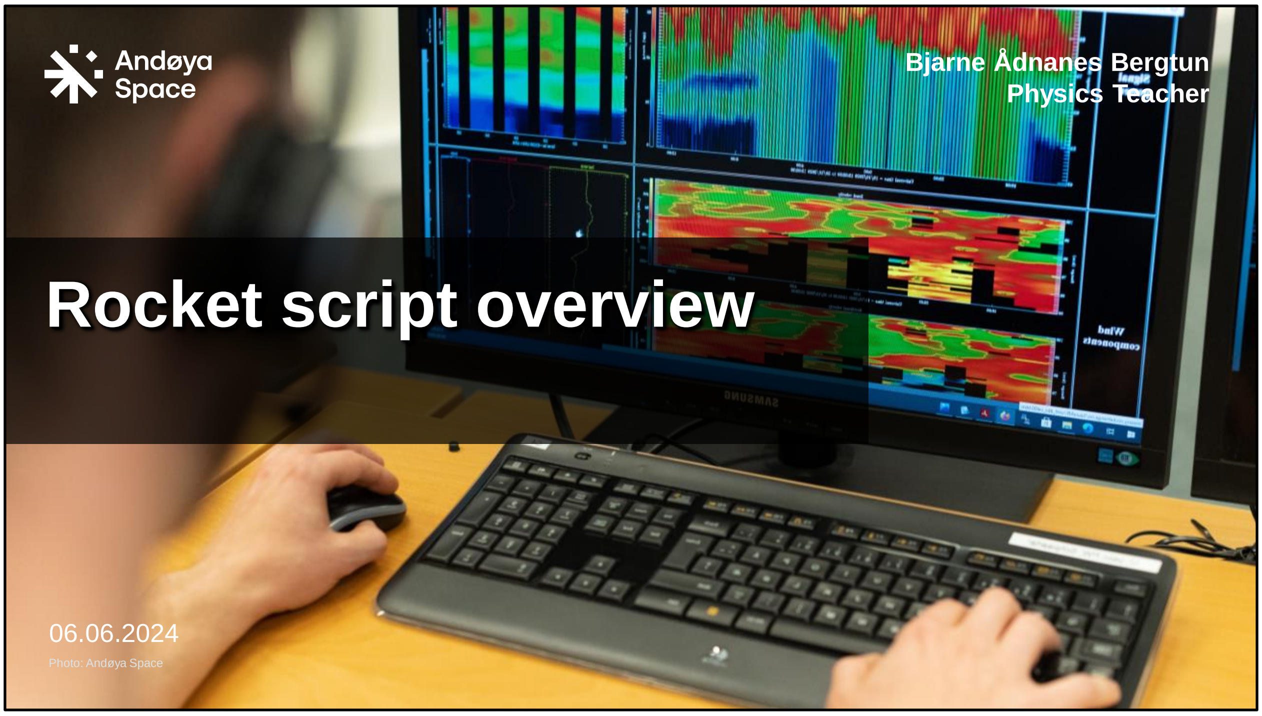
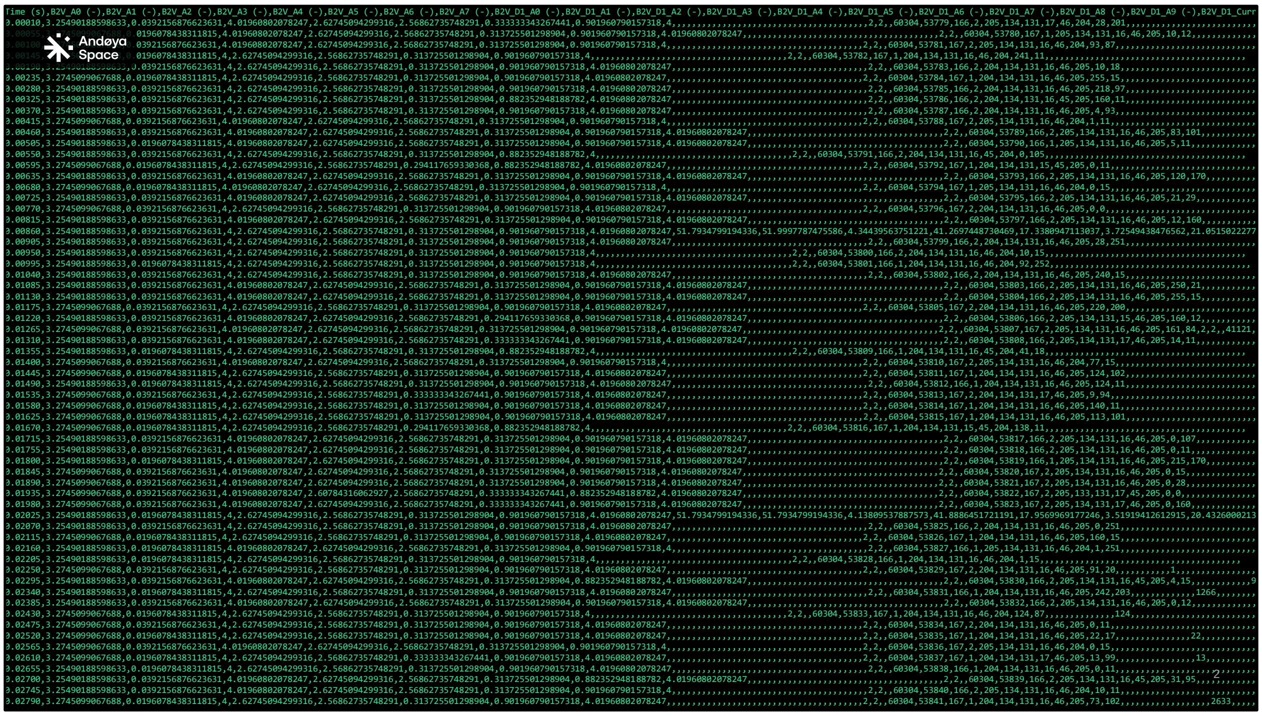


