Utility of Live Tension Measurements

T. U. F. F. DOS
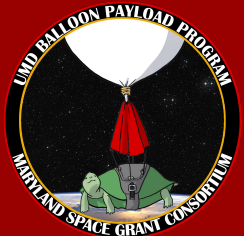
TUFF DOS

T: Tension
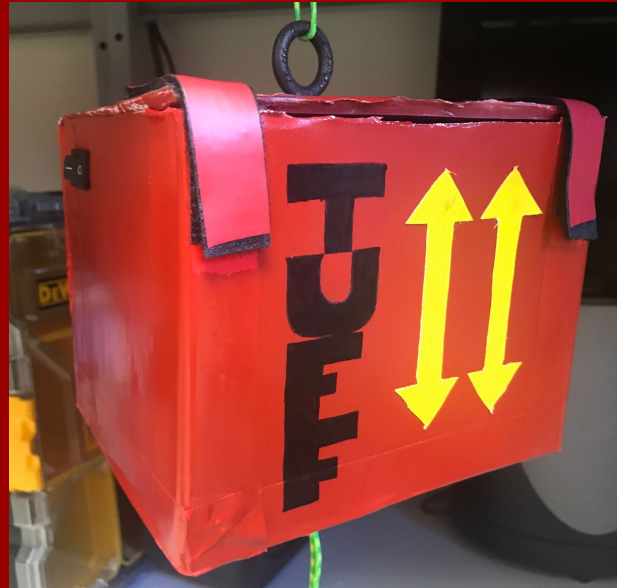**U: Under**
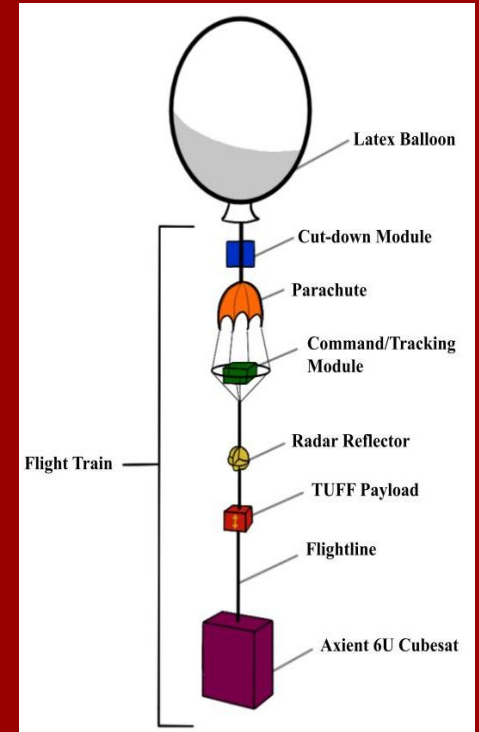**F: Flight**
F: Forces

D: Drag
O: Oscillations
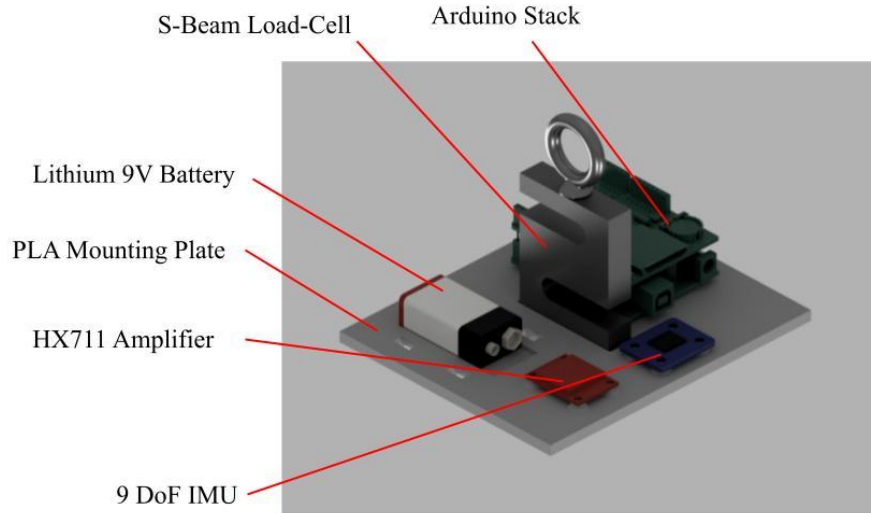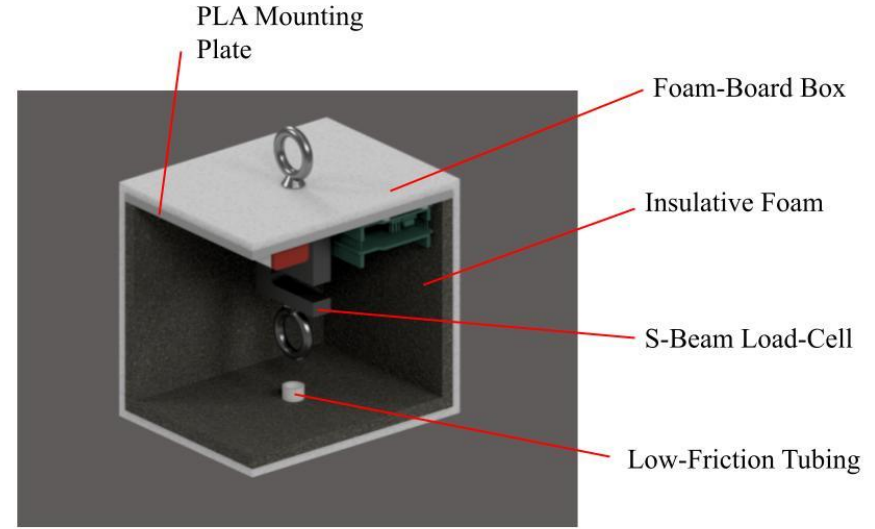**S: Shear-Winds**

