Overview

<u>Original Work Proposal</u>

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Date: January 6, 2026

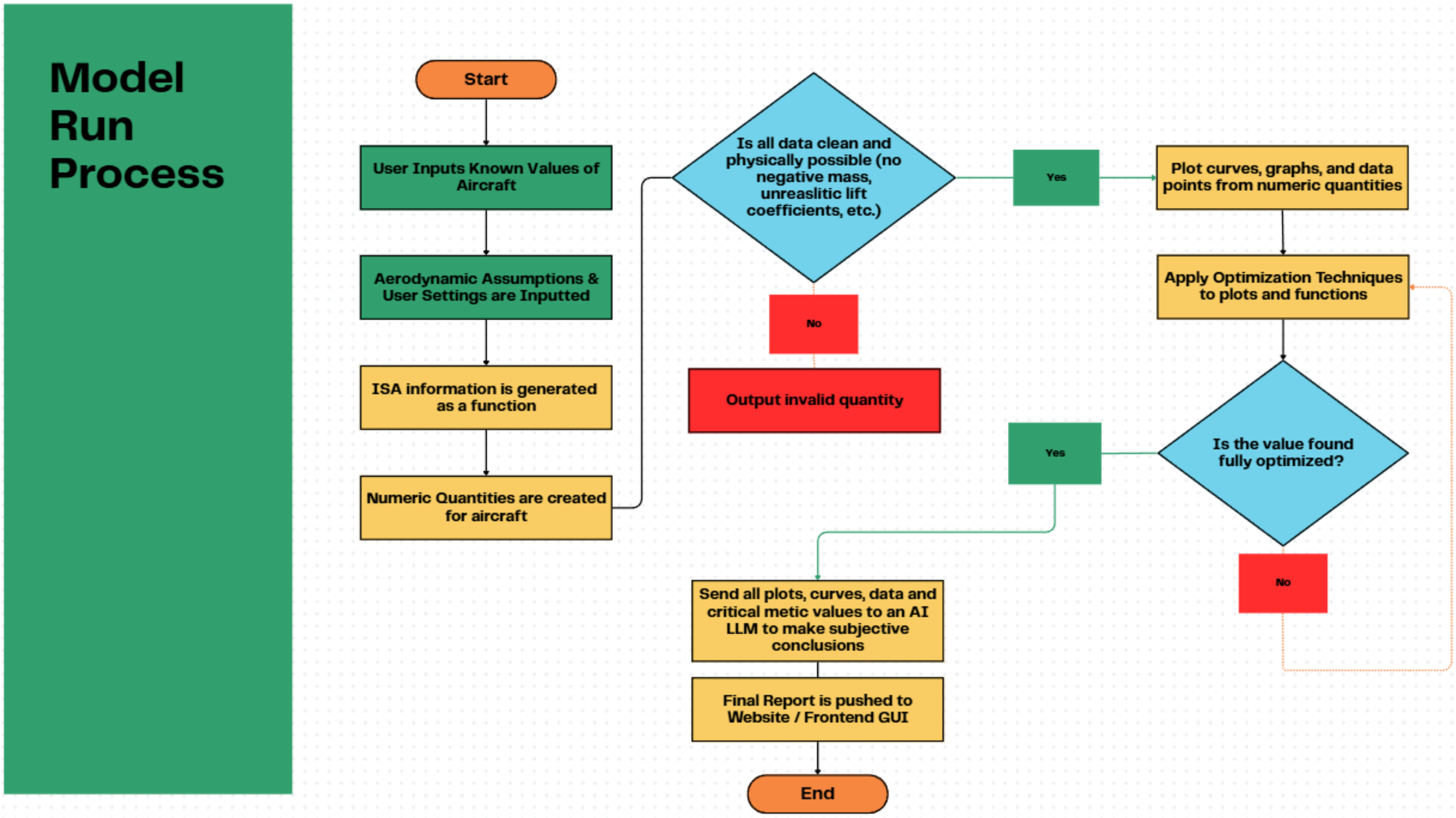
Introduction and Statement of Purpose

Over the course of my life, particularly in the past few years, my insatiable curiosity and quest for knowledge have fueled an ambition within me to create, innovate, and discover. My aspirations as an aerospace engineer are to advance human technology and make meaningful contributions to society. My most meaningful work has been the development of a spacecraft (currently US Patent Pending) that serves to clear Earth's orbit of space debris. As a novel and completely feasible idea, it is currently being submitted to various contests and conferences, and will hopefully be pitched to provide a tangible and functional impact.