Bjarne Ådnanes Bergtun
Physics Teacher

Rocket script overview

06.06.2024

Photo: Andøya Space



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Time (s),B2V_A0 (-),B2V_A1 (-),B2V_A2 (-),B2V_A3 (-),B2V_A4 (-),B2V_A5 (-),B2V_A6 (-),B2V_A7 (-),B2V_D1_A0 (-),B2V_D1_A1 (-),B2V_D1_A2 (-),B2V_D1_A3 (-),B2V_D1_A4 (-),B2V_D1_A5 (-),B2V_D1_A6 (-),B2V_D1_A7 (-),B2V_D1_A8 (-),B2V_D1_A9 (-),B2V_D1_Curr
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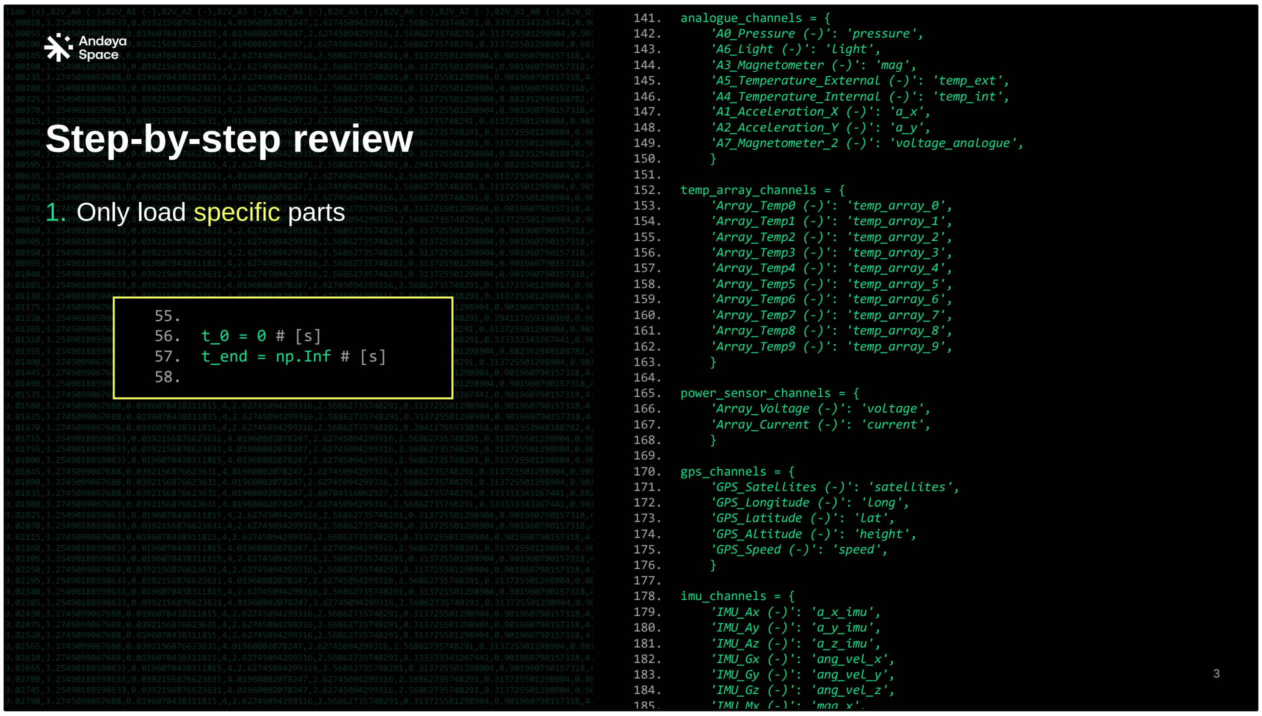
0.02565,3.2745099067688,0.0392156876623631,4.01960802078247,2.62745094299316,2.56862735748291,0.313725501298904,0.901960790157318,4,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,2,2,,60304,53836,167,2,205,134,131,16,46,204,0,15,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
0.02610,3.2745099067688,0.0196078438311815,4,2.62745094299316,2.56862735748291,0.333333343267441,0.901960790157318,4.01960802078247,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,2,2,,60304,53837,167,1,204,134,131,17,46,205,13,99,,,,,,,,,,,,,,,,13,,,,,,,,,,
0.02655,3.25490188598633,0.0196078438311815,4,2.62745094299316,2.56862735748291,0.313725501298904,0.901960790157318,4.01960802078247,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,2,2,,60304,53838,166,1,204,134,131,16,46,205,0,11,,,,,,,,,,,,,,,,,,,,,,,,,,,,
0.02700,3.25490188598633,0.0392156876623631,4.01960802078247,2.62745094299316,2.56862735748291,0.313725501298904,0.882352948188782,4.01960802078247,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,2,2,,60304,53839,166,2,205,134,131,16,45,205,31,95,,,,,,,,,,,,
0.02745,3.25490188598633,0.0392156876623631,4.01960802078247,2.62745094299316,2.56862735748291,0.313725501298904,0.901960790157318,4,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,2,2,,60304,53840,166,2,205,134,131,16,46,204,10,11,,,,,,,,,,,,,,,,,,,,,,,,,,,
0.02790,3.2745099067688,0.0196078438311815,4,2.62745094299316,2.56862735748291,0.313725501298904,0.901960790157318,4.01960802078247,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,2,2,,60304,53841,167,1,204,134,131,16,46,205,73,102,,,,,,,,,,,,,,,,,,2633,,,,,
```

Part of the rocket data from the first 28 ms (taken from Fly a Rocket! cycle 2).



Andøya Space

Step-by-step review

1. Only load specific parts