TUFF DOS Payload

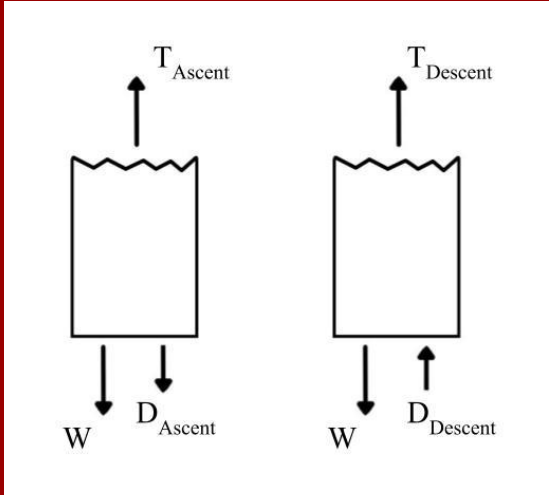Flight NS-111 TUFF DOS Configuration
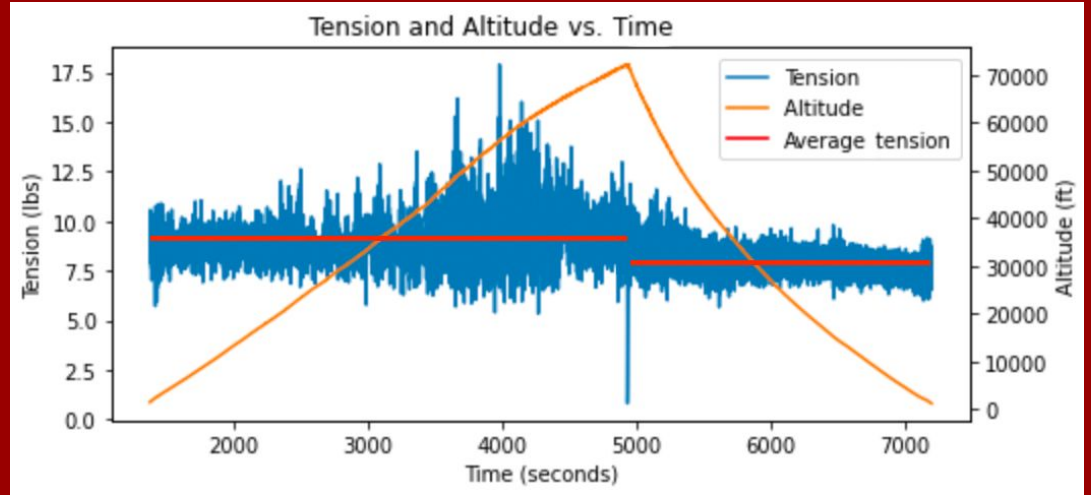
Design Overview

