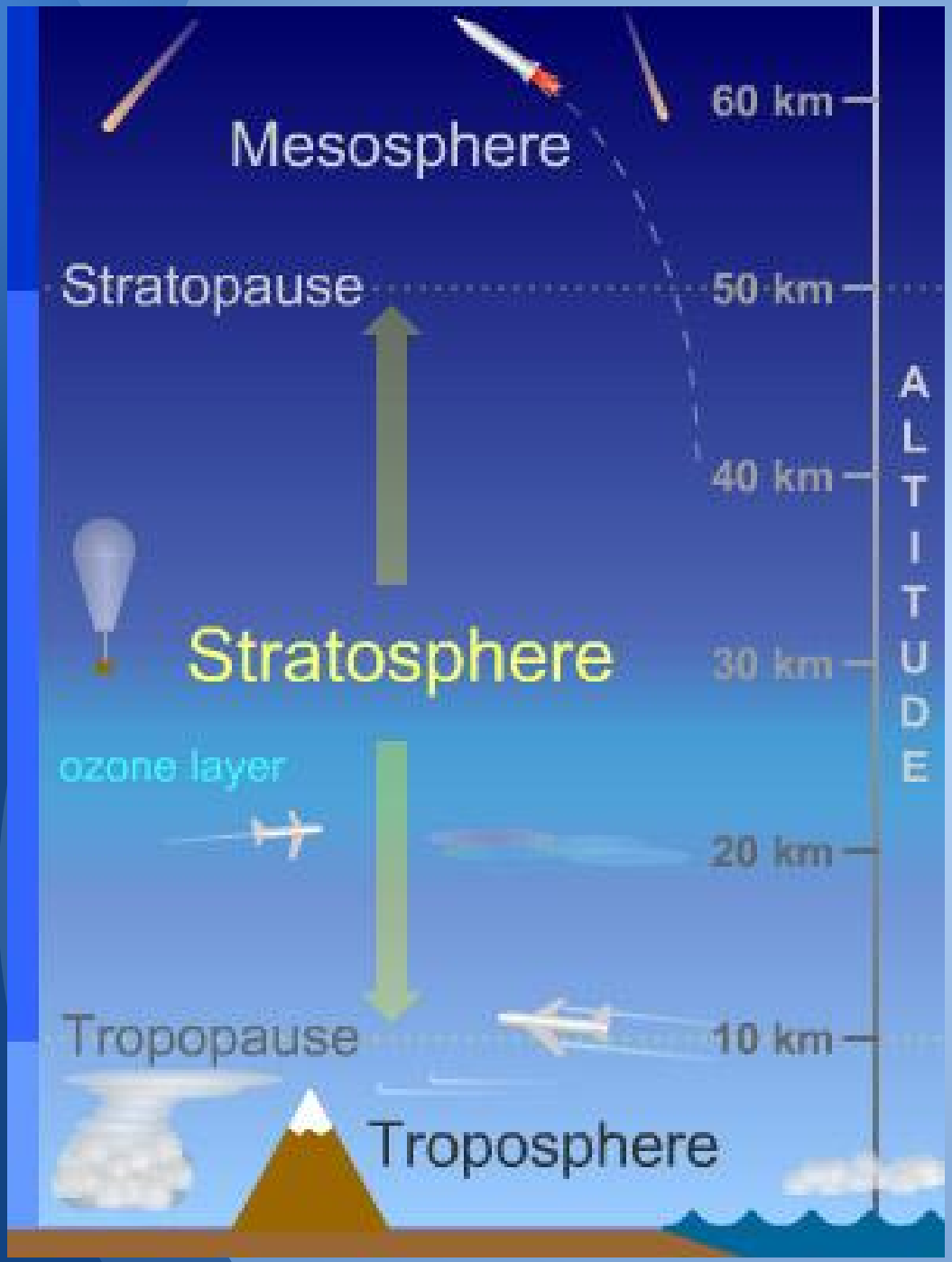
Using The Raspberry Pi for High Altitude Ballooning

Space Shuttle Picture: Cost per mission £300,000,000


HAB Picture:
Cost per
mission £300



Balloons fly up to 44km high. This is:

4 times as high as a jumbo jet

5 times the height of Everest

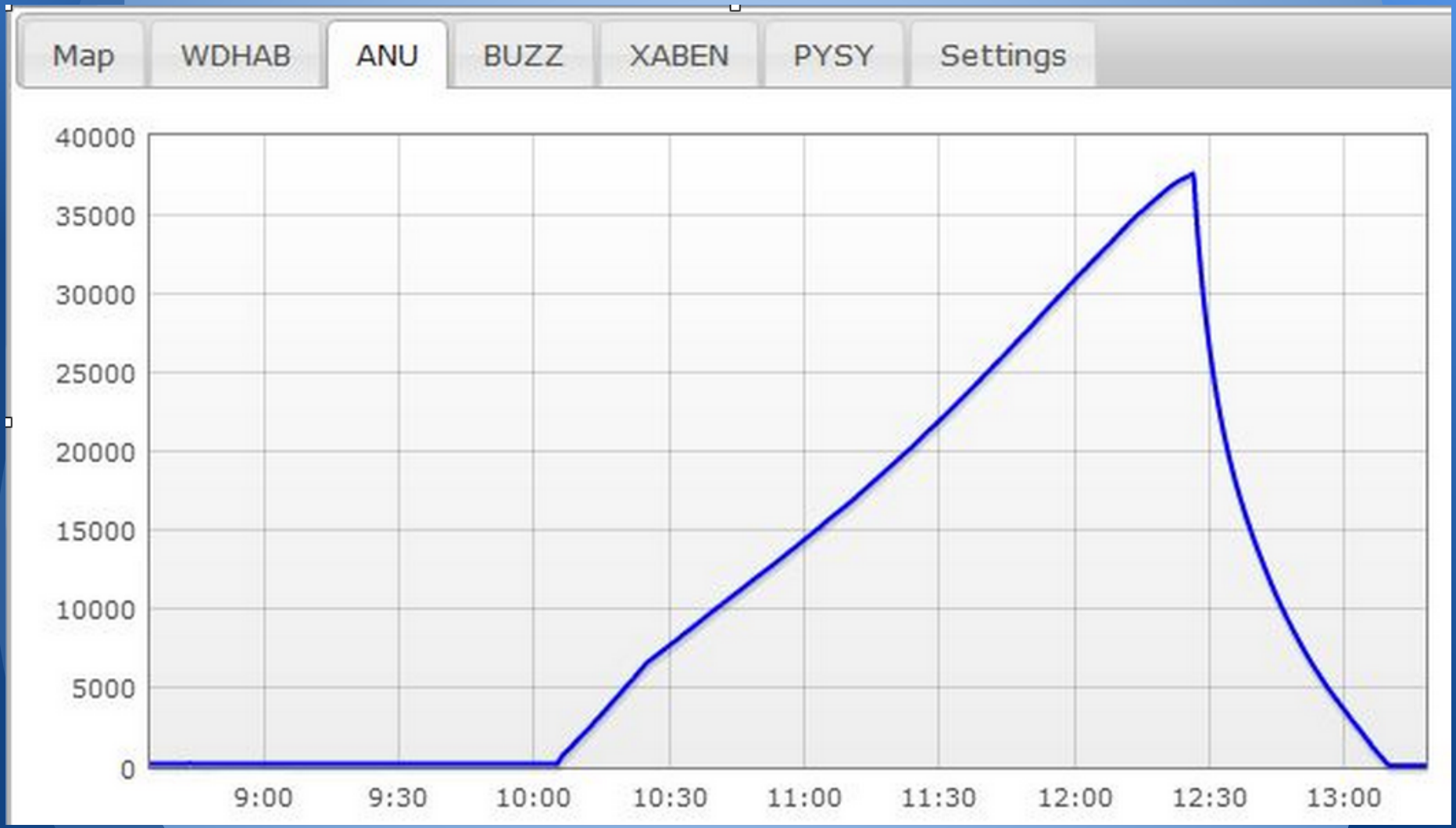
50 times higher than the highest building

24,000 times higher than an average human adult male.

