# Aircraft_dynamics.jl

Open Source Aircraft Design Software

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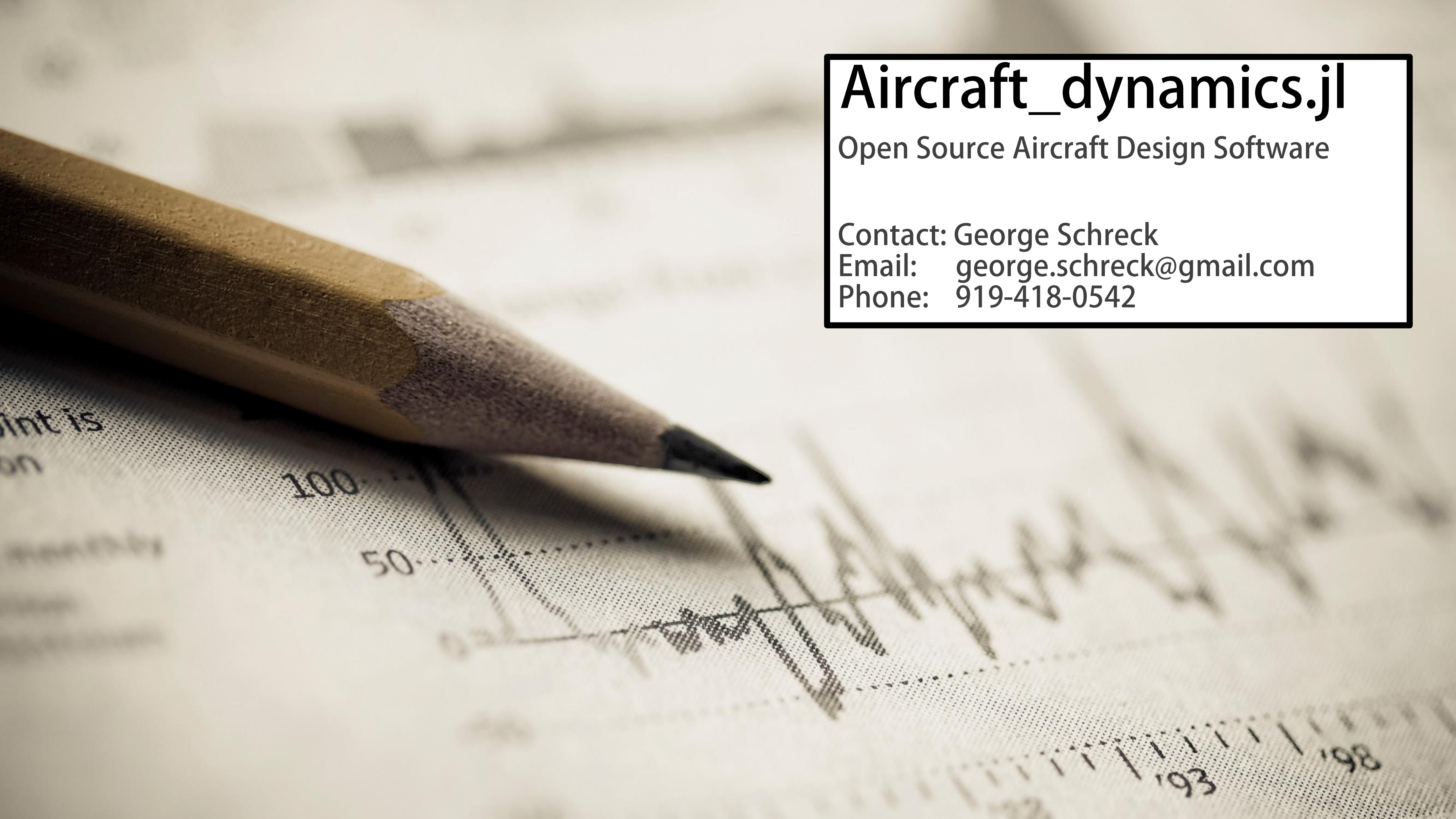