TUFF DOS internals

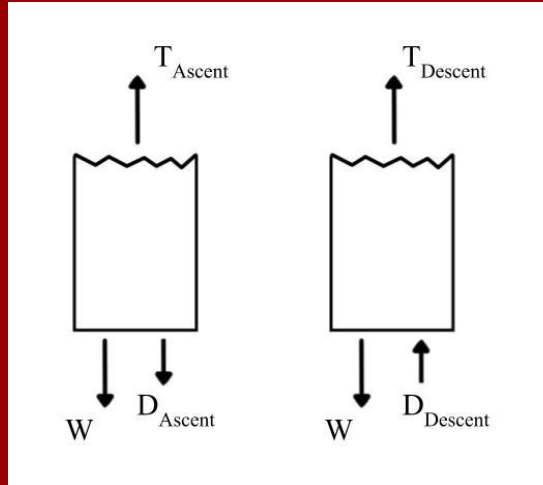Section-view of TUFF DOS

Drag

Tension-Drag Relationship Partial FBD

Tension w/ Altitude Overlain and Averages Drawn (Flight NS-110)

Drag

Tension-Drag Relationship Partial FBD

$$\text{Xa: } \left|D_{Ascent}\right| = T_{Ascent} - W$$

$$\text{Xb: } \left|D_{Descent}\right| = W - T_{Descent}$$
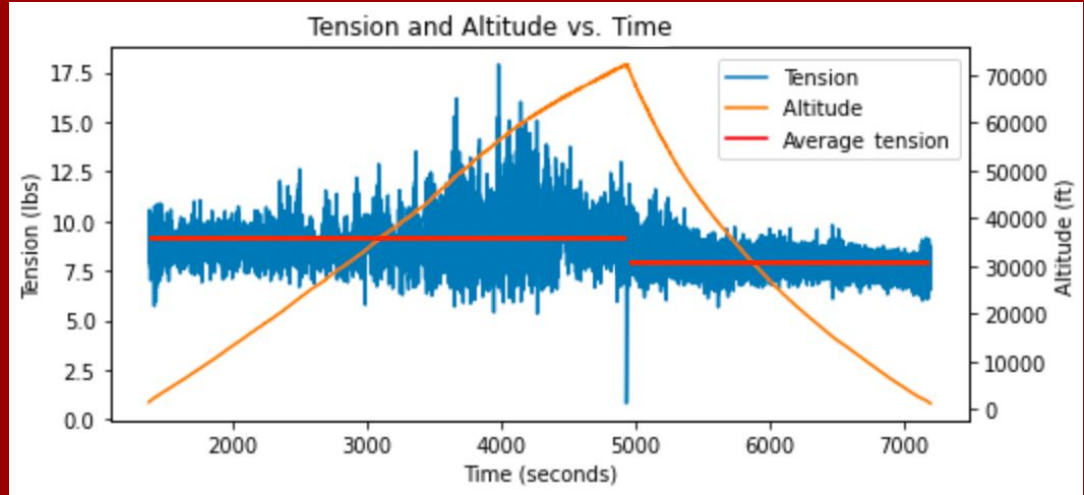
Drag Calculation

Drag

$$\frac{\left|D_{Ascent}\right|}{\left|D_{Descent}\right|} = \frac{V_{Ascent}^2}{V_{Descent}^2}$$

