

Example to plot directly into latex

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1 Introduction

2 Genetic Algorithm Performance

To illustrate how the python code exports the figures directly into the report, this second "hw2" is included. Below are the pictures that are created by the code listed in ?? and ??.



Figure 1: Performance of some genetic algorithm

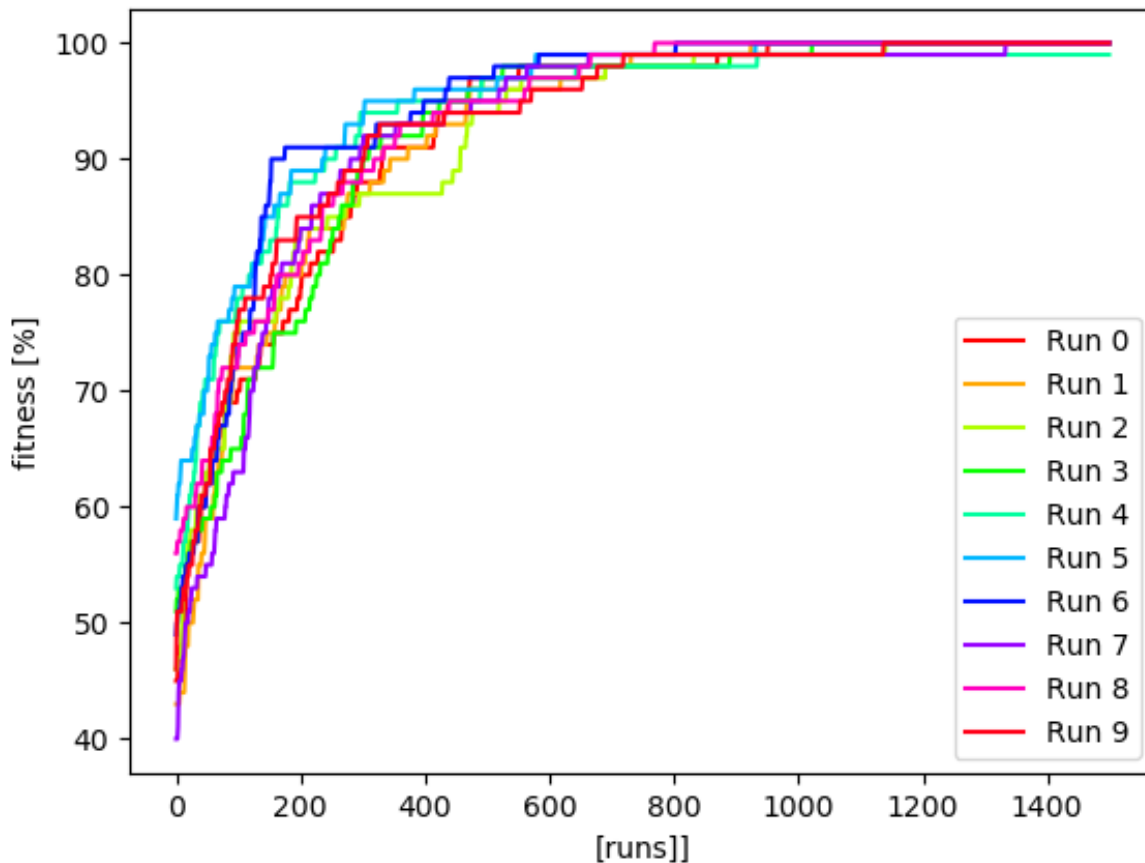


Figure 2: Performance of some genetic algorithm

A Appendix __main__.py

```

1 import os
2 from .Main import Main
3
4 print(f'Hi, I\'ll be running the main code, and I\'ll let you know
   ↳ when I\'m done.')
5 project_nr = 1
6 main = Main()
7
8 notebook_names = ['AE4868_example_notebook_update20201025.ipynb']
9 notebook_names = [] # TODO: re-enable
10
11 # run the jupyter notebooks for assignment 1
12 main.run_jupyter_notebooks(project_nr, notebook_names)
13
14 # convert jupyter notebook for assignment 1 to pdf
15 main.convert_notebooks_to_pdf(project_nr, notebook_names)
16
17 # export the code to latex
18 main.export_code_to_latex(project_nr)
19
20 # compile the latex report
21 main.compile_latex_report(project_nr)
22
23 #####

```

```

24 #####example code to illustrate python-latex image sync
    ↳ #####
25 #####runs arbitrary genetic algorithm, can be deleted
    ↳ #####
26 #####
27 # run a genetic algorithm to create some data for a plot.
28 print("now running a")
29 res = main.do_run_a()
30
31 # plot some graph with a single line, general form is:
32 # plt_tex.plotSingleLines(plt_tex,x,y,"x-axis label","y-axis label",
    ↳ lineLabels,"filename",legend_position,project_nr)
33 # main.plt_tex.plotSingleLine(plt_tex,range(0, len(res)),res,"[runs
    ↳ ]]", "fitness [%]", "run 1", "4a", 4, project_nr)
34
35 # run a genetic algorithm to create some data for another plot.
36 print("now running b")
37 main.do4b(project_nr)
38
39 # run a genetic algorithm to create some data for another plot.
40 print("now running 4c")
41 main.do4c(project_nr)
42
43 print(f'Done.')
```

B Appendix Main.py

```
1 # Example code that creates plots directly in report
2 # Code is an implementation of a genetic algorithm
3 import random
4 from matplotlib import pyplot as plt
5 from matplotlib import lines
6 import matplotlib.pyplot as plt
7 import numpy as np
8
9 from .Compile_latex import Compile_latex
10 from .Plot_to_tex import Plot_to_tex as plt_tex
11 from .Run_jupyter_notebooks import Run_jupyter_notebook
12 from .Export_code_to_latex import export_code_to_latex
13
14 # define global variables for genetic algorithm example
15 string_length = 100
16 mutation_chance= 1.0/string_length
17 max_iterations = 1500
18
19 class Main:
20
21     def __init__(self):
22         self.run_jupyter_notebook = Run_jupyter_notebook()
23         pass
24
25
26     def run_jupyter_notebooks(self,project_nr,notebook_names):
27         '''runs a jupyter notebook'''
28         notebook_path = f'code/project{project_nr}/src/'
29
30         for notebook_name in notebook_names:
31             self.run_jupyter_notebook.run_notebook(f'{notebook_path}{
32                 ↪ notebook_name}')
33
34     def convert_notebooks_to_pdf(self,project_nr,notebook_names):
35         '''converts a jupyter notebook to pdf'''
36         notebook_path = f'code/project{project_nr}/src/'
37
38         for notebook_name in notebook_names:
39             self.run_jupyter_notebook.convert_notebook_to_pdf(f'{
40                 ↪ notebook_path}{notebook_name}')
41
42     def export_code_to_latex(self, project_nr):
43         export_code_to_latex('main.tex', project_nr)
44
45     def compile_latex_report(self,project_nr):
46         '''compiles latex code to pdf'''
47         compile_latex =Compile_latex(project_nr ,'main.tex')
48
49     #####
50     #####example code to illustrate python-latex image sync
51     ↪ #####
52     #####runs arbitrary genetic algorithm, can be deleted
53     ↪ #####
54     #####
55     def count(self,bits):
56         count = 0
57         for bit in bits:
58             if bit:
59                 count = count + 1
60         return count
```

```

57
58 def gen_bit_sequence(self):
59     bits = []
60     for _ in range(string_length):
61         bits.append(True if random.randint(0, 1) == 1 else False)
62     return bits
63
64 def mutate_bit_sequence(self, sequence):
65     retval = []
66     for bit in sequence :
67         do_mutation = random.random() <= mutation_chance
68         if(do_mutation):
69             retval.append(not bit)
70         else:
71             retval.append(bit)
72     return retval
73
74 #execute a run a
75 def do_run_a(self):
76
77     seq = self.gen_bit_sequence()
78     fitness = self.count(seq)
79     results = [fitness]
80     for run in range(max_iterations-1):
81         new_seq = self.mutate_bit_sequence(seq)
82         new_fitness = self.count(new_seq)
83         if new_fitness > fitness:
84             seq = new_seq
85             fitness = new_fitness
86         results.append(max(results[-1], fitness))
87     return results
88
89
90 #execute a run c
91 def do_run_c(self):
92     seq = self.gen_bit_sequence()
93     fitness = self.count(seq)
94     results = [fitness]
95     for run in range(max_iterations):
96         new_seq = self.mutate_bit_sequence(seq)
97         new_fitness = self.count(new_seq)
98         seq = new_seq
99         fitness = new_fitness
100         results.append(max(results[-1], fitness))
101     return results
102
103 def do4b(self, project_nr):
104     optimum_found = 0
105
106     # generate plot data
107     plotResult = np.zeros((10, max_iterations), dtype=int);
108     lineLabels = []
109
110     # perform computation
111     for run in range(10):
112         res = self.do_run_a()
113         if res[-1] == string_length:
114             optimum_found +=1
115
116     # store computation data for plotting
117     lineLabels.append(f'Run {run}')
118     plotResult[run, :] = res;

```

```

119         # plot multiple lines into report (res is an array of
120         ↪ dataseries (representing the lines))
121     # plt_tex.plotMultipleLines(plt_tex,x,y,"x-axis label","y-
122     ↪ axis label",lineLabels,"filename",legend_position,
123     ↪ project_nr)
124     plt_tex.plotMultipleLines(plt_tex,range(0, len(res)),
125     ↪ plotResult,"[runs]", "fitness [%]",lineLabels,"4b",4,
126     ↪ project_nr)
127     print("total optimum found: {} out of {} runs".format(
128     ↪ optimum_found,10))
129
130 def do4c(self,project_nr):
131     optimum_found = 0
132
133     # generate plot data
134     plotResult = np.zeros((10,max_iterations+1), dtype=int);
135     lineLabels = []
136
137     # perform computation
138     for run in range(10):
139         res = self.do_run_c()
140         if res[-1] == string_length:
141             optimum_found +=1
142
143         # Store computation results for plot
144         lineLabels.append(f'Run {run}')
145         plotResult[run,:]=res;
146
147     # plot multiple lines into report (res is an array of
148     ↪ dataseries (representing the lines))
149     # plt_tex.plotMultipleLines(plt_tex,x,y,"x-axis label","y-
150     ↪ axis label",lineLabels,"filename",legend_position,
151     ↪ project_nr)
152     plt_tex.plotMultipleLines(plt_tex,range(0, len(res)),
153     ↪ plotResult,"[runs]", "fitness [%]",lineLabels,"4c",4,
154     ↪ project_nr)
155
156     print("total optimum found: {} out of {} runs".format(
157     ↪ optimum_found, 10))
158
159 def addTwo(self,x):
160     ''' adds two to the incoming integer and returns the result
161     ↪ of the computation.'''
162     return x+2
163
164 if __name__ == '__main__':
165     # initialize main class
166     main = Main()