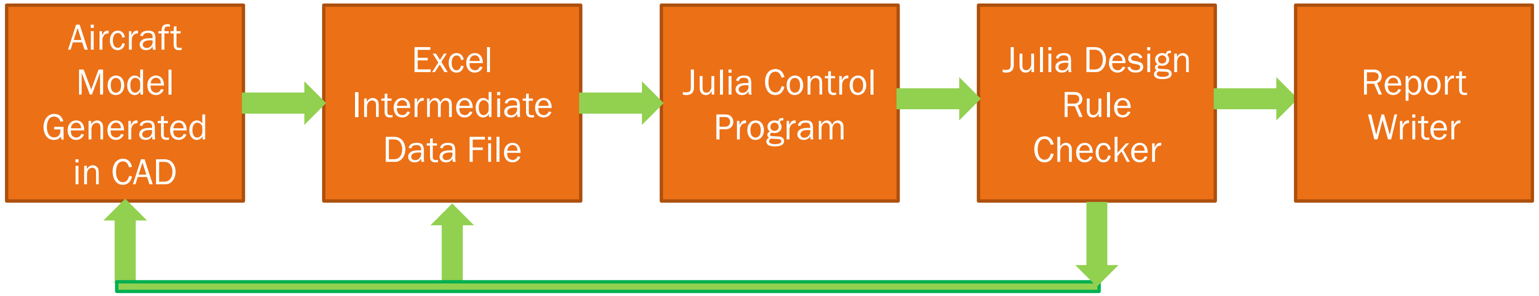
# Problems

- Open source or inexpensive software does not exist to do the end to end calculations of a sub-sonic, fixed wing aircraft
- Much of the software that is available requires extensive training to use effectively
- Multiple software packages exist that perform part of the solution, e.g. XFLR
- A significant number of designs have been produced that are inefficient, unstable or just plain unsafe.

# Goals

- Produce a single, extensible library of software routines that can perform many of the calculations in basic aircraft design
- Provide a wrapper program that executes the library to analyze a basic aircraft design
- Flag potential design problems that violate best known design practices
- Code the software using a modern scientific, open source language
- Provide the source and examples that can be used to help understand the tool
- Write the software as a collaborative learning exercise

# High Level Initial Architecture

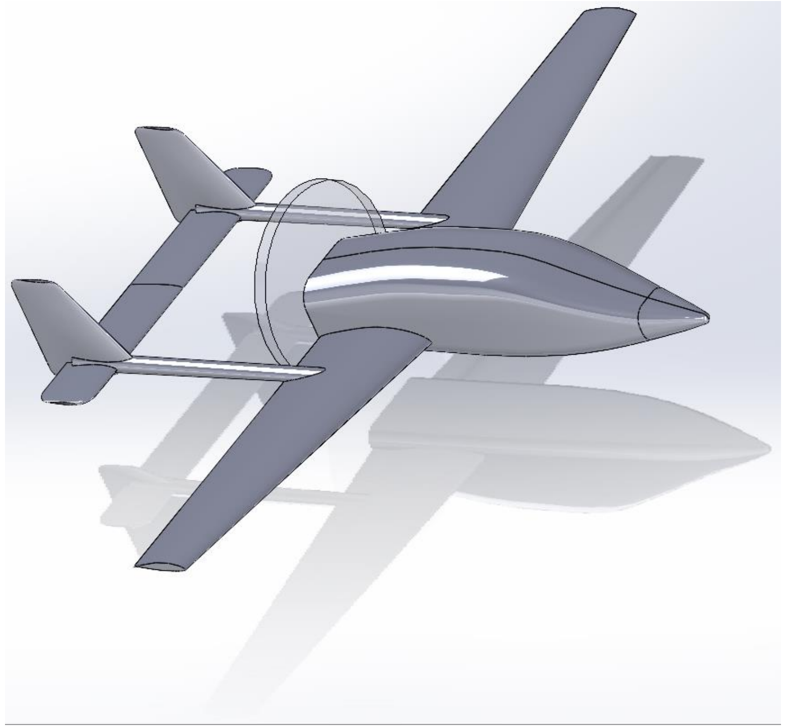



- Julia programming language was chosen because, since its inception at MIT, it has gained a great deal of support worldwide by universities as well as industry
- It has many of the same features as Matlab and Python
- The software is deliberately written as a library of subroutines that can be independently modified, tested or added to as necessary to improve operation or enhance capabilities