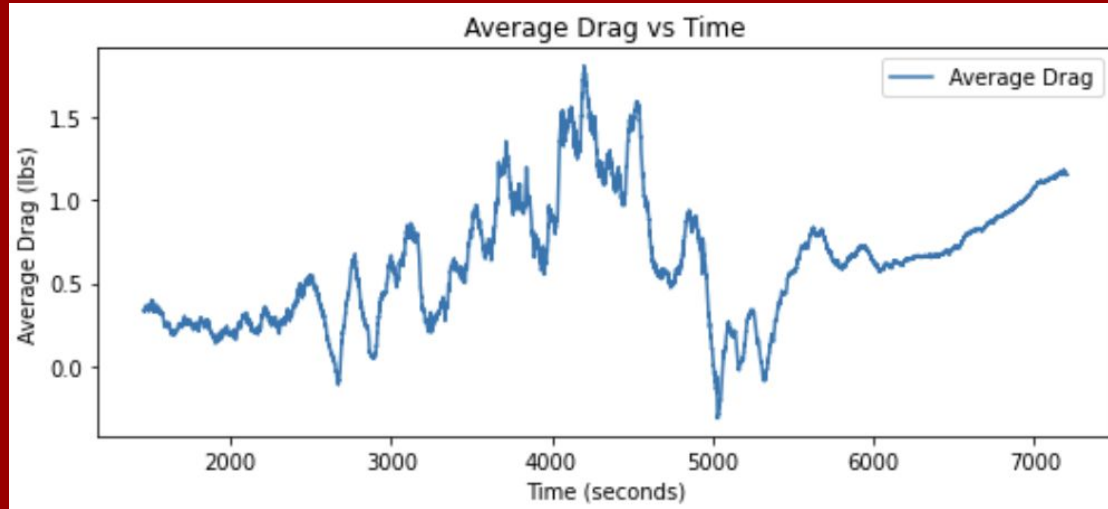**Drag Relationship Test (V is known)**

$$D = C_d \frac{\rho V^2}{2} A$$

Drag Equation

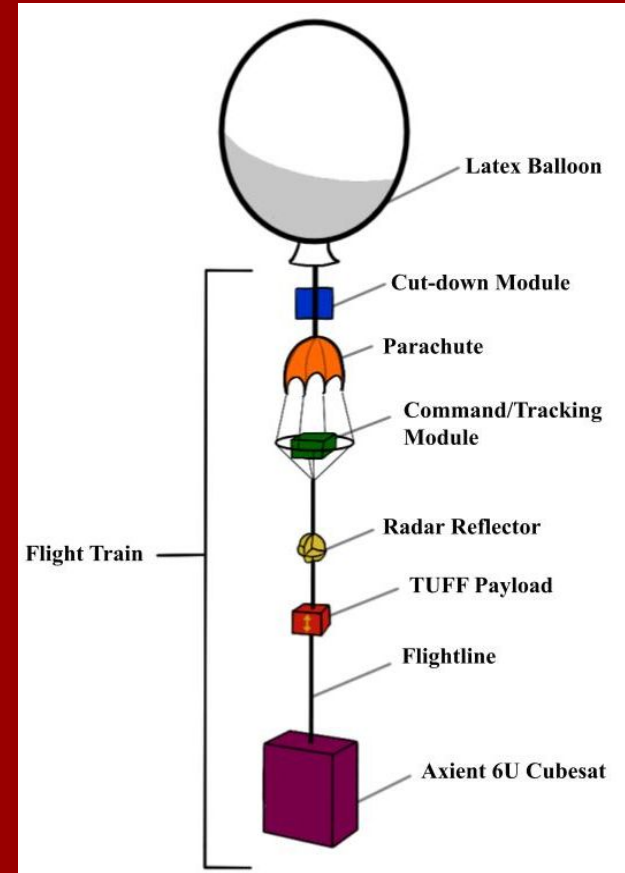**Tension w/ Altitude Overlaid and Averages Drawn (Flight NS-110)**

