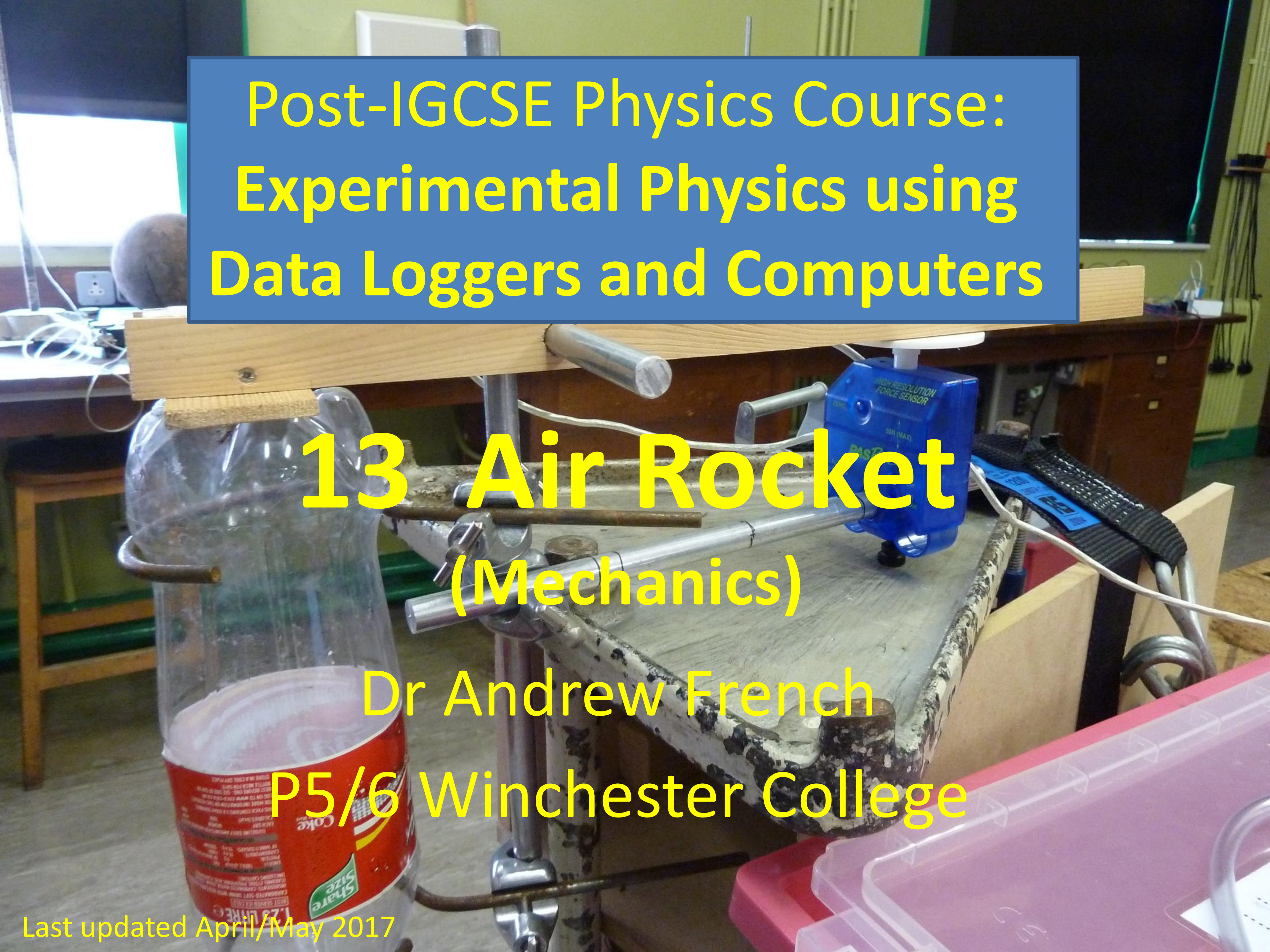


Post-IGCSE Physics Course:

# Experimental Physics using Data Loggers and Computers

# 13 Air Rocket

## (Mechanics)

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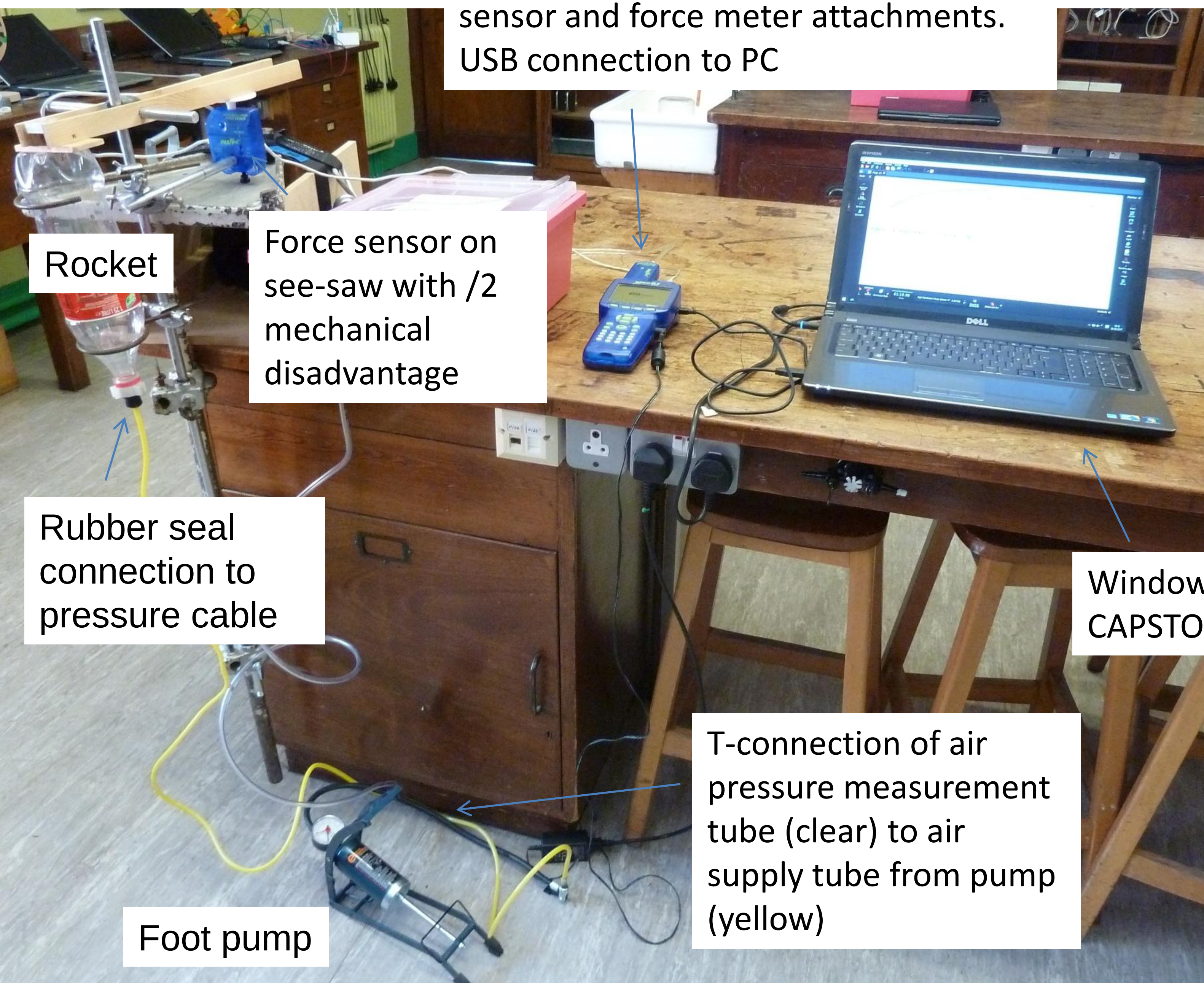
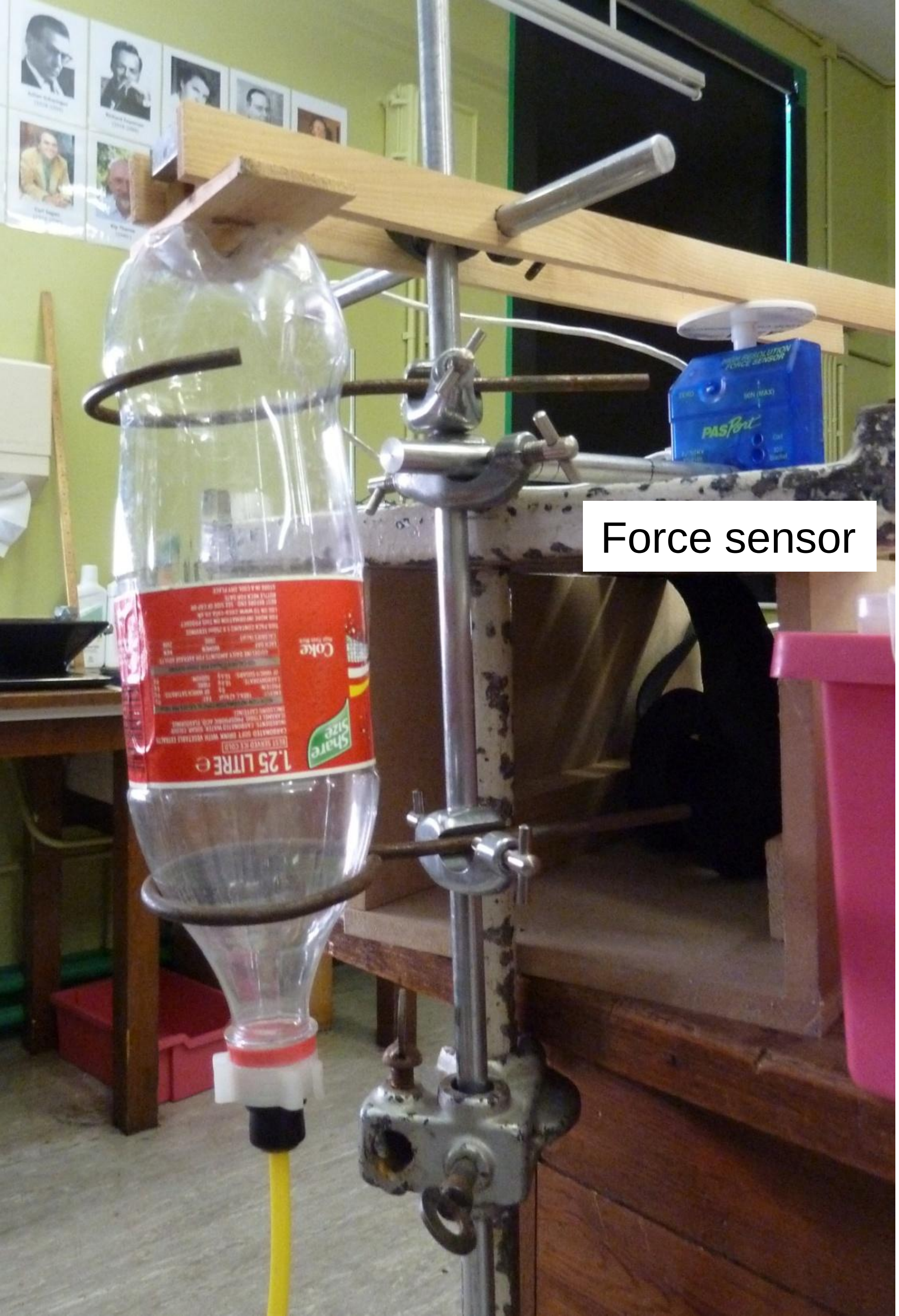
Last updated April/May 2017

