

```

1 # vehicle_setup.py
2 #
3 # Created: Nov 2023, J. Frank
4 # Modified:
5
6 """ Setup File for the Aircraft Design Seminar 2023/24 Reference
7 Aircraft
8 """
9
10 # -----
11 #   Imports
12 # -----
13
14 import numpy as np
15 import SUAVE
16 from SUAVE.Core import Units
17 from SUAVE.Methods.Propulsion.turbofan_sizing import turbofan_sizing
18 from SUAVE.Methods.Geometry.Two_Dimensional.Planform import
19 wing_segmented_planform
20 from copy import deepcopy
21
22 # -----
23 #   Define the Vehicle
24 # -----
25
26 def vehicle_setup():
27
28     # -----
29     #   Initialize the Vehicle
30
31     # -----
32     vehicle = SUAVE.Vehicle()
33     vehicle.tag = 'Reference_Aircraft'
34
35
36     #   Vehicle-level Properties
37
38     # -----
39     # mass properties
40     vehicle.mass_properties.max_takeoff          = 79015.8    # kg
41     vehicle.mass_properties.takeoff               = 79015.8    # kg
42     vehicle.mass_properties.operating_empty      = 62746.4    # kg
43     vehicle.mass_properties.takeoff              = 79015.8    # kg

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44     vehicle.mass_properties.max_zero_fuel          = 62732.0    # kg
45     vehicle.mass_properties.cargo                = 10000. * Units.kilogram
46     vehicle.mass_properties.center_of_gravity    = [[ 15.30987849
47 , 0. , -0.48023939]]
47     vehicle.mass_properties.moments_of_inertia.tensor = [[3173074.17,
48 0 , 28752.77565],[0 , 3019041.443, 0],[0, 0, 5730017.433]] # estimated
48 , not correct
48     vehicle.design_mach_number                  = 0.78
49     vehicle.design_range                      = 3582 * Units.miles
50     vehicle.design_cruise_alt                 = 35000.0 * Units.ft
51
52     # envelope properties
53     vehicle.envelope.ultimate_load = 3.75
54     vehicle.envelope.limit_load   = 1.5
55
56     # basic parameters
57     vehicle.reference_area        = 124.862
58     vehicle.passengers           = 170
59     vehicle.systems.control      = "fully powered"
60     vehicle.systems.accessories = "longe range"
61
62
# -----
63     # Main Wing
64
# -----
65
66     wing = SUAVE.Components.Wings.Main_Wing()
67     wing.tag = 'main_wing'
68
69     wing.aspect_ratio          = 10.18
70     wing.sweeps.quarter_chord = 25 * Units.deg
71     wing.thickness_to_chord   = 0.1
72     wing.taper                 = 0.1
73
74     wing.spans.projected      = 34.32
75
76     wing.chords.root          = 7.760 * Units.meter
77     wing.chords.tip            = 0.782 * Units.meter
78     wing.chords.mean_aerodynamic = 4.235 * Units.meter
79
80     wing.areas.reference      = 124.862
81     wing.areas.wetted          = 225.08
82
83     wing.twists.root          = 4.0 * Units.degrees
84     wing.twists.tip            = 0.0 * Units.degrees
85
86     wing.origin                = [[13.61,0,-0.93]]
87     wing.aerodynamic_center    = [0,0,0]
88

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89     wing.vertical          = False
90     wing.symmetric         = True
91     wing.high_lift        = True
92
93     wing.flap_ratio       = 0.3
94
95     wing.dynamic_pressure_ratio = 1.0
96
97
98     # Wing Segments
99     root_airfoil           = SUAVE.Components.Airfoils
100    .Airfoil()
101    root_airfoil.coordinate_file = 'Airfoils/B737a.txt'
102    segment                 = SUAVE.Components.Wings.
103    Segment()
104    segment.tag             = 'Root'
105    segment.percent_span_location = 0.0
106    segment.twist            = 4. * Units.deg
107    segment.root_chord_percent = 1.