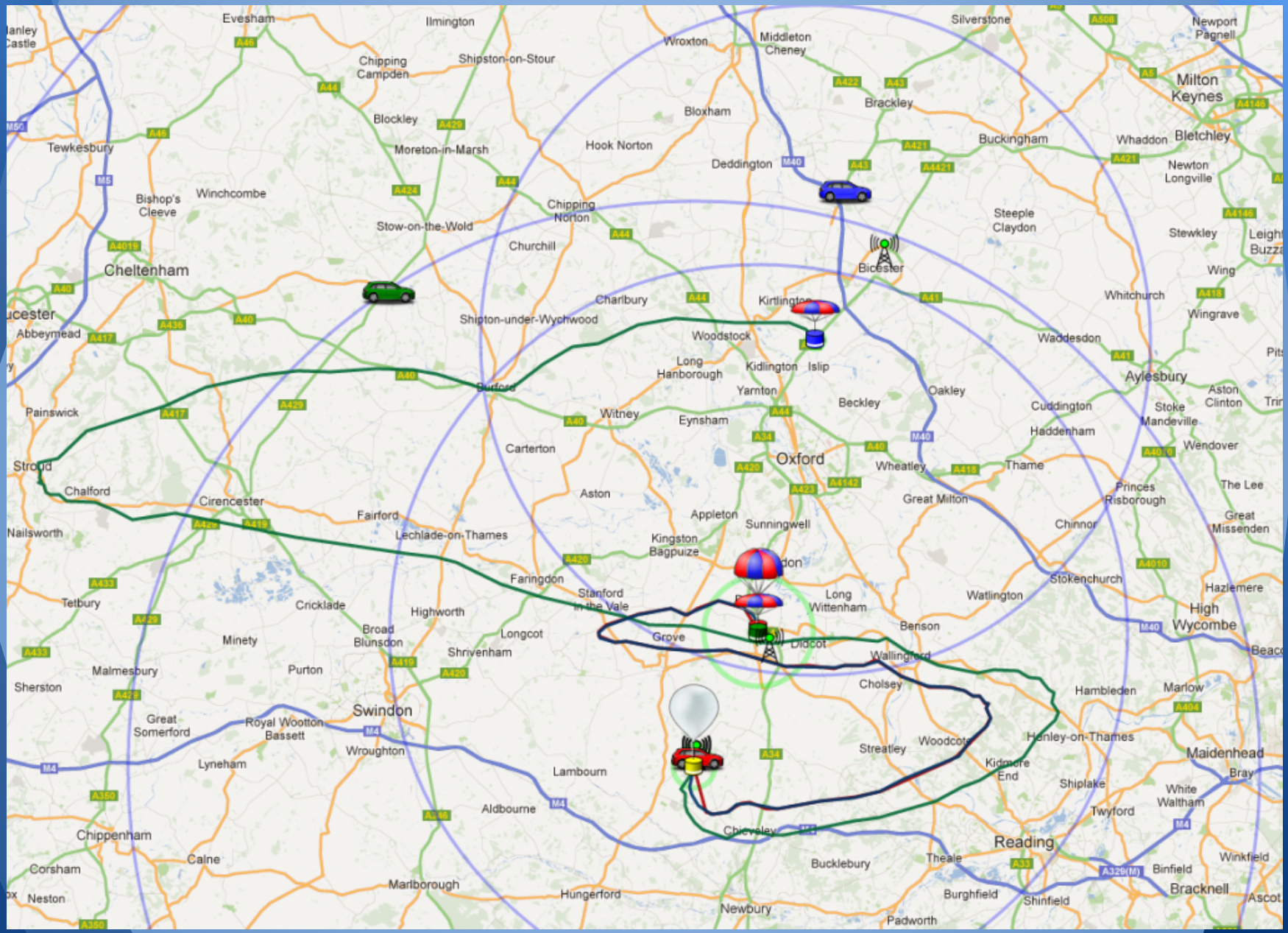
"Space" officially starts at 100km.

ISS orbits at 400km

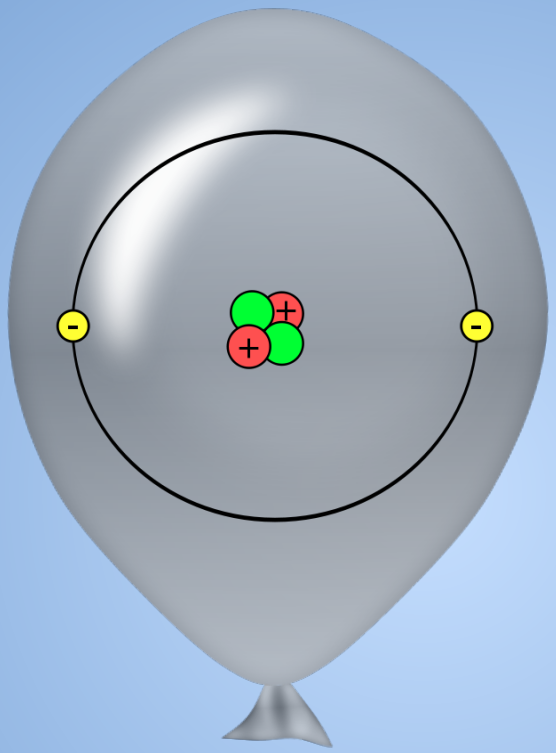
Typical Flight Profile

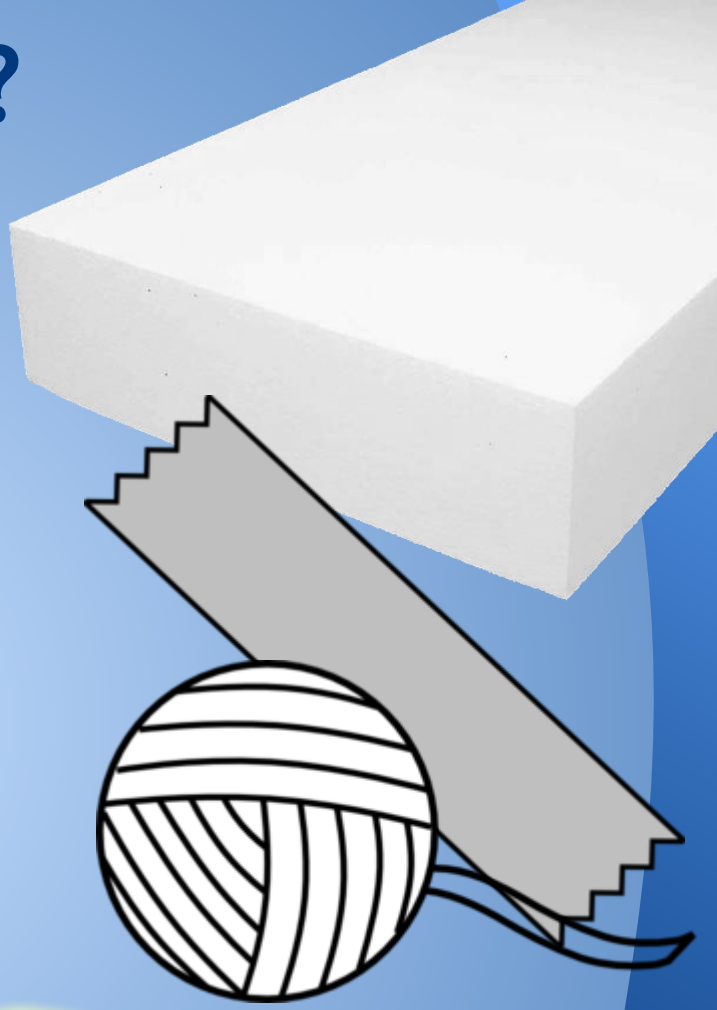


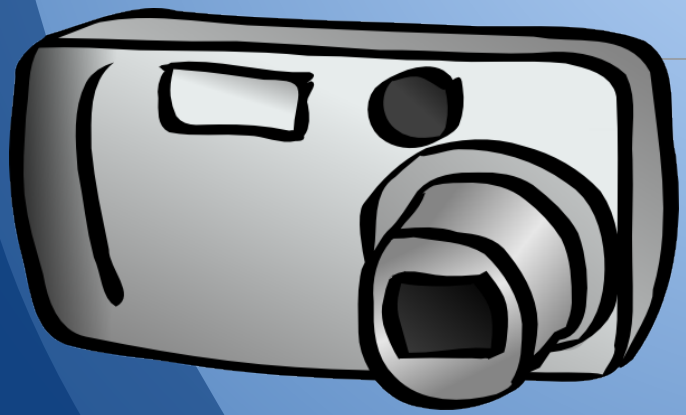
Typical Flight Path



What do you need?



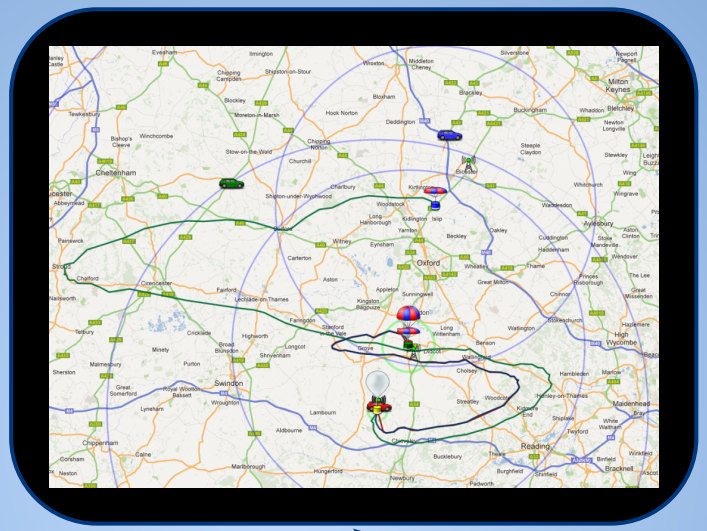


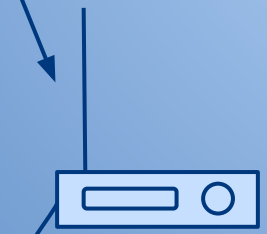


Tracking

- GSM/GPS Tracker. Gives long/lat only. Only works on the ground and at very low altitudes. Only works with a GSM signal!
- SPOT Satellite Tracker. Gives long/lat only. Does not work above 18km.
- RADIO - Full data throughout flight. More reliable. More work. More fun!