```

C Appendix Compile_latex.py

```
1 # runs a jupyter notebook and converts it to pdf
2
3 import os
4 import shutil
5 import nbformat
6 from nbconvert.preprocessors import ExecutePreprocessor
7
8 class Compile_latex:
9
10     def __init__(self, project_nr, latex_filename):
11         self.script_dir = self.get_script_dir()
12         relative_dir = f'latex/project{project_nr}/'
13         self.compile_latex(relative_dir, latex_filename)
14         self.clean_up_after_compilation(latex_filename)
15         self.move_pdf_into_latex_dir(relative_dir, latex_filename)
16
17     # runs jupyter notebook
18     def compile_latex(self, relative_dir, latex_filename):
19         os.system(f'pdflatex {relative_dir}{latex_filename}')
20
21     def clean_up_after_compilation(self, latex_filename):
22         latex_filename_without_extention = latex_filename[:-4]
23         print(f'latex_filename_without_extention={
24             ↪ latex_filename_without_extention}')
25         self.delete_file_if_exists(f'{
26             ↪ latex_filename_without_extention}.aux')
27         self.delete_file_if_exists(f'{
28             ↪ latex_filename_without_extention}.log')
29         self.delete_file_if_exists(f'texput.log')
30
31     def move_pdf_into_latex_dir(self, relative_dir, latex_filename):
32         pdf_filename = f'{latex_filename[:-4]}.pdf'
33         destination= f'{self.get_script_dir()}/../../{relative_dir
34             ↪ }{pdf_filename}'
35
36         try:
37             shutil.move(pdf_filename, destination)
38         except:
39             print("Error while moving file ", pdf_filename)
40
41     def delete_file_if_exists(self, filename):
42         try:
43             os.remove(filename)
44         except:
45             print(f'Error while deleting file: {filename} but that is
46                 ↪ not too bad because the intention is for it to not
47                 ↪ be there.')
48
49     def get_script_dir(self):
50         ''' returns the directory of this script regardless of from
51             ↪ which level the code is executed '''
52         return os.path.dirname(__file__)
53
54 if __name__ == '__main__':
55     main = Compile_latex()
```

D Appendix Export_code_to_latex.py

```
1 # runs a jupyter notebook and converts it to pdf
2 import os
3 import shutil
4 import nbformat
5 from nbconvert.preprocessors import ExecutePreprocessor
6
7 def export_code_to_latex(main_latex_filename, project_nr):
8     script_dir = get_script_dir()
9     relative_dir = f'latex/project{project_nr}/'
10    appendix_dir = script_dir+'../../../../../'+relative_dir+'
11        ↳ Appendices/'
12    path_to_main_latex_file = f'{script_dir}/../../../../../{
13        ↳ relative_dir}/{main_latex_filename}'
14    root_dir = script_dir[0:script_dir.rfind(f'code/project{
15        ↳ project_nr}')]
16
17    python_filepaths = get_filenames_in_dir('py', script_dir, ['
18        ↳ __init__.py'])
19    compiled_notebook_pdf_filepaths = get_compiled_notebook_paths
20        ↳ (script_dir)
21
22    python_files_already_included_in_appendices =
23        ↳ get_code_files_already_included_in_appendices('.py',
24        ↳ python_filepaths, appendix_dir, project_nr, root_dir)
25    notebook_pdf_files_already_included_in_appendices =
26        ↳ get_code_files_already_included_in_appendices('.ipynb',
27        ↳ compiled_notebook_pdf_filepaths, appendix_dir,
28        ↳ project_nr, root_dir)
29
30    missing_python_files_in_appendices =
31        ↳ get_code_files_not_yet_included_in_appendices('.py',
32        ↳ python_files_already_included_in_appendices,
33        ↳ python_filepaths)
34    missing_notebook_files_in_appendices =
35        ↳ get_code_files_not_yet_included_in_appendices('.pdf',
36        ↳ notebook_pdf_files_already_included_in_appendices,
37        ↳ compiled_notebook_pdf_filepaths)
38
39    created_python_appendix_filenames =
40        ↳ create_appendices_with_code('.py',
41        ↳ missing_python_files_in_appendices, appendix_dir,
42        ↳ project_nr, root_dir)
43    created_notebook_appendix_filenames =
44        ↳ create_appendices_with_code('.ipynb',
45        ↳ missing_notebook_files_in_appendices, appendix_dir,
46        ↳ project_nr, root_dir)
47
48    appendices = get_list_of_appendix_files(appendix_dir,
49        ↳ compiled_notebook_pdf_filepaths, python_filepaths)
50
51    main_tex_code, start_index, end_index, appendix_tex_code =
52        ↳ get_appendix_tex_code(path_to_main_latex_file)
53    # assumes non-included non-code appendices should not be
54        ↳ included:
55    non_code_appendices, main_non_code_appendix_inclusion_lines =
56        ↳ get_order_of_non_code_appendices_in_main(appendices,
57        ↳ appendix_tex_code)
58
59    python_appendix_filenames = list(map(lambda x: x.
60        ↳ appendix_filename, filter_appendices_by_type(appendices
```



```

33     ↪ , 'python'))))
sorted_created_python_appendices = sort_python_appendices(
34     ↪ filter_appendices_by_type(appendices, 'python'))
sorted_python_appendix_filenames = list(map(lambda x: x.
35     ↪ appendix_filename, sorted_created_python_appendices))
36
notebook_appendix_filenames = list(map(lambda x: x.
37     ↪ appendix_filename, filter_appendices_by_type(appendices
38     ↪ , 'notebook'))))
sorted_created_notebook_appendices = sort_notebook_appendices
39     ↪ (filter_appendices_by_type(appendices, 'notebook'))
sorted_notebook_appendix_filenames = list(map(lambda x: x.
40     ↪ appendix_filename, sorted_created_notebook_appendices))
41
appendix_latex_code = create_appendices_latex_code(
42     ↪ main_non_code_appendix_inclusion_lines,
43     ↪ sorted_created_notebook_appendices, project_nr,
44     ↪ sorted_created_python_appendices)
45
46
updated_main_tex_code = substitute_appendix_code(
47     ↪ main_tex_code, start_index, end_index,
48     ↪ appendix_latex_code)
49
46 overwrite_content_to_file(path_to_main_latex_file,
47     ↪ updated_main_tex_code)
48
49
def create_appendices_latex_code(
50     ↪ main_non_code_appendix_inclusion_lines, notebook_appendices,
51     ↪ project_nr, python_appendices):
52     ''' creates the appendix text for main. '''
53     main_appendix_inclusion_lines =
54     ↪ main_non_code_appendix_inclusion_lines
55     for appendix in python_appendices:
56         line = update_appendix_tex_code(appendix.appendix_filename,
57         ↪ project_nr)
58         main_appendix_inclusion_lines.append(line)
59
60     for appendix in notebook_appendices:
61         line = update_appendix_tex_code(appendix.appendix_filename,
62         ↪ project_nr)
63         main_appendix_inclusion_lines.append(line)
64     return main_appendix_inclusion_lines
65
66
def filter_appendices_by_type(appendices, appendix_type):
67     ''' Returns the list of appendices of certain type from a list of
68     ↪ appendix objects. '''
69     return_appendices = []
70     for appendix in appendices:
71         if appendix.appendix_type == appendix_type:
72             return_appendices.append(appendix)
73     return return_appendices
74
75
def sort_python_appendices(appendices):
76     ''' First puts __main__.py, followed by main.py followed by a-z
77     ↪ code files. '''
78     return_appendices = []
79     for appendix in appendices: # first get appendix containing
80     ↪ __main__.py

```

```

73         if (appendix.code_filename=="__main__.py") or (appendix.
74             ↪ code_filename=="__Main__.py"):
75             return_appendices.append(appendix)
76             appendices.remove(appendix)
77     for appendix in appendices: # second get appendix containing main
78         ↪ .py
79         if (appendix.code_filename=="main.py") or (appendix.
80             ↪ code_filename=="Main.py"):
81             return_appendices.append(appendix)
82             appendices.remove(appendix)
83     return return_appendices
84
85     # Filter remaining appendices in order of a-z
86     filtered_remaining_appendices = [i for i in appendices if i.
87         ↪ code_filename is not None]
88     appendices_sorted_a_z = filter_list_on_property(
89         ↪ filtered_remaining_appendices)
90     return return_appendices+appendices_sorted_a_z
91
92 def sort_notebook_appendices(appendices):
93     ''' Sorts notebooks on a-z pdf filenames. '''
94     return_appendices = []
95     filtered_remaining_appendices = [i for i in appendices if i.
96         ↪ code_filename is not None]
97     appendices_sorted_a_z = filter_list_on_property(
98         ↪ filtered_remaining_appendices)
99     return return_appendices+appendices_sorted_a_z
100
101 def filter_list_on_property(appendices):
102     ''' Returns a list based on the property: code_filename'''
103     attributes = list(map(lambda x: x.code_filename, appendices))
104     sorted_indices = sorted(range(len(attributes)), key=lambda k:
105         ↪ attributes[k])
106     sorted_list = []
107     for i in sorted_indices:
108         sorted_list.append(appendices[i])
109     return sorted_list
110
111 def get_order_of_non_code_appendices_in_main(appendices,
112     ↪ appendix_tex_code):
113     ''' Scans the lines of appendices in the main code, and returns
114         ↪ the lines that
115         of appendices that do not contain code, in specified order. '''
116     non_code_appendices = []
117     non_code_appendix_lines = []
118     appendix_tex_code = list(dict.fromkeys(appendix_tex_code))
119     for line in appendix_tex_code:
120         appendix_filename = get_filename_from_latex_appendix_line(
121             ↪ appendices, line)
122
123         # Check if line is not commented
124         if not appendix_filename is None:
125             if not line_is_commented(line, appendix_filename):
126                 appendix = get_appendix_from_filename(appendices,
127                     ↪ appendix_filename)
128                 if appendix.appendix_type == "no_code":
129                     non_code_appendices.append(appendix)
130                     non_code_appendix_lines.append(line)
131     return non_code_appendices, non_code_appendix_lines