Drag

Rolling Average (100s) of Drag Throughout Flight NS-110
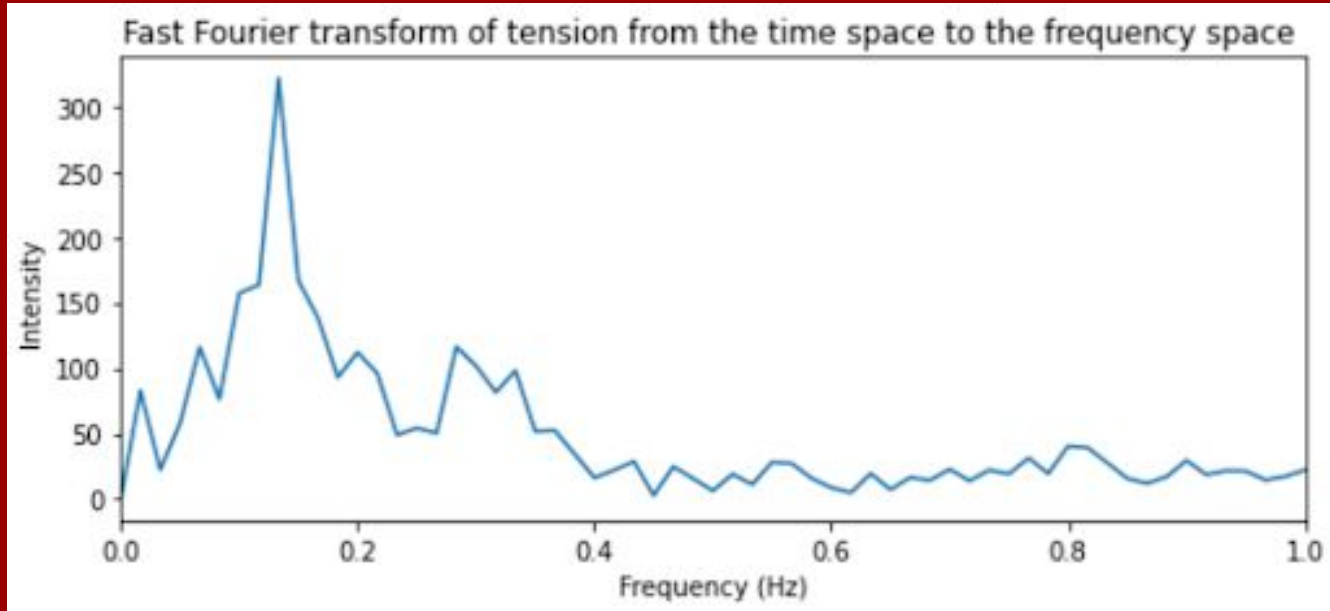
Drag Applications
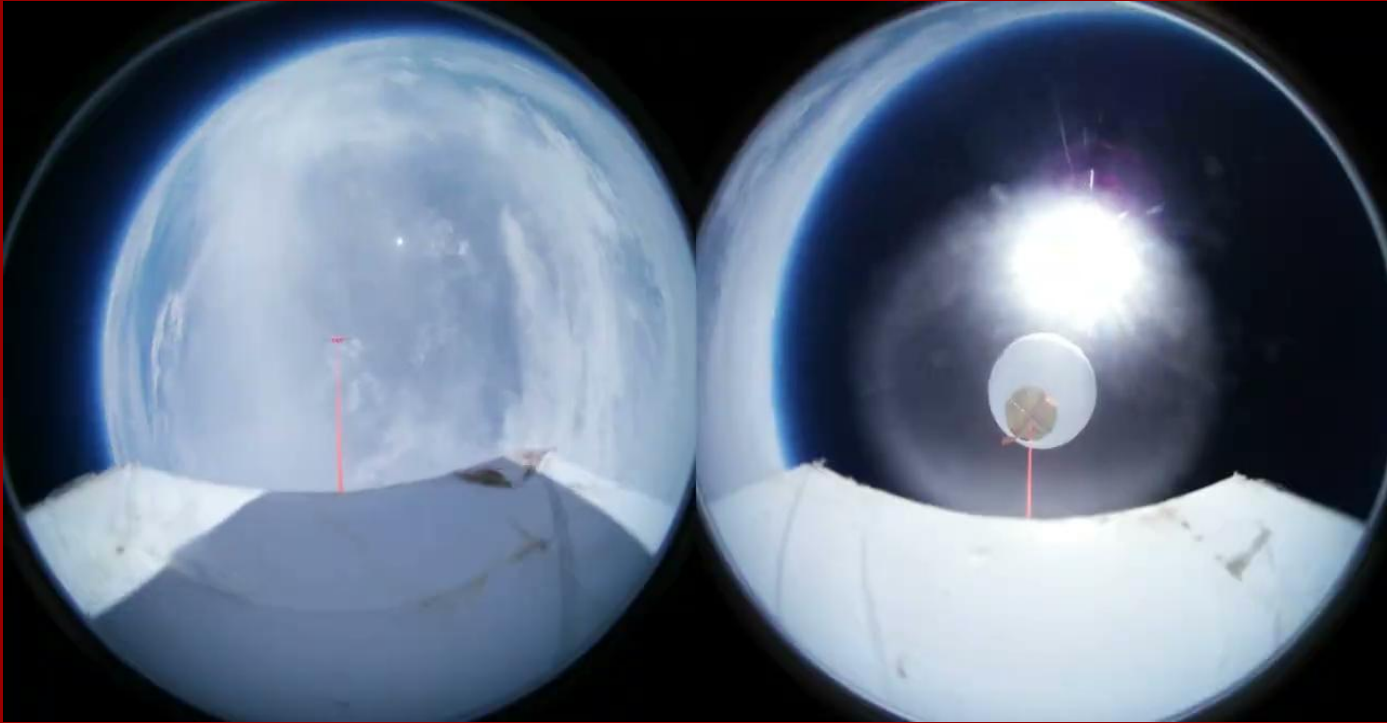