# Software Status

- Experiments have been run to use named variables in Solidworks to generate the required data for the Intermediate Data file. This work is still in its infancy. Note, that any CAD system could be used. There is no attempt to use a particular tool.
- Excel Intermediate Data File contains formatted data with preset variable names. It does not require particular data ordering or units. It converts all units to metric and stores the data within the program. This file can be generated by a CAD system with scripting or “by hand”. The software ignores additional variables it doesn’t require.
- The Julia control program and software libraries are in work with some features demonstratable. There are about 24 discrete calculations that are being reported. Additional support subroutines are included in the library. The code base is approximately 800 lines and growing. Some of the code is ‘demonstration code” that can be rewritten to execute more efficiently.
- The design rule checker and report writer are not started.

# Example Input File



| Name | Value | Units | Notes |
|---|---|---|---|
| SVstart | 30 | m/s | Simulation starting velocity |
| SVend | 200 | m/s | Simulation ending velocity |
| SVincr | 5 | m/s | Simulation velocity increment size |
| T | 21 | C | Air temperature |
| m | 1504 | lb | Takeoff mass |
| M | 182864 | in lb | Aircraft moment (from nose) |
| WSF | 108 | % | Wing load safety factor |
| b | 26 | ft | Wing span |
| Ct | 24 | in | Wing tip chord |
| Cr | 54 | in | Wing root chord |
| λ | 7.31 | degrees | Wing Sweep Angle |
| lwdle | 113.78 | in | Distance datum (nose) to wing LE |
| lhdle | 240 | in | Distance datum (nose) to HS LE |
| lvdle | 229.5 | in | Distance datum (nose) to VS LE |
| Cth | 18 | in | Horizontal stab tip chord |
| Crh | 18 | in | Horizontal stab root chord |
| bh | 132 | in | Horizontal stab span |
| λh | 0 | degrees | Horizontal stab sweep Angle |
| λv | 30.69 | degrees | Vertical stab sweep Angle |
| Ctv | 18.5 | in | Vertical stab tip chord |
| Crv | 44.8 | in | Vertical stab root chord |
| bv | 45 | in | Vertical stab height |
| Nv | 2 | count | Number of vertical stabs |
| Cl | 1.8 | kg/m^3 | Main wing coefficient of lift |
| Clh | 1.8 | kg/m^3 | Horizontal Stab Coefficient of lift |
| Swetf | 20 | m^2 | Fuselage area exposed to air |
| dfuse | 0.8 | m | Fuselage maximum diameter |
| lf | 7 | m | Fuselage maximum length |

```
>>> Converted 1504.00 lb to 682.20 kg
>>> Converted 182864.00 in lb to 2106.82 kgm
>>> Converted 24.00 in to 0.61 m
>>> Converted 54.00 in to 1.37 m
>>> Converted 26.00 ft to 7.92 m
>>> Converted 18.00 in to 0.46 m
>>> Converted 18.00 in to 0.46 m
>>> Converted 132.00 in to 3.35 m
>>> Converted 18.50 in to 0.47 m
>>> Converted 44.80 in to 1.14 m
>>> Converted 45.00 in to 1.14 m
>>> Converted 113.78 in to 2.89 m
>>> Converted 240.00 in to 6.10 m
>>> Converted 229.50 in to 5.83 m
>>> Converted 750.25 kg to 7357.46 N
>>> Converted 68.05 kg to 667.34 N
```