**Experimental setup**



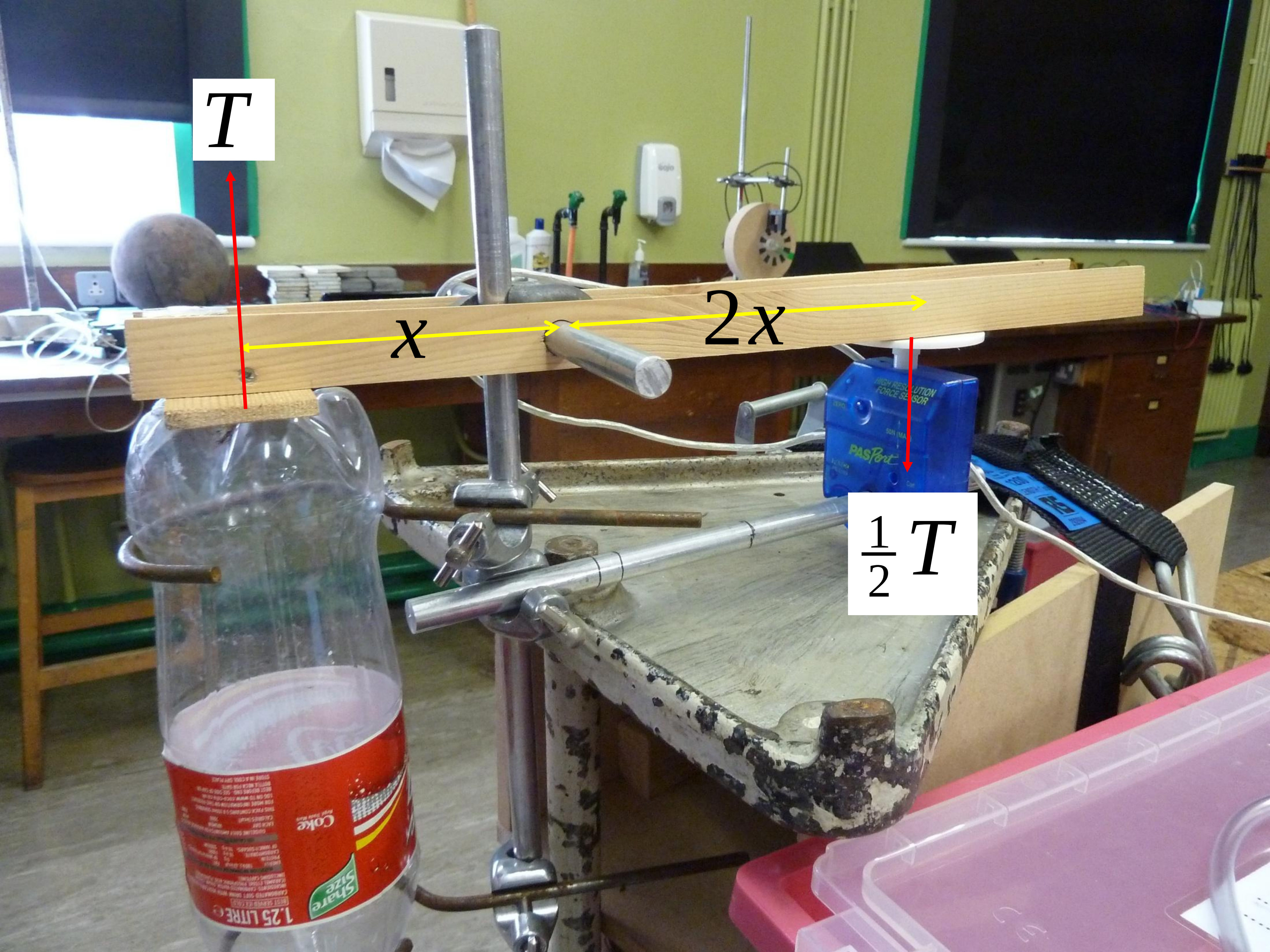


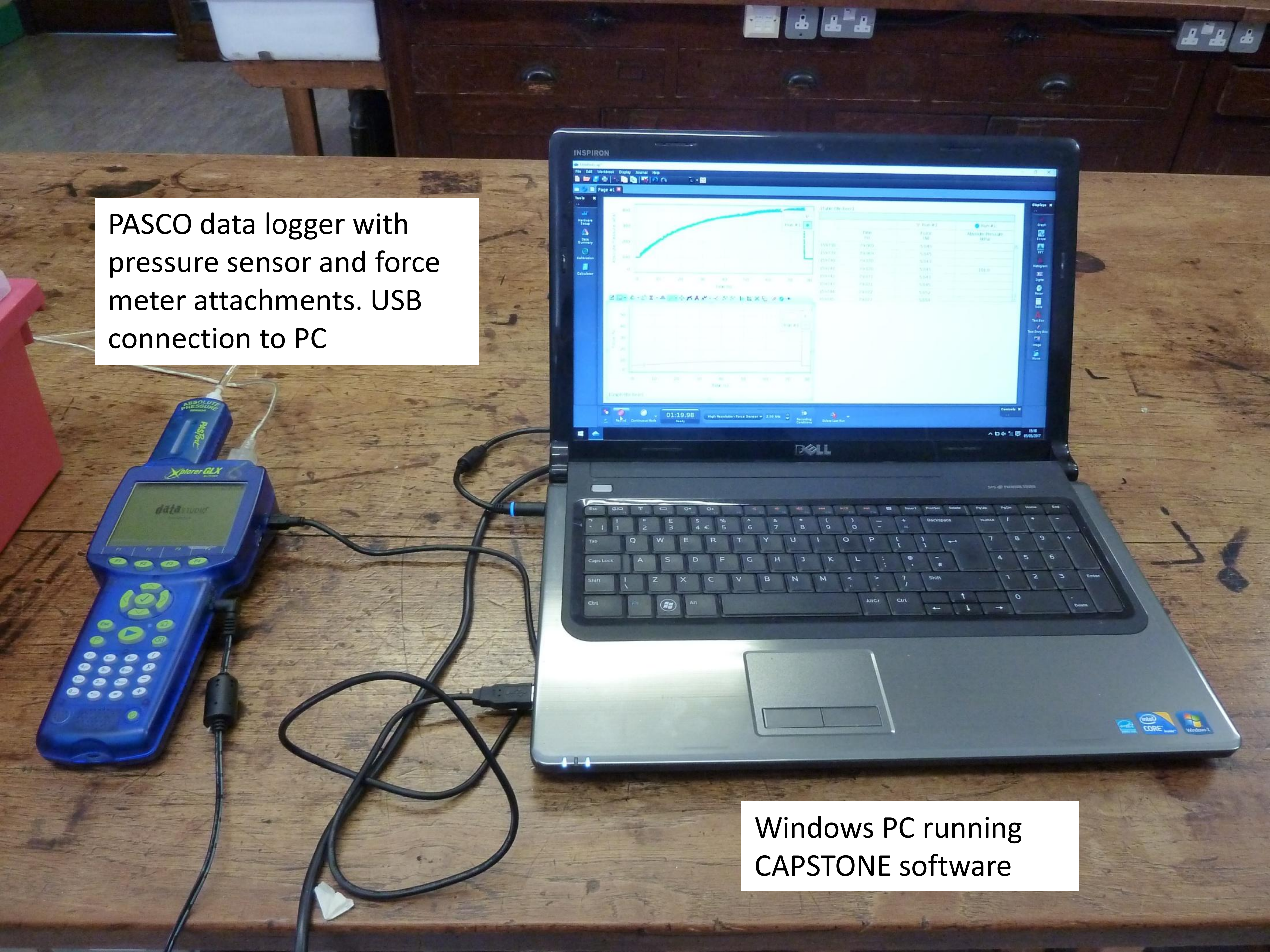

Lemonade bottle rocket. In this experiment no water is present, merely air is compressed.