```
55.
56.  t_0 = 0 # [s]
57.  t_end = np.Inf # [s]
58.
```

```
analogue_channels = {
    'A0_Pressure (-)': 'pressure',
    'A6_Light (-)': 'light',
    'A3_Magnetometer (-)': 'mag',
    'A5_Temperature_External (-)': 'temp_ext',
    'A4_Temperature_Internal (-)': 'temp_int',
    'A1_Acceleration_X (-)': 'a_x',
    'A2_Acceleration_Y (-)': 'a_y',
    'A7_Magnetometer_2 (-)': 'voltage_analogue',
    }

temp_array_channels = {
    'Array_Temp0 (-)': 'temp_array_0',
    'Array_Temp1 (-)': 'temp_array_1',
    'Array_Temp2 (-)': 'temp_array_2',
    'Array_Temp3 (-)': 'temp_array_3',
    'Array_Temp4 (-)': 'temp_array_4',
    'Array_Temp5 (-)': 'temp_array_5',
    'Array_Temp6 (-)': 'temp_array_6',
    'Array_Temp7 (-)': 'temp_array_7',
    'Array_Temp8 (-)': 'temp_array_8',
    'Array_Temp9 (-)': 'temp_array_9',
    }

power_sensor_channels = {
    'Array_Voltage (-)': 'voltage',
    'Array_Current (-)': 'current',
    }

gps_channels = {
    'GPS_Satellites (-)': 'satellites',
    'GPS_Longitude (-)': 'long',
    'GPS_Latitude (-)': 'lat',
    'GPS_Altitude (-)': 'height',
    'GPS_Speed (-)': 'speed',
    }