Distributed Tracking System





Radio Power

- We are limited by law to 10mW
- A mobile phone is about 1W and has a range of a few km
- A digital TV transmitter is about 50kW and has a range of about 50km

Even so, the distance record for 10mW from a balloon is .... 800km !

Anatomy Of A Basic Tracker

Processor Board

Pi or Arduino?

Why an Arduino?

- Smaller
- Lighter
- Lower power consumption
- More robust
- Simpler
- More I/O available
- Analog Inputs available
- Bare metal programming

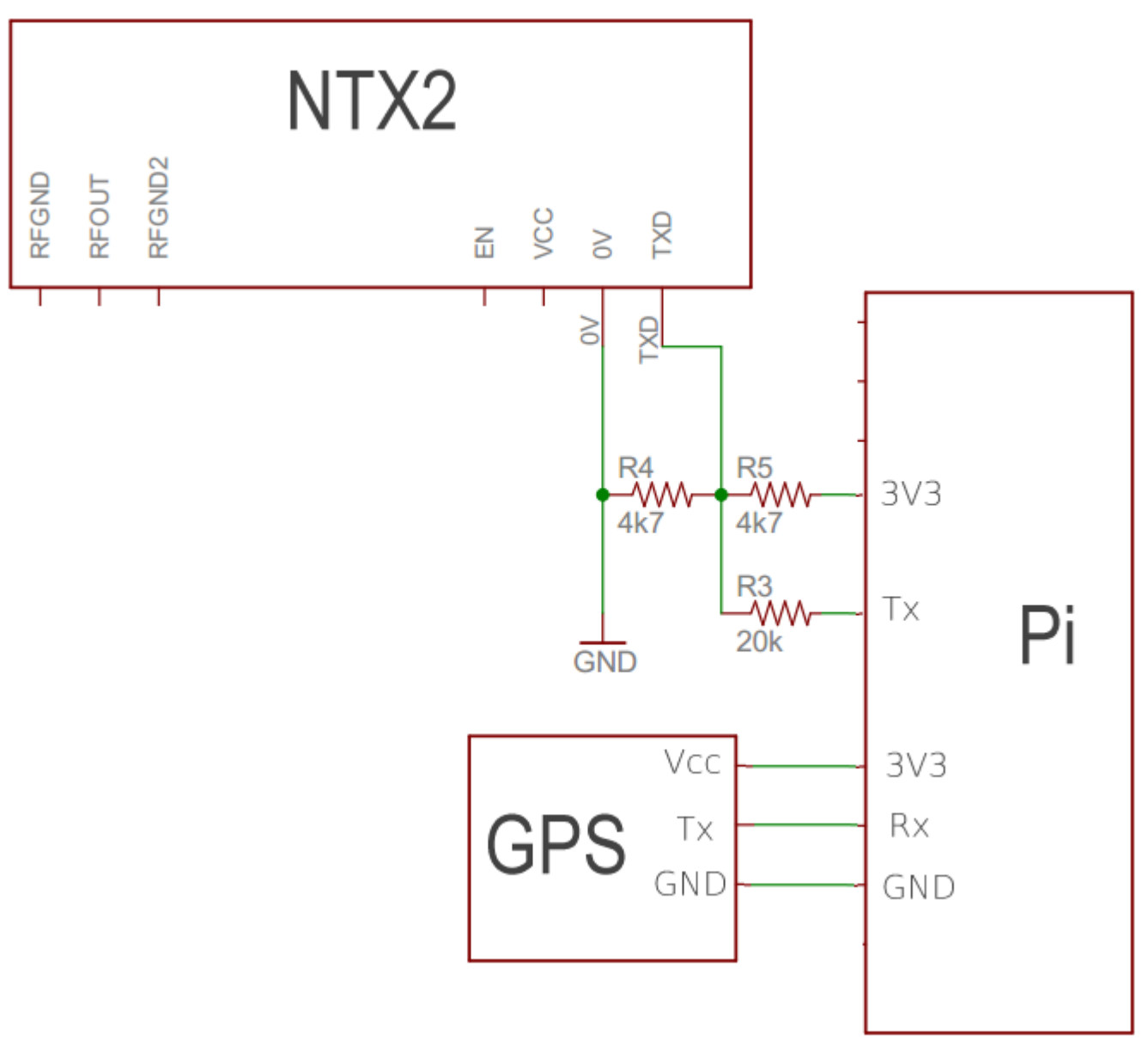
Why the Pi?

- USB provides simple access to webcam, 3G
- Plenty of processor power and memory

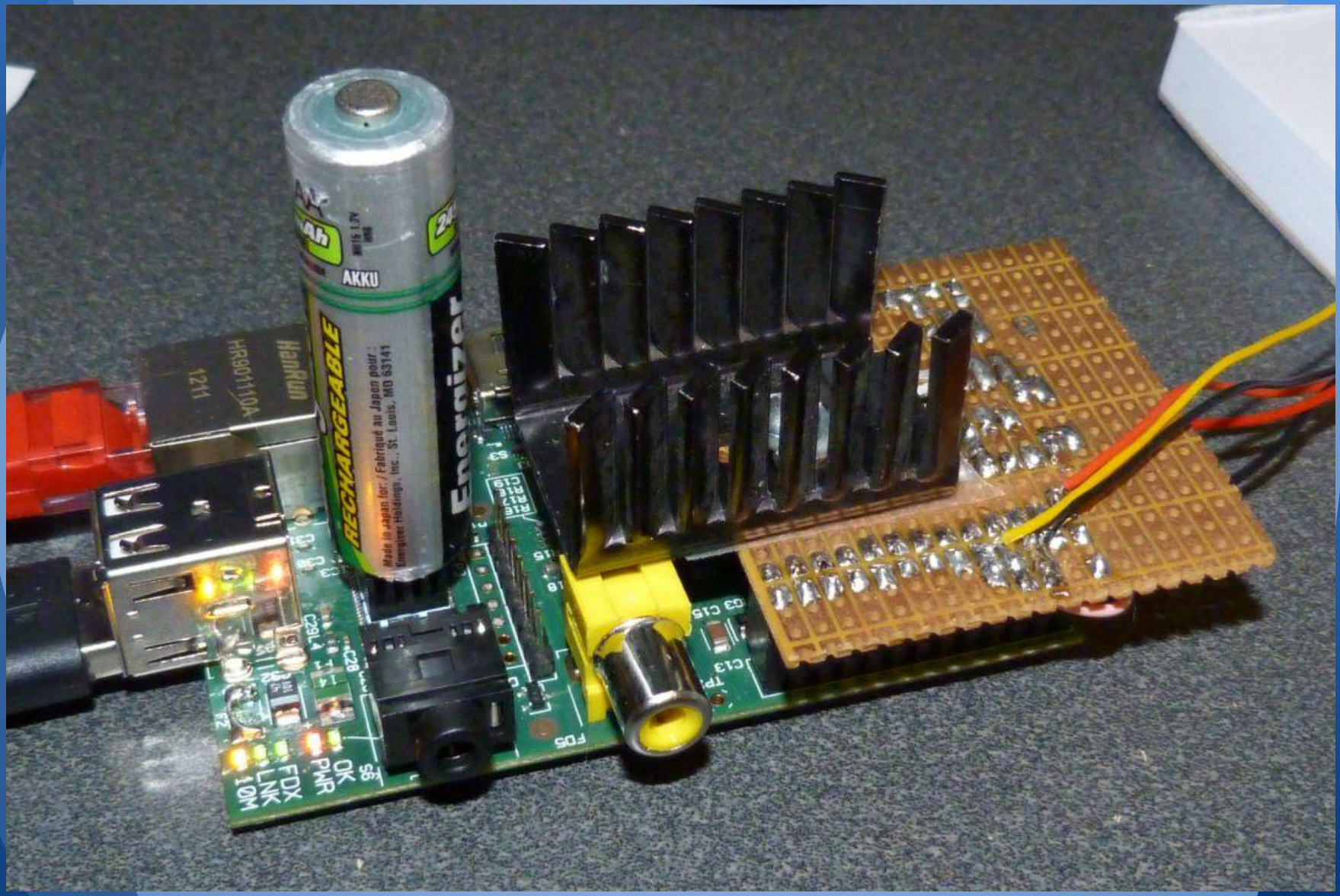
For a Pi Tracker, You Will Need ...

