

Weather Balloon Experiments with Amateur Radio (BEAR), 9V1UP-11, Singapore



BEAR-1 2021-09-04 BEAR-2 2021-10-16 Window 23:00-03:00

Overview

It is the intent of a team of <u>Singapore amateur radio operators</u> to conduct technical investigations by deploying a high altitude weather balloon carrying amateur radio.

Intended tests will involve the use of <u>APRS (Automatic Packet Reporting System)</u> to track flight path, transmit telemetry, and offer beaconing to ground operators in the region. Results from the flight may guide the team in considering a series of further flights and expanding on more experiments, subject to approval by CAAS and IMDA.



Problems to solve



Flight System that provides lift consists of balloon filled with Helium and rigging.

Flight Stack = Flight System + Payload



Payload that contains APRS tracker, antenna, battery, packaging, and information for finder if recovered.



Tracking that involves launch site, APRS tracking team, ground stations in region, and APRS portal displaying path.



Approval for flight from CAAS/RSAF and the operation of airborne amateur radio and use of special callsign 9V1UP from IMDA.

BEAR-2 Team

Mission Director	Daniel Wee, 9V1ZV
Flight System	Benjamin Koe, 9V1KB Chew Lip Heng, 9V1YP
Payload Specialists	Xavier Tong, 9V1XV (paternity leave) Daniel Wee, 9V1ZV Benjamin Koe, 9V1KB Dr Sampath KP, 9V1DT (home leave)
Ground Tracking Team	Solomon Tan, 9V1BC Ho Jie Feng, 9V1BD Ragul Balaji, 9V1BN Darryl Ee, 9V1DE Thum Fu Hang, 9V1FH <i>Chia Lih Wei, 9V1LW</i>
Media Assets	Chu Hao Yuan, 9V1HY
Flight Coordinator	Chew Lip Heng, 9V1YP

Authorities



Civil Aviation Authority of Singapore

Enabling opportunities through aviation





The "Balloon"



Balloon, Helium, and rigging

Weather Balloon



Balloon Performance Calculator

Calculate

Input

Balloon Size (grams)

600 -

Payload Weight (grams, 1-20000)

100

Positive Lift (grams, 1-20000)

100

Output

Required Helium (in cubic feet)

28.760311899649675

Estimated Burst Altitude (in meters)

34880

Average Ascent Rate (in meters/second)

2.4645972829035223

Ascent Time (in minutes)

235.8735592893575

"The <u>HAB-600</u> is our most popular balloon for first-time launches and training." —*Kaymont, Florida* **Balloon:** Weight: 600g Manufacturer & P/N: Totex TA600 Material: Natural Latex Inflation Gas: Helium/ Hydrogen Payload: 1-2 lbs (<900g) Rate of Ascent: 350m/min (approx 6m/s) Burst Diameter: 19.8ft (6m) Burst Altitude: 75,000- 90,000ft (23-27km) Neck Diameter: 3.0cm Neck Length: 12.0cm

Source of Helium:

Air Liquide P50H01 HE PUR 1.4M3 N5.5 (H) Pressure 150 (barg)



Chew 9V1YP 2021-08-30

Helium



How-to inflate a Helium balloon: Watch plenty of YouTube videos.

We have enough Helium for one balloon. We cannot use real balloons for practice.

Props + Dry Run (zoom + F2F)

Helium Inflation

- Helium as Lifting Gas
- Full tank, 1.4 m³, 150 bar
- Flow Regulator with Pressure Gauge
- PVC filling tube
- Adequate for one balloon with some allowance to spare



How much to fill?

- Open cylinder tank valve
- Pressure gauge should read 150 bar
- Observe for any leakage
- This regulator calibrated for Argon, rotameter will not be accurate but pressure reading not affected

Use, $P_1 / V_1 = P_2 / V_2$ Hence, 150 / 1.4 = $P_2 / 0.3^*$ P_2 = approximately 32 bar

* 1.4 m3 - 1.1 m3 = 0.3 m3 Where 1.1 m3 is the intended filling volume.



Cont' How much to fill?

- Turn on regulator to start filling
- Rotameter indicates gas flow rate
- Cylinder pressure gradually falls
- Maintain gentle & constant flow to prevent pressure surge and static build up
- Allow the balloon to gently inflate
- Use rotameter as alternative filling reference
- I.e. 25 LPM x 44 minutes = approx. 1,100 Litre

Final Decision to stop based on:

- 1. Cylinder pressure (32 bar)
- 2. Filling time (44 minutes)
- 3. Balloon size (dia. 1.4m)



Filling Nozzle

- 3D printed tube, approx neck dia. 3cm
- Act as support structure for payload
- Facilitates the filling process as so the tube can be inserted or removed
- Cable ties are used to secure the balloon to the filling nozzle
- Generous amount of electrical tape is used to mask sharp edges
- Safety line is attached from before inflation



The 'Death Grip'

- Grip tightly to prevent gas escaping during the filling process
- Observe for leak (hissing)
- Cable tie can be used instead of hand grip but removal of cable tie can be challenging (sharps)
- Can be stressful as it is a potential show stopper

Imagine Helium gushing out and there is only one cylinder! And the balloon escapes and flies off...