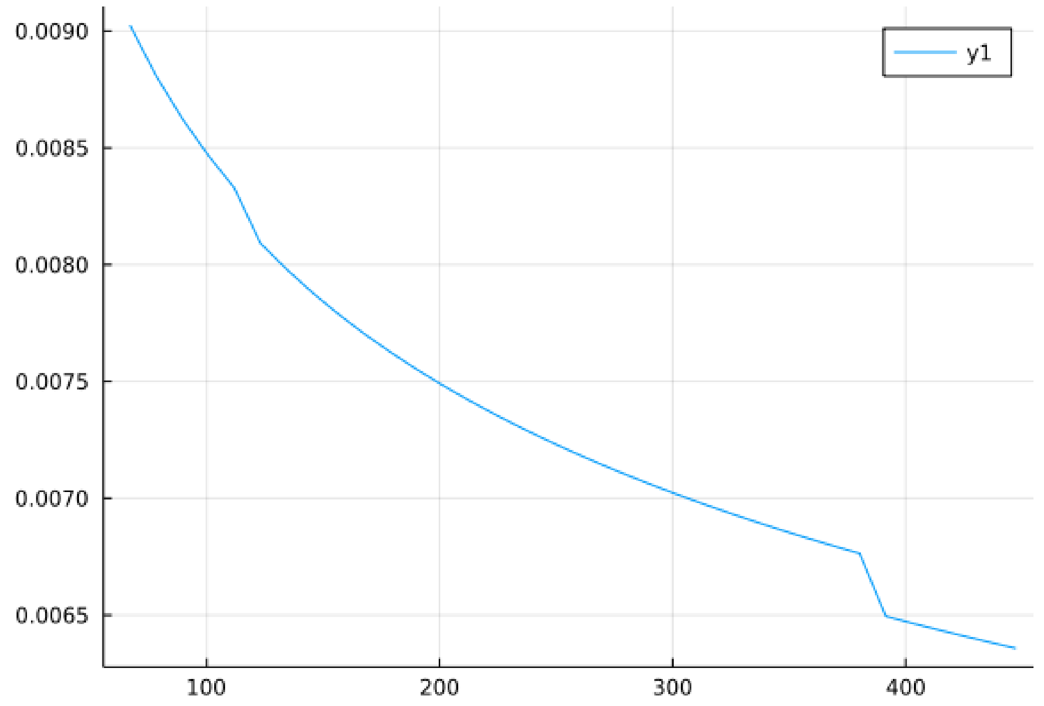
- The model above was generated in Solidworks and serves as the basis for the test design
- The spreadsheet at the right was hand generated from the CAD data.
- The black box at the right contains the Julia processor adjusting the units to be appropriate for each calculation performed

