# A quick guide to small superpressure

https://github.com/richardeoin/a-quick-guide

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# Superpressure is..

- Gas sealed within the envelope.
- Envelope is intended to be inelastic.

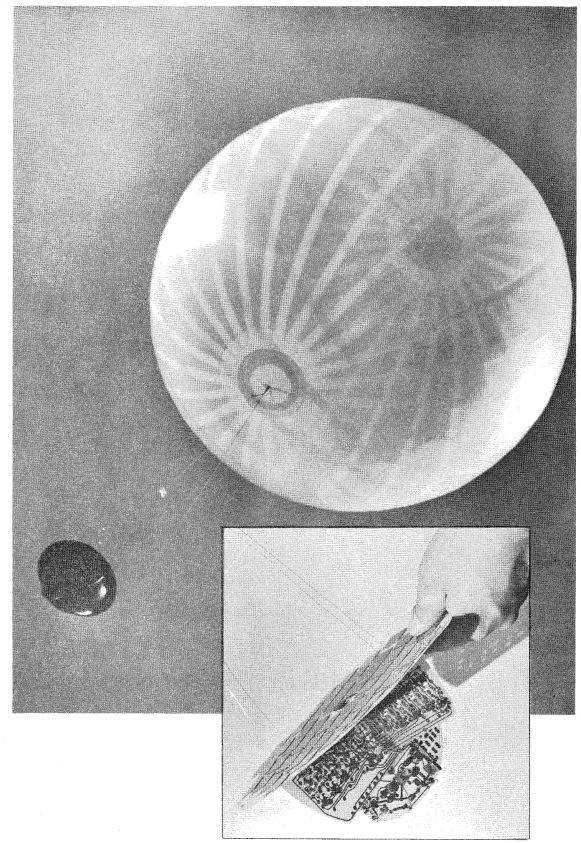


Figure : GHOST Balloon, Lally 1967

# Can Amateurs do this too?

- Yes!
- See also Dan Bowen at UKHAS 2011.