- A GPS receiver that works above 18km (e.g. Lassen iQ, UBlox Max-6)
- A suitable radio transmitter (e.g. Radiometrix NTX2)
- Prototyping board
- Linear or switching 5V regulator
- AA Lithium Energizer Batteries and holder

Simplest Pi Tracker

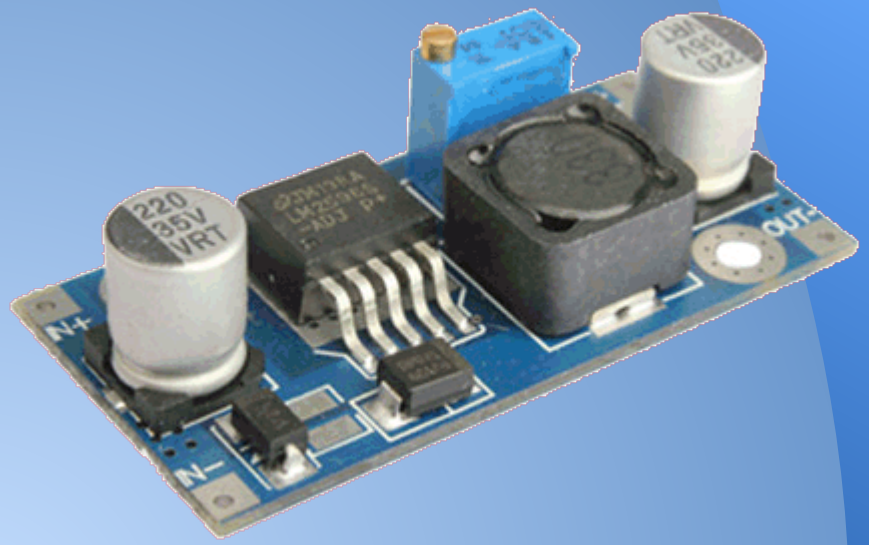


Prototype Tracker



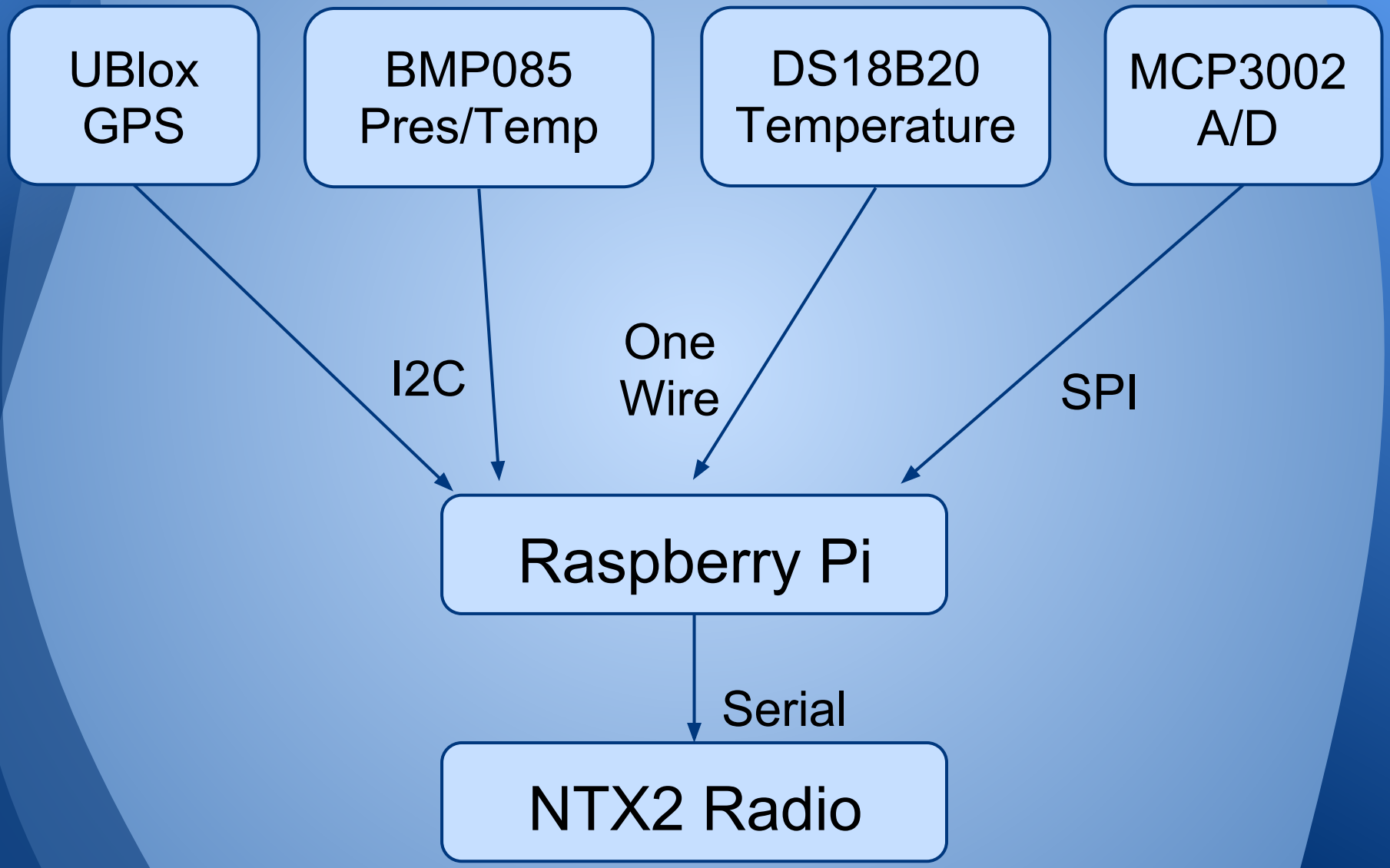

FRAY BENTOS
RADIOMETRIX
NTX2-434.650-10
25kHz NBFM UHF Transmitter
Batch No: SO110711T
GPIO0
GPIO1
GPIO2
GPIO3
GPIO4
GPIO5
GPIO6
GND
GND
5.0V
GND
3.3V
Pi & Chips V0
CUT IF USING BATTERY
y70129
2070STGWH2
u-blox
MAX-6Q-0-000
R1
R7
J1

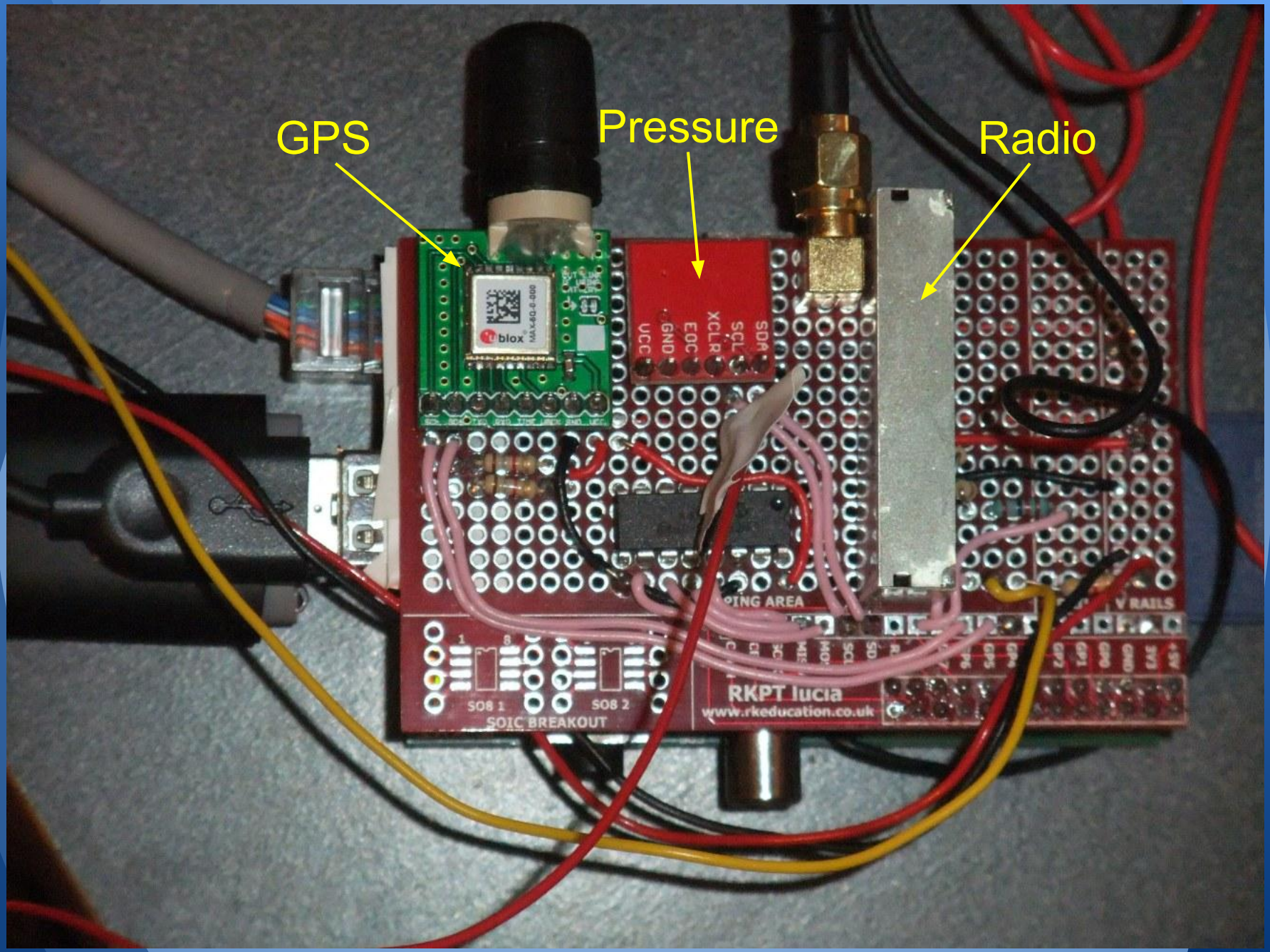
Power Supply



- Use Energizer Lithium AA cells
- Model B + GPS etc uses about 500mA
- A single step-down converter to the 5V line will give about 9 hours run time.
- LM2596 modules work well
- Don't use a linear regulator!