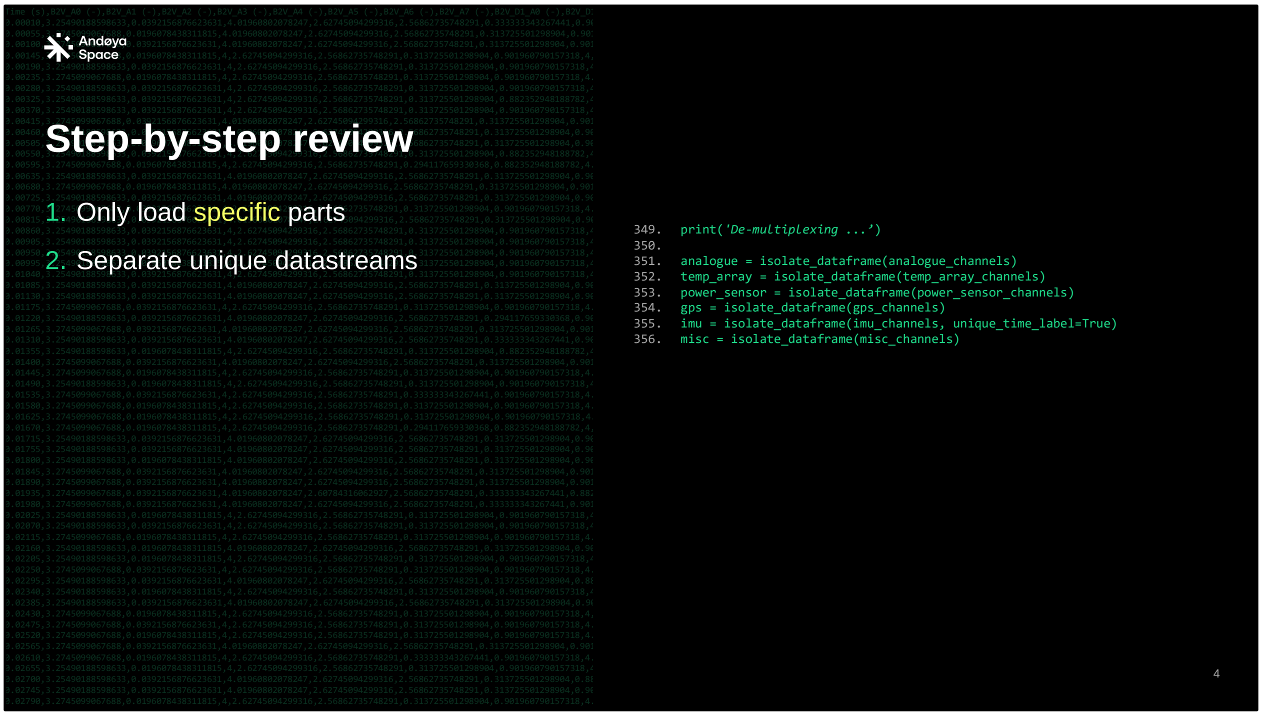
imu_channels = {
    'IMU_Ax (-)': 'a_x_imu',
    'IMU_Ay (-)': 'a_y_imu',
    'IMU_Az (-)': 'a_z_imu',
    'IMU_Gx (-)': 'ang_vel_x',
    'IMU_Gy (-)': 'ang_vel_y',
    'IMU_Gz (-)': 'ang_vel_z',
    'IMU_Mx (-)': 'mag_x',
```

3

In line 57, np.Inf is the numpy-implimentation of infinity, meaning that the script will load all available data. If we only want data from e.g. the first 100 seconds, line 57 should be changed to t_end = 100.

The telemetry section is responsible for providing lists of channel names. There are 2 lists, one for each telemetry station (Student TM and TM Readout).

The names on the left is the channel names used by the respective telemetry stations; the names on the right is the channel names used in the script.



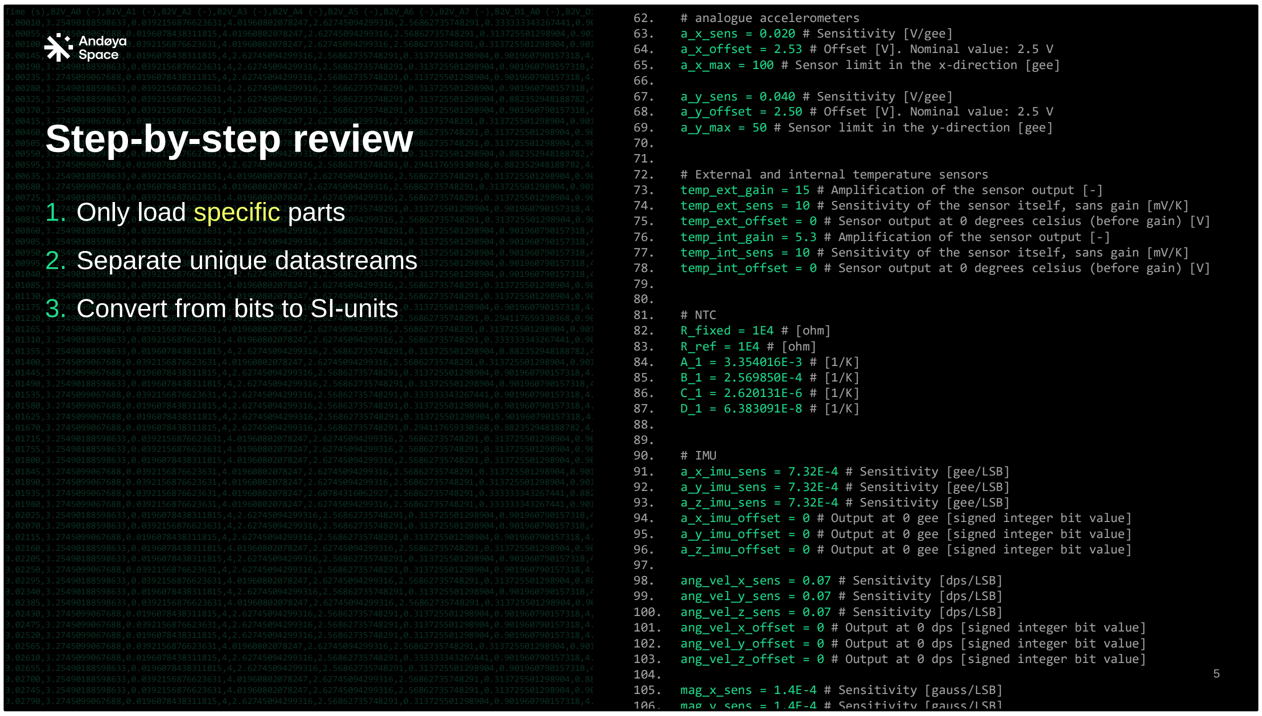
Step-by-step review

1. Only load specific parts
2. Separate unique datastreams

