The use of software to optimize a system

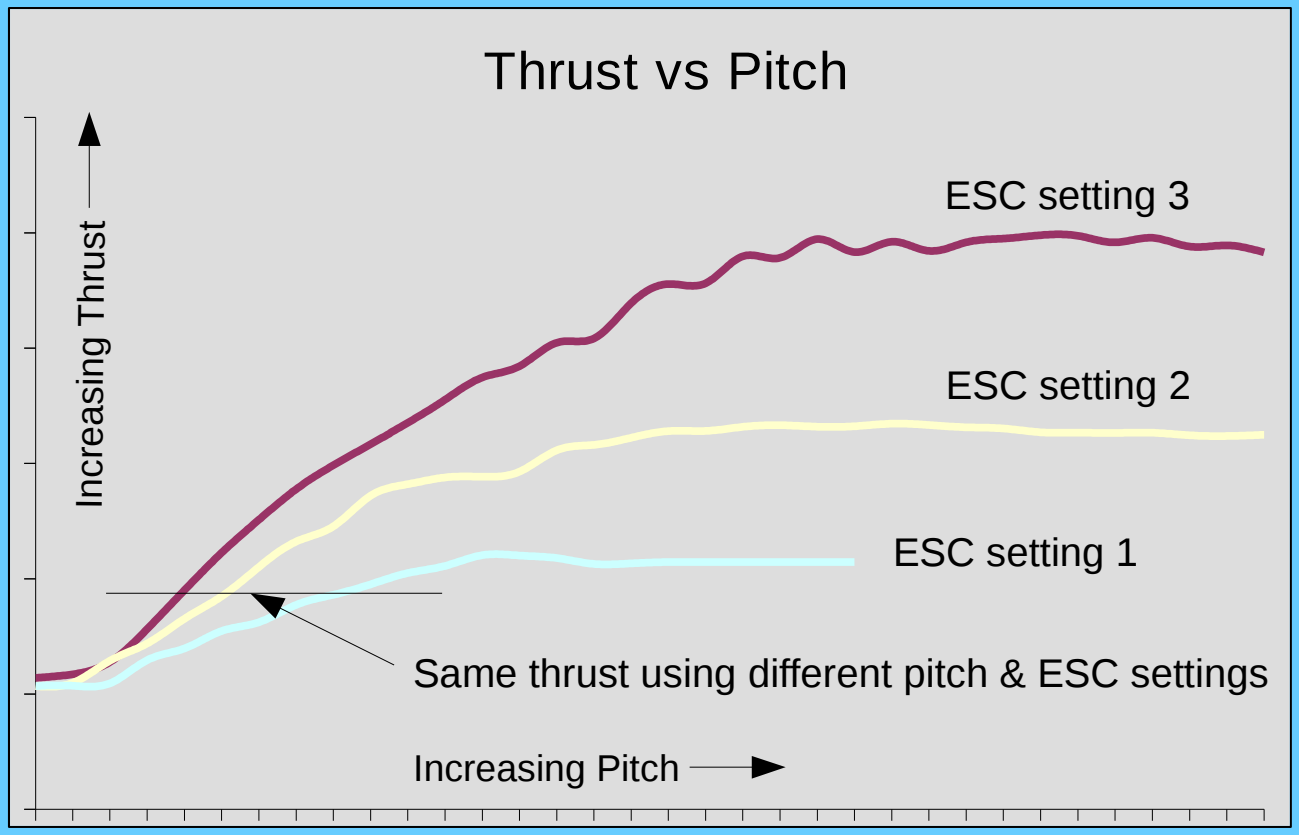
- It is desirable for a system to be as efficient as possible for a given task
- All the components that make up a system may not be operating at maximum efficiency for a given task
- It is desirable to perform the task using minimum energy
- Maximum system efficiency is when the sum of the components loses are at a minimum
- This presentation will introduce the use of software to achieve maximum system efficiency

Propulsion Example

- This example will use the propulsion system of a small unmanned air vehicle (UAV)
- The components consist of a motor, electronic speed control (ESC), variable pitch propeller, and a lithium battery
- This example will focus on the motor and variable pitch propeller
- The efficiency of the motor is a function of rpm, voltage and current
- The efficiency of the variable pitch propeller is a function of rpm, pitch, density and free stream velocity

Propulsion Example

- For a given airspeed and density altitude, thrust is a function of both pitch and the Electronic Speed Control (ESC) setting
- What setting uses the least amount of power for the selected thrust?

