B

- 1.5 x 0.5 inches
- 1.5 grams  
(0.05 ounces)
- SMD  
components  
both sides
- GPIO





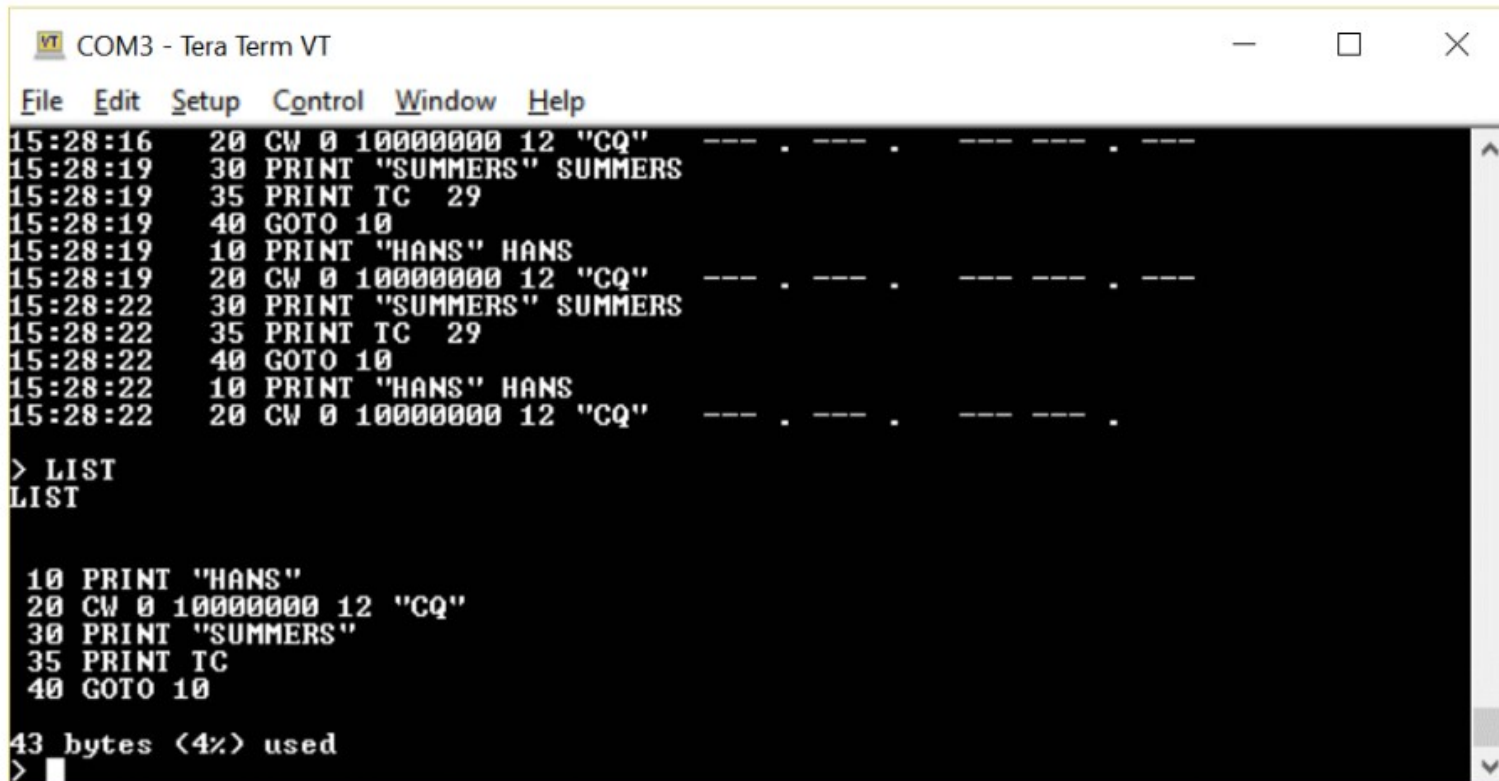
# U3B prototype (continued)