108    segment.thickness_to_chord = 0.1
109    segment.dihedral_outboard = 2.5 * Units.degrees
110    segment.sweeps.quarter_chord = 28.225 * Units.degrees
111    segment.thickness_to_chord = .1
112    segment.append_airfoil(root_airfoil)
113    wing.append_segment(segment)
114
115    yehudi_airfoil          = SUAVE.Components.Airfoils
116    .Airfoil()
117    yehudi_airfoil.coordinate_file = 'Airfoils/B737b.txt'
118    segment                 = SUAVE.Components.Wings.
119    Segment()
120    segment.tag             = 'Yehudi'
121    segment.percent_span_location = 0.324
122    segment.twist            = 0.047193 * Units.deg
123    segment.root_chord_percent = 0.5
124    segment.thickness_to_chord = 0.1
125    segment.dihedral_outboard = 5.5 * Units.degrees
126    segment.sweeps.quarter_chord = 25. * Units.degrees
127    segment.thickness_to_chord = .1
128    segment.append_airfoil(yehudi_airfoil)
129    wing.append_segment(segment)
130
131    mid_airfoil              = SUAVE.Components.Airfoils
132    .Airfoil()
133    mid_airfoil.coordinate_file = 'Airfoils/B737c.txt'
134    segment                 = SUAVE.Components.Wings.
135    Segment()
136    segment.tag             = 'Section_2'
137    segment.percent_span_location = 0.963
138    segment.twist            = 0.00258 * Units.deg
139    segment.root_chord_percent = 0.220
140    segment.thickness_to_chord = 0.1
141    segment.dihedral_outboard = 5.5 * Units.degrees

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136     segment.sweeps.quarter_chord      = 56.75 * Units.degrees
137     segment.thickness_to_chord       = .1
138     segment.append_airfoil(mid_airfoil)
139     wing.append_segment(segment)
140
141     tip_airfoil                      = SUAVE.Components.
142         Airfoils.Airfoil()
143     tip_airfoil.coordinate_file        = 'Airfoils/B737d.txt'
144     segment                           = SUAVE.Components.Wings.
145         Segment()
146     segment.tag                      = 'Tip'
147     segment.percent_span_location    = 1.
148     segment.twist                   = 0. * Units.degrees
149     segment.root_chord_percent      = 0.10077
150     segment.thickness_to_chord       = 0.1
151     segment.dihedral_outboard      = 0.
152     segment.sweeps.quarter_chord      = 0.
153     segment.thickness_to_chord       = .1
154     segment.append_airfoil(tip_airfoil)
155     wing.append_segment(segment)
156
157     # Fill out more segment properties automatically
158     wing = wing_segmented_planform(wing)
159
160     # control surfaces -----
161     slat                           = SUAVE.Components.Wings.
162         Control_Surfaces.Slat()
163     slat.tag                        = 'slat'
164     slat.span_fraction_start        = 0.2
165     slat.span_fraction_end          = 0.963
166     slat.deflection                = 0.0 * Units.degrees
167     slat.chord_fraction            = 0.075
168     wing.append_control_surface(slat)
169
170     flap                           = SUAVE.Components.Wings.
171         Control_Surfaces.Flap()
172     flap.tag                        = 'flap'
173     flap.span_fraction_start        = 0.2
174     flap.span_fraction_end          = 0.7
175     flap.deflection                = 0.0 * Units.degrees
176     flap.configuration_type         = 'double_slotted'
177     flap.chord_fraction            = 0.30
178     wing.append_control_surface(flap)
179
180     aileron                         = SUAVE.Components.Wings.