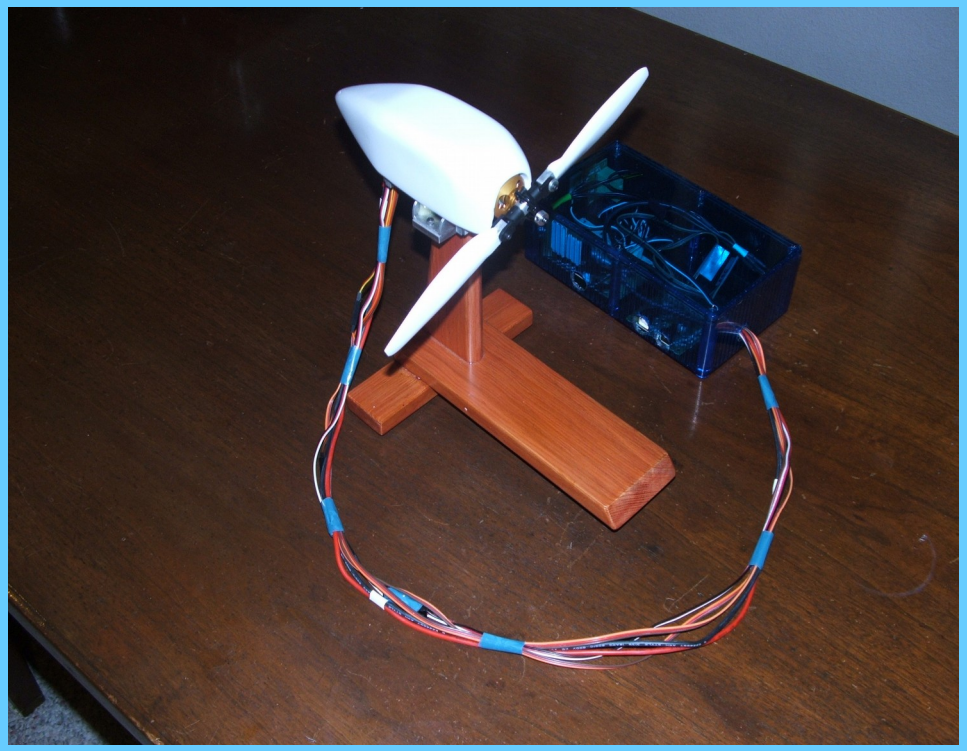


Propulsion Example

- The goal of this project was to determine the ESC and pitch settings that used the least amount of energy for a required thrust
- A physical model was constructed to better understand the the above problem
- The physical model could also be used to test and validate the software

Physical Model

The physical model used already available products as much possible. The remaining items were constructed as necessary.



- 90 Watt Brushless DC motor
- Variable pitch propeller (23 cm dia.) servo controlled
- Thrust measuring motor mount
- Pitch and ESC controlled by hardware/software interface
- Thrust, voltage, amperage, pitch, ECS data was recorded