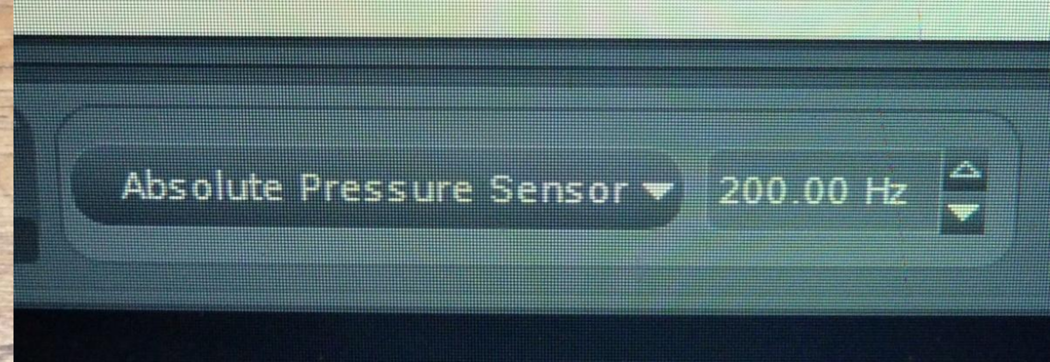
Rings prevent unwanted lateral movement.

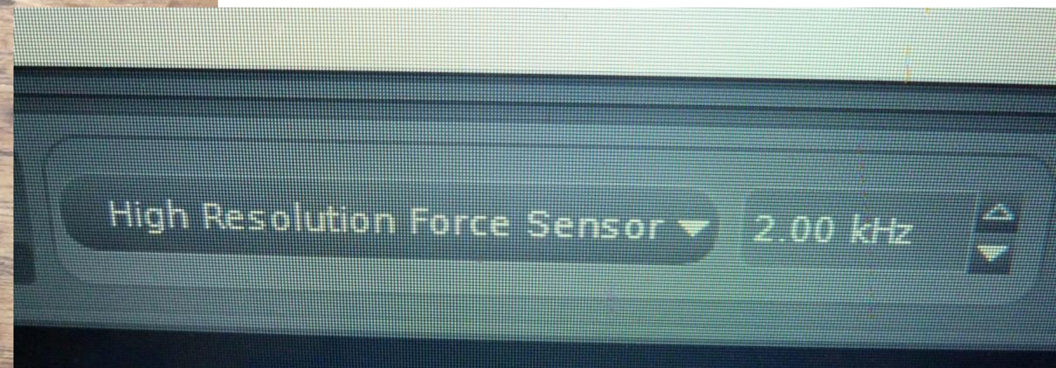
The rocket thrust is measured using the see-saw assembly.
To avoid exceeding the maximum thrust measureable by the sensor, a mechanical disadvantage of 2 is used. i.e. the rocket is half as close to the pivot as the force sensor.

Therefore to calculate the rocket thrust, the sensor measurement must be multiplied by two.