181         Control_Surfaces.Aileron()
182     aileron.tag                      = 'aileron'
183     aileron.span_fraction_start      = 0.7
184     aileron.span_fraction_end        = 0.963
185     aileron.deflection              = 0.0 * Units.degrees
186     aileron.chord_fraction           = 0.16
187     wing.append_control_surface(aileron)
188

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184
185
186     # add to vehicle
187     vehicle.append_component(wing)
188
189
190
# -----
191     # Horizontal Stabilizer
192
# -----
193
194     wing = SUAVE.Components.Wings.Horizontal_Tail()
195     wing.tag = 'horizontal_stabilizer'
196
197     wing.aspect_ratio          = 4.99
198     wing.sweeps.quarter_chord = 28.2250 * Units.deg
199     wing.thickness_to_chord   = 0.08
200     wing.taper                = 0.3333
201
202     wing.spans.projected      = 14.4
203
204     wing.chords.root          = 4.2731
205     wing.chords.tip           = 1.4243
206     wing.chords.mean_aerodynamic = 8.0
207
208     wing.areas.reference      = 41.49
209     wing.areas.exposed        = 59.354    # Exposed area of the
210     horizontal tail
211     wing.areas.wetted         = 71.81      # Wetted area of the
212     horizontal tail
213
214     wing.twists.root          = 3.0 * Units.degrees
215     wing.twists.tip           = 3.0 * Units.degrees
216
217     wing.origin               = [[33.02,0,1.466]]
218     wing.aerodynamic_center    = [0,0,0]
219
220     wing.dynamic_pressure_ratio = 0.9
221
222
223     # Wing Segments
224     segment                  = SUAVE.Components.Wings.Segment()
225     segment.tag                = 'root_segment'
226     segment.percent_span_location = 0.0
227     segment.twist               = 0. * Units.deg
228     segment.root_chord_percent = 1.0
229     segment.dihedral_outboard  = 8.63 * Units.degrees
230     segment.sweeps.quarter_chord = 28.2250 * Units.degrees
231     segment.thickness_to_chord = .1
232     wing.append_segment(segment)

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233
234     segment                      = SUAVE.Components.Wings.Segment()
235     segment.tag                  = 'tip_segment'
236     segment.percent_span_location = 1.
237     segment.twist                = 0. * Units.deg
238     segment.root_chord_percent  = 0.3333
239     segment.dihedral_outboard   = 0 * Units.degrees
240     segment.sweeps.quarter_chord = 0 * Units.degrees
241     segment.thickness_to_chord  = .1
242     wing.append_segment(segment)
243
244     # Fill out more segment properties automatically
245     wing = wing_segmented_planform(wing)
246
247     # control surfaces -----
248     elevator                     = SUAVE.Components.Wings.
249     Control_Surfaces.Elevator()
250     elevator.tag                = 'elevator'
251     elevator.span_fraction_start = 0.09
252     elevator.span_fraction_end   = 0.92
253     elevator.deflection         = 0.0 * Units.deg
254     elevator.chord_fraction     = 0.3
255     wing.append_control_surface(elevator)
256
257     # add to vehicle
258     vehicle.append_component(wing)
259
260
# -----
261     # Vertical Stabilizer
262
# -----
263
264     wing = SUAVE.Components.Wings.Vertical_Tail()
265     wing.tag = 'vertical_stabilizer'
266
267     wing.aspect_ratio            = 1.98865
268     wing.sweeps.quarter_chord   = 31.2 * Units.deg
269     wing.thickness_to_chord     = 0.08
270     wing.taper                  = 0.1183
271
272     wing.spans.projected        = 8.33
273     wing.total_length           = wing.spans.projected
274
275     wing.chords.root            = 10.1
276     wing.chords.tip              = 1.20
277     wing.chords.mean_aerodynamic = 4.0
278
279     wing.areas.reference         = 34.89
280     wing.areas.wetted            = 57.25
281
282     wing.twists.root             = 0.0 * Units.degrees

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283     wing.twists.tip          = 0.0 * Units.degrees
284
285     wing.origin              = [[26.944,0,1.54]]
286     wing.aerodynamic_center = [0,0,0]
287
288     wing.vertical            = True
289     wing.symmetric           = False
290     wing.t_tail              = False
291
292     wing.dynamic_pressure_ratio = 1.0
293
294
295     # Wing Segments
296     segment                  = SUAVE.Components.Wings.
297     Segment()
298     segment.tag               = 'root'
299     segment.percent_span_location = 0.0
300     segment.twist              = 0. * Units.deg
301     segment.root_chord_percent = 1.
302     segment.dihedral_outboard = 0 * Units.degrees
303     segment.sweeps.quarter_chord = 61.485 * Units.degrees
304     segment.thickness_to_chord = .1
305     wing.append_segment(segment)
306
307     segment                  = SUAVE.Components.Wings.