Physical Model

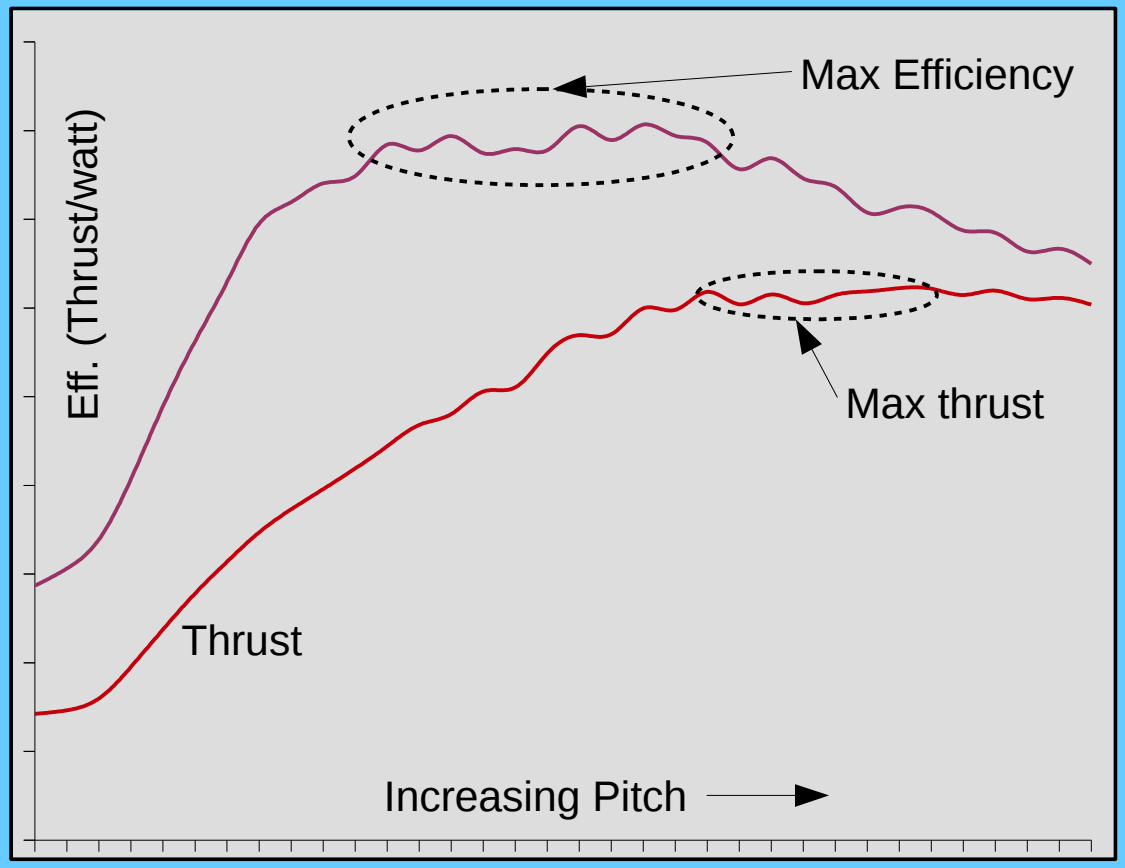
Software was written to perform the following tasks.

Tasks

- Find how thrust and thrust efficiency (thrust/watt) varies with ESC and pitch settings
- Find maximum thrust for a given ESC setting
- Find maximum thrust/power for a given ESC setting
- Find the most efficient thrust vs power curve for a given free stream velocity
- Find the corresponding Pitch and ESC setting for the above cure

