How Tail Sizing Effects the Performance and Stability of an Aircraft

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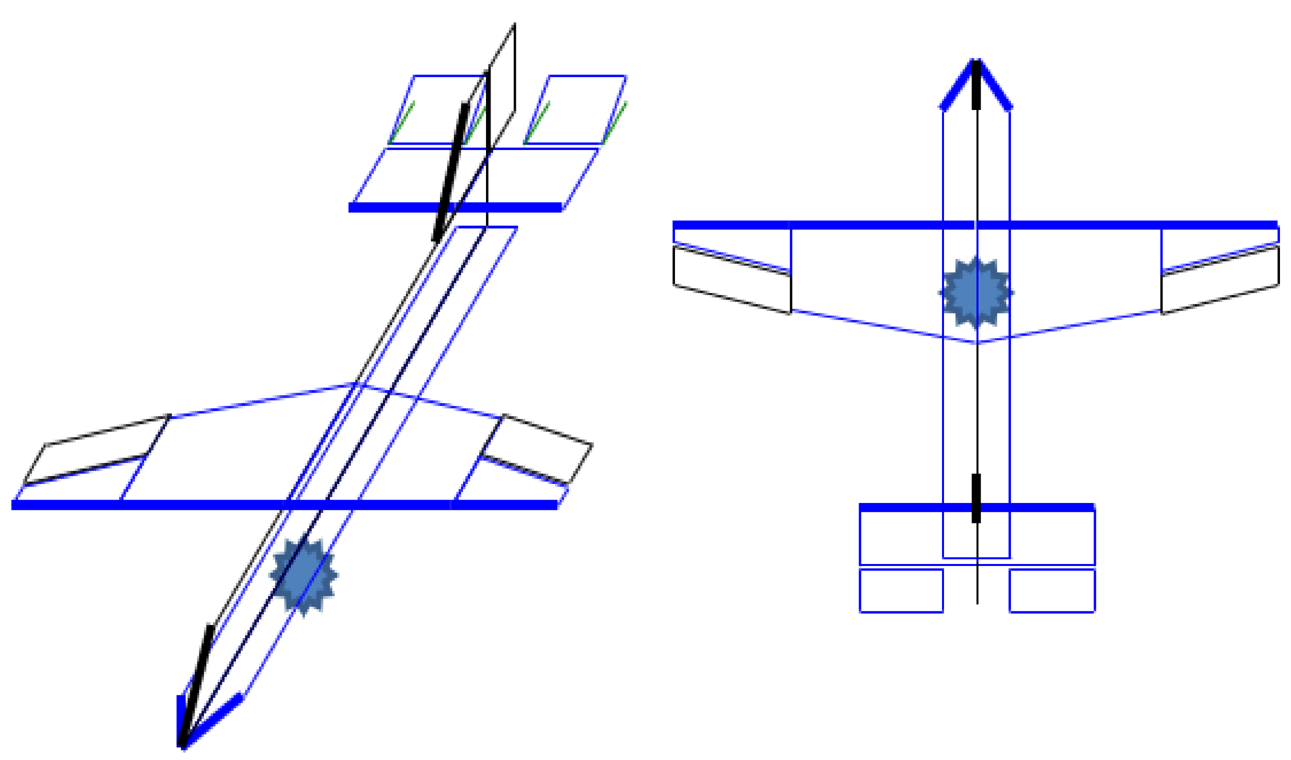
The computational fluid dynamics code used for this analysis is called Vorlax, which uses a vortex lattice method for computations. The aircraft is first modeled in Vorlax as a series of flat plates and then run to obtain key aerodynamic data.

Key Aspects of the Models Created in Vorlax:

- 3ft wingspan
- Length of 2.75ft
- High wing configuration
- Same aileron configuration

Part Changed	Small Tail (M1)	Balanced Tail (M2)	Large Tail (M3)
Vertical Tail Height (in)	3	5	7
Vertical Tail Length (in)	5	7.5	9
Horizontal Tail Width (in)	10	14	20
Horizontal Tail Length (in)	4.5	6	7.5



Vorlax Model of the Balanced Configuration (M2)

Research question:

How does tail sizing and the location of the center of gravity effect the stability and performance of an aircraft?