Tracker With Sensors




GPS
Pressure
Radio
blox
VCC
GND
EOC
XCLR
SCL
SDA
SO8 1
SO8 2
SOIC BREAKOUT
RKPT lucia
www.rkeducation.co.uk

Tracker Software

- Read current position from the GPS
- Read any other sensors (temperatures, pressure, humidity, UV level, battery voltage)
- Build a telemetry string containing the above
- Transmit it

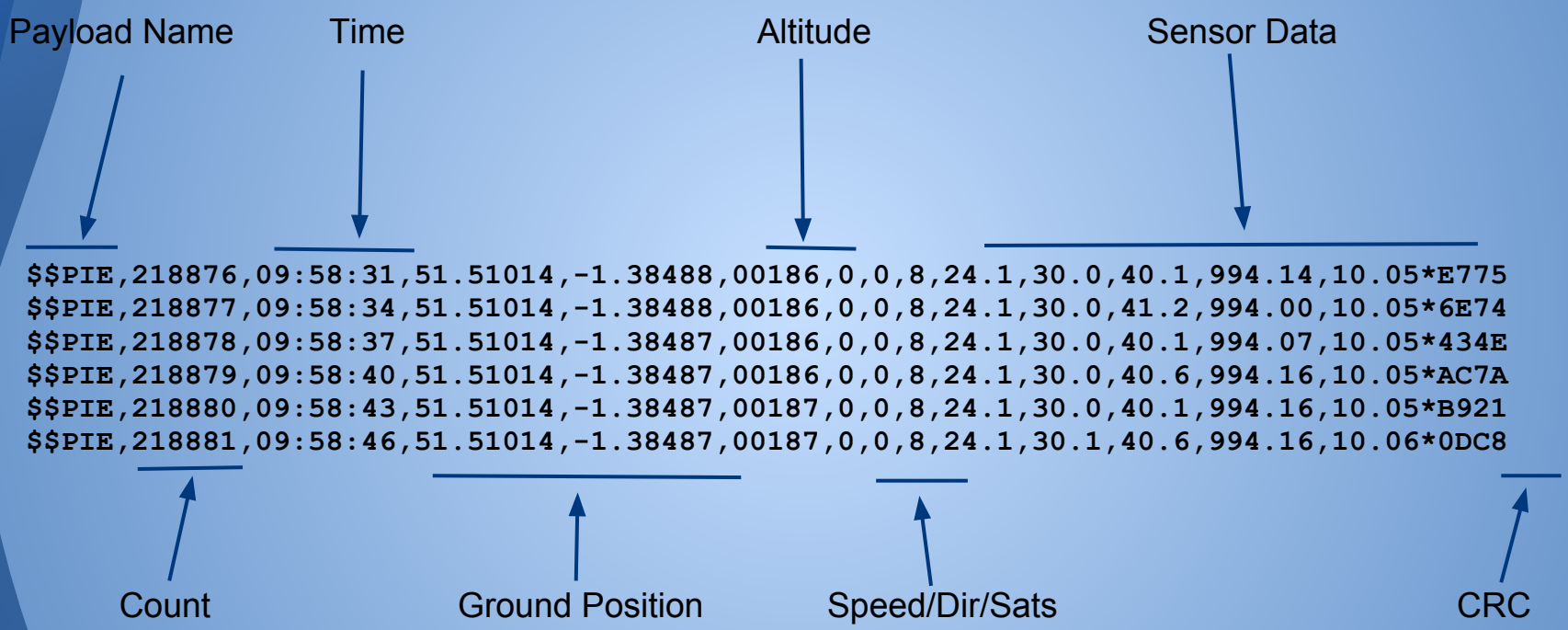
GPS NMEA Sentences

$GPRMC,225446,A,4916.45,N,12311.12,W,000.5,054.7,191194,020.3,E*68

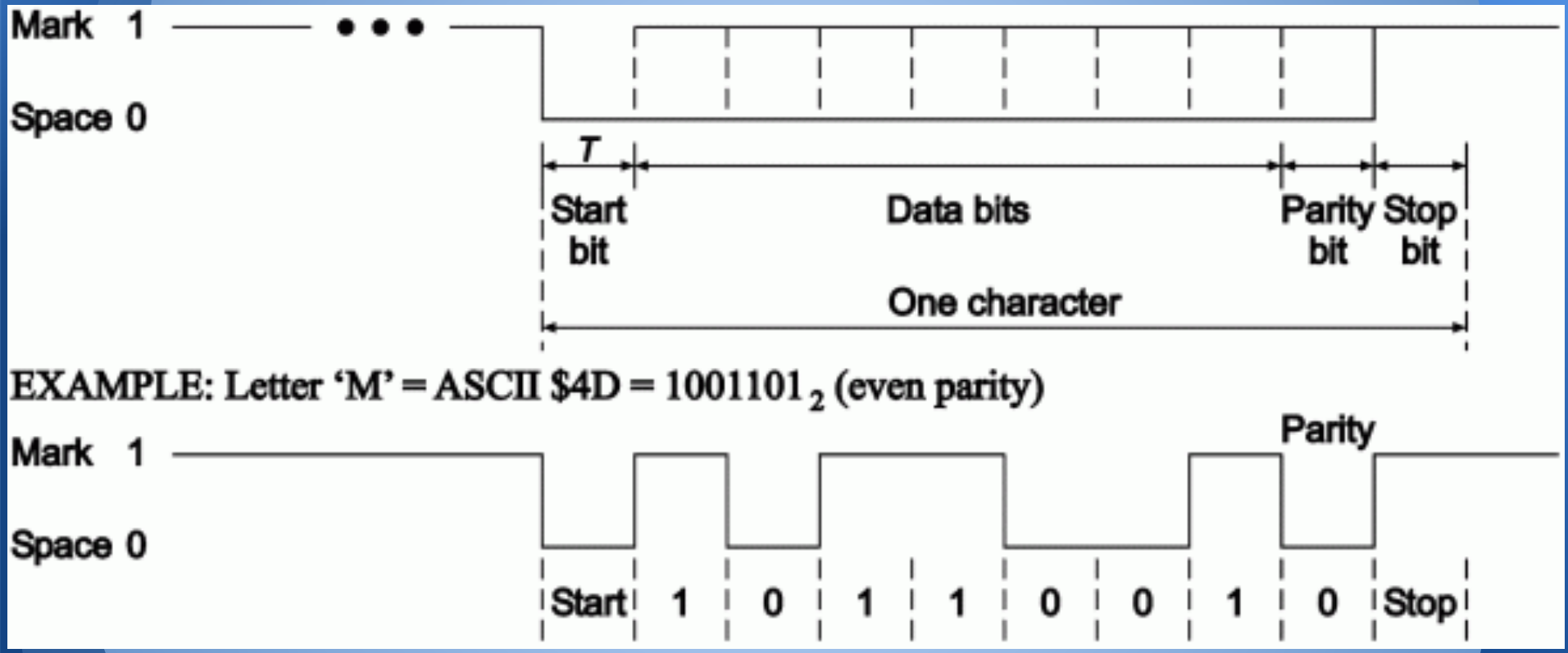
225446	Time of fix 22:54:46 UTC
A	Navigation receiver warning A = OK, V = warning
4916.45,N	Latitude 49 deg. 16.45 min North
12311.12,W	Longitude 123 deg. 11.12 min West
000.5	Speed over ground, Knots
054.7	Course Made Good, True
191194	Date of fix 19 November 1994
020.3,E	Magnetic variation 20.3 deg East
*68	mandatory checksum