# U3B prototype (continued)

- BASIC interpreter virtual machine developed for the U3B; flight computer configured by BASIC program



```
COM3 - Tera Term VT
File Edit Setup Control Window Help
15:28:16 20 CW 0 10000000 12 "CQ" --- . --- . --- --- . ---
15:28:19 30 PRINT "SUMMERS" SUMMERS
15:28:19 35 PRINT IC 29
15:28:19 40 GOTO 10
15:28:19 10 PRINT "HANS" HANS
15:28:19 20 CW 0 10000000 12 "CQ" --- . --- . --- --- --- . ---
15:28:22 30 PRINT "SUMMERS" SUMMERS
15:28:22 35 PRINT IC 29
15:28:22 40 GOTO 10
15:28:22 10 PRINT "HANS" HANS
15:28:22 20 CW 0 10000000 12 "CQ" --- . --- . --- --- --- . ---
> LIST
LIST

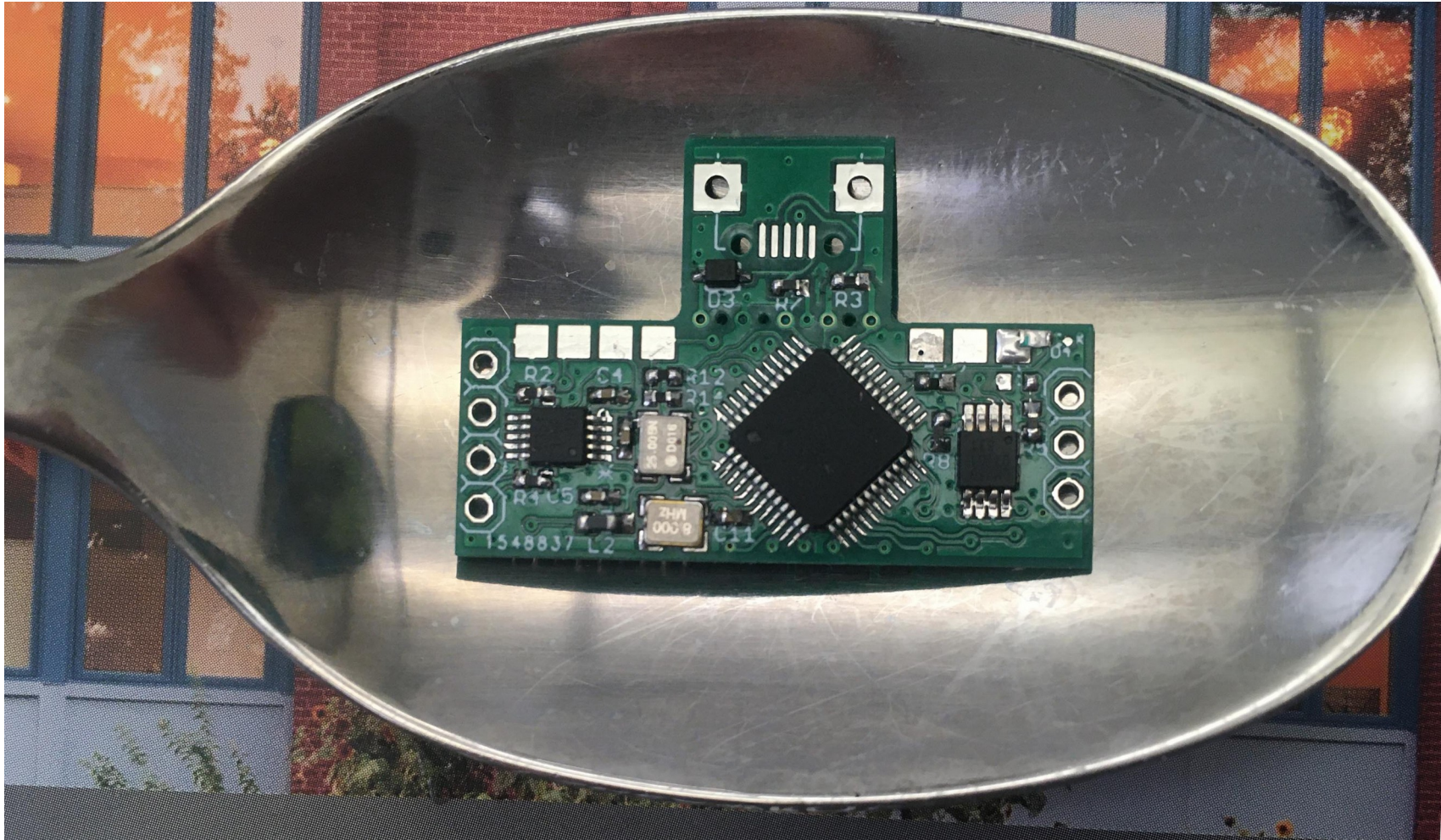
10 PRINT "HANS"
20 CW 0 10000000 12 "CQ"
30 PRINT "SUMMERS"
35 PRINT IC
40 GOTO 10

43 bytes <4%> used
>
```