Inflation cont'





Positive Lift

- Verify positive lift amount
- Payload requires 200g of positive lift
- Affects ascend rate



Ready to fly!

- Make sure safety line is anchored at all times prior to release
- Rigging is attached to filling nozzle
- All sharp edges masked
- Final test on rigging integrity



Ready



Darryl 9V1DE 2021-09-04

Lift off



Chew 9V1YP 2021-09-04

Payload: APRS tracker, antenna and packaging

Tracker Survey

by Dr Sampath

Considerations

- Cost (because it's not coming back)
- Dimensions and weight
- Power
- APRS Tx at 2m band
- GPS Enabled
- Sensors: altitude, pressure and temperature...humidity
- Coding: open source?
- Extendable: I2C, SPI, GPIO

Surveyed

- StratoTrack
- PicoAPRS-Lite
- LightAPRS
- Light APRS-W (WSPR)
- TrackSoar
- ptFlex Flight Controller
- SkyTracker
- Picoballoon
- Pecan Pico 9
- Arduino Pro Mini APRS

The BEAR-1 "Tracker"



http://www.qrp-labs.com/lightaprs.html

APRS Test Tx and Rx on 2021-08-28:

9V1UP-11>BEACON,9V1ZV-2*,WIDE2-1:/15351 9h0118.46N/10347.77E0086/001/A=000011 272TxC 51.20C 991.13hPa 7.89V 07S Happy 56th SGP!

LightAPRS tracker

- Software: Open Source
- Weight: 8 grams
- Dimensions: 3 cm x 5 cm
- IDE: Arduino
- Platform: MightyCore
- CPU: Atmega1284P-AU
- Flash: 128 KB
- Ram: 16 KB
- EEPROM: 4 KB
- Operating Frequency: 8 MHz
- Operating Voltage: 3.3V
- Input Voltage: 4.5V (min) 10V (max) via USB or VBat pin
- BOD: 2.7V

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- Sensor: BMP180 (pressure and temperature)
- Radio Module: Dorji DRA818V
- Radio Operating Frequency: 134-174 MHz (configurable by software)
- Low Pass Filter: Available (7 elements)
- Radio Power: 0.5W or 1W (configurable by software)
- Power Consumption (Sleep): ~5 mA
- Power Consumption (TX): ~460 mA (0.5W) / ~760mA (1W) (Automatically selected based on input voltage by code)
- **GPS:** Ublox MAX-M8Q (GPS-GLONASS)
- Gps Antenna Gain: 4.3dBi
- Extended Pins: I2C, SPI
- USB Serial: CH340G



Payload (BEAR-1)



Chew 9V1YP 2021-08-30

Payload (BEAR-1)



Chew 9V1YP 2021-08-30

Payload packaging and rigging



Flight ops: launch pad and coordination





Military Airbases operating hours:

Mon-Fri 07:00-19:00 Sat 07:00-13:00

Balloon flights strictly prohibited.



Chew 9V1YP 2021-08-29

BEAR Getting to lift off

"No Objections" (in writing) from:

- CAAS
- **RSAF** Air Operations Control Group
- □ IMDA (use of RF device and callsign)

At least 7 working days notification.

Although no permit required.

"Positive Clearance" (by phone / vox) from:

RSAF 203 Sqn Duty Controller
Air Surveillance Control Group (ASCG)

At least 15 minutes prior to release of balloon (and advise on completion of release).

NOTAM BEAR-1

FIR Flight Information Region

WLLW WL Ascent of free balloon LW will take place

WSAP Paya Lebar Air Base RSAF 207 Squadron (ATC)

Chew 9V1YP 2021-09-04 Ref: https://www.theairlinepilots.com/flightplanningforairlinepilots/notamdecode.php

NOTAM BEAR-2



D-Day



Ben 9V1KB 2021-09-04

BEAR-1 D-Day Wx

Taboo to mention the four letter word "rain" prior to launch.



Chew 9V1YP 2021-09-04



APRS signal coverage, approx.



Chew 9V1YP 2021-08-30

Test Tx by 9V1ZV aprs.fi



Chew 9V1YP 2021-08-31

Test Tx



Ben 9V1KB 2021-06-24



On-Site APRS Digipeater, BEAR-2

Making sure APRS is received and digipeated! Equipment used for APRS Digipeater

- Yaesu FTM-7250D¹
- RG-213 Coax ¹
- Diamond X-50 Dual Band Antenna¹
- <u>Nexus DR-X</u> by WB7FHC, Budd²
- 3s 11.1V 2500mAh Lipo Batteries ³
- Acer Laptop running <u>PinPoint APRS</u> as a iGate ^{1,4}



Fu Hang 9V1FH 2021-10-16



Nexus DR-X from WB7FHC Website



Ben 9V1KB 2021-10-16

1 Provided by 9V1FH, Fu Hang 2 Provided by 9V1MH, Matt 3 Provided by 9V1ZV, Daniel 4 As the Nexus DR:X have trouble connecting to the hotspot on my phone. PinPoint APRS is used as a iGate.