$GPGGA,HHMMSS.SS,DDMM.MMMMM,K,DDDMM.MMMMM,L,N,QQ,PP.P,**AAAA.AA**,M,±XX.XX,M,SSS,AAAA*CC

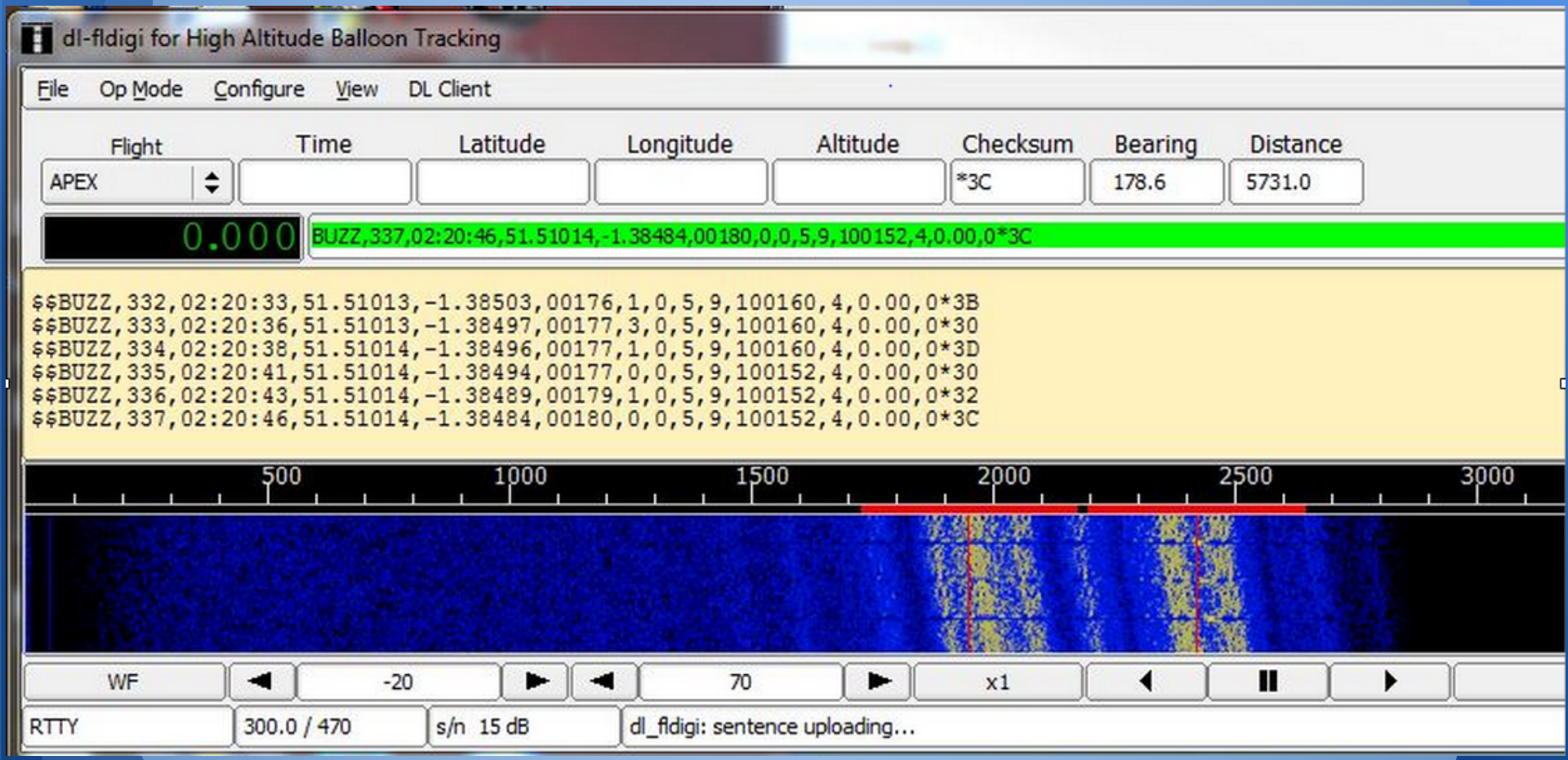
Typical Telemetry String



Serial Data Format



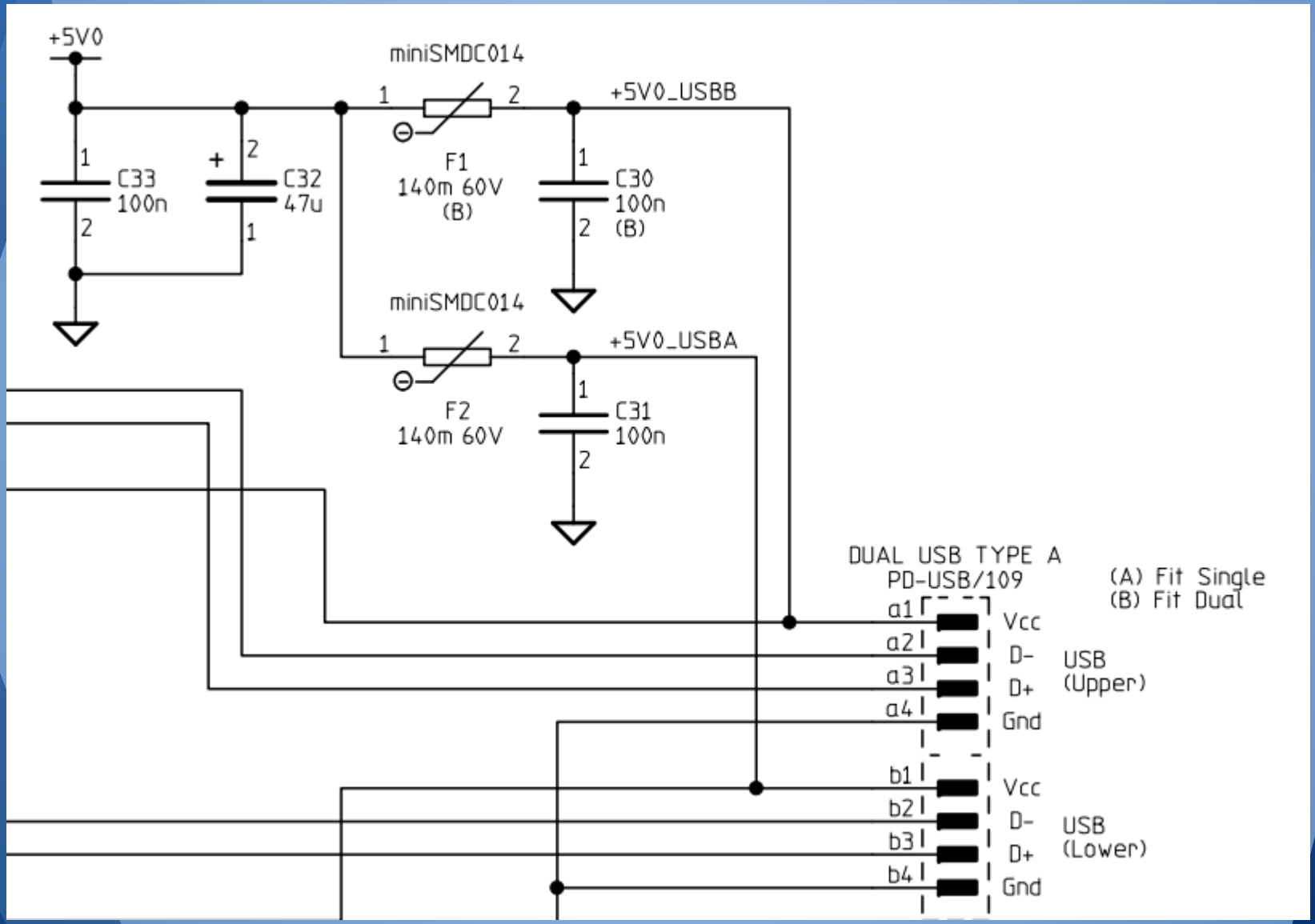
Radio Telemetry Decoding

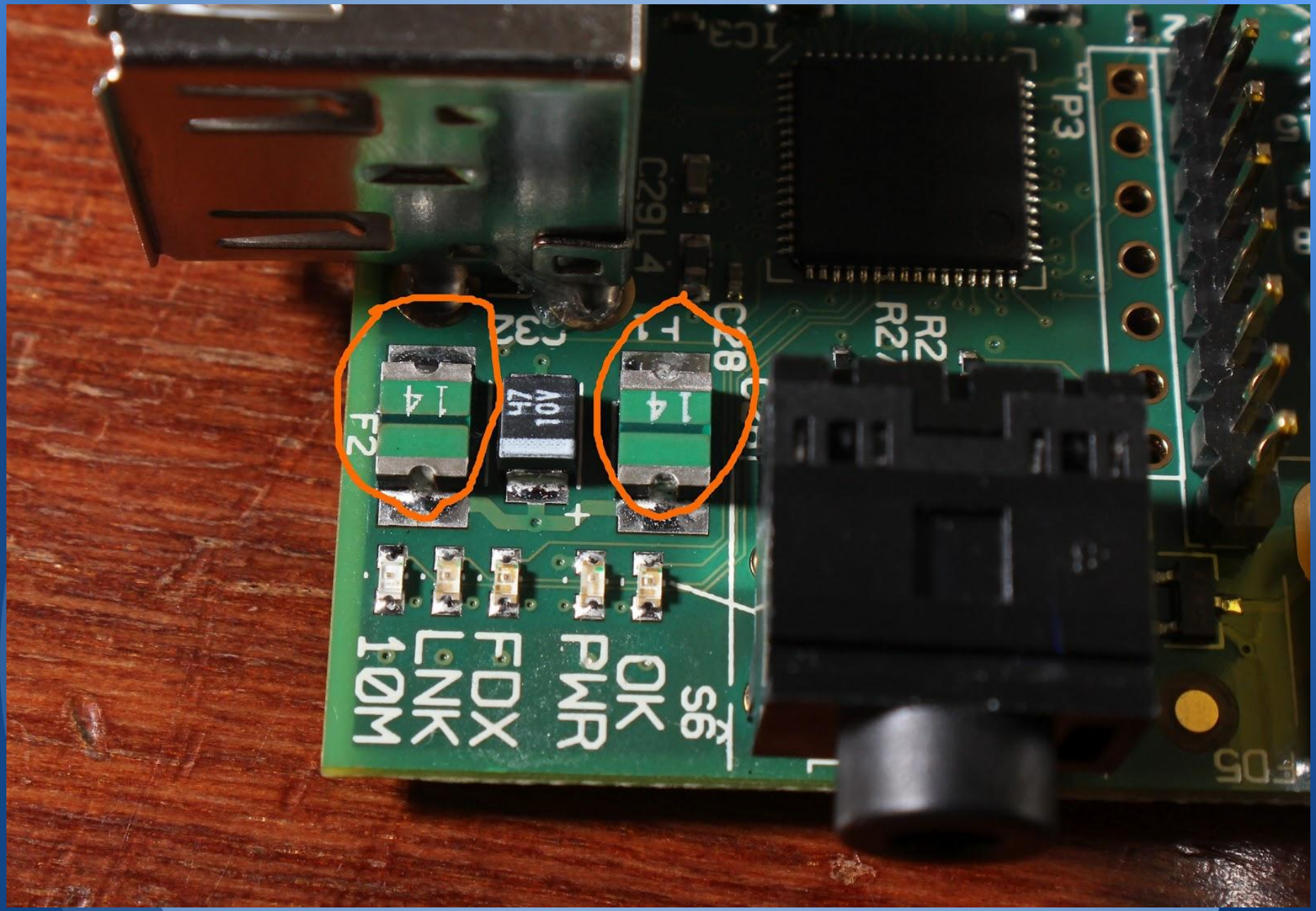


SSDV

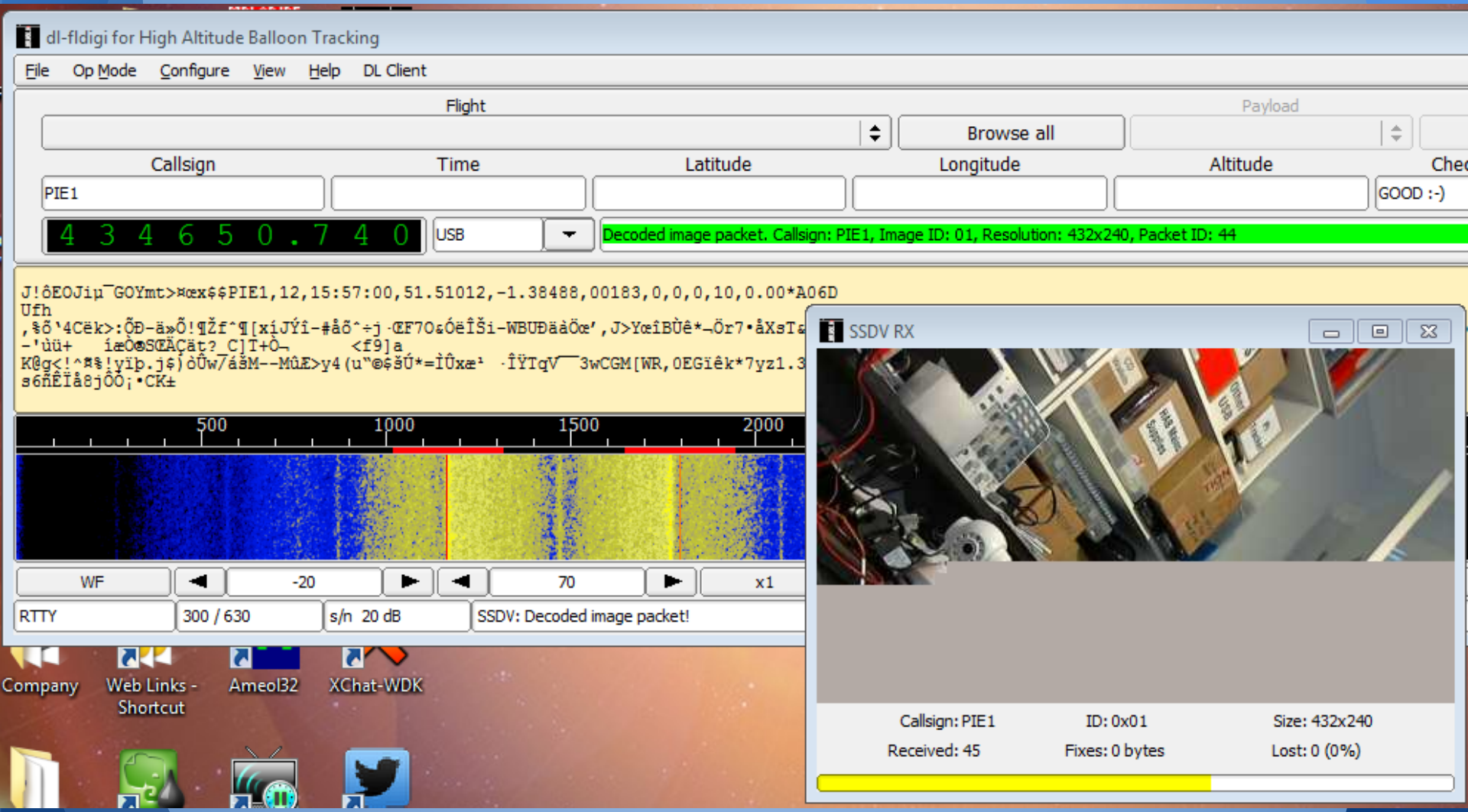
- Add a webcam
- (V1) Short out the USB fuses
- Take photos periodically
- Convert jpeg to SSDV format
- Send SSDV packets over radio

USB Ports


+5V0
C33
100n
C32
47u
miniSMDC014
F1
140m 60V
(B)
+5V0_USBB
C30
100n
(B)
miniSMDC014
F2
140m 60V
+5V0_USBA
C31
100n
DUAL USB TYPE A
PD-USB/109
(A) Fit Single
(B) Fit Dual
a1
a2
a3
a4
Vcc
D-
D+
Gnd
USB
(Upper)
b1
b2
b3
b4
Vcc
D-
D+
Gnd
USB
(Lower)


F2
14
10V
14
C32
C28
R2
P3
FDX
LNK
10M
PWR
OK
S6

Receiving


dl-fldigi for High Altitude Balloon Tracking
File
Op Mode
Configure
View
Help
DL Client
Flight
Browse all
Payload
Callsign
Time
Latitude
Longitude
Altitude
PIE1
GOOD :-)
434650.740
USB
Decoded image packet. Callsign: PIE1, Image ID: 01, Resolution: 432x240, Packet ID: 44
$$PIE1,12,15:57:00,51.51012,-1.38488,00183,0,0,0,10,0.00*A06D
500
1000
1500
2000
WF
-20
70
x1
RTTY
300 / 630
s/n 20 dB
SSDV: Decoded image packet!
SSDV RX
Callsign: PIE1
ID: 0x01
Size: 432x240
Received: 45
Fixes: 0 bytes
Lost: 0 (0%)
Company
Web Links - Shortcut
Ameol32
XChat-WDK

PIE1 image 0x12 2012-07-14 13:41:53
Received: 13 packets, 0 missing