Balloon Inflation Process

Flight NS-111 TUFF DOS Configuration

Oscillations

FFT of Representative 60 Second Sample of Payload Oscillation Rate
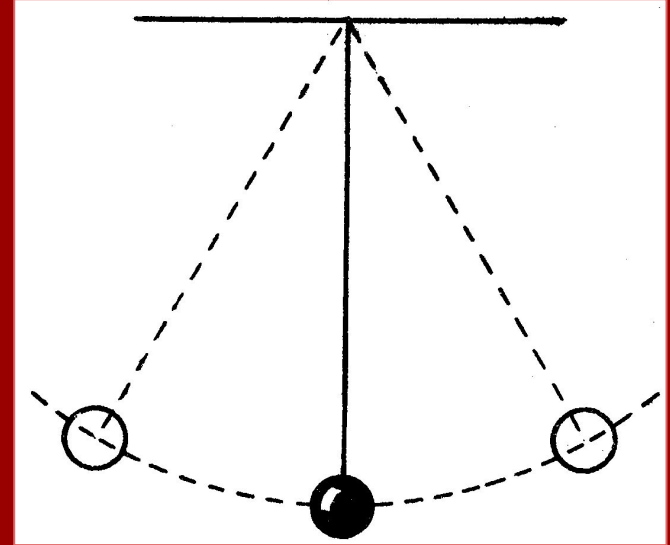
Oscillations

Swinging Sample from NS-111 (Cubesat similar w/out TUFF)
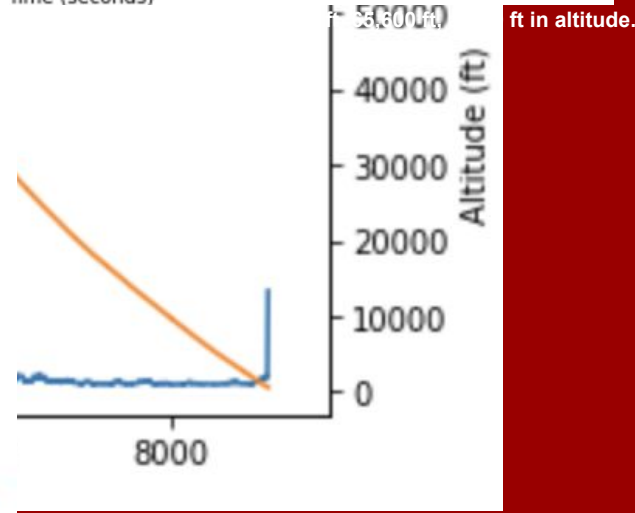
Oscillations Applications

Video Stabilization Application
SOURCE: Phys.org

Payload Swinging Application

Shear-Winds

Variance and Altitude vs Time

Variance an...

Fast Fourier transform of tension from the time space to the frequency space
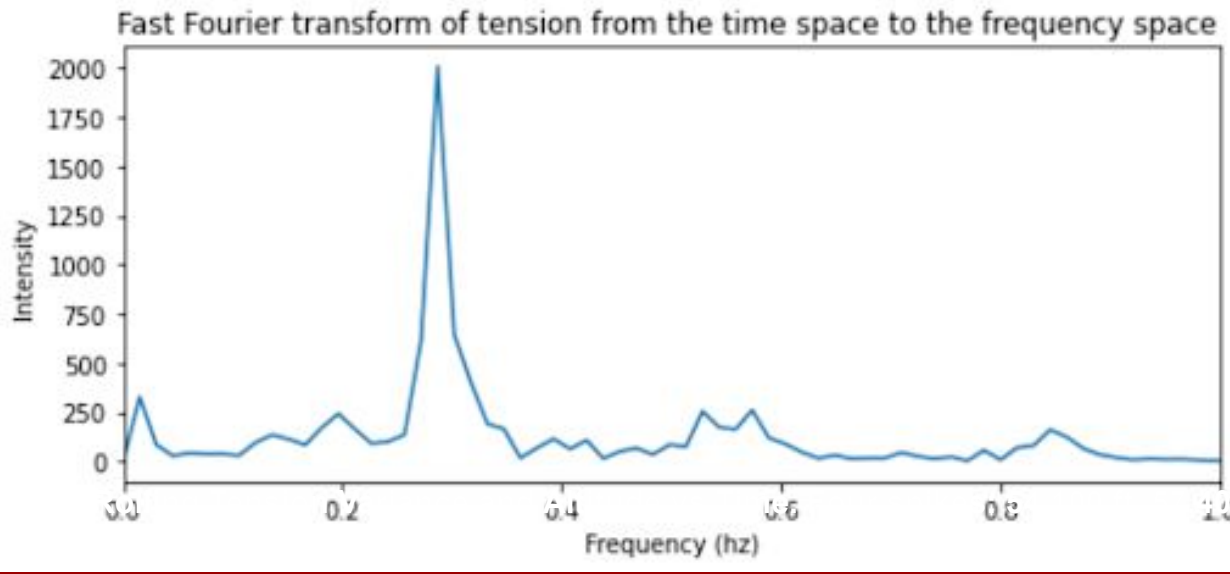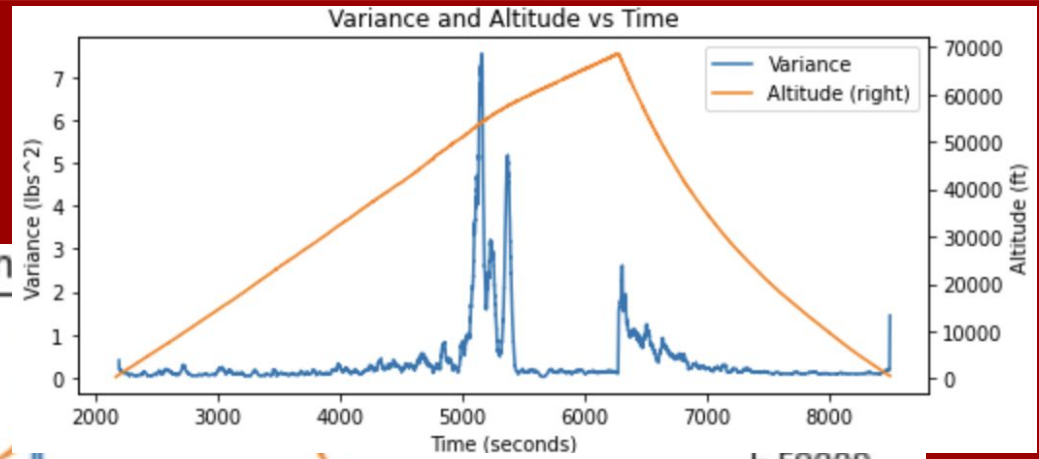
ft in altitude.