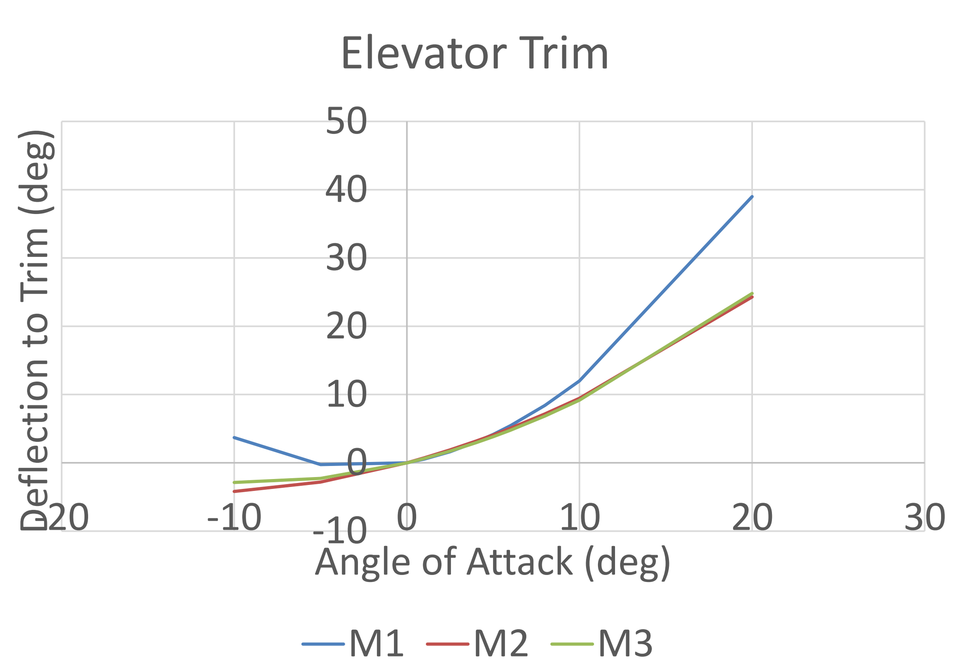
Methods:

- The first step to solving this problem was learning how to use the Vorlax code to collect theoretical data based on the aircraft's geometry.
- Three model were then created with different sized tails.
- Using data collected from Vorlax, short period and Dutch roll frequency, elevator trim, and other stability data was computed

Trim:

Trim is the deflection of an aircrafts control surfaces in order to move the aircraft in the desired maneuver such a turn or increase in altitude.

- Elevators- Pitch motion (nose up or down)
  - Need to be able to have enough control power to reach the desired angle of attack before reaching the mechanical limits of the system.
- Ailerons – Rolling motion (banking)
- Rudder- Yawing motion (nose right or left)
  - In commercial aircraft, there must be enough control power in order to maintain control during an engine out situation.
  - For the RC model, there must be enough control power to remain stable is unfavorable crosswind situations.



References:

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- Miranda, Luis R., et al. "A Generalized Vortex Lattice Method for Subsonic and Super Sonic Flow Applications." *NASA Contractor Report 2865*, Dec. 1977.
- Takahashi, Timothy. *Aircraft Performance and Sizing, Volume II*. Momentum Press, 2016.