# Current Output Data

| Row | Name | Value | Units | Notes |
|---|---|---|---|---|
| | Any | Any | Any | Any |
| 1 | SVstart | 30 | m/s | Simulation starting velocity |
| 2 | SVend | 200 | m/s | Simulation ending velocity |
| 3 | SVincr | 5 | m/s | Simulation velocity increment si… |
| 4 | T | 21 | C | Air temperature |
| 5 | m | 682.202 | kg | Takeoff mass |
| 6 | M | 2106.82 | kgm | Aircraft moment (from nose) |
| 7 | WSF | 108 | % | Wing load safety factor |
| 8 | b | 7.9248 | m | Wing span |
| 9 | Ct | 0.6096 | m | Wing tip chord |
| 10 | Cr | 1.3716 | m | Wing root chord |
| 11 | λ | 7.31 | degrees | Wing Sweep Angle |
| 12 | lwdle | 2.89001 | m | Distance datum (nose) to wing LE |
| 13 | lhdle | 6.096 | m | Distance datum (nose) to HS LE |
| 14 | lvdle | 5.8293 | m | Distance datum (nose) to VS LE |
| 15 | Cth | 0.4572 | m | Horizontal stab tip chord |
| 16 | Crh | 0.4572 | m | Horizontal stab root chord |
| 17 | bh | 3.3528 | m | Horizontal stab span |
| 18 | λh | 0 | degrees | Horizontal stab sweep Angle |
| 19 | λv | 30.69 | degrees | Vertical stab sweep Angle |
| 20 | Ctv | 0.4699 | m | Vertical stab tip chord |
| 21 | Crv | 1.13792 | m | Vertical stab root chord |
| 22 | bv | 1.143 | m | Vertical stab height |
| 23 | Nv | 2 | count | Number of vertical stabs |
| 24 | Cl | 1.8 | kg/m^3 | Main wing coefficient of lift |
| 25 | Clh | 1.8 | kg/m^3 | Horizontal Stab Coefficient of l… |
| 26 | Swetf | 20 | m^2 | Fuselage area exposed to air |
| 27 | dfuse | 0.8 | m | Fuselage maximum diameter |
| 28 | lf | 7 | m | Fuselage maximum length |
| 29 | Cg | 3.08826 | m | Center of gravity |
| 30 | cMAC | 1.03945 | m | Mean wing chord |
| 31 | Sw | 7.85031 | m^2 | Wing area |
| 32 | AR | 8.0 | | Wing aspect ratio |
| 33 | AC | 0.481427 | m | Wing AC from LE |
| 34 | d | 1.7272 | m | Wing MAC Distance to root |
| 35 | cMACh | 0.4572 | m | Horizontal stab mean chord |
| 36 | Sht | 1.5329 | m^2 | Horizontal stab area |
| 37 | ARh | 7.33333 | | Horizontal stab aspect ratio |
| 38 | ACh | 0.1143 | m | Horizontal stab AC from LE |
| 39 | cMACv | 0.4572 | m | Vertical stab mean chord |
| 40 | Svt | 1.83774 | m^2 | Vertical stab area |
| 41 | ARv | 1.4218 | | Vertical stab aspect ratio |
| 42 | ACv | 0.26041 | m | Vertical stab AC from LE |
| 43 | Lht | 2.83886 | m | Length ACs of wing to h stab |
| 44 | Lvt | 2.71827 | m | Length ACs of wing to v stab |
| 45 | Cht | 0.533297 | | Coefficient of horizontal tail |
| 46 | Cvt | 0.0802974 | | Coefficient of vertical tail |
| 47 | W | 7357.46 | N | Wing load (level flight) |
| 48 | Wh | 667.335 | N | Horizontal stab load |
| 49 | Wload | 95.5697 | kg/m^2 | Wing loading |
| 50 | Vstall | 29.1562 | m/s | Wing stall speed |
| 51 | Vhstall | 19.8713 | m/s | Horizontal stab stall speed |

>> End of Script <<

- The output at the left is the internal data matrix that is used for storing the aircraft data. Rows 1 – 28 match the data being read in. The balance are calculated values.
- The software adjusts the units to remain consistent for each calculation type. Ultimately, the report generator will determine the output units
- The graph at the bottom represents the first unformatted drag plot generated from the calculated Reynolds number using the velocity and fuselage dimensions. Note that it is currently not interpolating the skin friction drag curves, hence the steps in the graph



# Next Steps

- The potential for development of the product is limited to the size of the team's imagination.
- Near term goals:
  - Completing the calculations for static analysis of the aircraft design:  additional drag components, basic performance, stability, etcetera
  - Update all coordinate calculations to 3D
  - Improve some of the calculation accuracies
  - More tightly integrate airfoil shapes into the calculations
  - Start building the framework for design rule checking the aircraft design
  - Add control surface forces to enable control system design
- Longer term goals:
  - Add a detailed report generator, with graphs and information on design margins against design rules
  - Add dynamic modeling/predictions

# Closing Thoughts

- The intent is to move the software to an open source repository for further development.
- It will be provided under one of the standard open source licenses.
- Hopefully, it will be embraced by multiple people to carry the torch of learning, improvement and enhancement while providing a tool to improve safety and design consistency