$T$
$x$
$2x$
$\frac{1}{2}T$
HIGH RESOLUTION FORCE SENSOR
PASPort

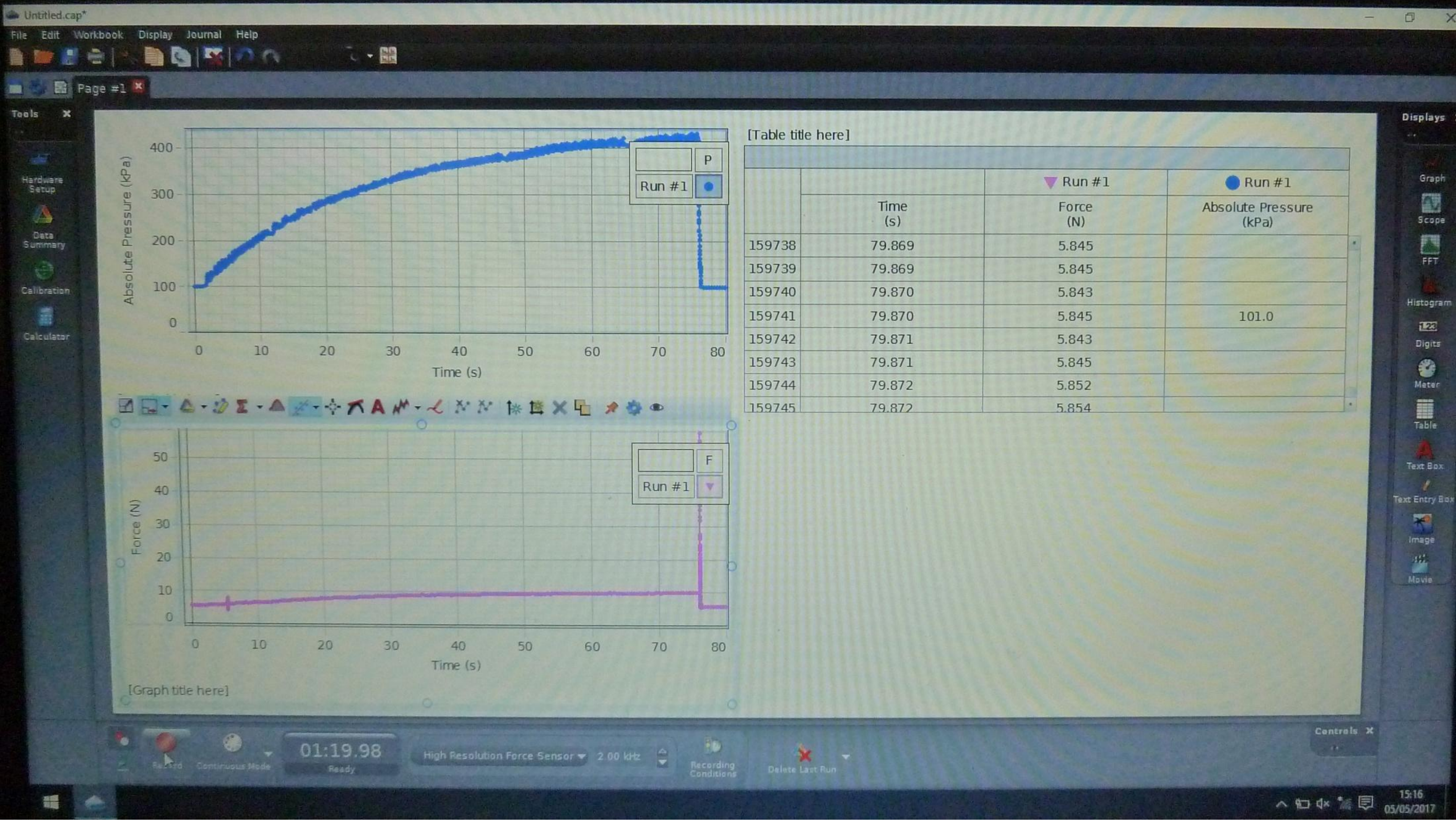

PASCO data logger with pressure sensor and force meter attachments. USB connection to PC
Windows PC running CAPSTONE software
INSPIRON
DELL
Xplorer GLX
ABSOLUTE PRESSURE
PASPORT
01:19.98

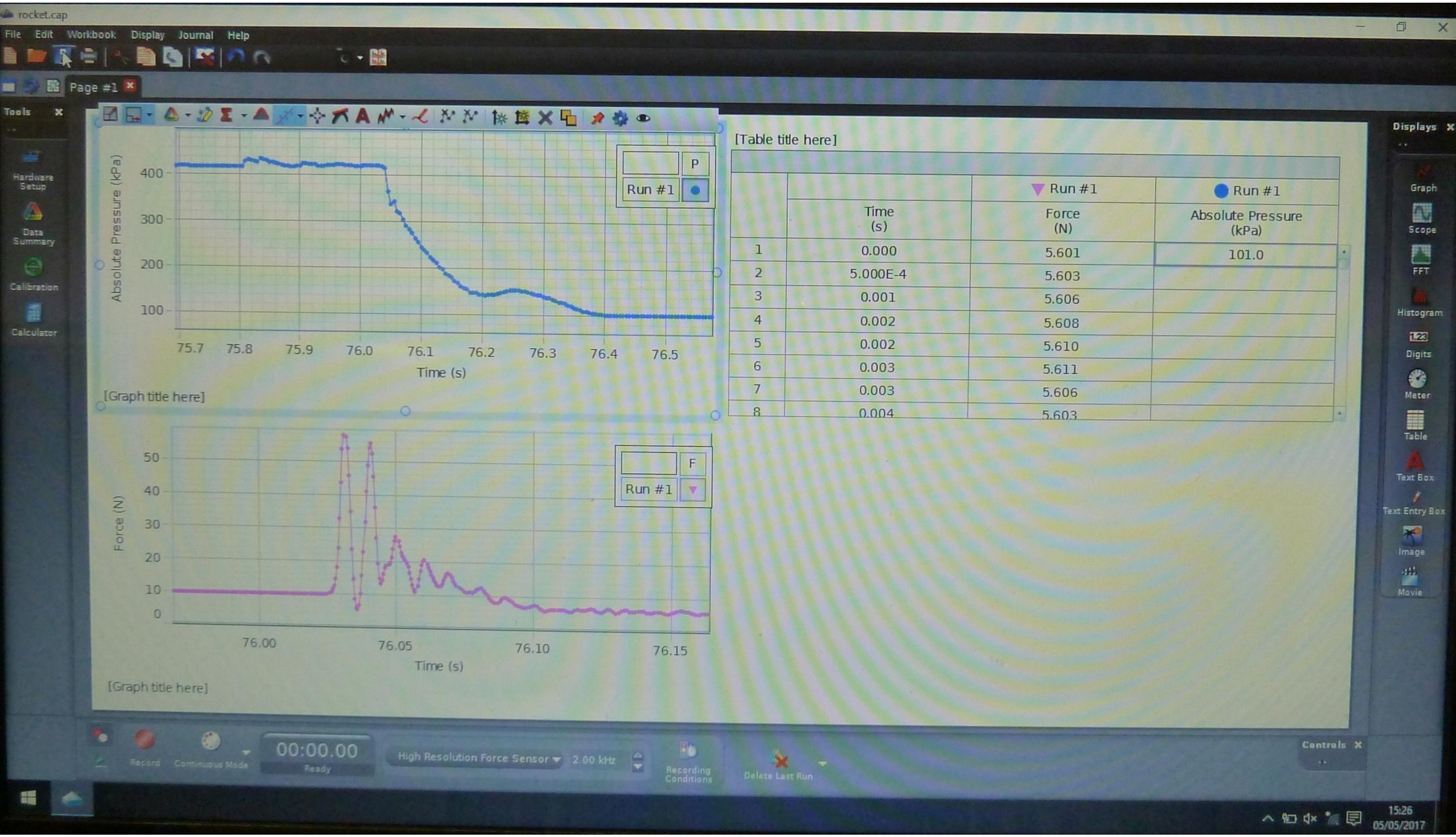




The default data measurement rates are insufficient to capture the force and pressure vs time during the launch event (about 0.2s)

Both sensors should be set at the maximum data rates as shown.




**Pressure vs time** and **Force vs time** traces in CAPSTONE software.
To export data, select all data in the table, copy to the clipboard (ctrl+C) and paste into a text editor such as **Notepad**. This file can then be imported into **MATLAB**. Note there will likely be too many data points for Excel to handle!