Receivers: ASTRA, WD, DAVEAKE, G8KNN, M0DTS, M0MDB

PIE1 image 0x11 2012-07-14 13:38:16
Received: 21 packets, 0 missing
Receivers: ASTRA, WD, DAVEAKE, M0MDB, G8KNN, M0DTS

PIE1 image 0x10 2012-07-14 13:35:27
Received: 18 packets, 0 missing
Receivers: M0DTS, M0MDB, ASTRA, G8KNN, WD, DAVEAKE

PIE1 image 0x0F 2012-07-14 13:32:19
Received: 17 packets, 0 missing
Receivers: ASTRA, M0DTS, M0MDB, G0NZO, G8KNN, DAVEAKE, WD

PIE1 image 0x0E 2012-07-14 13:29:15
Received: 18 packets, 0 missing
Receivers: ASTRA, DAVEAKE, G8KNN, M0MDB, M0DTS, G0NZO, WD

PIE1 image 0x0D 2012-07-14 13:25:41
Received: 21 packets, 0 missing
Receivers: G0NZO, G8KNN, DAVEAKE, ASTRA, M0DTS

PIE1 image 0x0C 2012-07-14 13:22:27
Received: 19 packets, 0 missing
Receivers: ASTRA, G0NZO, DAVEAKE, G8KNN

PIE1 image 0x0B 2012-07-14 13:19:12
Received: 19 packets, 0 missing
Receivers: DAVEAKE, G0NZO, ASTRA

PIE1 image 0x0A 2012-07-14 13:16:07
Received: 18 packets, 0 missing
Receivers: DAVEAKE, M0MDB

PICTURES FROM AN EXcellent HAB MISSION

Image Quality/Size vs Time

It's currently a problem of access to gigabytes through punybaud

J. C. R. Licklider

I chose:

- Size 432 x 240 pixels
- Quality 50%
- Resulting in average size 7k bytes
- Which at 300 baud is ~ 4.5 minutes
- So about 25 "in flight" images

SSDV - Choosing And Converting

1. Find the best* JPEG
2. Convert jpeg to SSDV format
3. Move JPEGS to another folder

* Largest file!