After self-reconciliation, my ISM original work will innovate a meaningful aerospace engineering tool that serves a real purpose, enabling specific calculations on aircraft. I am making a physics-based aircraft flight performance simulator intended for preliminary aerospace engineering analysis. This will be a custom-built computational tool that models the performance of a subsonic aircraft, utilizing aerodynamic and performance equations to establish a first-principles model. Real use cases for this could include, but are not limited to, engineers testing whether a proposed aircraft configuration can meet arbitrary predetermined mission requirements. Finally, this simulator will determine performance margins and can provide curve analysis information on set data quantities. To serve as a physical demonstration, I will input set data into this simulator, analyze and interpret the data to showcase the use cases of this.

Simulator Capabilities:

- Model atmospheric conditions using the ISA
- Calculate lift, drag, and power required for a steady and level flight
- Compare power available vs power required
- Generate the following performance metrics:
    - Stall speed
    - Power required vs. airspeed
    - Power available vs. airspeed
    - Rate of climb
    - Best endurance speed
    - Best range speed
    - Service and absolute ceiling



Model Run Process
Start
User Inputs Known Values of Aircraft
Aerodynamic Assumptions & User Settings are Inputted
ISA information is generated as a function
Numeric Quantities are created for aircraft
Is all data clean and physically possible (no negative mass, unreaslitic lift coefficients, etc.)
Yes
No
Output invalid quantity
Plot curves, graphs, and data points from numeric quantities
Apply Optimization Techniques to plots and functions
Is the value found fully optimized?
Yes
No
Send all plots, curves, data and critical metic values to an AI LLM to make subjective conclusions
Final Report is pushed to Website / Frontend GUI
End

Subsystems

Atmospheric Condition & Standard Earth Systems model

This model is the foundation of the aircraft performance simulator; its primary purpose is to compute set atmospheric properties affecting the aircraft as a function of altitude using standardized, physics-based approaches. Without an accurate atmospheric model, the simulator would not produce meaningful results, making this subsystem critical to the overall practicality and usability of the project. This model will be based on the International Standard Atmosphere (ISA), the industry standard reference atmosphere. The ISA assumes a dry, hydrostatic atmosphere with no weather effects. For the scope of this project and constraints, the model will be implemented and cover the scope all the way from sea level through the troposphere, up to approximately 11 kilometers, which fully covers the operational gradient of most subsonic aircraft. This is an appropriate assumption and aligns with real aerospace engineering practices.

The Standard Earth portion of the model defines all the necessary physical constants that describe the properties of the Earth and air. These constants include sea-level temperature, sea-level pressure, sea-level density, gravitational acceleration, the temperature lapse rate, the specific gas constant for air, and the ratio of specific heats. These values will be defined once and used consistently throughout the simulator to ensure numerical stability and repeatability. All constants will be documented throughout the final report to maintain transparency and scientific rigor, along with fact-checking purposes. Using these constants, the atmospheric model will compute temperature as a function of altitude using multiple equations and separate functions. Pressure will be calculated using the hydrostatic equilibrium equation combined with the ideal gas law, which relates pressure changes to altitude under the assumption of a static atmosphere. Density will then be derived directly from the ideal gas law using the calculated temperature and pressure values.

The Atmospheric Condition model will be implemented as a modular computational function (most likely MATLAB and Python for verification). This function will accept altitude as an input and return a structured set of atmospheric properties. As a modular function, it can be called repeatedly during the performance curve generation optimization routines. To ensure accuracy and reliability, before publishing the model, I will manually validate the atmospheric model against published ISA reference tables at multiple altitudes between the aforementioned 0-11km. Computed values will be compared against standard values, and any deviations from the norm will be quantified and flagged. As part of a report, results will be documented to demonstrate that the model adheres to accepted aerospace standards and produces physically accurate outputs.

Notable assumptions and limitations will be stated for this subsystem. The model will not account for real-world weather phenomena such as wind, turbulence, humidity, or temperature deviations from standard day conditions. Gravity will be treated as a constant value (9.81 m/s/s), and Earth will be assumed to be non-rotating and perfectly spherical. Unfortunately, attempting to incorporate these quantities in the model would conflate the technical scope beyond feasibility.