ft, 65,600 ft, and 0 ft in altitude.

Oscillation Rate at 55,000 ft
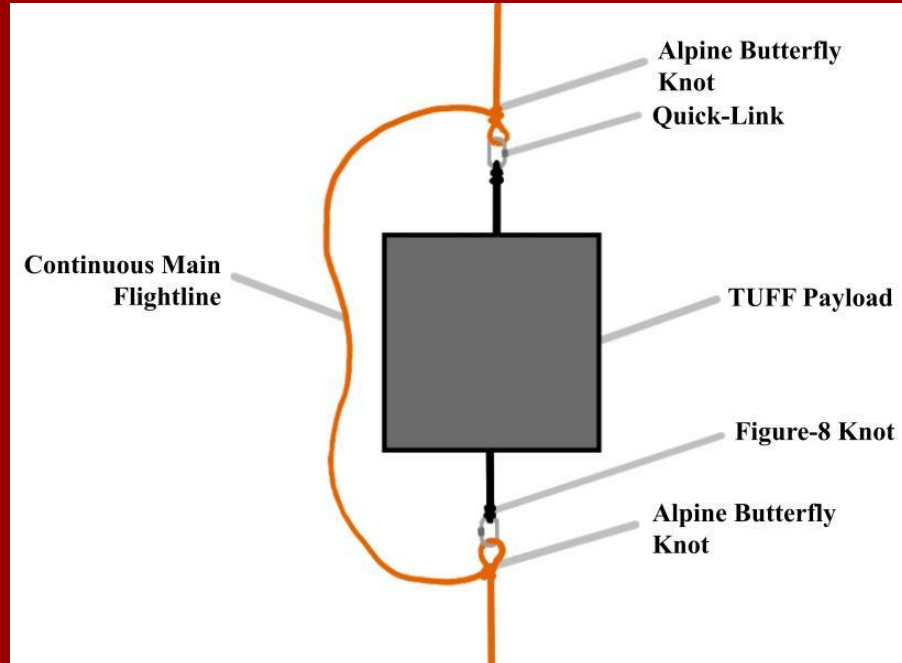
Shear-Winds Applications
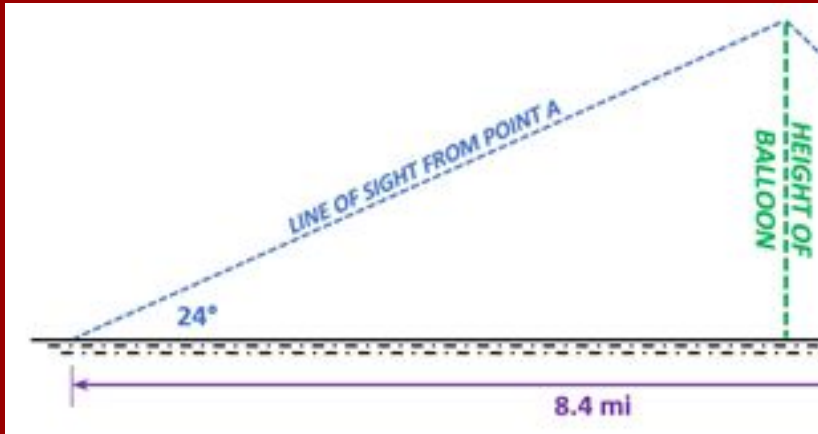
Ground Tracking Application
SOURCE: Study.com