# U4B tracker

- STM32F103 processor
- Same tiny board size and weight
- On-board USB interface
- Same Si5351A Synth as transmitter, LM75 temperature sensor, and now a TCXO reference
- Completely new firmware called QDOS (**Q**RP Labs **D**isk **O**perating **S**ystem)

# U4B tracker prototype





# U4B tracker prototype



# QDOS QRP Labs Disk Operating System

- 128K “Disk” (implemented on EEPROM chip)
- Simple flight configuration tool
- Text Editor, Debugger, File Manager, Command Line
- Analog inputs, Digital pins (in/out), I2C bus sensors, serial data sensors
- Capability to log data to files



# Ballooning isn't easy...

- Weather takes you down – height is everything
- Balloon failure; over or under filled
- Electronics failure
- Launch drama
- Requires persistence!

# Regulations

- Vary by country
- UK doesn't allow aeronautical transmissions
- Often a grey area...
  - Unattended beacon operation
  - CEPT licensing

# Safety

- Avoid power lines etc. at launch!
- Launch in a large open area without people or traffic to get in your way
- Helium is safe, but expensive and a non-renewable resource on Earth
- Hydrogen has higher lift, is cheaper, but is explosive so needs handling with care

# Aviation Safety



- 650,000 WX balloons annually – 1,800 daily from 900 locations worldwide
- WX balloons are much larger and heavier
- No recorded incidents since 1929
- In most countries such small balloons don't require permission to fly
- Some bird species fly at similar altitudes such as Ruppell's vulture (2.6m wingspan, 9kg weight)
- Pilots don't care



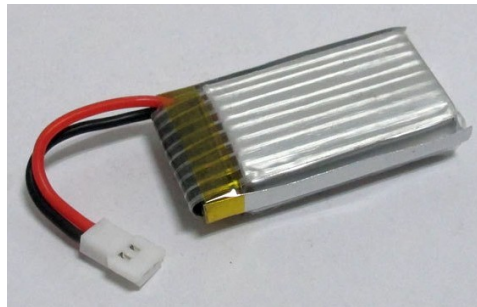
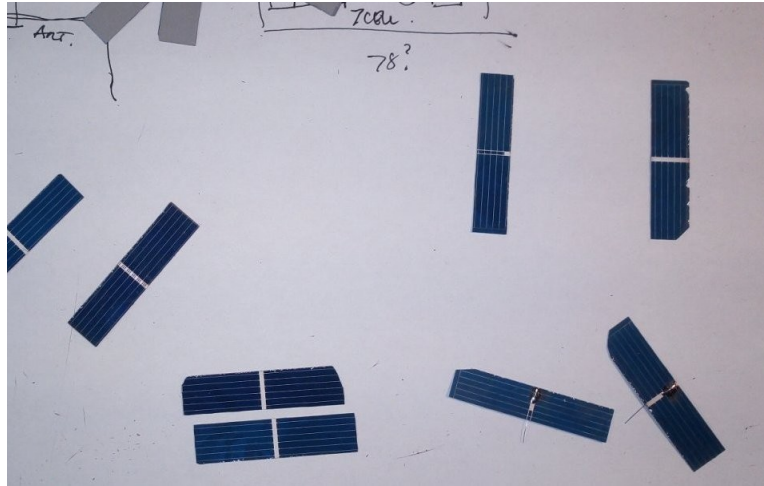
# Balloons