```

```

123
124
125 def get_filename_from_latex_appendix_line(appendices, appendix_line):
126     for filename in list(map(lambda appendix: appendix.
        ↳ appendix_filename, appendices)):
127         if filename in appendix_line:
128             return filename
129
130
131 def get_appendix_from_filename(appendices, appendix_filename):
132     for appendix in appendices:
133         if appendix_filename == appendix.appendix_filename:
134             return appendix
135
136
137 def get_compiled_notebook_paths(script_dir):
138     ''' Returns the list of jupyter notebook filepaths that were
        ↳ compiled successfully'''
139     notebook_filepaths= get_filenames_in_dir('.ipynb', script_dir)
140     compiled_notebook_filepaths = []
141
142     # check if the jupyter notebooks were compiled
143     for notebook_filepath in notebook_filepaths:
144
145         # swap file extension
146         notebook_filepath = notebook_filepath.replace('.ipynb', '.pdf'
        ↳ )
147
148         # check if file exists
149         if os.path.isfile(notebook_filepath):
150             compiled_notebook_filepaths.append(notebook_filepath)
151     return compiled_notebook_filepaths
152
153
154 def get_list_of_appendix_files(appendix_dir,
    ↳ absolute_notebook_filepaths, absolute_python_filepaths):
155     ''' Returns a list with all the appendix files with .tex
        ↳ extension.'''
156     appendices = []
157     appendices_paths = get_filenames_in_dir('.tex', appendix_dir)
158
159     for appendix_filepath in appendices_paths:
160         appendix_type = "no_code"
161         appendix_filecontent = read_file(appendix_filepath)
162         line_nr_python_file_inclusion = get_line_of_latex_command(
        ↳ appendix_filecontent, "\pythonexternal{")
163         line_nr_notebook_file_inclusion = get_line_of_latex_command(
        ↳ appendix_filecontent, "\includepdf[pages=]")
164         if line_nr_python_file_inclusion > -1:
165             appendix_type = "python"
166             # get python filename
167             line = appendix_filecontent[line_nr_python_file_inclusion
        ↳ ]
168             filename = get_filename_from_latex_inclusion_command('.py
        ↳ ', line, "\pythonexternal{")
169             appendices.append(Appendix(appendix_filepath,
        ↳ appendix_filecontent, appendix_type, filename, line
        ↳ ))
170         if line_nr_notebook_file_inclusion > -1:
171             appendix_type = "notebook"
172             line = appendix_filecontent[
        ↳ line_nr_notebook_file_inclusion]

```

```

173         filename = get_filename_from_latex_inclusion_command('.
        ↪ pdf', line, "\includepdf[pages=")
174     appendices.append(Appendix(appendix_filepath,
        ↪ appendix_filecontent, appendix_type, filename, line
        ↪ ))
175     else:
176         appendices.append(Appendix(appendix_filepath,
        ↪ appendix_filecontent, appendix_type))
177     return appendices
178
179
180 def get_filename_from_latex_inclusion_command(extension,
        ↪ appendix_line, start_substring):
181     ''' returns the filename in a latex inclusion command that is
        ↪ located in an appendix.
182     The inclusion command includes a python code or jupyter notebook
        ↪ pdf.'''
183     start_index = appendix_line.index(start_substring)
184     end_index = appendix_line.index(extension)
185     return get_filename_from_dir(appendix_line[start_index:end_index+
        ↪ len(extension)])
186
187
188 def get_filenames_in_dir(extension, path, excluded_files=None):
189     '''Returns a list of the relative paths to all files within the
        ↪ code/projectX/src/ folder that match
190     the given file extension.'''
191     filepaths=[]
192     for r, d, f in os.walk(path):
193         for file in f:
194             if file.endswith(extension):
195                 if (excluded_files is None) or ((not excluded_files
        ↪ is None) and (not file in excluded_files)):
196                     filepaths.append(r+'/'+file)
197     return filepaths
198
199
200 def get_code_files_already_included_in_appendices(extension,
        ↪ absolute_filepaths, appendix_dir, project_nr, root_dir):
201     ''' Returns a list of filepaths that are already properly
        ↪ included in some appendix of this projectX,'''
202     appendix_files = get_filenames_in_dir('.tex', appendix_dir)
203     contained_codes = []
204     for code_filepath in absolute_filepaths:
205         for appendix_filepath in appendix_files:
206             appendix_filecontent = read_file(appendix_filepath)
207             line_nr = check_if_appendix_contains_file(extension,
        ↪ code_filepath, appendix_filecontent, project_nr,
        ↪ root_dir)
208             if line_nr>-1:
209                 # add filepath to list of files that are already in
        ↪ the appendices
210                 contained_codes.append(Appendix_with_code(
        ↪ code_filepath,
211                 appendix_filepath,
212                 appendix_filecontent,
213                 line_nr,
214                 '.py'))
215     return contained_codes
216
217

```

```

218 def check_if_appendix_contains_file(extension, code_filepath,
    ↳ appendix_content, project_nr, root_dir):
219     ''' scans an appendix content to determine whether it contains a
        ↳ substring that
220     includes the python code file.'''
221     # convert code_filepath to the inclusion format in latex format
222     latex_relative_filepath = f'latex/project{project_nr}/../../{
        ↳ code_filepath[len(root_dir):]}'
223     latex_command = get_latex_inclusion_command(extension,
        ↳ latex_relative_filepath)
224     return get_line_of_latex_command(appendix_content, latex_command)
225
226
227 def get_line_of_latex_command(appendix_content, latex_command):
228     ''' Returns the line number of a latex command if it is found.
        ↳ Returns -1 otherwise.'''
229     # check if the file is in the latex code
230     line_nr = 0
231     for line in appendix_content:
232         if latex_command in line:
233             if line_is_commented(line, latex_command):
234                 commented=True
235             else:
236                 return line_nr
237             line_nr=line_nr+1
238     return -1
239
240
241 def line_is_commented(line, target_substring):
242     ''' Returns true if a line is commented, returns false otherwise
        ↳ '''
243     left_of_command = line[:line.rfind(target_substring)]
244     if '%' in left_of_command:
245         return True
246     return False
247
248
249 def get_latex_inclusion_command(extension,
    ↳ latex_relative_filepath_to_codefile):
250     if extension==".py":
251         left = "\pythonexternal{"
252         right = "}"
253         latex_command = f'{left}{latex_relative_filepath_to_codefile
            ↳ }{right}'
254     elif extension==".ipynb":
255
256         left = "\includepdf[pages=-]{"
257         right = "}"
258         latex_command = f'{left}{latex_relative_filepath_to_codefile
            ↳ }{right}'
259     return latex_command
260
261
262 def read_file(filepath):
263     ''' Reads content of a file and returns it as a list of strings
        ↳ '''
264     with open(filepath) as f:
265         content = f.readlines()
266     return content
267
268

```

```

269 def get_code_files_not_yet_included_in_appendices(extension,
    ↪ contained_codes, code_filepaths):
270     ''' Returns a list of filepaths that are not yet properly
    ↪ included in some appendix of this projectX, '''
271     contained_filepaths = list(map(lambda contained_file:
    ↪ contained_file.code_filepath, contained_codes))
272     not_contained = []
273     for filepath in code_filepaths:
274         if not filepath in contained_filepaths:
275             not_contained.append(filepath)
276     return not_contained
277
278
279 def create_appendices_with_code(extension, code_filepaths,
    ↪ appendix_dir, project_nr, root_dir):
280     ''' Creates the latex appendix files in with relevant codes
    ↪ included. '''
281     appendix_filenames = []
282     appendix_reference_index = 0
283
284     for code_filepath in code_filepaths:
285         latex_relative_filepath = f'latex/project{project_nr}/../../{
    ↪ code_filepath[len(root_dir):]}'
286         content = []
287         filename = get_filename_from_dir(code_filepath)
288         content = create_section(content, filename,
    ↪ appendix_reference_index)
289         inclusion_command = get_latex_inclusion_command(extension,
    ↪ latex_relative_filepath)
290         content.append(inclusion_command)
291         overwrite_content_to_file(f'{appendix_dir}Auto_generated_{
    ↪ extension[1:]}_App{appendix_reference_index}.tex',
    ↪ content, False)
292         appendix_filenames.append(f'Auto_generated_{extension[1:]}
    ↪ _App{appendix_reference_index}.tex')
293         appendix_reference_index = appendix_reference_index+1
294     return appendix_filenames
295
296
297 def create_section(content, code_filename, appendix_reference_index):
298     # write section
299     left = "\section{Appendix "
300     middle = code_filename.replace("_", "\_")
301     right = "} \label{app:"
302     end = "}" # TODO: update appendix reference index
303     content.append(f'{left}{middle}{right}{appendix_reference_index}{
    ↪ end}')
304     return content
305
306
307 def overwrite_content_to_file(filepath, content, content_has_newlines
    ↪ =True):
308     ''' Writes the content of an appendix to a new appendix'''
309     with open(filepath, 'w') as f:
310         for line in content:
311             if content_has_newlines:
312                 f.write(line)
313             else:
314                 f.write(line+'\n')
315
316
317 def get_appendix_tex_code(main_latex_filename):