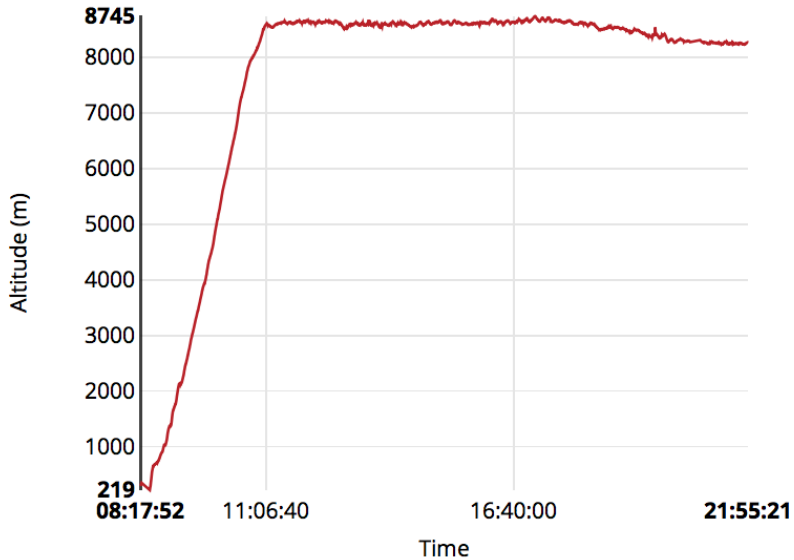



Figure : UBSEDS6, 7th June 2015

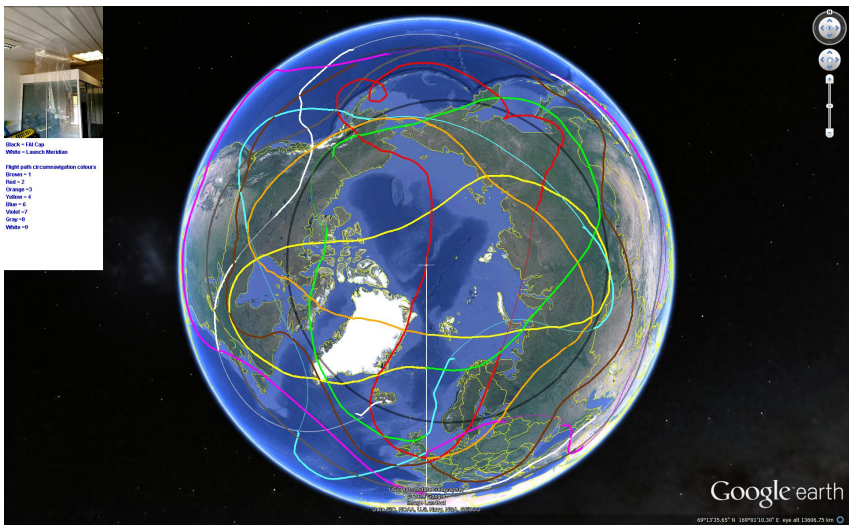



Figure : B-64, Leo Bodnar 2014

# In Flight

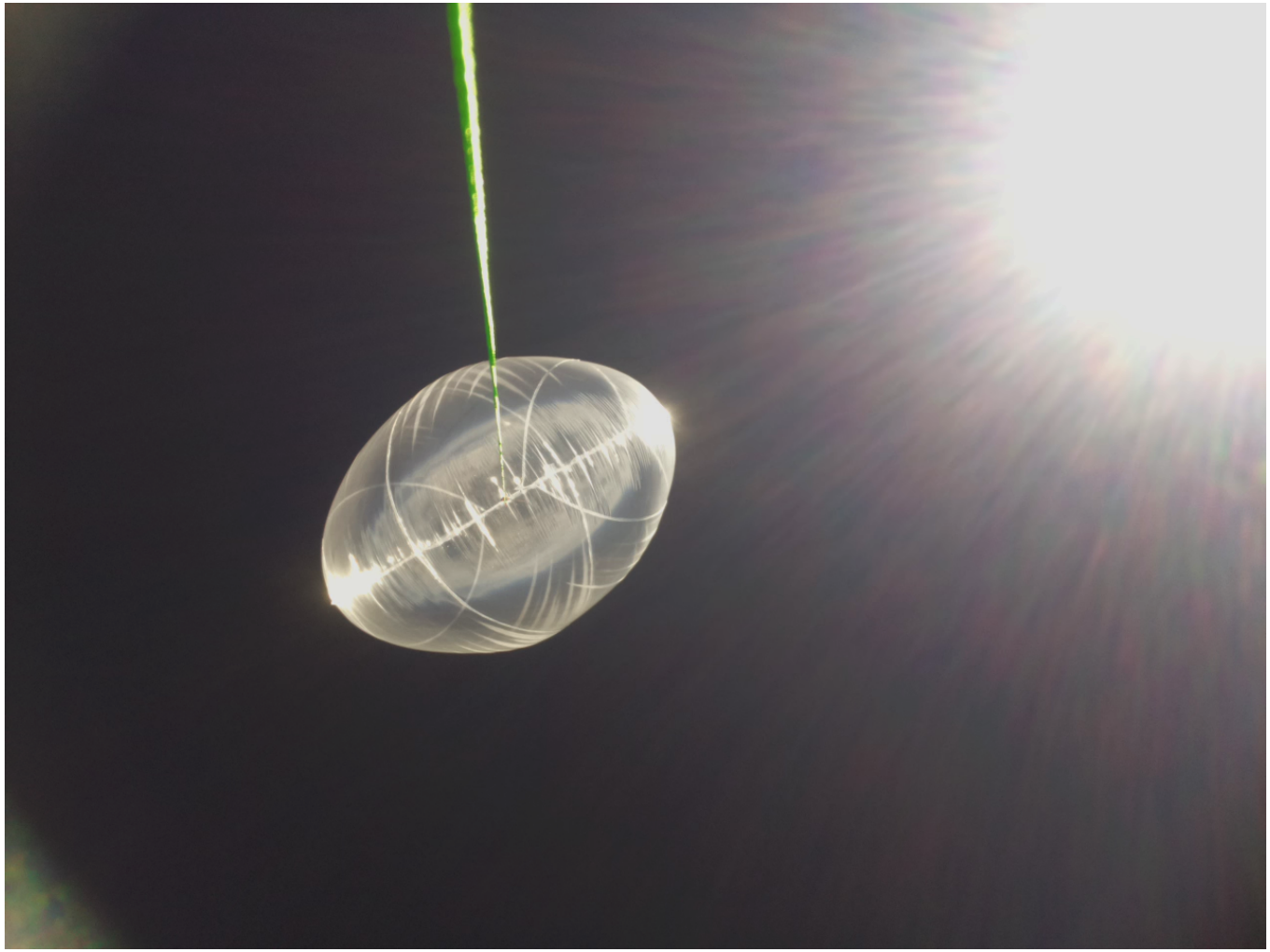


Figure : UBSEDS20 balloon at 12.5km float, 29th August 2016

# Floating

Float when:

$$\text{Atmospheric Density} = \text{System Density} = \frac{\Sigma m}{V}$$

However, the balloon envelope stretches somewhat:

$$V = V_{initial} \times \Gamma$$

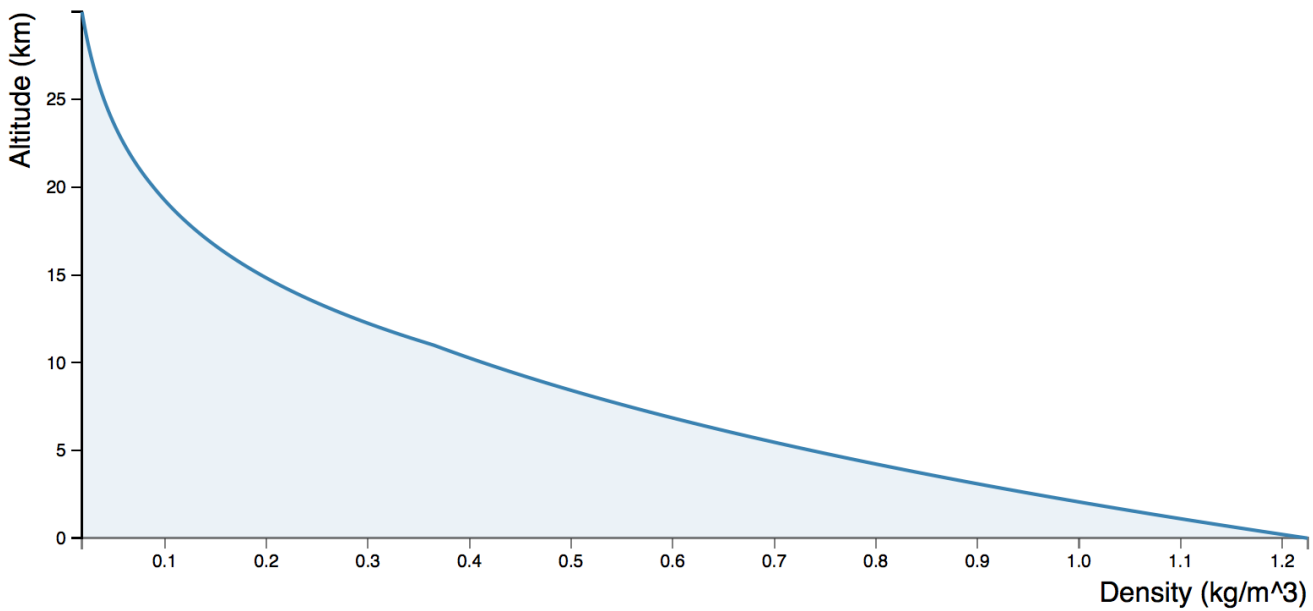


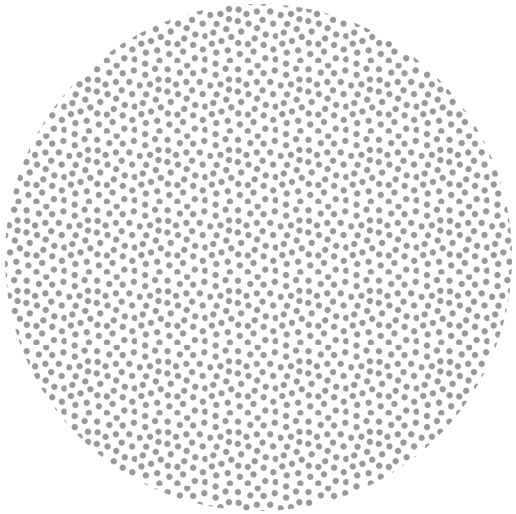

Figure : Density in the International Standard Atmosphere

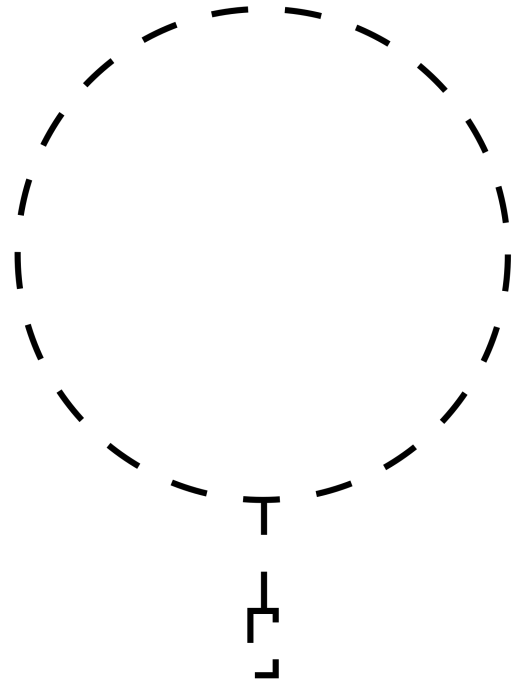
# The Origins of Superpressure

- Free lift
- Supertemperature
- Vertical Air Currents (Lally 1967, VI. D. p.31)

# Calculating Superpressure 1

Ideal gas law $PV = nRT$





$$P_{gas}V = \frac{m_{gas}}{M_{gas}}RT_{gas}$$

$$P_{air}V = \frac{m_{system}}{M_{air}}RT_{air}$$

# Calculating Superpressure 2

Definitions of Superpressure and Supertemperature:

$$P_{super} = P_{gas} - P_{air}$$

$$T_{super} = T_{gas} - T_{air}$$

Assuming volumes are equal:

$$P_{super} = \frac{R}{V}\left[\left(\frac{m_{gas}}{M_{gas}} - \frac{m_{system}}{M_{air}}\right)T_{air} + \frac{m_{gas}}{M_{gas}}T_{super}\right]$$

The second term dominates, so:

$$\frac{P_{super}}{T_{super}} \approx \frac{m_{gas}}{M_{gas}}\frac{R}{V}$$

# Supertemperature

Table 9

RADIATION ENVIRONMENT FOR SUPERPRESSURE BALLOON

| Altitude | Season | Air Temperature °C | Mylar balloon ($\alpha_o$ = 0.05) | | |
|---|---|---|---|---|---|
| | | | Temperature increase per w/m² increment, °C | Maximum added solar flux w/m² | Maximum daytime temperature increase, °C |
| 9 km (300 mb) | Temperate, winter | -50 | 0.36 | 40 | 14 |
| | Temperate, summer | -35 | 0.34 | 40 | 13 |
| | Tropic | -30 | 0.34 | 40 | 13 |
| 12 km (200 mb) | Temperate, winter | -55 | 0.36 | 45 | 16 |
| | Temperate, summer | -55 | 0.36 | 45 | 16 |
| | Tropic | -50 | 0.36 | 45 | 16 |
| 16 km (100 mb) | Temperate, winter | -60 | 0.42 | 45 | 19 |
| | Temperate, summer | -65 | 0.42 | 45 | 19 |
| | Tropic | -80 | 0.47 | 45 | 21 |
| 24 km (30 mb) | Temperate, winter | -55 | 0.45 | 45 | 20 |
| | Temperate, summer | -55 | 0.45 | 45 | 20 |
| | Tropic | -55 | 0.45 | 45 | 20 |

Figure : Lally 1967, Table 9 p.24 (edited)