308     Segment()
309     segment.tag               = 'segment_1'
310     segment.percent_span_location = 0.2962
311     segment.twist              = 0. * Units.deg
312     segment.root_chord_percent = 0.45
313     segment.dihedral_outboard = 0. * Units.degrees
314     segment.sweeps.quarter_chord = 31.2 * Units.degrees
315     segment.thickness_to_chord = .1
316
317     segment                  = SUAVE.Components.Wings.
318     Segment()
319     segment.tag               = 'segment_2'
320     segment.percent_span_location = 1.0
321     segment.twist              = 0. * Units.deg
322     segment.root_chord_percent = 0.1183
323     segment.dihedral_outboard = 0.0 * Units.degrees
324     segment.sweeps.quarter_chord = 0.0
325     segment.thickness_to_chord = .1
326
327     # Fill out more segment properties automatically
328     wing = wing_segmented_planform(wing)
329
330     # add to vehicle
331     vehicle.append_component(wing)
332

```

```

333
334     # -----
335     # Fuselage
336
337     fuselage = SUAVE.Components.Fuselages.Fuselage()
338     fuselage.tag = 'fuselage'
339
340     fuselage.number_coach_seats      = vehicle.passengers
341     fuselage.seats_abreast         = 6
342     fuselage.seat_pitch            = 31. * Units.inches
343     fuselage.fineness.nose        = 1.6
344     fuselage.fineness.tail        = 2.
345
346     fuselage.lengths.nose          = 6.4
347     fuselage.lengths.tail          = 8.0
348     fuselage.lengths.cabin         = 28.85
349     fuselage.lengths.total         = 38.02
350     fuselage.lengths.fore_space   = 6.
351     fuselage.lengths.aft_space    = 5.
352
353     fuselage.width                = 3.74
354
355     fuselage.heights.maximum       = 3.74
356     fuselage.heights.at_quarter_length = 3.74
357     fuselage.heights.at_three_quarters_length = 3.65
358     fuselage.heights.at_wing_root_quarter_chord = 3.74
359
360     fuselage.areas.side_projected = 142.1948
361     fuselage.areas.wetted        = 385.51
362     fuselage.areas.front_projected = 12.57
363
364     fuselage.effective_diameter  = 3.74
365
366     fuselage.differential_pressure = 5.0e4 * Units.pascal # Maximum
367           differential pressure
368
369     # Segment
370     segment                         = SUAVE.Components.
371           Lofted_Body_Segment.Segment()
372     segment.tag                      = 'segment_0'
373     segment.percent_x_location       = 0.0000
374     segment.percent_z_location       = -0.00144
375     segment.height                  = 0.0100
376     segment.width                   = 0.0100
377     fuselage.Segments.append(segment)
378
379     # Segment
380     segment                         = SUAVE.Components.
381           Lofted_Body_Segment.Segment()
382     segment.tag                      = 'segment_1'
383     segment.percent_x_location       = 0.00576

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```

381     segment.percent_z_location      = -0.00144
382     segment.height                 = 0.7500
383     segment.width                  = 0.6500
384     fuselage.Segments.append(segment)
385
386     # Segment
387     segment                         = SUAVE.Components.
388         Lofted_Body_Segment.Segment()
389         segment.tag                  = 'segment_2'
390         segment.percent_x_location   = 0.02017
391         segment.percent_z_location   = 0.00000
392         segment.height              = 1.52783
393         segment.width               = 1.20043
394         fuselage.Segments.append(segment)
395
396     # Segment
397     segment                         = SUAVE.Components.
398         Lofted_Body_Segment.Segment()
399         segment.tag                  = 'segment_3'
400         segment.percent_x_location   = 0.03170
401         segment.percent_z_location   = 0.00000
402         segment.height              = 1.96435
403         segment.width               = 1.52783
404         fuselage.Segments.append(segment)
405
406     # Segment
407     segment                         = SUAVE.Components.
408         Lofted_Body_Segment.Segment()
409         segment.tag                  = 'segment_4'
410         segment.percent_x_location   = 0.04899
411         segment.percent_z_location   = 0.00431
412         segment.height              = 2.72826
413         segment.width               = 1.96435
414         fuselage.Segments.append(segment)
415
416     # Segment
417     segment                         = SUAVE.Components.