```python
print('De-multiplexing ...')

analogue = isolate_dataframe(analogue_channels)
temp_array = isolate_dataframe(temp_array_channels)
power_sensor = isolate_dataframe(power_sensor_channels)
gps = isolate_dataframe(gps_channels)
imu = isolate_dataframe(imu_channels, unique_time_label=True)
misc = isolate_dataframe(misc_channels)
```

4

Each of the datastreams shown here (analogue, temp_array, etc.) have their own time-array, accesible through e.g. gps['t']. Otherwise, the content is as specified in the lists shown on the previous page. Hence, if we want e.g. the lightsensor data, we get them by typing analogue['light'].



Andøya Space

Step-by-step review

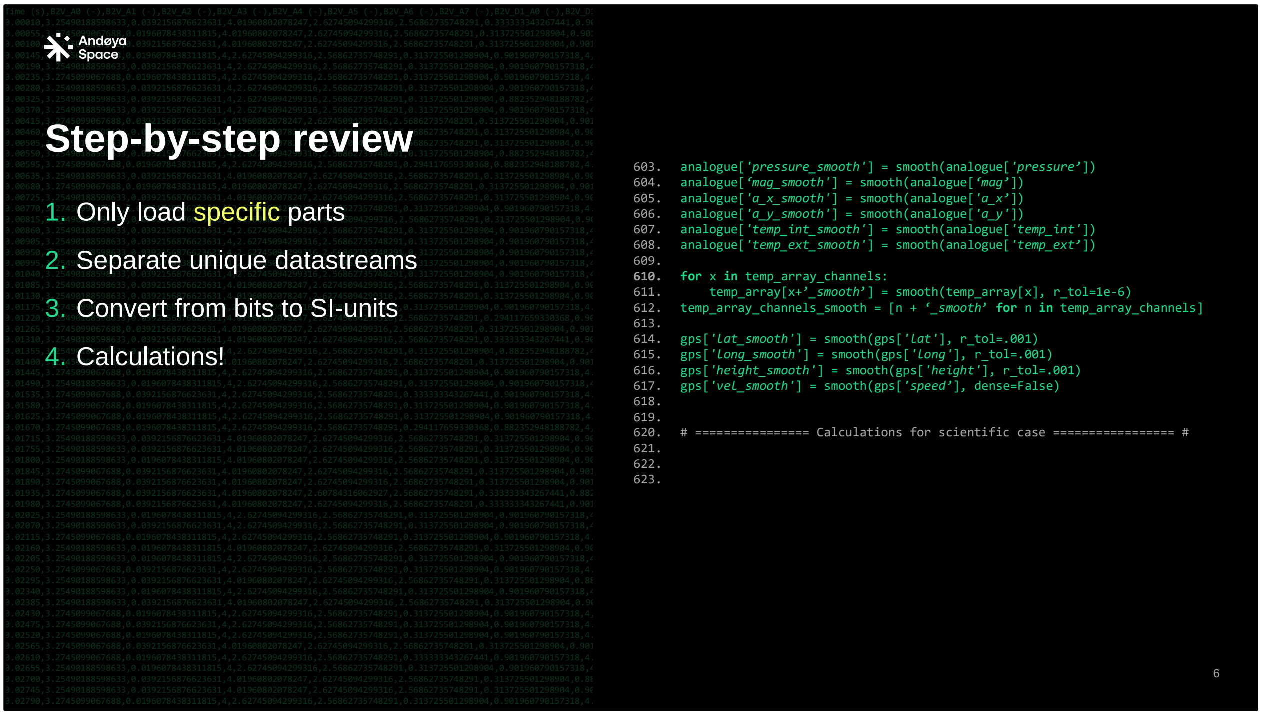
1. Only load specific parts
2. Separate unique datastreams
3. Convert from bits to SI-units