Additional Option: (to demonstrate additional rigor and growth potential if this model is to be professionally presented) In addition to temperature, pressure, and density, the model will compute the local speed of sound as a multivariable function of temperature, altitude, and other quantities. This calculates the Mach number and opens doors to support compressibility-related quantities. This opens the scope to supersonic aircraft, and including the speed of sound increases the robustness and extensibility of the simulator for future improvements.

Raw Logistic Modulator

The Raw Logistic Modulator serves as a liaison between the input aircraft values and the core physics-based calculations of the simulator. The primary function is to take raw input data, such as geometry, weight, propulsion information, and aerodynamic coefficients, and convert them into standardized, numeric variables specific to each aircraft **(see variable list below)**. The result is that the simulator now operates on clean, validated data, preventing physically impossible scenarios (e.g., negative mass or unrealistic lift coefficients).

In addition, the Raw Logistic Modulator manages the configuration of the algorithmic logic required for different analysis modes. For example, it determines which flight assumptions apply and selects the appropriate aerodynamic model.

Variable List

Optimal Statistics Calculator

The Optimal Statistics Calculator has the duty for extracting meaningful performance metrics from the raw numerical outputs generated by the previous modules. The main deliverables are performance curves, contour plots, and critical metric values (minimum thrust required, maximum level flight speed, etc.).

Critical metric values are determined using techniques such as curve analysis, interpolation, and various optimization methods applied to numerical quantities and functions. Beyond identifying optimal points, the Optimal Statistics Calculator also evaluates performance margins and sensitivities, helping end users understand how much risk or how close to limits the aircraft is operating at. This system is ultimately the creator of the engineering insight.

Performance Curves Examples (non-exhaustive):

1. Drag vs Airspeed
2. Power Required vs Airspeed
3. Lift Coefficient vs Airspeed

Report Summarizer

The report summarizer will be the final part of the framework; its main purpose is to synthesize all the raw data and statistics and turn that into a written/visual format for end users to easily understand and draw conclusions from. Powered by an AI Learning-Language Model, users will get almost instantaneous reports once the simulation is finished. An API key will be used to link the interface to a backend model available to public access. A template will be created to ensure similarity between all reports and to prevent AI model deviation.

Review of Skills and Research

This product will be the successful integration of many of my past research and research assessments. Namely, my analysis on Computational Fluid Dynamics (CFDs) will be instrumental as I explored how aerospace models are generated. Additionally, through exploring quantum computing, I have learned a litany of knowledge on the implications of aerospace models, which can be implemented in this model. My exceptional math and physics base, including advanced calculus, linear algebra, and mechanics, will support me in creating the backend of the model, while statistical analysis will help me with the report. Skills in programming, specifically Python and, in the near future, MATLAB, will be utilized in the programming and creation of the model, as is the industry standard.

I foresee a competent understanding of lift, drag, and aerodynamic coefficients to be used, as well as knowledge of aircraft performance theory, which will be my first areas of further research. Focusing on technicality, I will require skills in numerical analysis (parameter sweeps and, more importantly, curve analysis), graph interpretation, and optimization analysis quotas. I will revisit my data science skills to help me generate plots and visualizations, as well as detailed quantitative analysis of these values. Touching base on overall engineering and project skills, I will need to define the scope and assumptions of this model. I will document my methodology and technical limitations of this model, as will be necessary if I professionally present this work. For further analysis and rigorous testing, I can validate my results against known real aircraft data. Finally, my reports will have to professionally and clearly communicate technical results.

Methodology

- **Participants:**
    - No human participants will be used
- **Materials**
    - International Standard Atmosphere information (ISA)
    - Metrics of known aircraft
    - CFD software, data analysis software, and numerical computing software
- **Description of Process and Procedures:**
    1. Research:
        a. Research and develop MATLAB skills
        b. Overview flight mechanics principles needed
            i. Performance Curves
            ii. Aerodynamic Equations
            iii. Range, Endurance, and Power metrics
    2. Create Model & Analyze
        a. Implement the Atmosphere
        b. Implement Aerodynamics
        c. Generate Performance Curves
        d. Extract Metrics
        e. Validate findings
    3. Deliver
        a. Document equations used
        b. Define assumptions and limitations
        c. Compare results to known aircraft