418         Lofted_Body_Segment.Segment()
419         segment.tag                  = 'segment_5'
420         segment.percent_x_location   = 0.07781
421         segment.percent_z_location   = 0.00861
422         segment.height              = 3.49217
423         segment.width               = 2.61913
424         fuselage.Segments.append(segment)
425
426     # Segment
427     segment                         = SUAVE.Components.
428         Lofted_Body_Segment.Segment()
429         segment.tag                  = 'segment_6'
430         segment.percent_x_location   = 0.10375
431         segment.percent_z_location   = 0.01005
432         segment.height              = 3.70130
433         segment.width               = 3.05565

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```

429     fuselage.Segments.append(segment)
430
431     # Segment
432     segment = SUAVE.Components.
433         Lofted_Body_Segment.Segment()
434         segment.tag = 'segment_7'
435         segment.percent_x_location = 0.16427
436         segment.percent_z_location = 0.01148
437         segment.height = 3.92870
438         segment.width = 3.71043
439         fuselage.Segments.append(segment)
440
441     # Segment
442     segment = SUAVE.Components.
443         Lofted_Body_Segment.Segment()
444         segment.tag = 'segment_8'
445         segment.percent_x_location = 0.22478
446         segment.percent_z_location = 0.01148
447         segment.height = 3.92870
448         segment.width = 3.92870
449         fuselage.Segments.append(segment)
450
451     # Segment
452     segment = SUAVE.Components.
453         Lofted_Body_Segment.Segment()
454         segment.tag = 'segment_9'
455         segment.percent_x_location = 0.69164
456         segment.percent_z_location = 0.01292
457         segment.height = 3.81957
458         segment.width = 3.81957
459         fuselage.Segments.append(segment)
460
461     # Segment
462     segment = SUAVE.Components.
463         Lofted_Body_Segment.Segment()
464         segment.tag = 'segment_10'
465         segment.percent_x_location = 0.71758
466         segment.percent_z_location = 0.01292
467         segment.height = 3.81957
468         segment.width = 3.81957
469         fuselage.Segments.append(segment)
470
471     # Segment
472     segment = SUAVE.Components.
473         Lofted_Body_Segment.Segment()
474         segment.tag = 'segment_11'
475         segment.percent_x_location = 0.78098
476         segment.percent_z_location = 0.01722
477         segment.height = 3.49217
478         segment.width = 3.71043
479         fuselage.Segments.append(segment)
480
481     # Segment

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```

477     segment = SUAVE.Components.
478     Lofted_Body_Segment.Segment()
479     segment.tag = 'segment_12'
480     segment.percent_x_location = 0.85303
481     segment.percent_z_location = 0.02296
482     segment.height = 3.05565
483     segment.width = 3.16478
484     fuselage.Segments.append(segment)
485
486     # Segment
487     segment = SUAVE.Components.
488     Lofted_Body_Segment.Segment()
489     segment.tag = 'segment_13'
490     segment.percent_x_location = 0.91931
491     segment.percent_z_location = 0.03157
492     segment.height = 2.40087
493     segment.width = 1.96435
494     fuselage.Segments.append(segment)
495
496     # Segment
497     segment = SUAVE.Components.
498     Lofted_Body_Segment.Segment()
499     segment.tag = 'segment_14'
500     segment.percent_x_location = 1.00
501     segment.percent_z_location = 0.04593
502     segment.height = 1.09130
503     segment.width = 0.21826
504     fuselage.Segments.append(segment)
505
506
507     # -----#
508     # Nacelles
509
510     # nacelle = SUAVE.Components.Nacelles.