# Mylar Balloon Shape 1

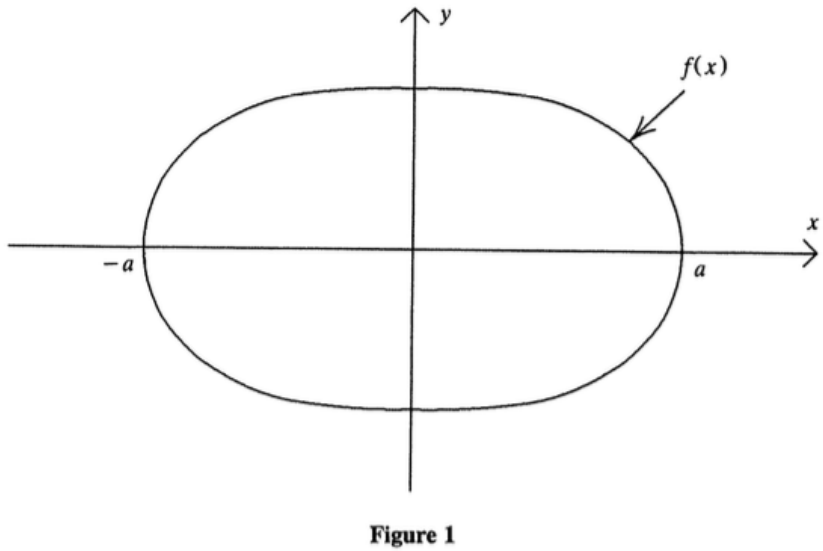



Figure 1

Figure : Paulsen 1994, Figure 1

$$\int_0^a \sqrt{1 + f'(x)^2}\, dx = r$$

# Mylar Balloon Shape

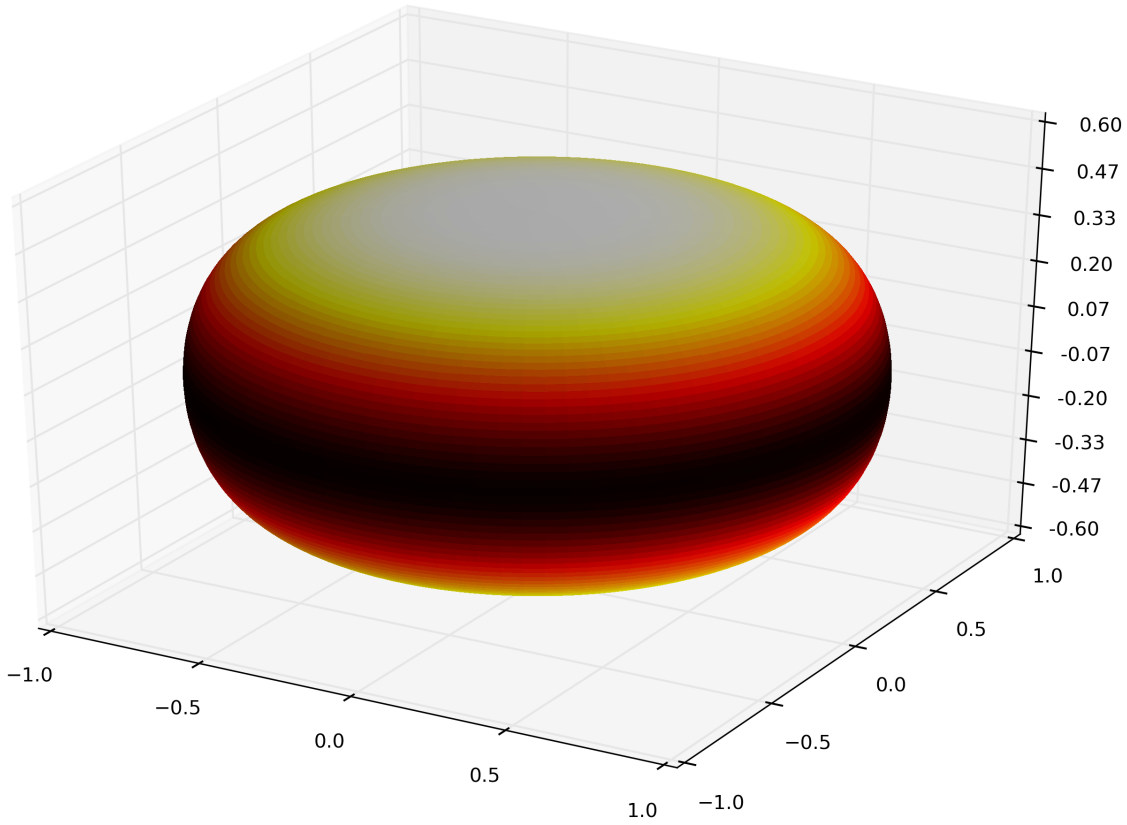



Figure : Crimping means a small area the in centre is stressed.

# The Magic of Pre-stretch

- Minimise Creep and relieve manufacturing stresses (Lally 1967, VI. C. p.28)
- Increases $\Gamma$, leading to higher float and lower superpressure.
- Re-distributes stresses around mylar balloon shape.