Conclusions

The final project will be a deliverable that is available for anyone to utilize immediately. Whether for experimentation or for testing a conceptual aircraft, any use will be permitted, and it serves as an innovation, specifically a general-purpose tool. I wish to add this to expand my portfolio of aerospace projects to use as backing for credibility to any professionals I may meet. The skills that I will learn while completing this project are vital for my future as an aerospace engineer. Many of the skills needed, especially technically, such as MATLAB, modeling, or analysis, are used in the everyday tasks of an engineer. Getting such an advanced head start on these tools will allow me to take part in even more meaningful projects as I advance into further education and my future career. Currently, I have not taken up a project that leans this far into technical work (most of my projects have required more rigor on other aspects), so this will be a challenge for me. Most likely, the information and skills that I have to research will change as I progress, and I will update my log accordingly to document all the progress I have made. I must stay accurate with my timeline, for if I end up behind, it will become almost impossible to recover, given the ambition and rigor of this project.

Development of Product Calendar/Timeline

4/29/2026 - Final Presentation Night
4/19/2026 - All work to be completed by

Week of 01/18/26
- Understanding of MATLAB, its capabilities, and the list of all software that is needed
- Research & Understand the meanings of the inputs/outputs (Range, Endurance, and Power metrics)

Week of 01/25/26
- Compile all necessary equations, formulas, coefficients, and constants needed

Week of 02/01/26
- Research and note-taking performance curves, and all other analyses that will be used in the model

Week of 02/08/26
- Module 1: Develop & Create (Find modules here: Information for Report)

Week of 02/15/26
- Module 2: Develop & Create

Week of 02/22/26
- Module 3: Develop & Create

Week of 03/01/26
- Module 4: Develop & Create

Week of 03/8/26
- REVIEW COMPLETED WORK AND COMPLETE STATUS REPORT (brainstorm if any functionality could be added or if anything is not practically possible). Complete tested model on predetermined aircraft (1st Time)

Week of 03/15/26
- Module 5: Determine specific curves and plots

Week of 03/22/26

- Module 5: Create

Week of 03/29/26

- Wrap Up / Add additional features

Week of 04/05/26

- Test model on another predetermined aircraft (2nd time)

Week of 04/12/26

- Finalize all data and findings, and publish the model
- List assumptions, metrics, and limitations
- Create a final report

Variable List

Inputs:

Geometry
Wing Area (S)
Aspect Ratio (AR)
Oswald Efficiency (e)
Weight (W)

Propulsion & Aerodynamics
Engine Power (P_{engine})
Prop efficiency (η_p)
Maximum lift coefficient ($C_{L_{max}}$)
Zero-lift drag (C_{D0})

Environment
Altitude (h)

ISA Standards:

Sea-Level
Pressure (P_0) = $101325\ Pa$
Temperature (T_0) = $288.15\ K$
Density (ρ_0) = $1.225\ kg/m^3$

Constant
Gravitational Acceleration (g_0)) $= 9.80665\ m/s^2$
Temperature Lapse Rate (L) = $0.0065 \cdot K/m$
Gas Constant for Air (R) = $287.058 \cdot J \cdot kg^{-1} \cdot K^{-1}$
Ratio of Specific Heats (γ) = 1.4

Troposphere Equations (0-11km)

Temperature as a function of altitude
$T(h) = T_0 - L \cdot h$
Pressure as a function of altitude
$P(h) = P_0 \left(1 - \frac{T_0 L \cdot h}{R L g_0}\right)^{\frac{g_0}{RL}}$
Density as a function of altitude
$\rho(h) = \frac{R \cdot T(h)}{P(h)}$
Speed of sound
$a(h) = \gamma R T(h)$

Derivations

Lift Coefficient
$C_L = \frac{2W}{\rho V^2 S}$

Induced Drag Factor
$k = \frac{1}{\pi e AR}$

Lift - N
$L = 0.5\,\rho V^2 S C_L$

Drag - N
$D = 0.5\,\rho V^2 S \left(C_{D0} + k C_L^2\right)$

Power Required - W
$P_{\text{required}} = \frac{D \cdot V}{\eta_p}$

Power Available - W
$P_{\text{available}} = P_{\text{engine}} \cdot \eta_p$

Excess Power - W
$P_{\text{excess}} = P_{\text{available}} - P_{\text{required}}$

Rate of Climb - m/s
$ROC = \frac{P_{\text{excess}}}{W}$

Stall Speed - m/s

$V_{\text{stall}} = \sqrt{\frac{2W}{\rho S C_{L_{\max}}}}$

Best Endurance Speed - m/s

$V_{\text{endurance}} \quad [\text{m/s}], \quad \text{Minimizes } P_{\text{required}}$