- Qualatex
- Chinese
- SBS
- Make your own
- Other questions...
  - How many balloons?
  - Pre-stretching
  - Fill



# Power sources

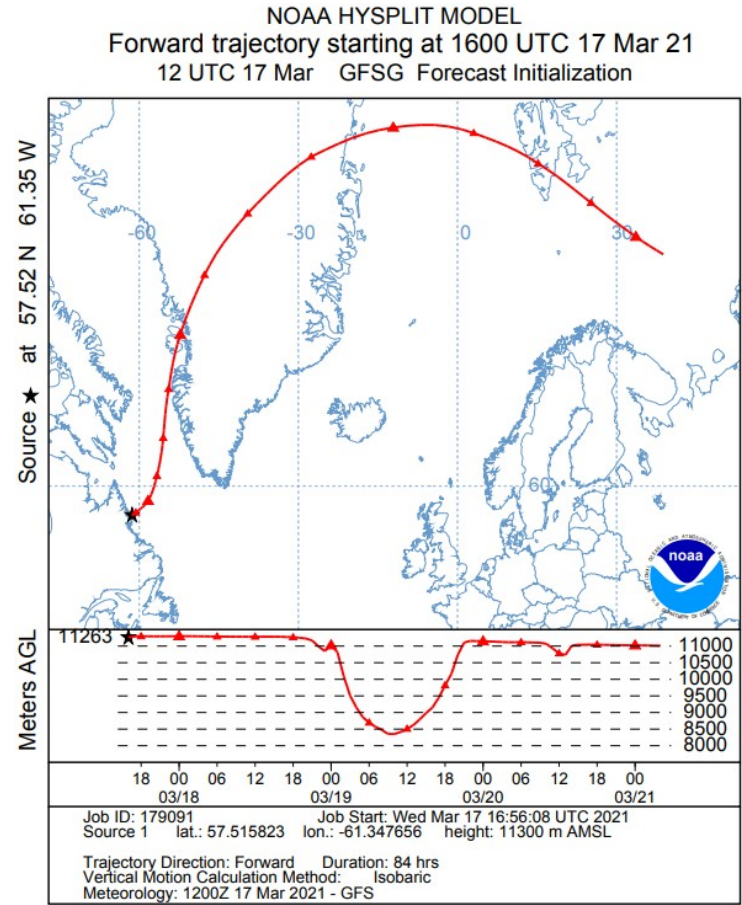
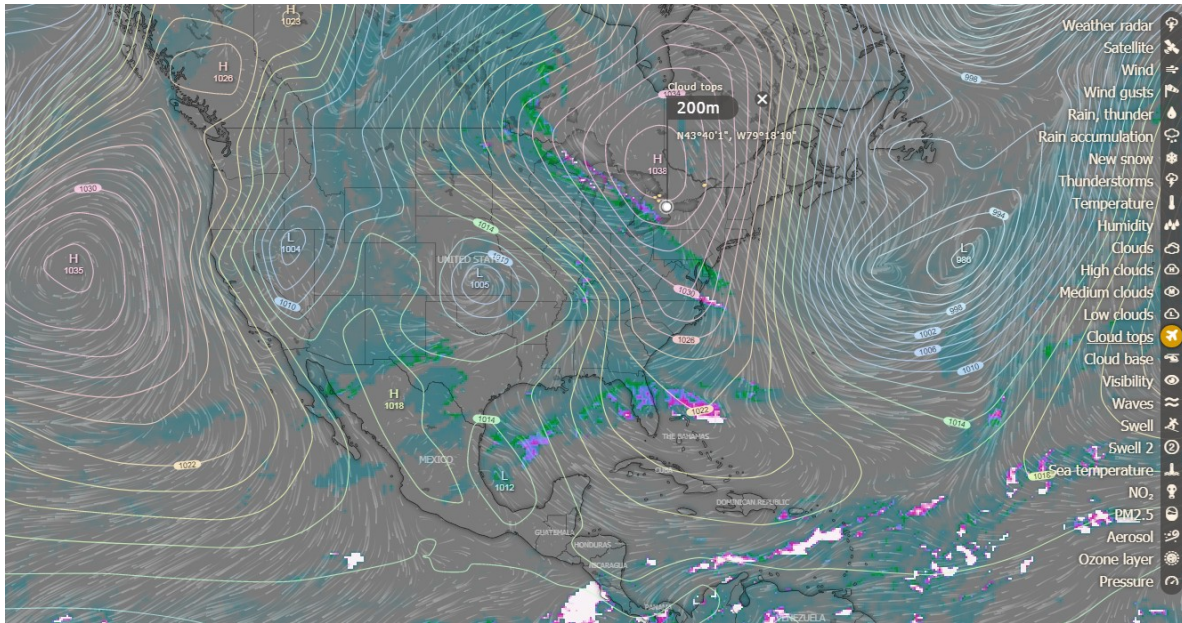
- Solar panels
  - Glass
  - Flexible
- Ultra-capacitors
- Battery types
  - NiCd
  - NiMH
  - LiPO