# Envelope Construction

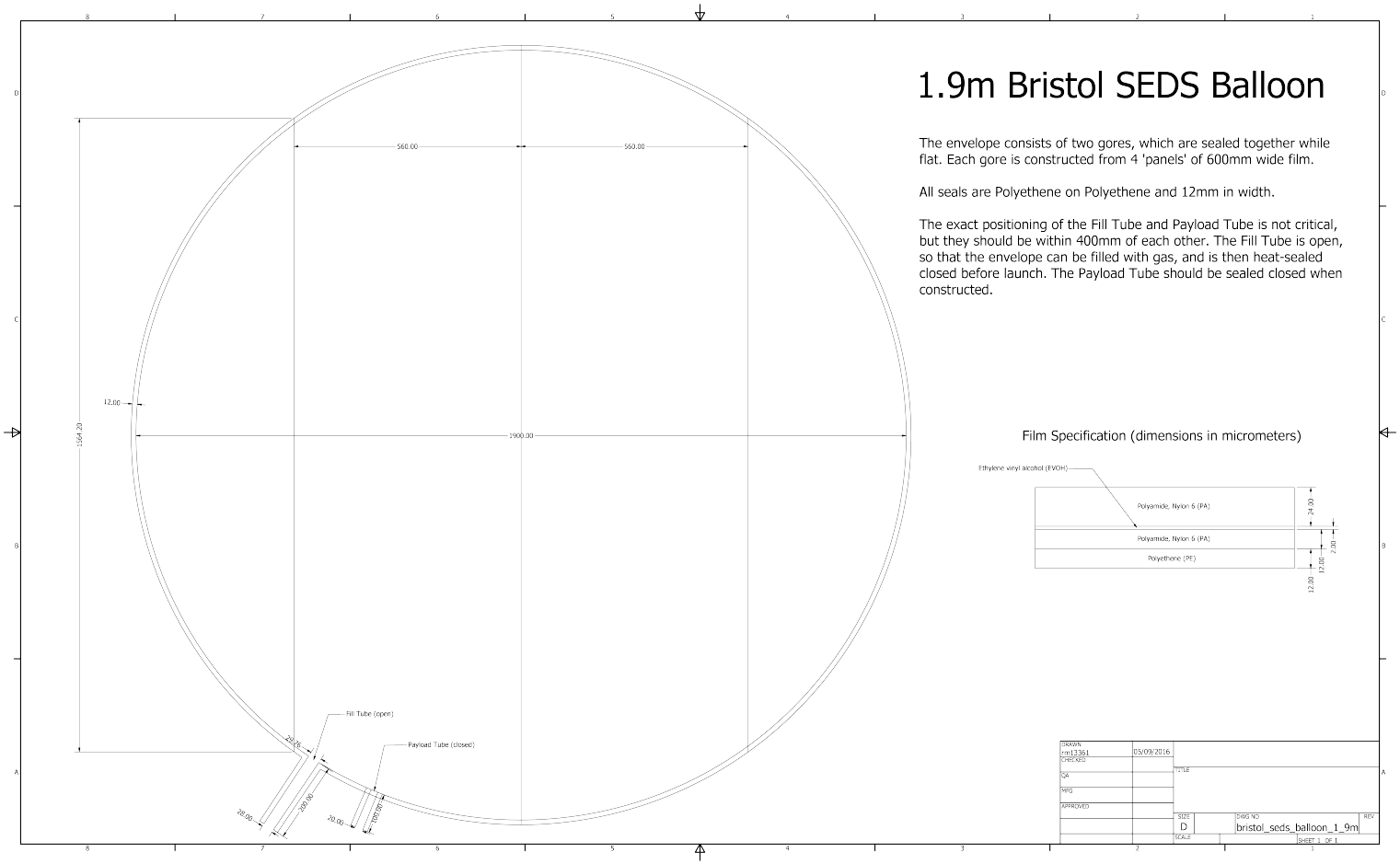



Figure : Drawing for 1.9m balloon

# Envelope Construction

Film Specification (dimensions in micrometers)