Physical Model

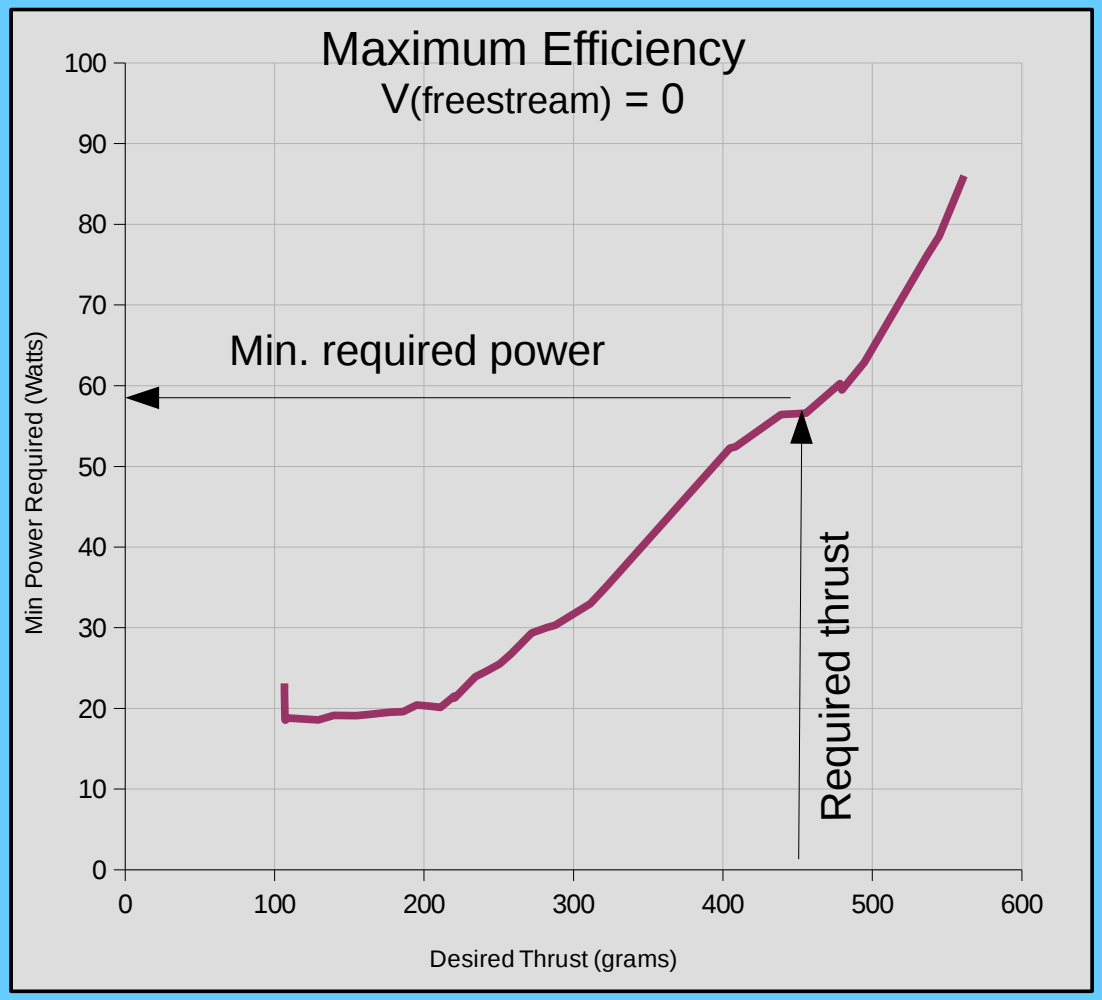
The results of the first set of task are shown below.



- Maximum thrust and maximum efficiency occurred at different pitch settings for a given ESC setting
- 7.4% additional thrust requires 16% more energy
- The above trend is seen at various ESC setting for this motor/prop combination

Software Results

The Software ran the Physical Model at various Pitch and ESC settings, recored the data and the most efficient Pitch/ECS settings were determined for a required thrust.



- The software uses various algorithms to compute the maximum thrust per minimum power curve
- ESC & Pitch settings vs. thrust was computed
- Data was analyzed
- For a required thrust, pitch & ECS are now known

Software Uses
(Current & Future)

- Preflight/ Analysis Features
- Select the best motor/ propeller for a mission profile.
- Determine if a UAV can fly a particular mission
- Determine if a variable or fixed pitch propeller should be selected for a UAV design (light propulsion system = larger battery)
- Determine the mission payload capability
- Real-time Features
- Adjust for maximum performance
- Adjust for maximum range
- Adjust for maximum loiter time
- Adjust UAV in flight for damages or mission changes

Next Steps

Software

- Further refinement of finding the optimum thrust power curve
- Allow either electric motor or internal combustion engines to be consider
- Include the airframe of the UAV in the optimization. Find maximum range, loiter time, etc.