rocket.cap
File Edit Workbook Display Journal Help
Page #1
Tools
Hardware Setup
Data Summary
Calibration
Calculator
Absolute Pressure (kPa)
400
300
200
100
75.7 75.8 75.9 76.0 76.1 76.2 76.3 76.4 76.5
Time (s)
P
Run #1
[Graph title here]
Force (N)
50
40
30
20
10
0
76.00 76.05 76.10 76.15
Time (s)
F
Run #1
[Graph title here]
[Table title here]
Run #1
Run #1
Time (s)
Force (N)
Absolute Pressure (kPa)
1 0.000 5.601 101.0
2 5.000E-4 5.603
3 0.001 5.606
4 0.002 5.608
5 0.002 5.610
6 0.003 5.611
7 0.003 5.606
8 0.004 5.603
Displays
Graph
Scope
FFT
Histogram
Digits
Meter
Table
Text Box
Text Entry Box
Image
Movie
Record
Continuous Mode
00:00.00
Ready
High Resolution Force Sensor
2.00 kHz
Recording Conditions
Delete Last Run
Controls
15:26
05/05/2017

```matlab
%rocket_analysis
%
% Loads in CAPSTONE dataloger output saved in space delimited .txt file
% rocket.txt. Columns are time /s, Force /N and Pressure /kPa.
% Pressure data is interpolated at the same times the higher data rate
% Force measurements are recorded. Both force and pressure are then plotted
% against time.
%
% LAST UPDATED by Andy French May 2017

function rocket_analysis

%Set fontsize for graphs
fsize = 16;

%Time range /s for launch close up
tstart = 75.75;
tstop = 76.5;

%Time range /s for thrust extremeclose up
ttstart = 76;
ttstop = 76.25;

%

%Load data
[t,F,P] = textread('rocket.txt',...
    '%f%f%f',...
    'delimiter',' ',...
    'emptyvalue',NaN,...
    'headerlines',2);

%Double force F to take into account mechanical disadvantage of pivot
F = 2*F;

%Remove NaN values from Pressure Data
tP = t;
nans = isnan(P);
tP(nans) = [];
P(nans) = [];

%Interpolate using t times
P = interp1( tP, P, t );

% Plot whole range of data
```

**MATLAB code** to analyse rocket data

Text file is three columns of numerical data (hence the %f%f%f syntax) with a space ‘delimiter.’

Interpolation is required since the force sensor records at 2KHz, ten times the rate of the pressure sensor. Interpolation means they can both be plotted against the same *vector* of times.

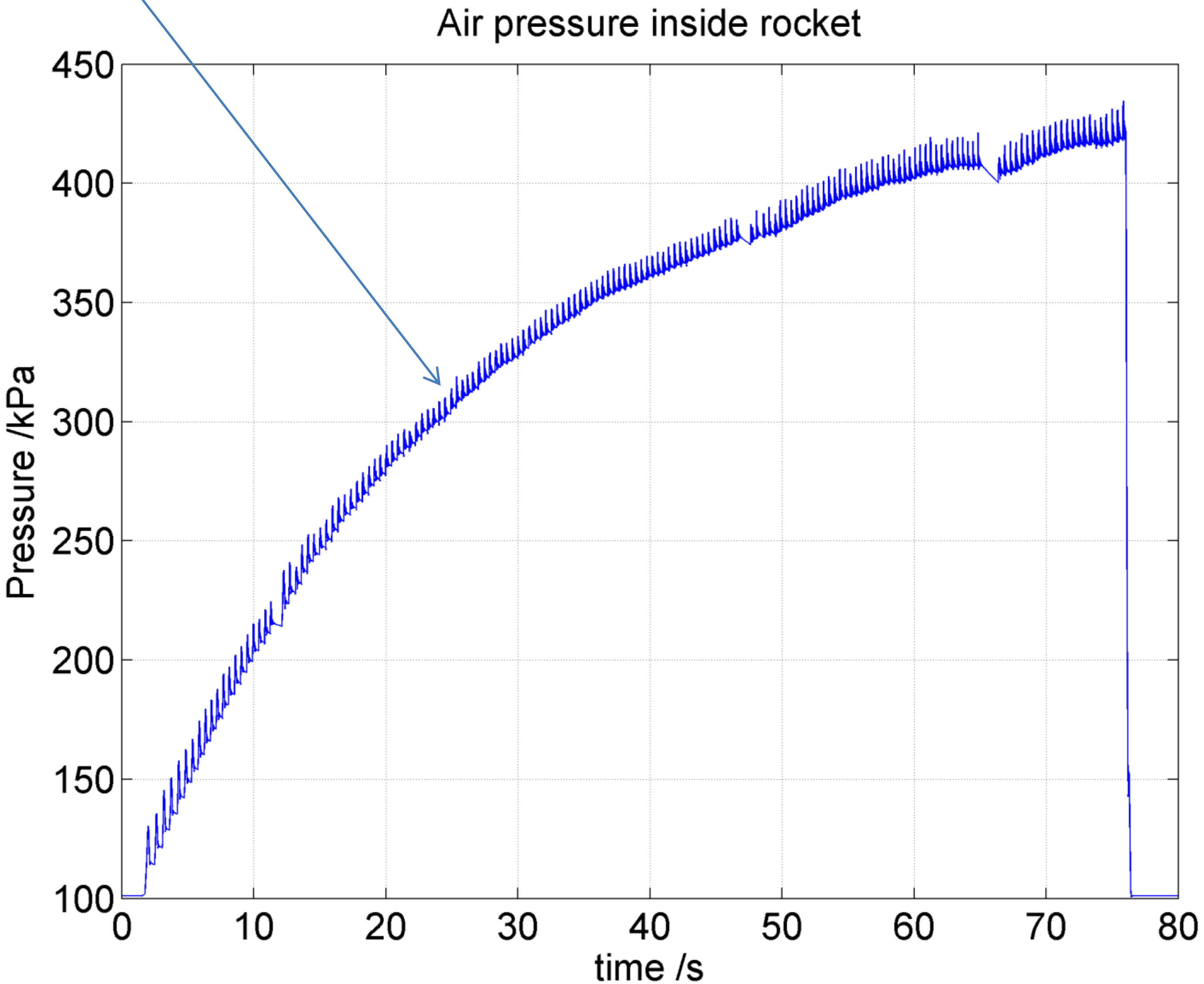
```
%Plot Pressure vs time and save a PNG file
plot(t,P);
xlabel('time /s','fontsize',fsize);
ylabel('Pressure /kPa','fontsize',fsize);
title('Air pressure inside rocket','fontsize',fsize);
set(gca,'fontsize',fsize);
grid on
print(gcf,'pressure vs time.png','-dpng','-r300');
clf

%Plot Force vs time
plot(t,F);
xlabel('time /s','fontsize',fsize);
ylabel('Force /N','fontsize',fsize);
title('Rocket thrust','fontsize',fsize);
set(gca,'fontsize',fsize);
grid on
print(gcf,'thrust vs time.png','-dpng','-r300');
clf

% Close up on launch

%Plot Pressure vs time and save a PNG file
plot(t,P);
xlabel('time /s','fontsize',fsize);
ylabel('Pressure /kPa','fontsize',fsize);
title('Air pressure inside rocket','fontsize',fsize);
set(gca,'fontsize',fsize);
xlim( [tstart,tstop] )
grid on
print(gcf,'launch pressure vs time.png','-dpng','-r300');
clf

%Plot Force vs time
plot(t,F);
xlabel('time /s','fontsize',fsize);
ylabel('Force /N','fontsize',fsize);
title('Rocket thrust','fontsize',fsize);
set(gca,'fontsize',fsize);
xlim( [tstart,tstop] )
grid on
print(gcf,'launch thrust vs time.png','-dpng','-r300');
clf

%Plot Force vs time extreme close up
plot(t,F);
xlabel('time /s','fontsize',fsize);
ylabel('Force /N','fontsize',fsize);
title('Rocket thrust','fontsize',fsize);
set(gca,'fontsize',fsize);
xlim( [ttstart,ttstop] )
grid on
print(gcf,'launch thrust vs time close up.png','-dpng','-r300');
clf
close(gcf);

%End of code
```