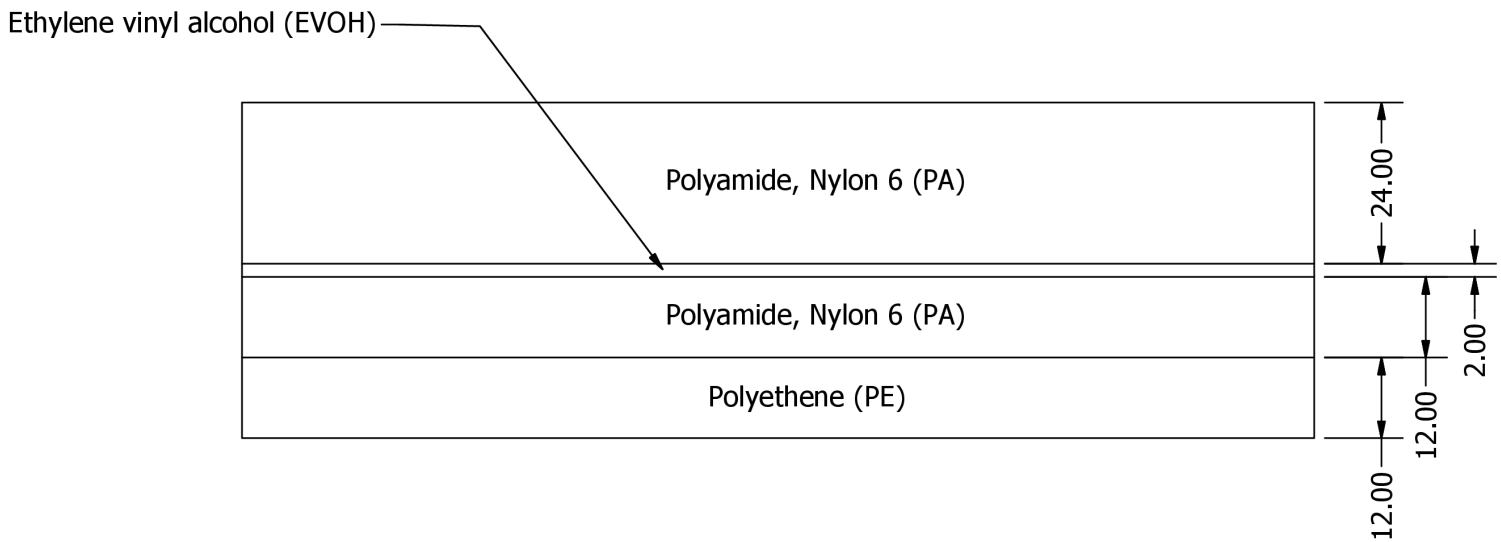



Figure : 50$\mu$m film cross section

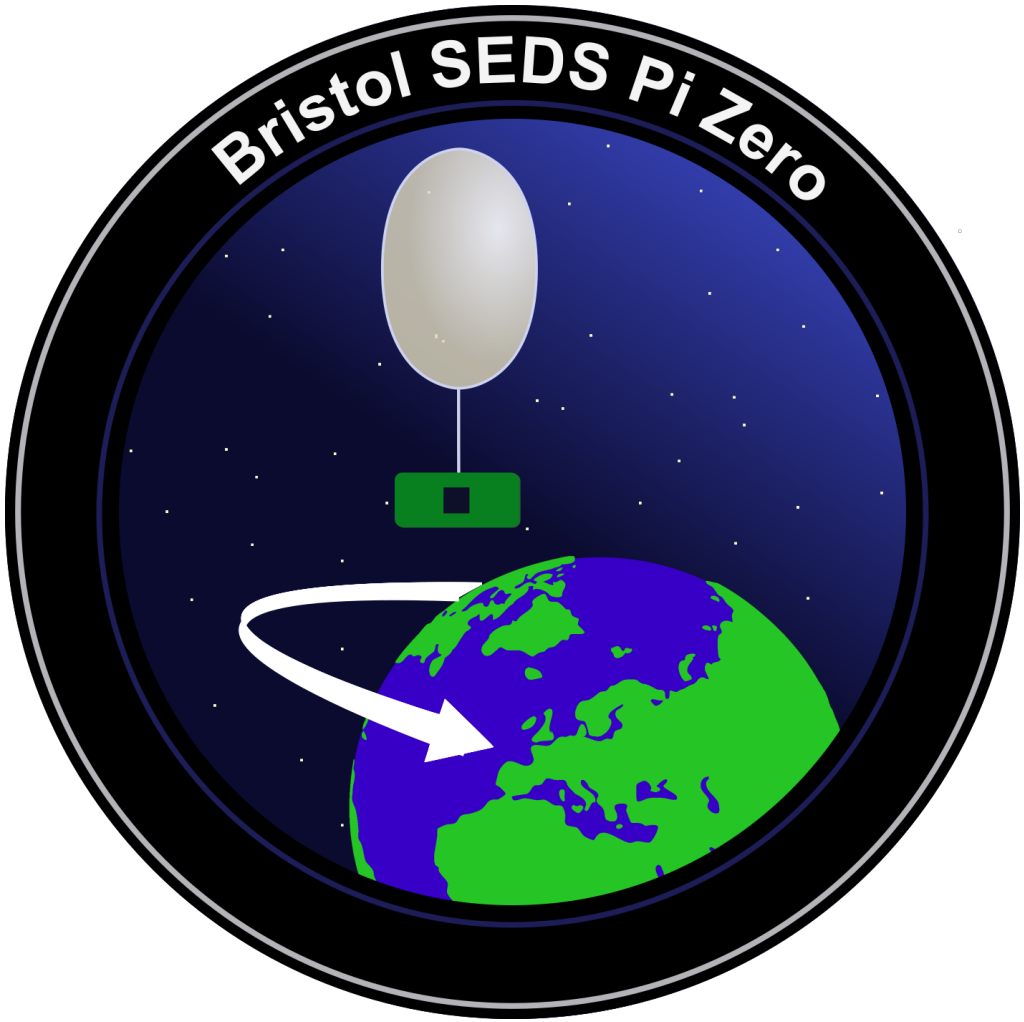
Thanks to Exploratory Ideas grant from CEOI.