```
62.   # analogue accelerometers
63.   a_x_sens = 0.020 # Sensitivity [V/gee]
64.   a_x_offset = 2.53 # Offset [V]. Nominal value: 2.5 V
65.   a_x_max = 100 # Sensor limit in the x-direction [gee]
66.
67.   a_y_sens = 0.040 # Sensitivity [V/gee]
68.   a_y_offset = 2.50 # Offset [V]. Nominal value: 2.5 V
69.   a_y_max = 50 # Sensor limit in the y-direction [gee]
70.
71.
72.   # External and internal temperature sensors
73.   temp_ext_gain = 15 # Amplification of the sensor output [-]
74.   temp_ext_sens = 10 # Sensitivity of the sensor itself, sans gain [mV/K]
75.   temp_ext_offset = 0 # Sensor output at 0 degrees celsius (before gain) [V]
76.   temp_int_gain = 5.3 # Amplification of the sensor output [-]
77.   temp_int_sens = 10 # Sensitivity of the sensor itself, sans gain [mV/K]
78.   temp_int_offset = 0 # Sensor output at 0 degrees celsius (before gain) [V]
79.
80.
81.   # NTC
82.   R_fixed = 1E4 # [ohm]
83.   R_ref = 1E4 # [ohm]
84.   A_1 = 3.354016E-3 # [1/K]
85.   B_1 = 2.569850E-4 # [1/K]
86.   C_1 = 2.620131E-6 # [1/K]
87.   D_1 = 6.383091E-8 # [1/K]
88.
89.
90.   # IMU
91.   a_x_imu_sens = 7.32E-4 # Sensitivity [gee/LSB]
92.   a_y_imu_sens = 7.32E-4 # Sensitivity [gee/LSB]
93.   a_z_imu_sens = 7.32E-4 # Sensitivity [gee/LSB]
94.   a_x_imu_offset = 0 # Output at 0 gee [signed integer bit value]
95.   a_y_imu_offset = 0 # Output at 0 gee [signed integer bit value]
96.   a_z_imu_offset = 0 # Output at 0 gee [signed integer bit value]
97.
98.   ang_vel_x_sens = 0.07 # Sensitivity [dps/LSB]
99.   ang_vel_y_sens = 0.07 # Sensitivity [dps/LSB]
100.  ang_vel_z_sens = 0.07 # Sensitivity [dps/LSB]
101.  ang_vel_x_offset = 0 # Output at 0 dps [signed integer bit value]
102.  ang_vel_y_offset = 0 # Output at 0 dps [signed integer bit value]
103.  ang_vel_z_offset = 0 # Output at 0 dps [signed integer bit value]
104.
105.  mag_x_sens = 1.4E-4 # Sensitivity [gauss/LSB]
106.  mag_y_sens = 1.4E-4 # Sensitivity [gauss/LSB]
```

Those who made/assembled a sensor are responsible for making sure that the parameters for their sensor(s) are correct and up-to-date. The parameters should be stored in a txt-file named “Sensor parameters NTNU TTT 2024.txt”, available from the course folder on nuno.

The 8th analogue channel (“A7”) is special in that if it is **not** occupied by an analogue sensor (in which case line 119 should read “a7_occupied = False”), it will be used to measure the battery voltage. The Payload section should make sure that the corresponding boolean variable (line 119) is set correctly.

The notation “*x*E*y*” used for some of the constants (i.e. R_fixed) is short for $x \cdot 10^y$. Hence, the parameter list shown above sets R_fixed to 10 kiloohm (line 82), while a_x_imu_sens is set to $7.32 \cdot 10^{-4}\ g/\mathrm{LSB}$ (line 91).



Andøya Space

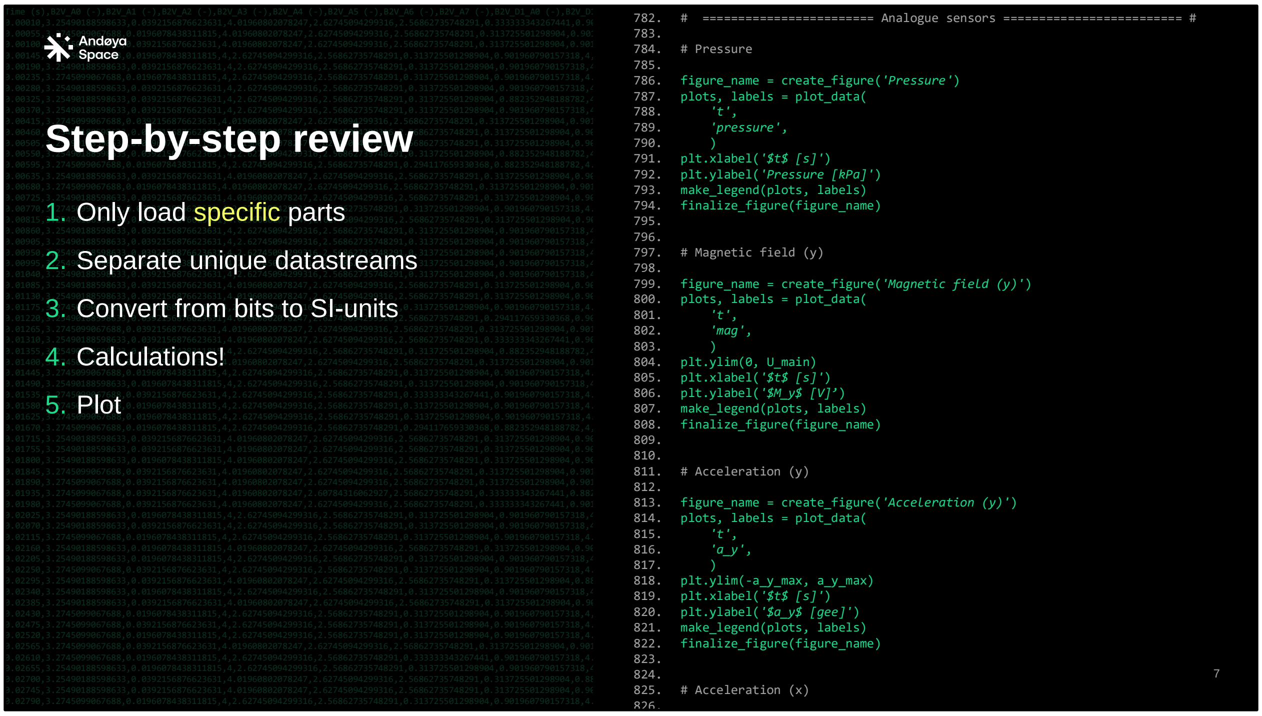
Step-by-step review

1. Only load specific parts
2. Separate unique datastreams
3. Convert from bits to SI-units
4. Calculations!

```
analogue['pressure_smooth'] = smooth(analogue['pressure’])
analogue[‘mag_smooth'] = smooth(analogue[‘mag’])
analogue['a_x_smooth'] = smooth(analogue['a_x’])
analogue['a_y_smooth'] = smooth(analogue['a_y'])
analogue['temp_int_smooth'] = smooth(analogue['temp_int'])
analogue['temp_ext_smooth'] = smooth(analogue['temp_ext’])

for x in temp_array_channels:
    temp_array[x+’_smooth’] = smooth(temp_array[x], r_tol=1e-6)
temp_array_channels_smooth = [n + ‘_smooth’ for n in temp_array_channels]

gps['lat_smooth'] = smooth(gps['lat'], r_tol=.001)
gps['long_smooth'] = smooth(gps['long'], r_tol=.001)
gps['height_smooth'] = smooth(gps['height'], r_tol=.001)
gps['vel_smooth'] = smooth(gps['speed’], dense=False)


# ================ Calculations for scientific case ================= #



```

6

If you need a specific plot for your scientific case, scroll down to the plotting section, and see next page.



Step-by-step review

1. Only load specific parts
2. Separate unique datastreams
3. Convert from bits to SI-units
4. Calculations!
5. Plot

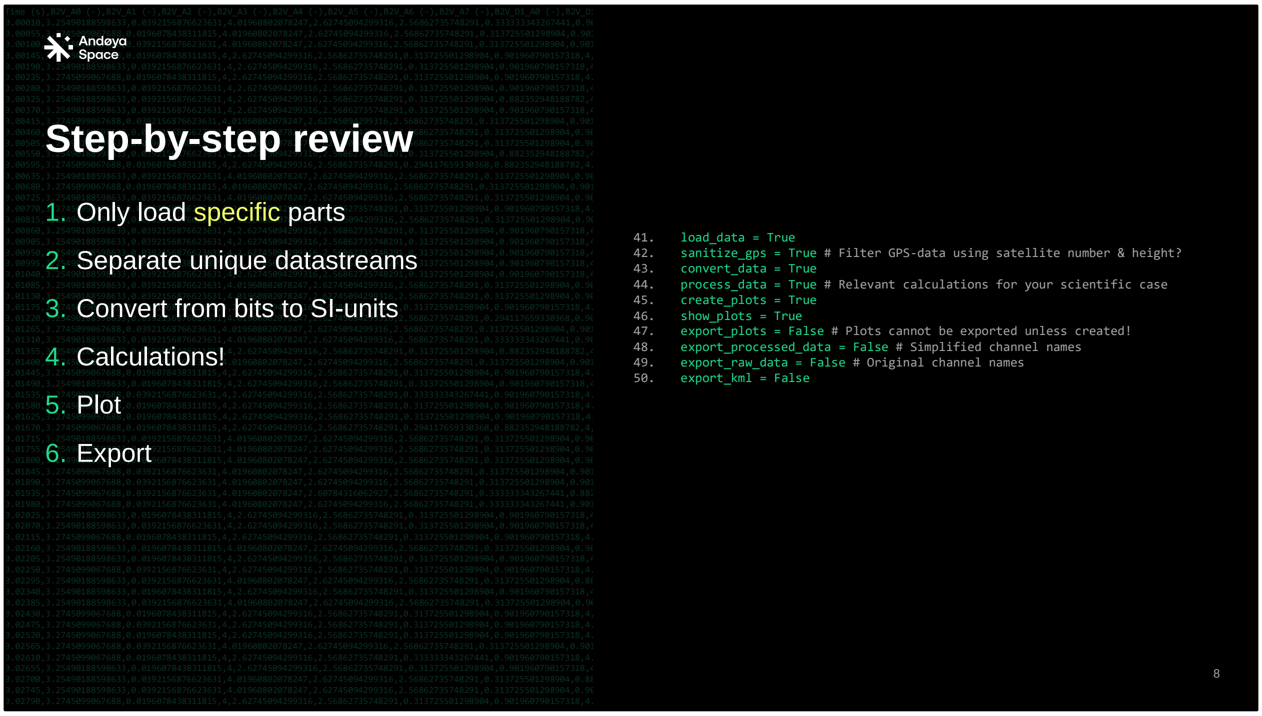
```python
#  ======================= Analogue sensors ======================== #

# Pressure

figure_name = create_figure('Pressure')
plots, labels = plot_data(
    't',
    'pressure',
    )
plt.xlabel('$t$ [s]')
plt.ylabel('Pressure [kPa]')
make_legend(plots, labels)
finalize_figure(figure_name)


# Magnetic field (y)

figure_name = create_figure('Magnetic field (y)')
plots, labels = plot_data(
    't',
    'mag',
    )
plt.ylim(0, U_main)
plt.xlabel('$t$ [s]')
plt.ylabel('$M_y$ [V]’)
make_legend(plots, labels)
finalize_figure(figure_name)


# Acceleration (y)

figure_name = create_figure('Acceleration (y)')
plots, labels = plot_data(
    't',
    'a_y',
    )
plt.ylim(-a_y_max, a_y_max)
plt.xlabel('$t$ [s]')
plt.ylabel('$a_y$ [gee]')
make_legend(plots, labels)
finalize_figure(figure_name)


# Acceleration (x)
```

7

The plots are grouped according to the groups shown in steps 1 & 2.

The special functions create_figure(), plot_data(), make_legend(), and finalize_figure() are defined at the start of the plotting ‘chapter’ in the script, and provide some nice functionalities for easy export and updating of figures when the script is re-run.

If you need a new figure, you could copy the code of a figure which is close to what you want, and edit your code from there. You might also want to comment out all figures you don’t need in order to get at faster code (your IDE should have tools for commenting out several lines at once; alternatively, you can comment out several lines at once by writing """ above and below the lines you want to comment out).


Andøya Space

Step-by-step review

1. Only load specific parts
2. Separate unique datastreams
3. Convert from bits to SI-units
4. Calculations!
5. Plot
6. Export

```
41.     load_data = True
42.     sanitize_gps = True # Filter GPS-data using satellite number & height?
43.     convert_data = True
44.     process_data = True # Relevant calculations for your scientific case
45.     create_plots = True
46.     show_plots = True
47.     export_plots = False # Plots cannot be exported unless created!
48.     export_processed_data = False # Simplified channel names
49.     export_raw_data = False # Original channel names
50.     export_kml = False
```

8

These boolean variables turns sections of the code on or off. Note that create_plots need to be set to True in order for export_plots to have any effect.

See lines 37–39 in the script for how load_data can be used to skip re-loading when re-running the script. Alternativly, you might want to have a look at lines 230–235.

Some final tips

- A Pandas user guide is available at https://pandas.pydata.org/docs/user_guide/
- Matplotlib.pyplot has a built-in spectrogram plotter called specgram, which can be used to plot how signal frequencies cange over time. See https://matplotlib.org/stable/api/_as_gen/matplotlib.pyplot.specgram.html
- If you prefer Numpy, a Pandas object `df` can be converted by writing `df.to_numpy()`
- If a custom data script is wanted, it *might* be useful to export converted datastreams (i.e. *processed data*) by editing line 48