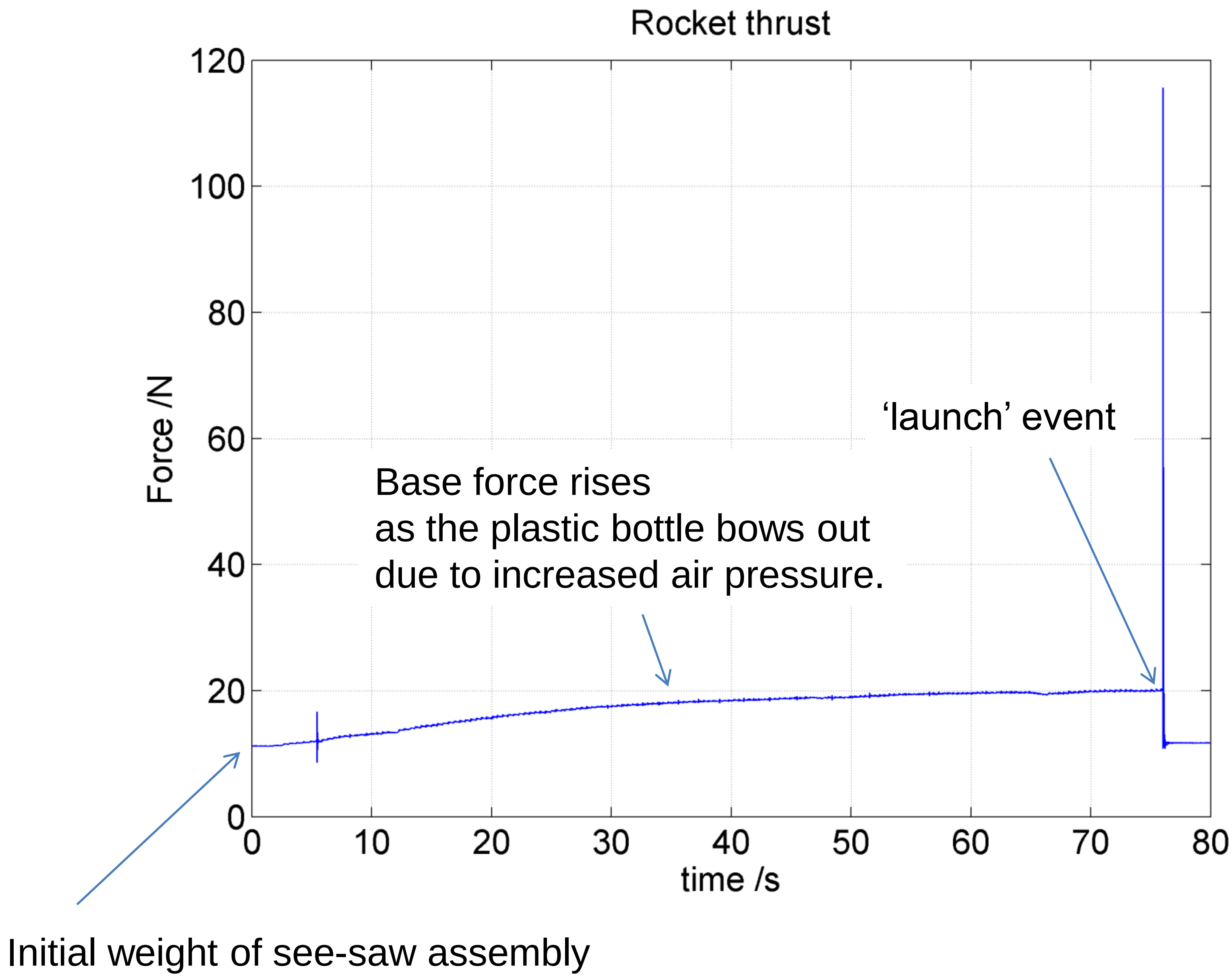
MATLAB plot routines to generate 300dpi PNG images of the pressure and force vs time graphs.

The whole experiment and a close up on the launch event are specified.