# Further Work

- Web based calcuator - like the Burst Calculator.
- Numerical analysis of previous flights.
- Guidelines for minimum free lift.
- Modelling and measuring supertemperature.
- Model for mylar tube shape.
- Explore $\Gamma > 2$
- Measuring strain on the ground (Angell and Pack, Apr. 1960).
- Relationship between stress and strain.

# Further Work

- Have fun flying round the world...



# Meridianal Hoop

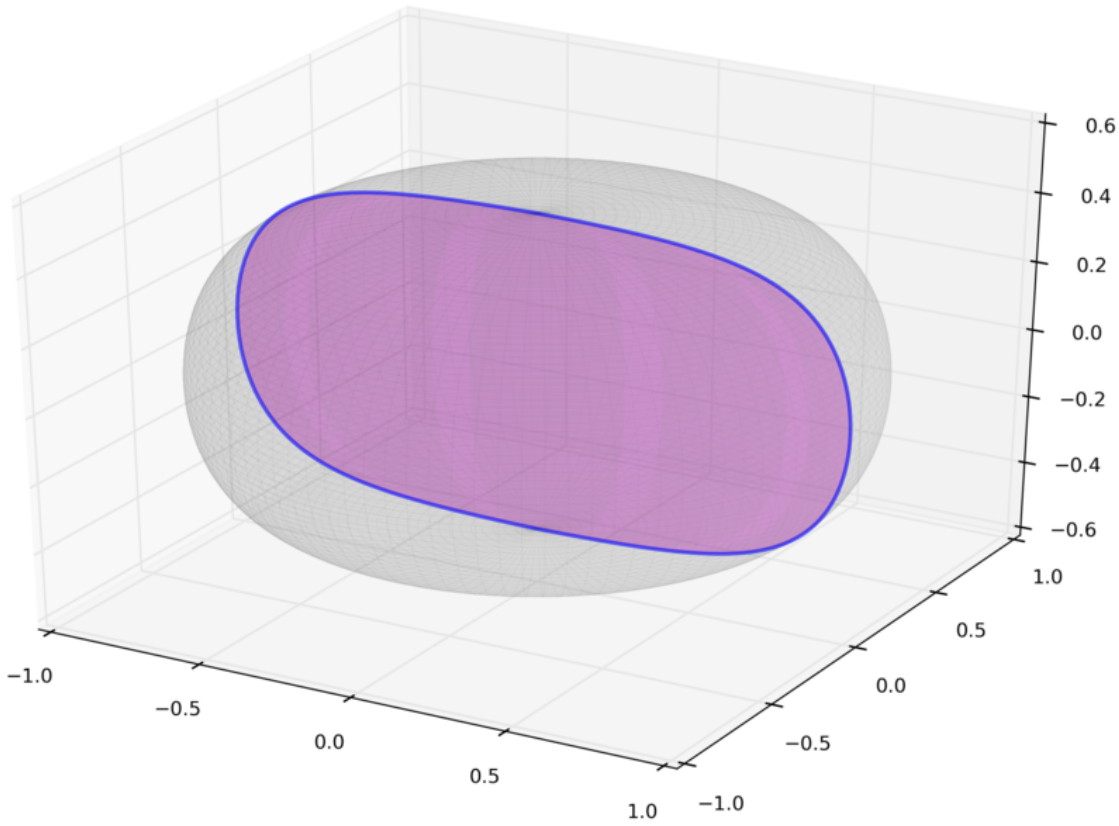



Figure : Meridianal Hoop of a Mylar Balloon