Tracking 9V1UP in comfort.

- 1. A tripod holds our yagi for us.
- 2. We have table and chairs.
- 3. And we ordered supper!

No one else had our level of comfort.



Solomon 9V1BC 2021-10-16



9V1BC, BD and BN worked together to create a 9V1UP tracker.

- 1. Offers 3D plots just like FlightRadar24.
- 2. Any browser can connect and see 9V1UP's updated and previous locations.
- 3. Any other receiving station can also upload packets to the server.
- 4. Independent of APRS.fi (Not a practical feature. We just wanted the challenge.)

Problems with the APRS

- 1. Delay due to constant GPS problems.
- 2. Inconsistent altitude reported.



Solomon 9V1BC 2021-10-16

The browser gets updated with a new location when a new packet is received.

(Watch the animation on the right for about 5s).

As a new packet is received, a new point appears on the browser.



Solomon 9V1BC 2021-10-16

3D plot of 9V1UP's location.

Note: The hot-air balloon is just a model from CesiumJS. We did not launch a hot-air balloon.



Solomon 9V1BC 2021-10-16

Arrow II Satellite antenna with only VHF elements installed

Wild Wild West

D878 in receive-only, mutually coupled to yagi to monitor signal quality

iPad running aprs.fi app for rough direction pointing



Lih Wei 9V1LW 2021-10-16

Arms very sore next day

Mobilinkd attached to TH-D72 (No portable way to use HT's built-in TNC)

Mobile phone acting as iGate

Our Trackers

ME BEFORE TRACKING 9V1UP-11

THE MORNING AFTER



Courtesy Ben 9V1KB



Got dog



A lot of mosquitos too

Not pictured: Frogs, rats, bats and lizards



Tuas



Google Maps

Tuas

Second-choice location Outside private jetty



Google Maps

Tuas

Second-choice location Outside private jetty

Third-choice location Open field beside the sea Too far North with blocked SSW view Expected to be chased away, but in the end nothing happened First-choice location Tuas Lamp Post Tuas Lamp Post 1 Too crowded that night, metal hoarding blocking WSW direction Google Map data @2021 Google Singapo

Google Maps





RX Data

Time is GPS timestamp from telemetry and is in UTC



Lih Wei 9V1LW 2021-10-17





Pretty much constant rate of ascent in SW direction

Initial loop and rapid ascent

Location of launch

Final gasps before LOS

ABCIDT € ♥ ₩ ₸ 178% ■ 03:34 APRSdro Project 2021-10-17 03:15:54 received 9V1UP-1->BEACON,WIDE1-1,WIDE2-1,qAR,9V1LW-10:>BEAR 2021-10-17 03:15:53 received 9W2DCW-4>51WG1,TCPIP*,qAC, T2FINLAND:>F52844A5007A49 APRS-51WIFI-20180630 2021-10-17 03:15:51 received 9V1KG-1>APDW16,TCPIP*,qAC,T2HK:; 9V1RS *11111z0119.08N/ 10345.36Er145.625MHz T156 -060 SARTS repeater 2021-10-17 03:15:48 recrived 9V1UP-1 >BEACON_WIDE1-1,WIDE2-1, qAR, 9V1LW-10:>BEAR 2021-10-17 03:15:35 received Send Position Stop Tracking

Google Maps + Lih Wei 9V1LW 2021-10-17



BEAR with us

Costs

Shared Costs	BEAR-1	For 2 balloons. Not costed to BEAR-2	
Chew	225.00	Shared Costs	BEAR-2
Ben	56.00		
Xavier	161.00	Chew	0.00
Sampath	0.00	Ben	56.00
Daniel	0.00	Daniel	161.65
Total Project Cost	442.00	Total Project Cost	217.65
divide by 5	88.40	divide by 3	72.55

Costs / BEAR		
Balloon	130	For BEAR-1 & 2, we excused the youth from cost sharing,
Helium	56	they are not working yet and have already incurred costs
LightAPRS	162	while supporting the projects.
Batt	30	
Total \$378 / shared by team members		

End Note



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Future BEARS are in progress. BEAR-3 is scheduled for launch on 18 Dec. BEAR-4 is in discussion, possibly involving party balloon! BEAR-5 akan datang.

Costs and availability of electronics components are affected by supply chain challenges during covid. Also, costs will go up with the introduction of GST on inbound online purchases. 3

Window of opportunity for BEARS may not be perpetual. Many are surprised by the approvals so far. It may (or may not) be due to the lower air traffic volume during covid.



BearX is a concept proposed by the current team. Reinventing the wheel is painful: navigating the regulatory framework, developing the flight system and the payload . Like SpaceX, *share with us what you'd like to fly, we'll help get it skyhigh*.



Above and Beyond.