```

```

318     ''' gets the latex appendix code from the main tex file.'''
319     main_tex_code = read_file(main_latex_filename)
320     start = "\\begin{appendices}"
321     end = "\\end{appendices}"
322     start_index = get_index_of_substring_in_list(start, main_tex_code
    ↪ )+1
323     end_index = get_index_of_substring_in_list(end, main_tex_code)
324     return main_tex_code, start_index, end_index, main_tex_code[
    ↪ start_index:end_index]
325
326
327 def get_index_of_substring_in_list(target_substring, lines):
328     for i in range(0, len(lines)):
329         if target_substring in lines[i]:
330             if not line_is_commented(lines[i], target_substring):
331                 return i
332
333
334 def update_appendix_tex_code(appendix_filename, project_nr):
335     ''' Includes the appendices as latex commands in the tex code
    ↪ string'''
336     left = "\\input{latex/project"
337     middle = "/Appendices/"
338     right = "} \\newpage\\n"
339     return f'{left}{project_nr}{middle}{appendix_filename}{right}'
340
341
342 def substitute_appendix_code(main_tex_code, start_index, end_index,
    ↪ updated_appendices_tex_code):
343     ''' Replaces the old latex code that include the appendices with
    ↪ the new latex
344     commands that include the appendices in the latex report.'''
345     updated_main_tex_code = main_tex_code[0:start_index]+
    ↪ updated_appendices_tex_code+main_tex_code[end_index:]
346     return updated_main_tex_code
347
348
349 def get_filename_from_dir(path):
350     return path[path.rfind("/") + 1:]
351
352
353 def get_script_dir():
354     ''' returns the directory of this script regardless of from which
    ↪ level the code is executed '''
355     return os.path.dirname(__file__)
356
357
358 class Appendix_with_code:
359     ''' stores in which appendix file and accompanying line number in
    ↪ the appendix in which a code file is
360     already included. Does not take into account whether this
    ↪ appendix is in the main tex file or not'''
361     def __init__(self, code_filepath, appendix_filepath,
    ↪ appendix_content, file_line_nr, extension):
362         self.code_filepath = code_filepath
363         self.appendix_filepath = appendix_filepath
364         self.appendix_content = appendix_content
365         self.file_line_nr = file_line_nr
366         self.extension = extension
367
368
369 class Appendix:

```

```
370 ''' stores in appendix files and type of appendix.'''
371 def __init__(self, appendix_filepath, appendix_content,
    ↳ appendix_type, code_filename=None, appendix_inclusion_line=
    ↳ None):
372     self.appendix_filepath = appendix_filepath
373     self.appendix_filename = get_filename_from_dir(self.
    ↳ appendix_filepath)
374     self.appendix_content = appendix_content
375     self.appendix_type = appendix_type # TODO: perform validation
    ↳ of input values
376     self.code_filename = code_filename
377     self.appendix_inclusion_line = appendix_inclusion_line
```

E Appendix Plot_to_tex.py

```
1  ### Call this from another file, for project 11, question 3b:
2  ### from Plot_to_tex import Plot_to_tex as plt_tex
3  ### multiple_y_series = np.zeros((nrOfDataSeries,nrOfDataPoints),
   ↪ dtype=int); # actually fill with data
4  ### lineLabels = [] # add a label for each dataseries
5  ### plt_tex.plotMultipleLines(plt_tex,single_x_series,
   ↪ multiple_y_series,"x-axis label [units]","y-axis label [units
   ↪ ]",lineLabels,"3b",4,11)
6  ### 4b=filename
7  ### 4 = position of legend, e.g. top right.
8  ###
9  ### For a single line, use:
10 ### plt_tex.plotSingleLine(plt_tex,range(0, len(dataseries)),
   ↪ dataseries,"x-axis label [units]","y-axis label [units]",
   ↪ lineLabel,"3b",4,11)
11
12 ### You can also plot a table directly into latex, see
   ↪ example_create_a_table(..)
13 ###
14 ### Then put it in latex with for example:
15 ### \begin{table}[H]
16 ###     \centering
17 ###     \caption{Results some computation.}\label{tab:some_computation
   ↪ }
18 ###     \begin{tabular}{|c|c|} % remember to update this to show all
   ↪ columns of table
19 ###         \hline
20 ###         \input{latex/project3/tables/q2.txt}
21 ###     \end{tabular}
22 ### \end{table}
23 import random
24 from matplotlib import lines
25 import matplotlib.pyplot as plt
26 import numpy as np
27 import os
28 class Plot_to_tex:
29
30     def __init__(self):
31         self.script_dir = self.get_script_dir()
32         print("Created main")
33
34     # plot graph (legendPosition = integer 1 to 4)
35     def plotSingleLine(self,x_path,y_series,x_axis_label,y_axis_label
   ↪ ,label,filename,legendPosition,project_nr):
36         fig=plt.figure();
37         ax=fig.add_subplot(111);
38         ax.plot(x_path,y_series,c='b',ls='-',label=label,fillstyle='
   ↪ none');
39         plt.legend(loc=legendPosition);
40         plt.xlabel(x_axis_label);
41         plt.ylabel(y_axis_label);
42         plt.savefig(os.path.dirname(__file__)+'../../../latex/
   ↪ project'+str(project_nr)+'/Images/'+filename+'.png');
43     #
   ↪ plt.show();
44
45     # plot graphs
46     def plotMultipleLines(self,x,y_series,x_label,y_label,label,
   ↪ filename,legendPosition,project_nr):
47         fig=plt.figure();
48         ax=fig.add_subplot(111);
```

```

49
50     # generate colours
51     cmap = self.get_cmap(len(y_series[:,0]))
52
53     # generate line types
54     lineTypes = self.generateLineTypes(y_series)
55
56     for i in range(0, len(y_series)):
57         # overwrite linetypes to single type
58         lineTypes[i] = "-"
59         ax.plot(x, y_series[i, :], ls=lineTypes[i], label=label[i],
60                 ↪ fillstyle='none', c=cmap(i)); # color
61
62     # configure plot layout
63     plt.legend(loc=legendPosition);
64     plt.xlabel(x_label);
65     plt.ylabel(y_label);
66     plt.savefig(os.path.dirname(__file__)+'../../../../../latex/
67                 ↪ project'+str(project_nr)+'/Images/'+filename+'.png');
68
69     print(f'plotted lines')
70
71     # Generate random line colours
72     # Source: https://stackoverflow.com/questions/14720331/how-to-
73     ↪ generate-random-colors-in-matplotlib
74     def get_cmap(n, name='hsv'):
75         '''Returns a function that maps each index in 0, 1, ..., n-1
76         ↪ to a distinct
77         RGB color; the keyword argument name must be a standard mpl
78         ↪ colormap name.'''
79         return plt.cm.get_cmap(name, n)
80
81     def generateLineTypes(y_series):
82         # generate varying linetypes
83         typeOfLines = list(lines.lineStyles.keys())
84
85         while(len(y_series)>len(typeOfLines)):
86             typeOfLines.append("-.");
87
88         # remove void lines
89         for i in range(0, len(y_series)):
90             if (typeOfLines[i]=='None'):
91                 typeOfLines[i]='-'
92             if (typeOfLines[i]==''):
93                 typeOfLines[i]=':'
94             if (typeOfLines[i]==' '):
95                 typeOfLines[i]='--'
96         return typeOfLines
97
98     # Create a table with: table_matrix = np.zeros((4,4),dtype=object
99     ↪ ) and pass it to this object
100     def put_table_in_tex(self, table_matrix, filename, project_nr):
101         cols = np.shape(table_matrix)[1]
102         format = "%s"
103         for col in range(1, cols):
104             format = format+" & %s"
105         format = format+" "
106         plt.savetxt(os.path.dirname(__file__)+"../../../../../latex/
107                     ↪ project"+str(project_nr)+"tables/"+filename+".txt",
108                     ↪ table_matrix, delimiter=' & ', fmt=format, newline='
109                     ↪ \\\n \hline \n')

```

101

```

102 # replace this with your own table creation and then pass it to
    ↪ put_table_in_tex(..)
103 def example_create_a_table(self):
104     project_nr = "1"
105     table_name = "example_table_name"
106     rows = 2;
107     columns = 4;
108     table_matrix = np.zeros((rows,columns),dtype=object)
109     table_matrix[:,:]="" # replace the standard zeros with empty
    ↪ cell
110     print(table_matrix)
111     for column in range(0,columns):
112         for row in range(0,rows):
113             table_matrix[row,column]=row+column
114     table_matrix[1,0]="example"
115     table_matrix[0,1]="grid sizes"
116
117     self.put_table_in_tex(table_matrix,table_name,project_nr)
118
119
120 def get_script_dir(self):
121     ''' returns the directory of this script regardless of from
    ↪ which level the code is executed '''
122     return os.path.dirname(__file__)
123
124 if __name__ == '__main__':
125     main = Plot_to_tex()
126     main.example_create_a_table()

```

F Appendix Run_jupyter_notebooks.py

```
1 # runs a jupyter notebook and converts it to pdf
2
3 import os
4 import nbformat
5 from nbconvert.preprocessors import ExecutePreprocessor
6
7 class Run_jupyter_notebook:
8
9     def __init__(self):
10         self.script_dir = self.get_script_dir()
11         print("Created main")
12
13     # runs jupyter notebook
14     def run_notebook(self, notebook_filename):
15
16         # Load your notebook
17         with open(notebook_filename) as f:
18             nb = nbformat.read(f, as_version=4)
19
20         # Configure
21         ep = ExecutePreprocessor(timeout=600, kernel_name='python3')
22
23         # Execute
24         ep.preprocess(nb, {'metadata': {'path': f'{self.
25             ↪ get_script_dir()}/.././.././'}})
26
27         # Save output notebook
28         with open(notebook_filename, 'w', encoding='utf-8') as f:
29             nbformat.write(nb, f)
30
31     # converts jupyter notebook to pdf
32     def convert_notebook_to_pdf(self, notebook_filename):
33         os.system(f'jupyter nbconvert --to pdf {notebook_filename}')
34
35     def get_script_dir(self):
36         ''' returns the directory of this script regardless of from
37             ↪ which level the code is executed '''
38         return os.path.dirname(__file__)
39
40 if __name__ == '__main__':
41     main = Run_jupyter_notebook()
```