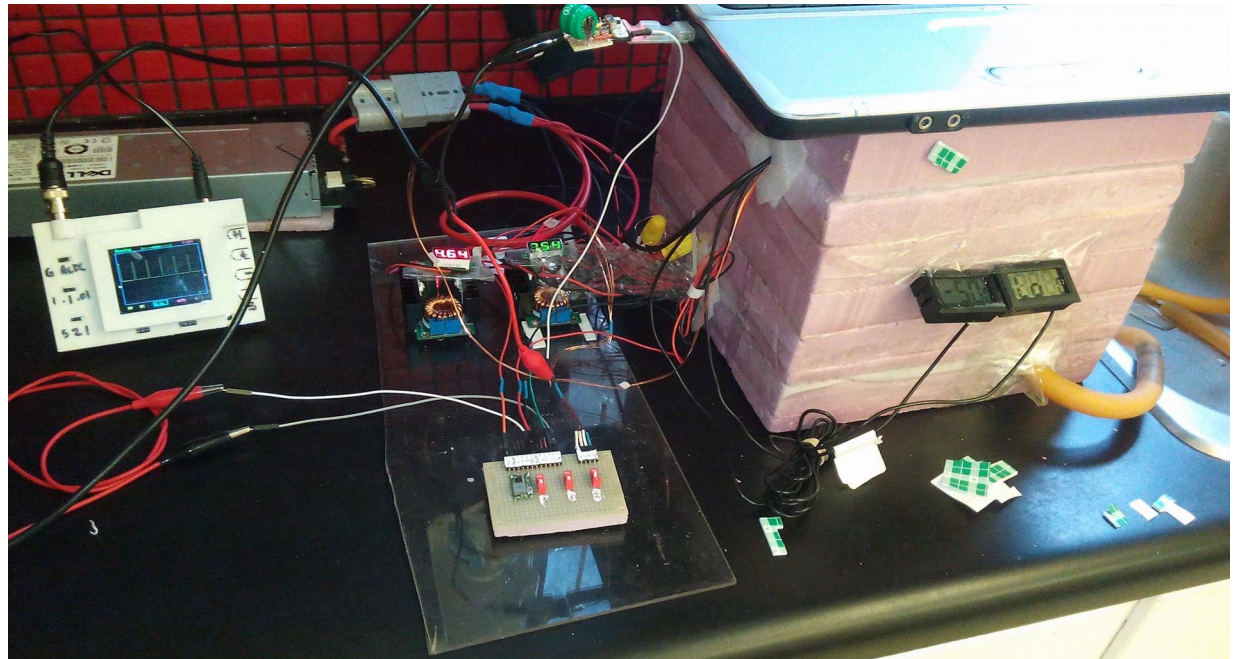
# Forecast tools

- NOAA simulations
- Wind speed



# Testing

- Test thoroughly on the ground!
- Testing in cold is worthwhile!
- Dave's Peltier extreme...





# Summary

- U4B available soon and inexpensively from QRP Labs (<\$50)
- Ballooning is addictive
- Ballooning is FUN
- Educational
- Ballooning is...  
**EXTREME QRP**