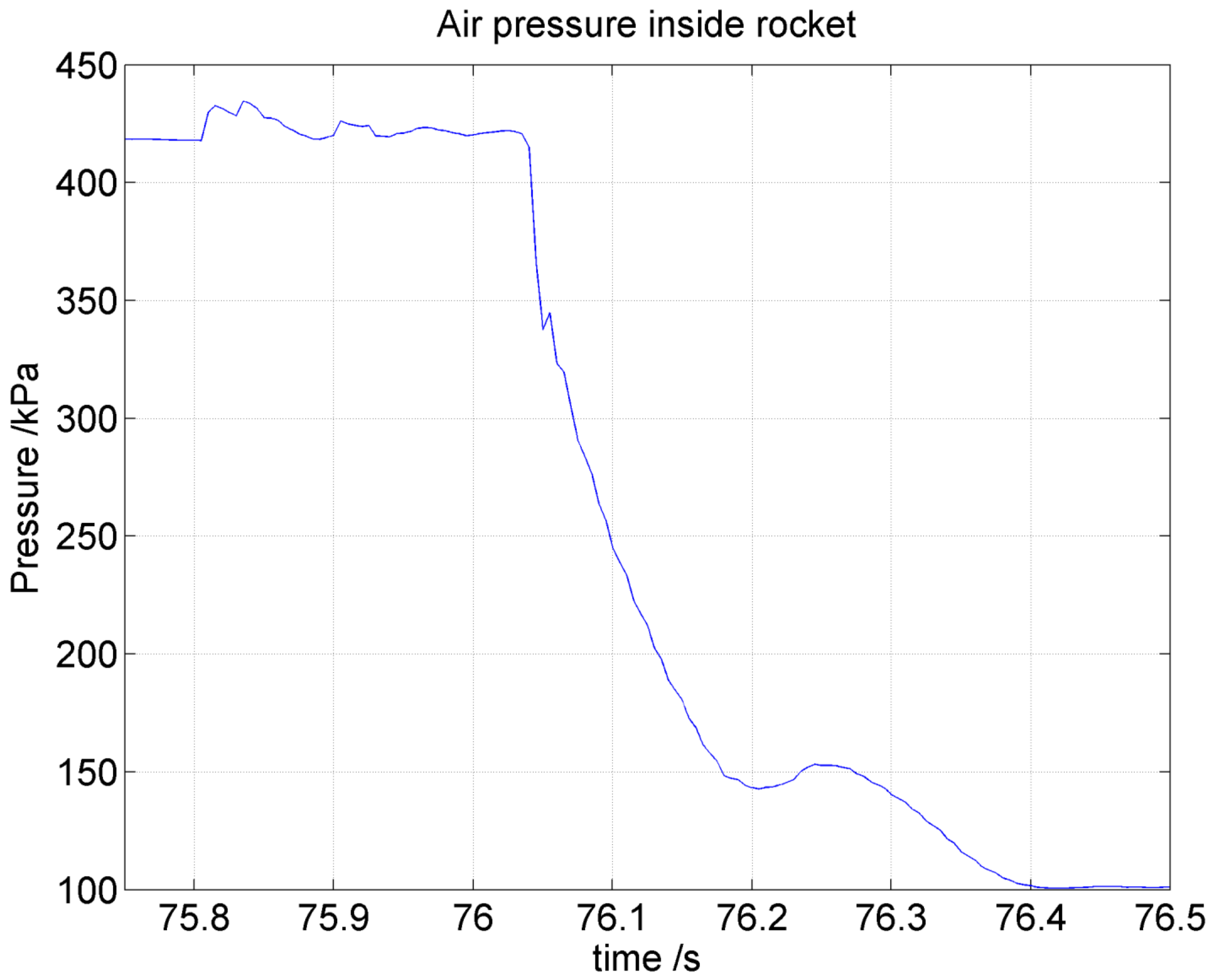
The up and down motion is a consequence of the pumping!

Max pressure is over four atmospheres

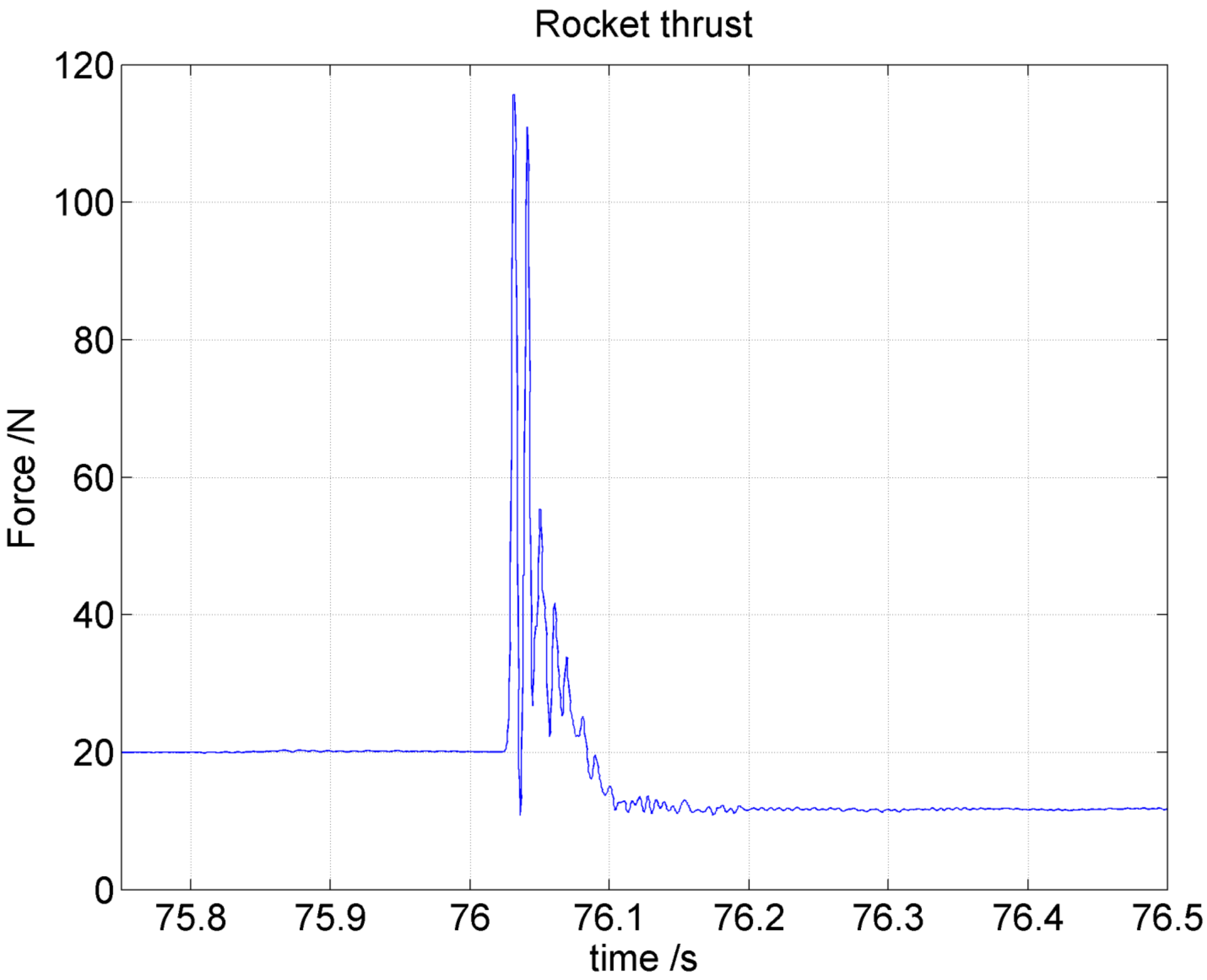



Rocket thrust
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
Force /N
time /s
Base force rises
as the plastic bottle bows out
due to increased air pressure.
'launch' event
Initial weight of see-saw assembly

# Air pressure vs time during launch event



Force vs time during launch event



Force vs time during launch event (close up). Significant mechanical oscillations observed due to the ‘impulse response’ of the see-saw rig