Stability Frequencies

Short Period: longitudinal (pitch) oscillations

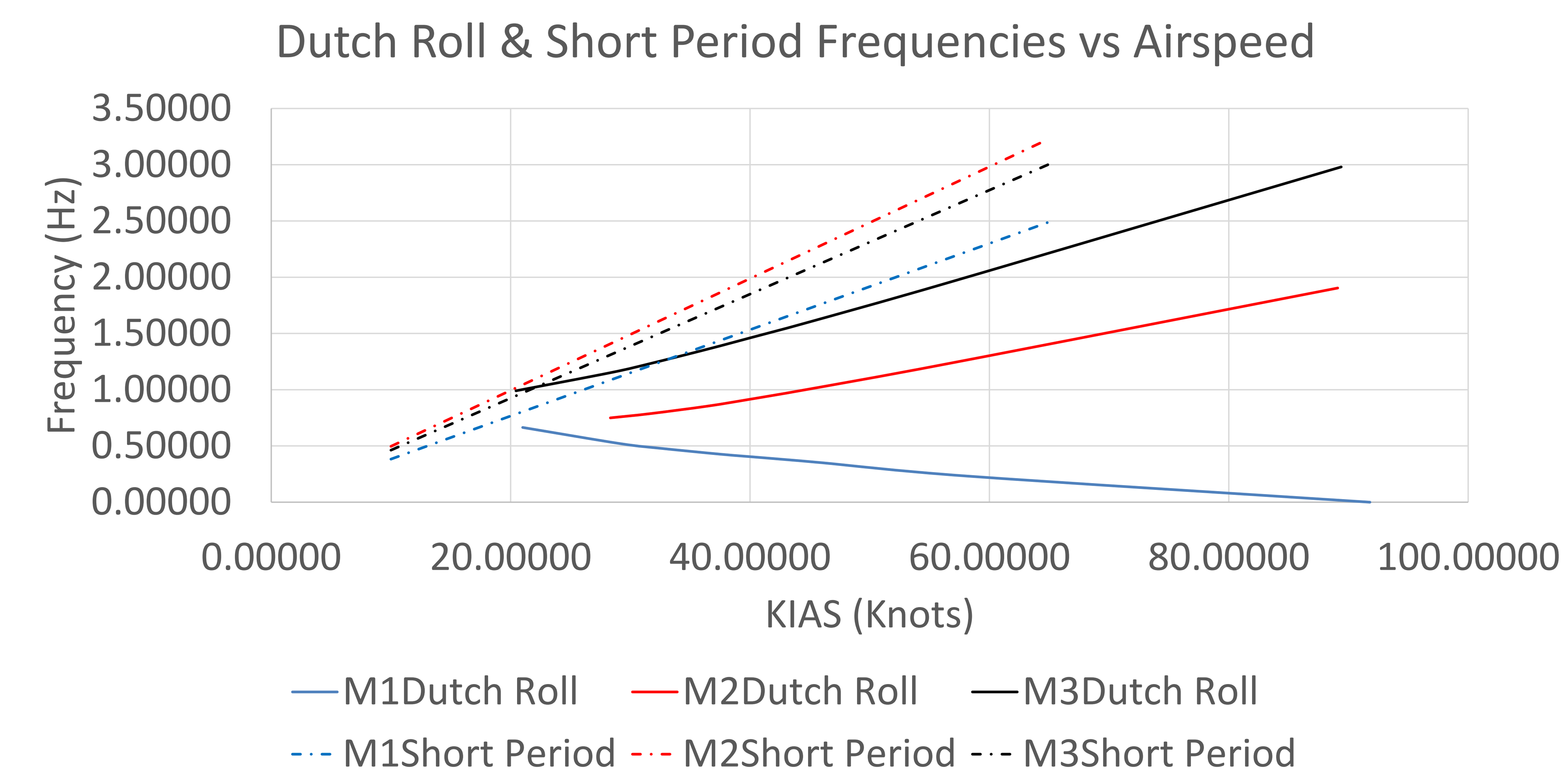
- As the CG is moved aft, the frequency will become slower → less stable
- As horizontal tail is made larger, the frequency becomes faster → more stable

Dutch Roll: lateral oscillations (roll) oscillations

- As vertical tail is made larger, the frequency becomes faster → more stable

Effect on Aircraft:

- Too fast will have the airplane shake apart
- Too slow causes phase response lag between the aircraft and pilot; pilot induced oscillation
- Imaginary frequencies are divergent and represent an unstable aircraft
- Do not want the two frequencies to cross as it creates a kind of corkscrew mode.



Conclusion and Further Progress:

Design problems have more than one answer. There are multiple solutions that provide acceptable frequencies with reasonable control surface deflections. The next step is to automate the design creation and analysis to find the configurations that best fit the requirements. Depending on the mission requirements that the aircraft must complete a certain configuration may be more ideal.

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