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.
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
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

UBlox GPS
BMP085 Pres/Temp
DS18B20 Temperature
MCP3002 A/D

I2C
One Wire
SPI

Raspberry Pi

Serial

NTX2 Radio
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

<table>
<thead>
<tr>
<th>Payload Name</th>
<th>Time</th>
<th>Altitude</th>
<th>Sensor Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>$$PIE,218876,09:58:31,51.51014,-1.38488,00186,0,0,8,24.1,30.0,40.1,994.14,10.05*E775</td>
<td>$$PIE,218877,09:58:34,51.51014,-1.38488,00186,0,0,8,24.1,30.0,40.1,994.00,10.05*6E74</td>
<td>$$PIE,218878,09:58:37,51.51014,-1.38487,00186,0,0,8,24.1,30.0,40.1,994.07,10.05*434E</td>
<td>$$PIE,218879,09:58:40,51.51014,-1.38487,00186,0,0,8,24.1,30.0,40.1,994.16,10.05*AC7A</td>
</tr>
<tr>
<td>$$PIE,218880,09:58:43,51.51014,-1.38487,00187,0,0,8,24.1,30.0,40.1,994.16,10.05*B921</td>
<td>$$PIE,218881,09:58:46,51.51014,-1.38487,00187,0,0,8,24.1,30.1,40.6,994.16,10.06*0DC8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Serial Data Format

EXAMPLE: Letter ‘M’ = ASCII $4D = 1001101_2$ (even parity)

Mark 1

Space 0

Start bit

Data bits

Parity bit

Stop bit

One character
Radio Telemetry Decoding

![Radio Telemetry Decoding](image_url)
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
Receiving
PICTURES FROM AN EXcellent HAB MISSION
Image Quality/Size vs Time

It's currently a problem of access to gigabytes through puny baud

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 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
CIVIL AVIATION AUTHORITY

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
CUSF Flight Path Predictor
# CUSF Balloon Burst Calculator

<table>
<thead>
<tr>
<th>Payload Mass (g)</th>
<th>Balloon Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>Kaymont - 1000</td>
</tr>
</tbody>
</table>

**THEN**

<table>
<thead>
<tr>
<th>Target Burst Altitude (m)</th>
<th>Target Ascent Rate (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR 5</td>
</tr>
</tbody>
</table>

**↓**

- **Burst Altitude:** 30999 m
- **Ascent Rate:** 5.58 m/s
- **Time to Burst:** 93 min
- **Neck Lift:** 2603 g
- **Launch Volume:** 3.51 m³
  - 3510 L
  - 123.9 ft³

[http://www.cusf.co.uk/calc/](http://www.cusf.co.uk/calc/)
Parachute Sizing

![Graph showing parachute size as a function of load](image)

- **Streamer**
- **Slow**
- **Fast**

Chute Size (m) vs Load (Kg)

- Steve Randall
- 2001
My Blog

www.daveakerman.com

More Information about HAB

www.ukhas.org.uk

Tracking System / Predictor Links

habhub.org