Conversion:

```
ssdv -e -c <payload> -i <n> <filename> snap.bin
```

Choosing The "Best" Image

Planning The Flight

- Build the tracker
- Write and TEST TEST TEST the software
- T-28 days Apply for permission
- Create payload doc and keep on testing
- T-7 days Start running predictions, make the payload box, weigh everything.
- You're still testing, right?
- T-3 days Order the Helium
- Keep on testing and running predictions
- T-2 days Get a "flight doc" approved

Flight Permission / NOTAM

CIVIL AVIATION AUTHORITY **Air Navigation Order 2005**

Unmanned Meteorological / Research Balloons
Application to release

Inside Notified Airspace / Outside Notified Airspace, for NOTAM action only

28 days notice MUST be given of the event

Please complete the form using block letters in black ink
If you require assistance with the completion of this form, please telephone 020 7453 6585

Completed forms should be sent to:

Airspace Utilisation Section, Directorate of Airspace Policy, Civil Aviation Authority, K702, CAA House, 45-59 Kingsway, London, WC2B 6TE. Fax: 020 7453 6593. E-mail: ausops@dap.caa.co.uk

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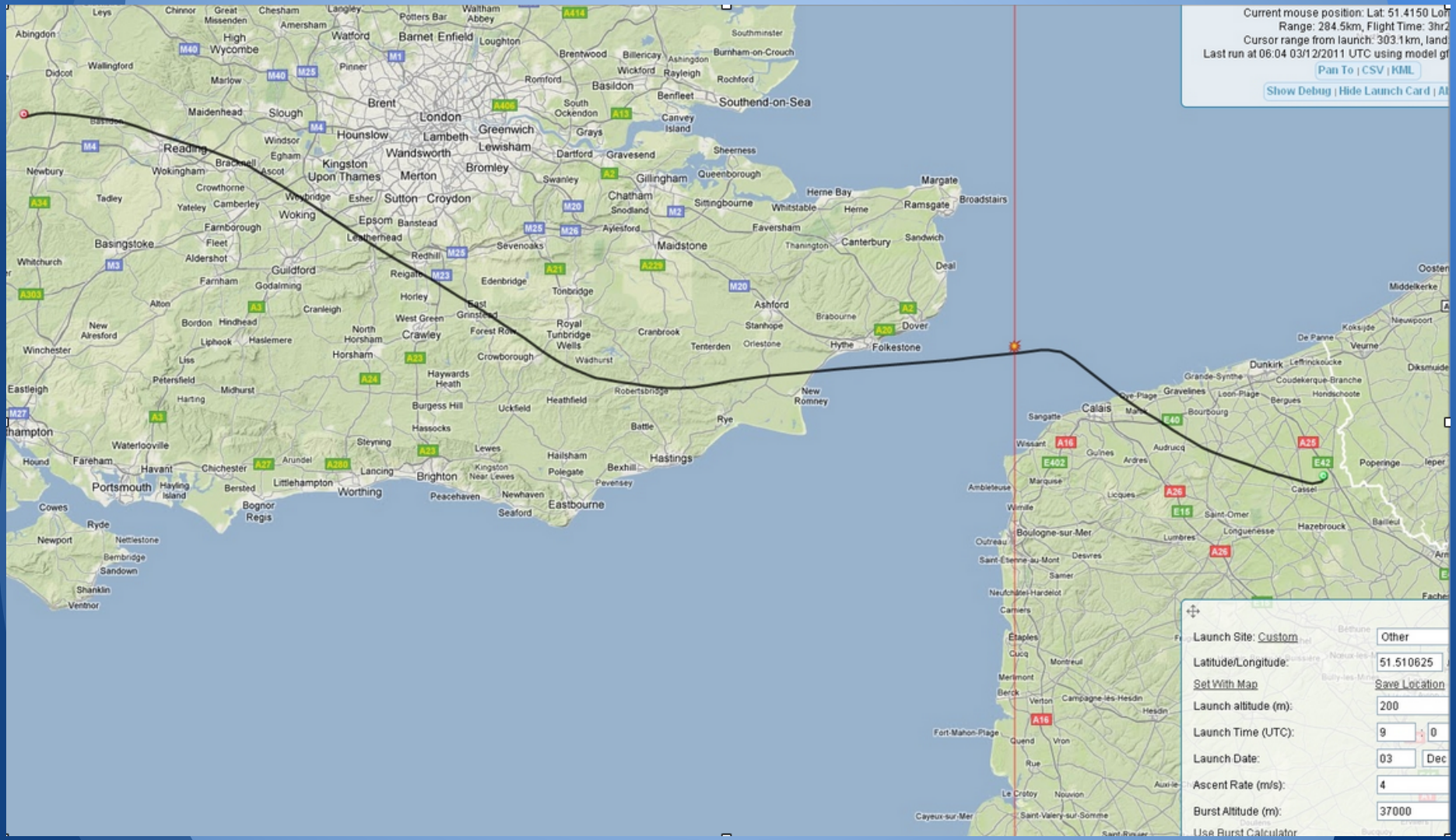
[illegible]

CUSF Flight Path Predictor



CUSF Balloon Burst Calculator

Payload Mass (g)		Balloon Mass (g)
1000	**AND**	Kaymont - 1000

THEN

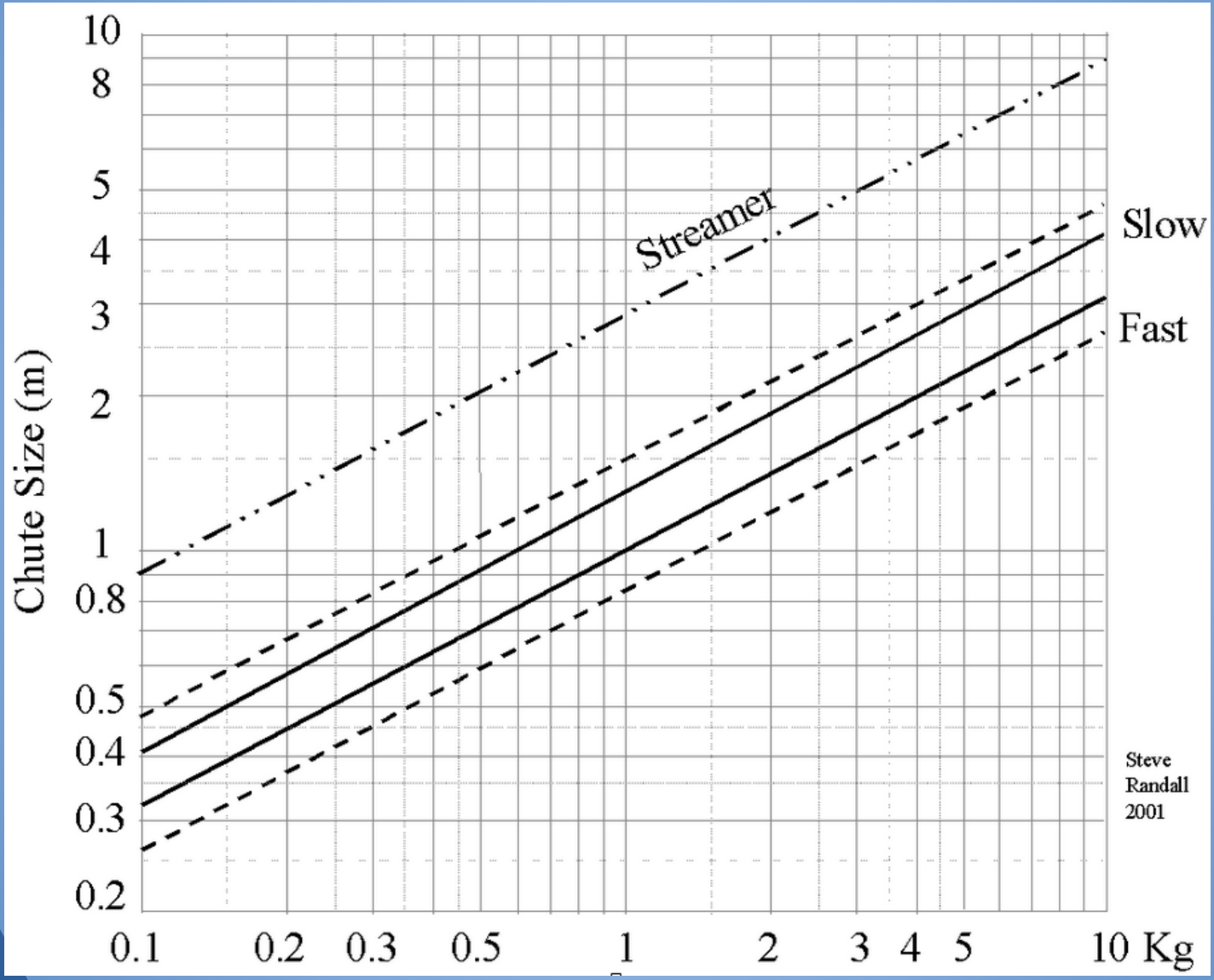
Target Burst Altitude (m)		Target Ascent Rate (m/s)
	OR	5

↓

Burst Altitude:	30999 m	Ascent Rate:	5.58 m/s
Time to Burst:	93 min	Neck Lift:	2603 g
Launch Volume:	3.51 m^3	3510 L	123.9 ft^3

http://www.cusf.co.uk/calc/

Parachute Sizing



Links

My Blog

www.daveakerman.com

More Information about HAB

www.ukhas.org.uk

Tracking System / Predictor Links

habhub.org