511     Nacelle()
512     # nacelle.tag = 'nacelle_1'
513     # nacelle.length = 2.71
514     # nacelle.inlet_diameter = 1.90
515     # nacelle.diameter = 2.05
516     # nacelle.areas.wetted = 1.1*np.pi*nacelle.diameter
517     *nacelle.length
518     # nacelle.origin = [[13.72, -4.86,-1.9]]
519     # nacelle.flow_through = True
520     # nacelle.Airfoil.NACA_4_series_flag = True
521     # nacelle.Airfoil.coordinate_file = '2410'
522     # nacelle_2 = deepcopy(nacelle)
523     # nacelle_2.tag = 'nacelle_2'
524     # nacelle_2.origin = [[13.72, 4.86,-1.9]]
525     #

```

```

523     # vehicle.append_component(nacelle)
524     # vehicle.append_component(nacelle_2)
525
526
# -----
527     # Propulsor
528
# -----
529
530     propulsor = SUAVE.Components.Energy.Networks.Simple_Propulsor()
531     propulsor.tag = 'turbofan'
532
533     # setup
534     # # This origin is overwritten by
535     compute_component_centers_of_gravity(base,compute_propulsor_origin=True)
536     propulsor.origin          = [[13.72, 4.86,-1.9],[13.72, -4.86,-1.9]]
537     propulsor.engine_length   = 2.
538     propulsor.number_of_engines = 2
539     propulsor.max_thrust      = 400e3
540     propulsor.fuel_flow       = 1.
541
542     vehicle.append_component(propulsor)
543
# -----
544     # Fuel
545
# -----
546     fuel                      = SUAVE.Components.
Physical_Component()
547     vehicle.fuel              = fuel
548     fuel.mass_properties.mass = vehicle.mass_properties.
max_takeoff_vehicle.mass_properties.max_fuel
549     fuel.origin               = vehicle.wings.main_wing.
mass_properties.center_of_gravity
550     fuel.mass_properties.center_of_gravity= vehicle.wings.main_wing.
aerodynamic_center
551
552
# -----
553     # Landing Gear
554
# -----
555     landing_gear              = SUAVE.Components.
Landing_Gear.Landing_Gear()
556     landing_gear.tag          = "main_landing_gear"
557     landing_gear.main_tire_diameter = 1.12000 * Units.m
558     landing_gear.nose_tire_diameter = 0.6858 * Units.m
559     landing_gear.main_strut_length = 1.8 * Units.m
560     landing_gear.nose_strut_length = 1.3 * Units.m
561     landing_gear.main_units    = 1      #number of nose

```

```

561 landing_gear
562     landing_gear.nose_units           = 1      #number of nose
563     landing_gear.main_wheels         = 2      #number of wheels on
564     landing_gear.nose_wheels         = 2      #number of wheels on
565     vehicle.landing_gear           = landing_gear
566
567 #
# -----
568     # Vehicle Definition Complete
569
570 #
# -----
571     return vehicle
572
573
574 #
# -----
575 # Define the Configurations
576 #
# -----
577
578 def configs_setup(vehicle):
579
580
581     # Initialize Configurations
582
583     configs = SUAVE.Components.Configs.Config.Container()
584
585     base_config = SUAVE.Components.Configs.Config(vehicle)
586     base_config.tag = 'base'
587     base_config.landing_gear.gear_condition
588                     = 'up'
589     configs.append(base_config)
590
591     # Cruise Configuration
592
593     config = SUAVE.Components.Configs.Config(base_config)
594     config.tag = 'cruise'
595     configs.append(config)
596     config.wings['main_wing'].control_surfaces.flap.deflection
597                     = 0. * Units.deg
598     config.wings['main_wing'].control_surfaces.slat.deflection
599                     = 0. * Units.deg

```

```
599 # -----
600     # Takeoff Configuration
601
602     config = SUAVE.Components.Configs.Config(base_config)
603     config.tag = 'takeoff'
604     config.wings['main_wing'].control_surfaces.flap.deflection
605         = 20. * Units.deg
606     config.wings['main_wing'].control_surfaces.slat.deflection
607         = 25. * Units.deg
608
609     configs.append(config)
610
611 # -----
612     # Landing Configuration
613
614     config = SUAVE.Components.Configs.Config(base_config)
615     config.tag = 'landing'
616
617     config.wings['main_wing'].control_surfaces.flap.deflection
618         = 30. * Units.deg
619     config.wings['main_wing'].control_surfaces.slat.deflection
620         = 25. * Units.deg
621
622     configs.append(config)
623
624 return configs
```