Best Range Speed - m/s

$V_{\text{range}} \quad [\text{m/s}], \quad \text{Maximizes } L/D$

Service Ceiling - m

$h_{\text{service}} \quad [\text{m}], \quad ROC = 0.508\,\text{m/s}$

Absolute Ceiling - m

$h_{\text{absolute}} \quad [\text{m}], \quad ROC \to 0$

Information For Report

Global Assumptions

- Steady, level flight
- Subsonic, incompressible flow
- Constant aircraft weight
- International Standard Atmosphere (ISA), troposphere only
- No wind, turbulence, or weather effects
- Propeller-driven aircraft
- Parabolic drag polar model

Module 1 -- Atmospheric Model (ISA)

Purpose: Compute atmospheric variables as functions of altitude

Inputs:

- Altitude, h [m]

Outputs:

- Temperature, $T(h) = T_0 - Lh$
- Pressure, $P(h) = P_0 \left(1 - \frac{Lh}{T_0}\right)^{\frac{g}{RL}}$
- Density, $\rho(h) = \frac{P(h)}{RT(h)}$

Notes: This module will be validated against published ISA tables.

Module 2 -- Aerodynamic Model

Purpose: Compute lift coefficient, drag coefficient, and drag force using equations

Inputs:

- Velocity, V [m/s]
- Density, ρ [kg/m³]
- Aircraft weight, W [N]
- Wing area, S [m²]
- Aspect ratio, AR
- Oswald efficiency factor, e
- Zero-lift drag coefficient, C_{D0}

Outputs:

- Lift coefficient, C_L
- Drag coefficient, C_D
- Drag force, D [N]

Governing Equations:

$C_L = \frac{2W}{\rho V^2 S}$

$k = \frac{1}{\pi e AR}$

$C_D = C_{D0} + kC_L^2$

$D = \frac{1}{2}\rho V^2 S C_D$

Module 3 -- Propulsion and Power Model

Purpose: Determine power required, power available, and excess power.

Inputs:

- Drag force, D [N]
- Velocity, V [m/s]
- Engine power, P_{engine} [W]
- Propeller efficiency, η_p

Outputs:

- Power required, P_{req} [W]
- Power available, P_{avail} [W]
- Excess power, P_{excess} [W]

Governing Equations:

$P_{\text{req}} = \frac{DV}{\eta_p}$

$P_{\text{avail}} = P_{\text{engine}} \cdot \eta_p$

$P_{\text{excess}} = P_{\text{avail}} - P_{\text{req}}$

Module 4 -- Performance Metrics Model

Purpose:
Extract meaningful aircraft performance parameters from numerical results.

Inputs:

- Power curves
- Density
- Weight
- Maximum lift coefficient, $C_{L_{max}}$

Outputs:

- Stall speed
- Best endurance speed
- Best range speed
- Rate of climb
- Service ceiling
- Absolute ceiling

Key Equations:

$$V_{\text{stall}} = \sqrt{\frac{2W}{\rho S C_{L_{\max}}}}$$

$$ROC = \frac{P_{\text{excess}}}{W}$$

Module 5 -- Curve Generation Model

Purpose: Generate performance curves

Inputs:

- Velocity range
- Aircraft parameters
- Altitude

Outputs:

- Power required vs airspeed
- Power available vs airspeed
- Rate of climb vs airspeed
- Lift-to-drag ratio vs airspeed

Atmospheric Model Results (TBD):

Validation Testing (TBD):

References

ISA Table: https://onlinelibrary.wiley.com/doi/pdf/10.1002/9781118534786.app1

https://www.engineeringtoolbox.com/international-standard-atmosphere-d_985.html?

Lift Drag etc

https://pressbooks.lib.vt.edu/aerodynamics/chapter/chapter-4/

https://en.wikipedia.org/wiki/Aircraft_flight_mechanics

https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/lift-to-drag-ratio/

https://agodemar.github.io/FlightMechanics4Pilots/mypages/drag-polar/

https://en.wikipedia.org/wiki/Zero-lift_drag_coefficient

https://en.wikipedia.org/wiki/Lift-induced_drag

https://fasttrack-atpl.com/wiki/technical-subjects/performance/performance-overview

https://society-of-flight-test-engineers.github.io/quarto-handbook/05-aero.html

https://aerotoolbox.com/drag-polar/