Appendix Example Jupyter Notebook

AE4868_example_notebook_update20201025

December 26, 2020

```
[1]: def addThree(input_nr):  
      '''returns the input integer plus 3, used to verify unit test'''  
      return input_nr + 3  
  
[2]: #####  
      # IMPORT STATEMENTS #####  
      #####  
      import os  
      import numpy as np  
      from tudatpy.kernel import constants  
      from tudatpy.kernel.interface import spice_interface  
      from tudatpy.kernel.simulation import environment_setup  
      from tudatpy.kernel.simulation import propagation_setup  
      from tudatpy.kernel.astro import conversion  
  
      # Set path to latex image folders for project 1  
      latex_image_path = 'latex/project1/Images/'  
  
      # Load spice kernels.  
      spice_interface.load_standard_kernels()  
  
      # Set simulation start and end epochs.  
      simulation_start_epoch = 0.0  
      simulation_end_epoch = constants.JULIAN_DAY  
  
      #####  
      # CREATE ENVIRONMENT #####  
      #####  
  
      # Create default body settings for selected celestial bodies  
      bodies_to_create = ["Sun", "Earth", "Moon", "Mars", "Venus"]  
  
      # Create default body settings for bodies_to_create, with "Earth"/"J2000" as  
      # global frame origin and orientation. This environment will only be valid  
      # in the indicated time range  
      # [simulation_start_epoch --- simulation_end_epoch]  
      body_settings = environment_setup.get_default_body_settings(
```

```

bodies_to_create,
simulation_start_epoch,
simulation_end_epoch,
"Earth", "J2000")

# Create system of selected celestial bodies
bodies = environment_setup.create_system_of_bodies(body_settings)

#####
# CREATE VEHICLE #####
#####

# Create vehicle objects.
bodies.create_empty_body( "Delfi-C3" )
bodies.get_body( "Delfi-C3").set_constant_mass(400.0)

# Create aerodynamic coefficient interface settings, and add to vehicle
reference_area = 4.0
drag_coefficient = 1.2
aero_coefficient_settings = environment_setup.aerodynamic_coefficients.constant(
    reference_area, [drag_coefficient, 0, 0]
)
environment_setup.add_aerodynamic_coefficient_interface(
    bodies, "Delfi-C3", aero_coefficient_settings )

# Create radiation pressure settings, and add to vehicle
reference_area_radiation = 4.0
radiation_pressure_coefficient = 1.2
occulting_bodies = ["Earth"]
radiation_pressure_settings = environment_setup.radiation_pressure.cannonball(
    "Sun", reference_area_radiation, radiation_pressure_coefficient,
    ↪ occulting_bodies
)
environment_setup.add_radiation_pressure_interface(
    bodies, "Delfi-C3", radiation_pressure_settings )

#####
# CREATE ACCELERATIONS #####
#####

# Define bodies that are propagated.
bodies_to_propagate = ["Delfi-C3"]

# Define central bodies.
central_bodies = ["Earth"]

# Define accelerations acting on Delfi-C3 by Sun and Earth.

```

```

accelerations_settings_delfi_c3 = dict(
    Sun=
    [
        propagation_setup.acceleration.cannonball_radiation_pressure(),
        propagation_setup.acceleration.point_mass_gravity()
    ],
    Earth=
    [
        propagation_setup.acceleration.spherical_harmonic_gravity(5, 5),
        propagation_setup.acceleration.aerodynamic()
    ])

# Define point mass accelerations acting on Delfi-C3 by all other bodies.
for other in set(bodies_to_create).difference({"Sun", "Earth"}):
    accelerations_settings_delfi_c3[other] = [
        propagation_setup.acceleration.point_mass_gravity()]

# Create global accelerations settings dictionary.
acceleration_settings = {"Delfi-C3": accelerations_settings_delfi_c3}

# Create acceleration models.
acceleration_models = propagation_setup.create_acceleration_models(
    bodies,
    acceleration_settings,
    bodies_to_propagate,
    central_bodies)

#####
# CREATE PROPAGATION SETTINGS #####
#####

# Set initial conditions for the Asterix satellite that will be
# propagated in this simulation. The initial conditions are given in
# Keplerian elements and later on converted to Cartesian elements.
earth_gravitational_parameter = bodies.get_body( "Earth" ).
    ↪gravitational_parameter
initial_state = conversion.keplerian_to_cartesian(
    gravitational_parameter=earth_gravitational_parameter,
    semi_major_axis=7500.0E3,
    eccentricity=0.1,
    inclination=np.deg2rad(85.3),
    argument_of_periapsis=np.deg2rad(235.7),
    longitude_of_ascending_node=np.deg2rad(23.4),
    true_anomaly=np.deg2rad(139.87)
)

# Define list of dependent variables to save.

```



```

dependent_variables_to_save = [
    propagation_setup.dependent_variable.total_acceleration( "Delfi-C3" ),
    propagation_setup.dependent_variable.keplerian_state( "Delfi-C3", "Earth" ),
    propagation_setup.dependent_variable.latitude( "Delfi-C3", "Earth" ),
    propagation_setup.dependent_variable.longitude( "Delfi-C3", "Earth"),
    propagation_setup.dependent_variable.single_acceleration_norm(
        propagation_setup.acceleration.point_mass_gravity_type, "Delfi-C3",
↪ "Sun"
    ),
    propagation_setup.dependent_variable.single_acceleration_norm(
        propagation_setup.acceleration.point_mass_gravity_type, "Delfi-C3",
↪ "Moon"
    ),
    propagation_setup.dependent_variable.single_acceleration_norm(
        propagation_setup.acceleration.point_mass_gravity_type, "Delfi-C3",
↪ "Mars"
    ),
    propagation_setup.dependent_variable.single_acceleration_norm(
        propagation_setup.acceleration.point_mass_gravity_type, "Delfi-C3",
↪ "Venus"
    ),
    propagation_setup.dependent_variable.single_acceleration_norm(
        propagation_setup.acceleration.spherical_harmonic_gravity_type,
↪ "Delfi-C3", "Earth"
    ),
    propagation_setup.dependent_variable.single_acceleration_norm(
        propagation_setup.acceleration.aerodynamic_type, "Delfi-C3", "Earth"
    ),
    propagation_setup.dependent_variable.single_acceleration_norm(
        propagation_setup.acceleration.cannonball_radiation_pressure_type,
↪ "Delfi-C3", "Sun"
    )
]

# Create propagation settings.
propagator_settings = propagation_setup.propagator.translational(
    central_bodies,
    acceleration_models,
    bodies_to_propagate,
    initial_state,
    simulation_end_epoch,
    output_variables = dependent_variables_to_save
)

# Create numerical integrator settings.
fixed_step_size = 10.0

```

```

integrator_settings = propagation_setup.integrator.runge_kutta_4(
    simulation_start_epoch,
    fixed_step_size
)

#####
# PROPAGATE ORBIT #####
#####

# Create simulation object and propagate dynamics.
dynamics_simulator = propagation_setup.SingleArcDynamicsSimulator(
    bodies, integrator_settings, propagator_settings)
states = dynamics_simulator.state_history
dependent_variables = dynamics_simulator.dependent_variable_history

#####
# PRINT INITIAL AND FINAL STATES #####
#####

print(
    f"""
Single Earth-Orbiting Satellite Example.
The initial position vector of Delfi-C3 is [km]: \n{
    states[simulation_start_epoch][:3] / 1E3}
The initial velocity vector of Delfi-C3 is [km/s]: \n{
    states[simulation_start_epoch][3:] / 1E3}
After {simulation_end_epoch} seconds the position vector of Delfi-C3 is [km]:
↪\n{
    states[simulation_end_epoch][:3] / 1E3}
And the velocity vector of Delfi-C3 is [km/s]: \n{
    states[simulation_end_epoch][3:] / 1E3}
    """
)

```

```

Single Earth-Orbiting Satellite Example.
The initial position vector of Delfi-C3 is [km]:
[7037.48400133 3238.05901792 2150.7241875 ]
The initial velocity vector of Delfi-C3 is [km/s]:
[-1.46565763 -0.04095839  6.62279761]
After 86400.0 seconds the position vector of Delfi-C3 is [km]:
[-4602.79426676 -1421.16740978  5883.69740624]
And the velocity vector of Delfi-C3 is [km/s]:
[-4.53846052 -2.36988263 -5.04163195]

```

```

[3]: import os
from matplotlib import pyplot as plt

time = dependent_variables.keys()
dependent_variable_list = np.vstack(list(dependent_variables.values()))
font_size = 20

plt.rcParams.update({'font.size': font_size})

# dependent variables
# 0-2: total acceleration
# 3-8: Keplerian state
# 9: latitude
# 10: longitude
# 11: Acceleration Norm PM Sun
# 12: Acceleration Norm PM Moon
# 13: Acceleration Norm PM Mars
# 14: Acceleration Norm PM Venus
# 15: Acceleration Norm SH Earth

total_acceleration = np.sqrt( dependent_variable_list[:,0] ** 2 +
    ↪ dependent_variable_list[:,1] ** 2 + dependent_variable_list[:,2] ** 2 )

time_hours = [ t / 3600 for t in time]
# Total Acceleration
plt.figure( figsize=(17,5))
plt.grid()
plt.plot( time_hours , total_acceleration )
plt.xlabel('Time [hr]')
plt.ylabel('Total Acceleration [m/s2]')
plt.xlim( [min(time_hours), max(time_hours)] )
plt.savefig( fname = f'{latex_image_path}total_acceleration.png',
    ↪ bbox_inches='tight')

# Ground Track
latitude = dependent_variable_list[:,9]
longitude = dependent_variable_list[:,10]

part = int(len(time)/24*3)
latitude = np.rad2deg( latitude[0:part] )
longitude = np.rad2deg( longitude[0:part] )
plt.figure( figsize=(17,5))
plt.grid()
plt.yticks(np.arange(-90, 91, step=45))
plt.scatter( longitude, latitude, s=1 )