Jet Stream Application
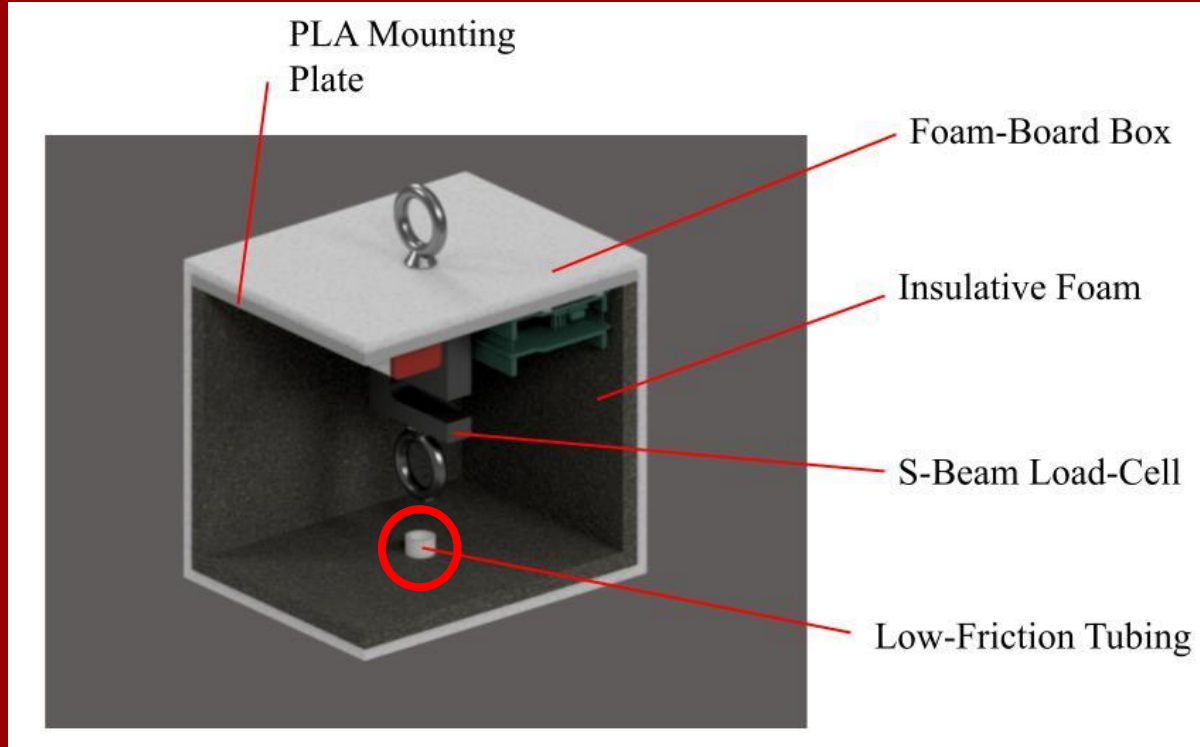**SOURCE: Electroverse**

Challenges - Flight Safety

TUFF Tie-On Slackline System

Challenges - Calibration Accuracy

TUFF Calibration Rig

Challenges - Human Error
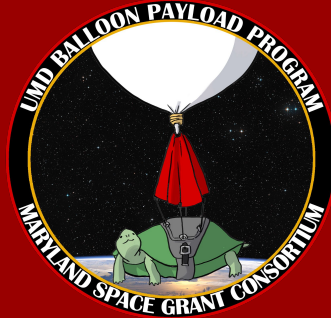

Section-view of TUFF DOS

Conclusions

- **Promising results**

- **Drag, oscillations, shear-winds have been detected**

- **Several ballooning applications**

- **More research is needed, expert opinions welcome**

TUFF DOS Payload

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