```

```

plt.xlabel('Longitude [deg]')
plt.ylabel('Latitude [deg]')
plt.xlim( [min(longitude), max(longitude)] )
plt.savefig( fname = f'{latex_image_path}ground_track.png', bbox_inches='tight')

# Kepler Elements
kepler_elements = dependent_variable_list[:,3:9]

fig, ((ax1, ax2), (ax3, ax4), (ax5, ax6)) = plt.subplots( 3, 2, figsize = (20,17) )

# Semi-major Axis
semi_major_axis = [ element/1000 for element in kepler_elements[:,0] ]
ax1.plot( time_hours, semi_major_axis )
ax1.set_ylabel( 'Semi-major axis [km]' )

# Eccentricity
eccentricity = kepler_elements[:,1]
ax2.plot( time_hours, eccentricity )
ax2.set_ylabel( 'Eccentricity [-]' )

# Inclination
inclination = [ np.rad2deg( element ) for element in kepler_elements[:,2] ]
ax3.plot( time_hours, inclination )
ax3.set_ylabel( 'Inclination [deg]' )

# Argument of Periapsis
argument_of_periapsis = [ np.rad2deg( element ) for element in kepler_elements[:,3] ]
ax4.plot( time_hours, argument_of_periapsis )
ax4.set_ylabel( 'Argument of Periapsis [deg]' )

# Right Ascension of the Ascending Node
raan = [ np.rad2deg( element ) for element in kepler_elements[:,4] ]
ax5.plot( time_hours, raan )
ax5.set_ylabel( 'RAAN [deg]' )

# True Anomaly
true_anomaly = [ np.rad2deg( element ) for element in kepler_elements[:,5] ]
ax6.scatter( time_hours, true_anomaly, s=1 )
ax6.set_ylabel( 'True Anomaly [deg]' )
ax6.set_yticks(np.arange(0, 361, step=60))

for ax in fig.get_axes():
    ax.set_xlabel('Time [hr]')
    ax.set_xlim( [min(time_hours), max(time_hours)] )
    ax.grid()

```

```

plt.savefig( fname = f'{latex_image_path}kepler_elements.png',
    ↳bbox_inches='tight')

plt.figure( figsize=(17,5))

# Point Mass Gravity Acceleration Sun
acceleration_norm_pm_sun = dependent_variable_list[:, 11]
plt.plot( time_hours, acceleration_norm_pm_sun, label='PM Sun')

# Point Mass Gravity Acceleration Moon
acceleration_norm_pm_moon = dependent_variable_list[:, 12]
plt.plot( time_hours, acceleration_norm_pm_moon, label='PM Moon')

# Point Mass Gravity Acceleration Mars
acceleration_norm_pm_mars = dependent_variable_list[:, 13]
plt.plot( time_hours, acceleration_norm_pm_mars, label='PM Mars')

# Point Mass Gravity Acceleration Venus
acceleration_norm_pm_venus = dependent_variable_list[:, 14]
plt.plot( time_hours, acceleration_norm_pm_venus, label='PM Venus')

# Spherical Harmonic Gravity Acceleration Earth
acceleration_norm_sh_earth = dependent_variable_list[:, 15]
plt.plot( time_hours, acceleration_norm_sh_earth, label='SH Earth')

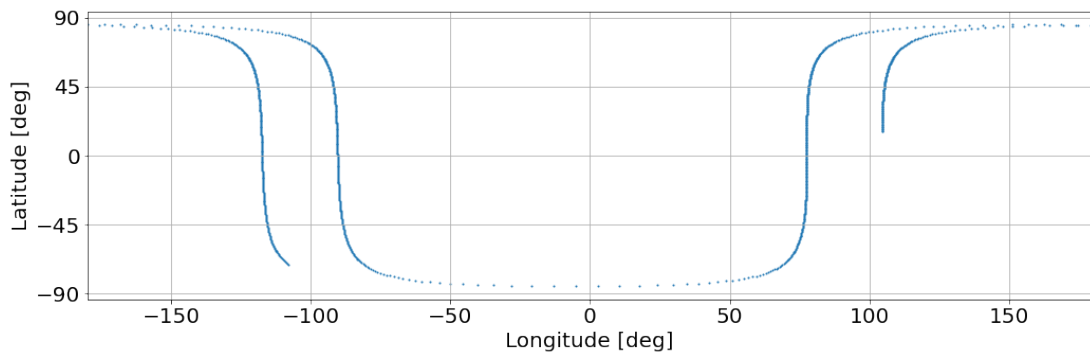
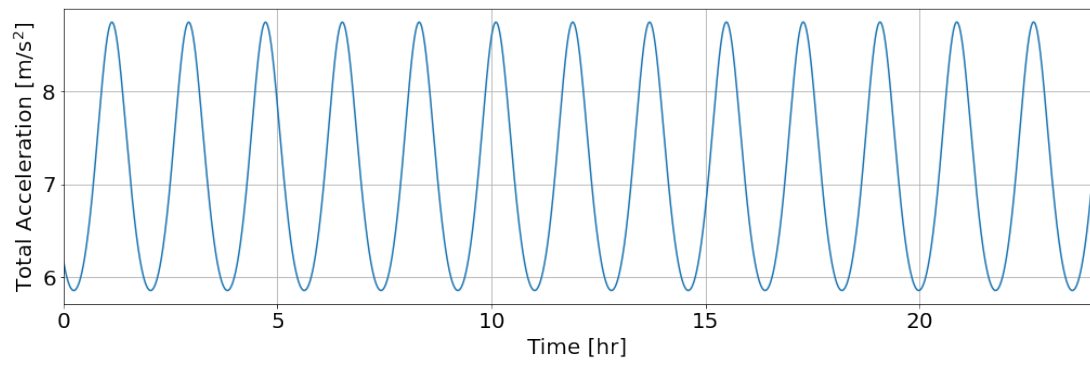
# Aerodynamic Acceleration Earth
acceleration_norm_aero_earth = dependent_variable_list[:, 16]
plt.plot( time_hours, acceleration_norm_aero_earth, label='Aerodynamic Earth')

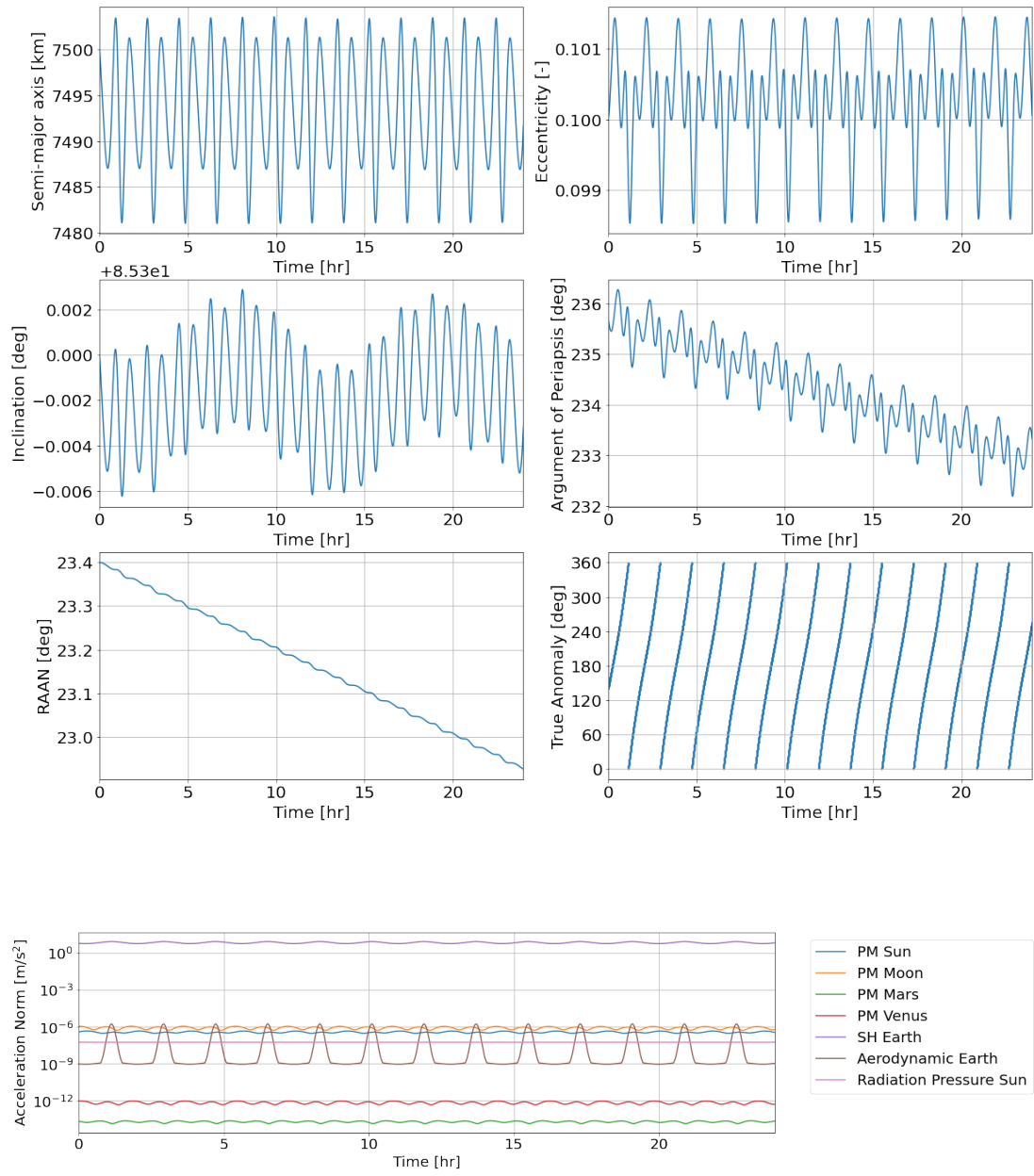
# Cannonball Radiation Pressure Acceleration Sun
acceleration_norm_rp_sun = dependent_variable_list[:, 17]
plt.plot( time_hours, acceleration_norm_rp_sun, label='Radiation Pressure Sun')

plt.grid()
plt.legend( bbox_to_anchor=(1.04,1) )
plt.xlim( [min(time_hours), max(time_hours)] )
plt.yscale('log')
plt.xlabel( 'Time [hr]' )
plt.ylabel( 'Acceleration Norm [m/s2]' )

plt.savefig( fname = f'{latex_image_path}acceleration_norms.png',
    ↳bbox_inches='tight')
#plt.savefig('acceleration_norms.png', bbox_inches='tight')

```





[]:

AE4868_example_notebook_update20201025

December 26, 2020

```
[1]: def addThree(input_nr):  
      '''returns the input integer plus 3, used to verify unit test'''  
      return input_nr + 3  
  
[2]: #####  
      # IMPORT STATEMENTS #####  
      #####  
      import os  
      import numpy as np  
      from tudatpy.kernel import constants  
      from tudatpy.kernel.interface import spice_interface  
      from tudatpy.kernel.simulation import environment_setup  
      from tudatpy.kernel.simulation import propagation_setup  
      from tudatpy.kernel.astro import conversion  
  
      # Set path to latex image folders for project 1  
      latex_image_path = 'latex/project1/Images/'  
  
      # Load spice kernels.  
      spice_interface.load_standard_kernels()  
  
      # Set simulation start and end epochs.  
      simulation_start_epoch = 0.0  
      simulation_end_epoch = constants.JULIAN_DAY  
  
      #####  
      # CREATE ENVIRONMENT #####  
      #####  
  
      # Create default body settings for selected celestial bodies  
      bodies_to_create = ["Sun", "Earth", "Moon", "Mars", "Venus"]  
  
      # Create default body settings for bodies_to_create, with "Earth"/"J2000" as  
      # global frame origin and orientation. This environment will only be valid  
      # in the indicated time range  
      # [simulation_start_epoch --- simulation_end_epoch]  
      body_settings = environment_setup.get_default_body_settings(
```

```

bodies_to_create,
simulation_start_epoch,
simulation_end_epoch,
"Earth", "J2000")

# Create system of selected celestial bodies
bodies = environment_setup.create_system_of_bodies(body_settings)

#####
# CREATE VEHICLE #####
#####

# Create vehicle objects.
bodies.create_empty_body( "Delfi-C3" )
bodies.get_body( "Delfi-C3").set_constant_mass(400.0)

# Create aerodynamic coefficient interface settings, and add to vehicle
reference_area = 4.0
drag_coefficient = 1.2
aero_coefficient_settings = environment_setup.aerodynamic_coefficients.constant(
    reference_area, [drag_coefficient, 0, 0]
)
environment_setup.add_aerodynamic_coefficient_interface(
    bodies, "Delfi-C3", aero_coefficient_settings )

# Create radiation pressure settings, and add to vehicle
reference_area_radiation = 4.0
radiation_pressure_coefficient = 1.2
occulting_bodies = ["Earth"]
radiation_pressure_settings = environment_setup.radiation_pressure.cannonball(
    "Sun", reference_area_radiation, radiation_pressure_coefficient,
    ↪ occulting_bodies
)
environment_setup.add_radiation_pressure_interface(
    bodies, "Delfi-C3", radiation_pressure_settings )

#####
# CREATE ACCELERATIONS #####
#####

# Define bodies that are propagated.
bodies_to_propagate = ["Delfi-C3"]

# Define central bodies.
central_bodies = ["Earth"]

# Define accelerations acting on Delfi-C3 by Sun and Earth.

```

```

accelerations_settings_delfi_c3 = dict(
    Sun=
    [
        propagation_setup.acceleration.cannonball_radiation_pressure(),
        propagation_setup.acceleration.point_mass_gravity()
    ],
    Earth=
    [
        propagation_setup.acceleration.spherical_harmonic_gravity(5, 5),
        propagation_setup.acceleration.aerodynamic()
    ])

# Define point mass accelerations acting on Delfi-C3 by all other bodies.
for other in set(bodies_to_create).difference({"Sun", "Earth"}):
    accelerations_settings_delfi_c3[other] = [
        propagation_setup.acceleration.point_mass_gravity()]

# Create global accelerations settings dictionary.
acceleration_settings = {"Delfi-C3": accelerations_settings_delfi_c3}

# Create acceleration models.
acceleration_models = propagation_setup.create_acceleration_models(
    bodies,
    acceleration_settings,
    bodies_to_propagate,
    central_bodies)

#####
# CREATE PROPAGATION SETTINGS #####
#####

# Set initial conditions for the Asterix satellite that will be
# propagated in this simulation. The initial conditions are given in
# Keplerian elements and later on converted to Cartesian elements.
earth_gravitational_parameter = bodies.get_body( "Earth" ).
↳gravitational_parameter
initial_state = conversion.keplerian_to_cartesian(
    gravitational_parameter=earth_gravitational_parameter,
    semi_major_axis=7500.0E3,
    eccentricity=0.1,
    inclination=np.deg2rad(85.3),
    argument_of_periapsis=np.deg2rad(235.7),
    longitude_of_ascending_node=np.deg2rad(23.4),
    true_anomaly=np.deg2rad(139.87)
)

# Define list of dependent variables to save.

```

```

dependent_variables_to_save = [
    propagation_setup.dependent_variable.total_acceleration( "Delfi-C3" ),
    propagation_setup.dependent_variable.keplerian_state( "Delfi-C3", "Earth" ),
    propagation_setup.dependent_variable.latitude( "Delfi-C3", "Earth" ),
    propagation_setup.dependent_variable.longitude( "Delfi-C3", "Earth"),
    propagation_setup.dependent_variable.single_acceleration_norm(
        propagation_setup.acceleration.point_mass_gravity_type, "Delfi-C3",
↪ "Sun"
    ),
    propagation_setup.dependent_variable.single_acceleration_norm(
        propagation_setup.acceleration.point_mass_gravity_type, "Delfi-C3",
↪ "Moon"
    ),
    propagation_setup.dependent_variable.single_acceleration_norm(
        propagation_setup.acceleration.point_mass_gravity_type, "Delfi-C3",
↪ "Mars"
    ),
    propagation_setup.dependent_variable.single_acceleration_norm(
        propagation_setup.acceleration.point_mass_gravity_type, "Delfi-C3",
↪ "Venus"
    ),
    propagation_setup.dependent_variable.single_acceleration_norm(
        propagation_setup.acceleration.spherical_harmonic_gravity_type,
↪ "Delfi-C3", "Earth"
    ),
    propagation_setup.dependent_variable.single_acceleration_norm(
        propagation_setup.acceleration.aerodynamic_type, "Delfi-C3", "Earth"
    ),
    propagation_setup.dependent_variable.single_acceleration_norm(
        propagation_setup.acceleration.cannonball_radiation_pressure_type,
↪ "Delfi-C3", "Sun"
    )
]

# Create propagation settings.
propagator_settings = propagation_setup.propagator.translational(
    central_bodies,
    acceleration_models,
    bodies_to_propagate,
    initial_state,
    simulation_end_epoch,
    output_variables = dependent_variables_to_save
)

# Create numerical integrator settings.
fixed_step_size = 10.0

```

```

integrator_settings = propagation_setup.integrator.runge_kutta_4(
    simulation_start_epoch,
    fixed_step_size
)

#####
# PROPAGATE ORBIT #####
#####

# Create simulation object and propagate dynamics.
dynamics_simulator = propagation_setup.SingleArcDynamicsSimulator(
    bodies, integrator_settings, propagator_settings)
states = dynamics_simulator.state_history
dependent_variables = dynamics_simulator.dependent_variable_history

#####
# PRINT INITIAL AND FINAL STATES #####
#####

print(
    f"""
Single Earth-Orbiting Satellite Example.
The initial position vector of Delfi-C3 is [km]: \n{
    states[simulation_start_epoch][:3] / 1E3}
The initial velocity vector of Delfi-C3 is [km/s]: \n{
    states[simulation_start_epoch][3:] / 1E3}
After {simulation_end_epoch} seconds the position vector of Delfi-C3 is [km]:
↪\n{
    states[simulation_end_epoch][:3] / 1E3}
And the velocity vector of Delfi-C3 is [km/s]: \n{
    states[simulation_end_epoch][3:] / 1E3}
    """
)

```

```

Single Earth-Orbiting Satellite Example.
The initial position vector of Delfi-C3 is [km]:
[7037.48400133 3238.05901792 2150.7241875 ]
The initial velocity vector of Delfi-C3 is [km/s]:
[-1.46565763 -0.04095839  6.62279761]
After 86400.0 seconds the position vector of Delfi-C3 is [km]:
[-4602.79426676 -1421.16740978  5883.69740624]
And the velocity vector of Delfi-C3 is [km/s]:
[-4.53846052 -2.36988263 -5.04163195]

```

```

[3]: import os
from matplotlib import pyplot as plt

time = dependent_variables.keys()
dependent_variable_list = np.vstack(list(dependent_variables.values()))
font_size = 20

plt.rcParams.update({'font.size': font_size})

# dependent variables
# 0-2: total acceleration
# 3-8: Keplerian state
# 9: latitude
# 10: longitude
# 11: Acceleration Norm PM Sun
# 12: Acceleration Norm PM Moon
# 13: Acceleration Norm PM Mars
# 14: Acceleration Norm PM Venus
# 15: Acceleration Norm SH Earth

total_acceleration = np.sqrt( dependent_variable_list[:,0] ** 2 +
    ↳ dependent_variable_list[:,1] ** 2 + dependent_variable_list[:,2] ** 2 )

time_hours = [ t / 3600 for t in time]
# Total Acceleration
plt.figure( figsize=(17,5))
plt.grid()
plt.plot( time_hours , total_acceleration )
plt.xlabel('Time [hr]')
plt.ylabel('Total Acceleration [m/s2]')
plt.xlim( [min(time_hours), max(time_hours)] )
plt.savefig( fname = f'{latex_image_path}total_acceleration.png',
    ↳ bbox_inches='tight')

# Ground Track
latitude = dependent_variable_list[:,9]
longitude = dependent_variable_list[:,10]

part = int(len(time)/24*3)
latitude = np.rad2deg( latitude[0:part] )
longitude = np.rad2deg( longitude[0:part] )
plt.figure( figsize=(17,5))
plt.grid()
plt.yticks(np.arange(-90, 91, step=45))
plt.scatter( longitude, latitude, s=1 )

```

```

plt.xlabel('Longitude [deg]')
plt.ylabel('Latitude [deg]')
plt.xlim( [min(longitude), max(longitude)] )
plt.savefig( fname = f'{latex_image_path}ground_track.png', bbox_inches='tight')

# Kepler Elements
kepler_elements = dependent_variable_list[:,3:9]

fig, ((ax1, ax2), (ax3, ax4), (ax5, ax6)) = plt.subplots( 3, 2, figsize = (20,17) )

# Semi-major Axis
semi_major_axis = [ element/1000 for element in kepler_elements[:,0] ]
ax1.plot( time_hours, semi_major_axis )
ax1.set_ylabel( 'Semi-major axis [km]' )

# Eccentricity
eccentricity = kepler_elements[:,1]
ax2.plot( time_hours, eccentricity )
ax2.set_ylabel( 'Eccentricity [-]' )

# Inclination
inclination = [ np.rad2deg( element ) for element in kepler_elements[:,2] ]
ax3.plot( time_hours, inclination )
ax3.set_ylabel( 'Inclination [deg]' )

# Argument of Periapsis
argument_of_periapsis = [ np.rad2deg( element ) for element in kepler_elements[:,3] ]
ax4.plot( time_hours, argument_of_periapsis )
ax4.set_ylabel( 'Argument of Periapsis [deg]' )

# Right Ascension of the Ascending Node
raan = [ np.rad2deg( element ) for element in kepler_elements[:,4] ]
ax5.plot( time_hours, raan )
ax5.set_ylabel( 'RAAN [deg]' )

# True Anomaly
true_anomaly = [ np.rad2deg( element ) for element in kepler_elements[:,5] ]
ax6.scatter( time_hours, true_anomaly, s=1 )
ax6.set_ylabel( 'True Anomaly [deg]' )
ax6.set_yticks(np.arange(0, 361, step=60))

for ax in fig.get_axes():
    ax.set_xlabel('Time [hr]')
    ax.set_xlim( [min(time_hours), max(time_hours)] )
    ax.grid()

```

```

plt.savefig( fname = f'{latex_image_path}kepler_elements.png',
    ↳bbox_inches='tight')

plt.figure( figsize=(17,5))

# Point Mass Gravity Acceleration Sun
acceleration_norm_pm_sun = dependent_variable_list[:, 11]
plt.plot( time_hours, acceleration_norm_pm_sun, label='PM Sun')

# Point Mass Gravity Acceleration Moon
acceleration_norm_pm_moon = dependent_variable_list[:, 12]
plt.plot( time_hours, acceleration_norm_pm_moon, label='PM Moon')

# Point Mass Gravity Acceleration Mars
acceleration_norm_pm_mars = dependent_variable_list[:, 13]
plt.plot( time_hours, acceleration_norm_pm_mars, label='PM Mars')

# Point Mass Gravity Acceleration Venus
acceleration_norm_pm_venus = dependent_variable_list[:, 14]
plt.plot( time_hours, acceleration_norm_pm_venus, label='PM Venus')

# Spherical Harmonic Gravity Acceleration Earth
acceleration_norm_sh_earth = dependent_variable_list[:, 15]
plt.plot( time_hours, acceleration_norm_sh_earth, label='SH Earth')

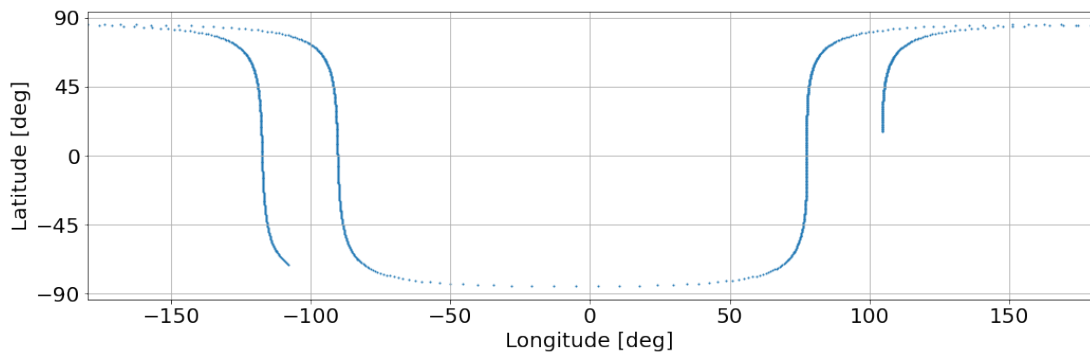
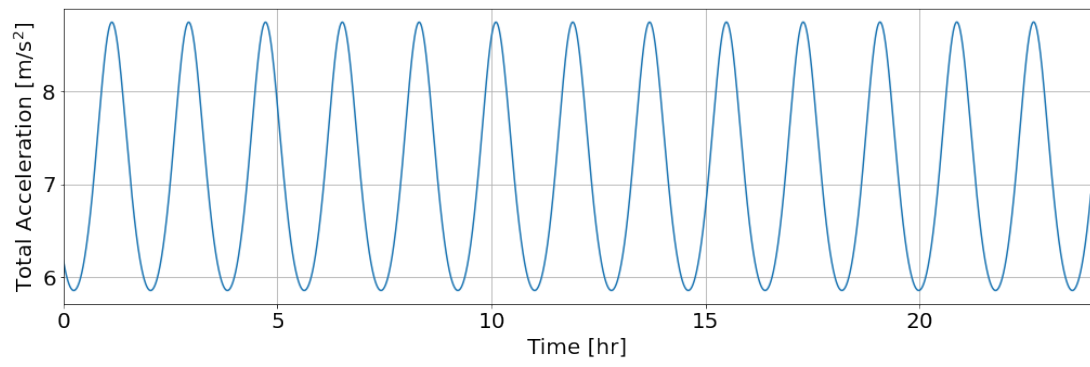
# Aerodynamic Acceleration Earth
acceleration_norm_aero_earth = dependent_variable_list[:, 16]
plt.plot( time_hours, acceleration_norm_aero_earth, label='Aerodynamic Earth')

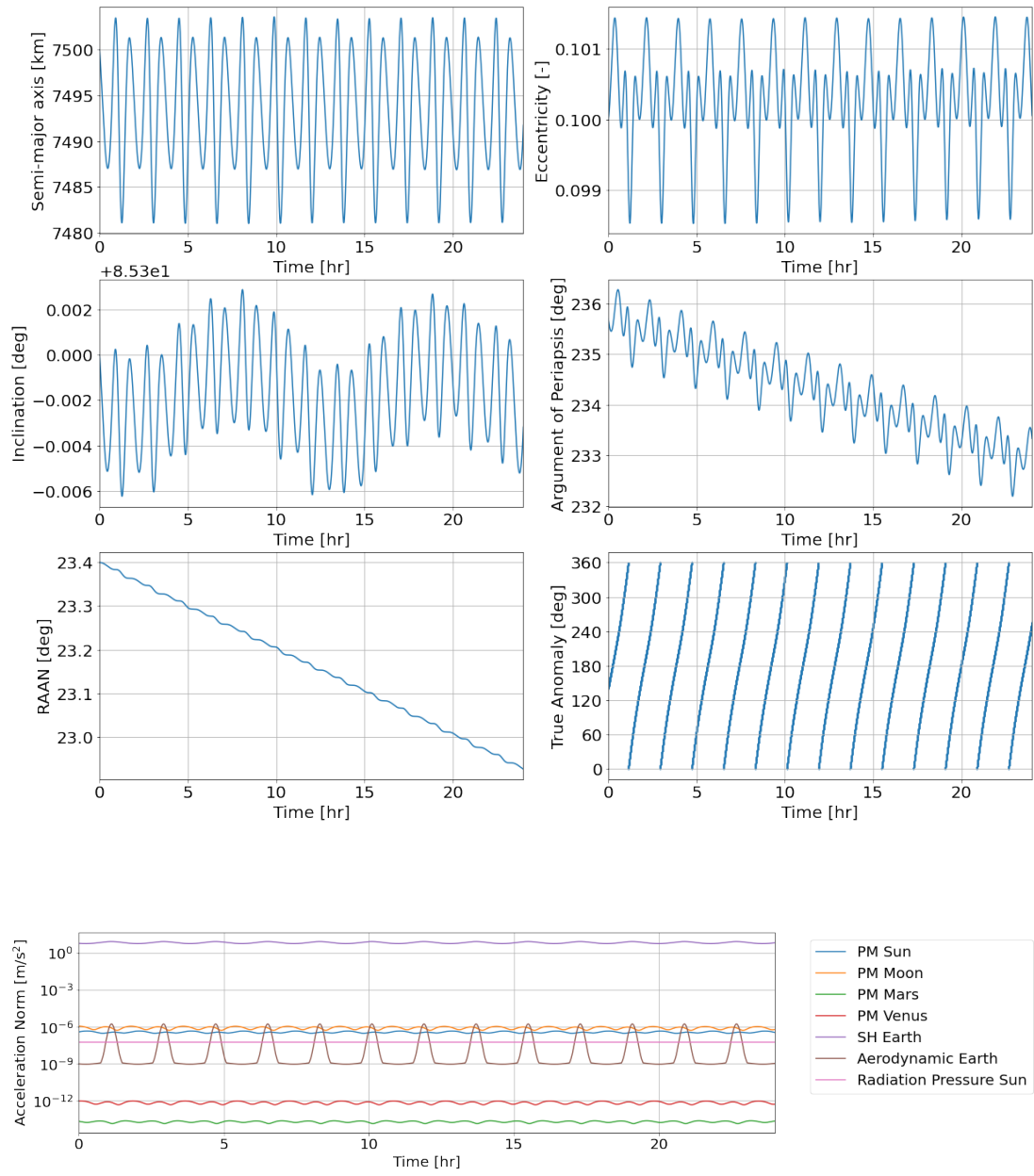
# Cannonball Radiation Pressure Acceleration Sun
acceleration_norm_rp_sun = dependent_variable_list[:, 17]
plt.plot( time_hours, acceleration_norm_rp_sun, label='Radiation Pressure Sun')

plt.grid()
plt.legend( bbox_to_anchor=(1.04,1) )
plt.xlim( [min(time_hours), max(time_hours)] )
plt.yscale('log')
plt.xlabel( 'Time [hr]' )
plt.ylabel( 'Acceleration Norm [m/s2]' )

plt.savefig( fname = f'{latex_image_path}acceleration_norms.png',
    ↳bbox_inches='tight')
#plt.savefig('acceleration_norms.png', bbox_inches='tight')

```



[]: