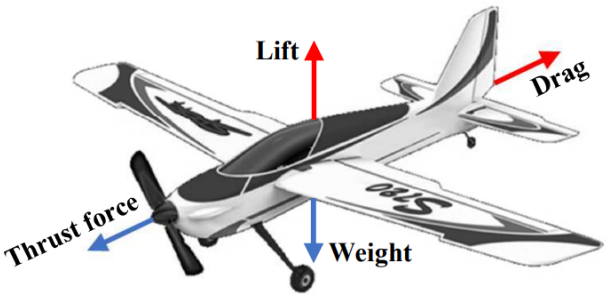
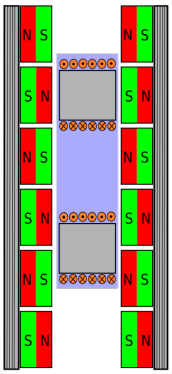
Bachelor thesis/ student research project

Design of an electromagnetic aircraft catapult

The principle of launched aircraft with the help of catapults is well known and is utilized on aircraft carriers, whereas mostly steam catapults are used. Furthermore, electromagnetic catapults have been developed in the 1940's due to their advantages, e.g., due to less maintenance [1]. However, this concept is not used for civil aircraft, therefore, in this work, an electromagnetic aircraft catapult should be designed, which is able to accelerate a civil aircraft. In addition, also the necessary energy, that is required to fly a specific distance, must be stored during the accelerating phase. After the aircraft leaves the ground, it should fly with (almost) no additional energy. For this scenario, a model of the aircraft must be developed to predict the flight trajectory. Fig. 1a shows exemplary acting forces on an aircraft. An example sketch of a linear motor, which should be designed, is shown in Fig. 1b.



(a) Forces acting on an aircraft [2].



(b) Exemplary linear motor [3].

Key research questions:

- What are the ground acceleration and power requirements to travel a certain distance considering a 4-seater civil airplane?
- What are the impacts of the weather conditions during the flight on the energy and acceleration demand on the ground?
- What are feasible acceleration profiles? What design requirements follow w.r.t. the linear motor and power electronics of the catapult?

Necessary requirements:

- Finished course work on electrical machine and power electronic fundamentals
- First experiences or interest in modeling and numerical simulations
- Interest in scientific programming languages (JAX, Julia, ...)

WP 1: Literature research **[2 weeks]**
Scanning the scientific literature for relevant publications and patents related to electromagnetic catapults is the first step. Also, getting familiar with linear electrical drives is part of this WP. Relevant work will be stored in a literature review software (e.g., JabRef) and summarized in the thesis.

WP 2: Model development **[4 weeks]**
A lateral model of the aircraft with the acting forces, as exemplary visualized in Fig. 1a, must be developed. Furthermore, a possible aircraft must be selected and parametrized with available parameters from the literature. The developed model is implemented in a simulation framework and after finishing this WP, an initial flight trajectory can be simulated.

WP 3: Simulation **[2 weeks]**
In this WP the best and worst case (weather) scenarios should be investigated. Therefore, the data should be taken from the literature or reasonable values must be selected. The required total energy demand for a defined distance and the final speed before the aircraft leaves the ground is the outcome of this WP.

WP 4: Design of the electrical drive **[6 weeks]**
With the calculated required energy and speed in the WP before, a torque trajectory has to be determined. This trajectory depends on the available length of the airstrip and the force of the linear electrical machine. Therefore, the main parameters of the electrical machine (power, voltage and current) and the inverter should be determined according to the literature.

WP 5: Documentation **[4 weeks]**
All work packages should be reported in a structured way within the thesis. A LaTeX template should be used for this purpose: `https://github.com/IAS-Uni-Siegen/thesis_latex_template`. Writing instructions can be found within the provided template source files. Based on the previous empirical findings, conclusions should be drawn, and future research directions should be outlined.

Gantt chart

The planned timetable is shown in the Gantt diagram below.

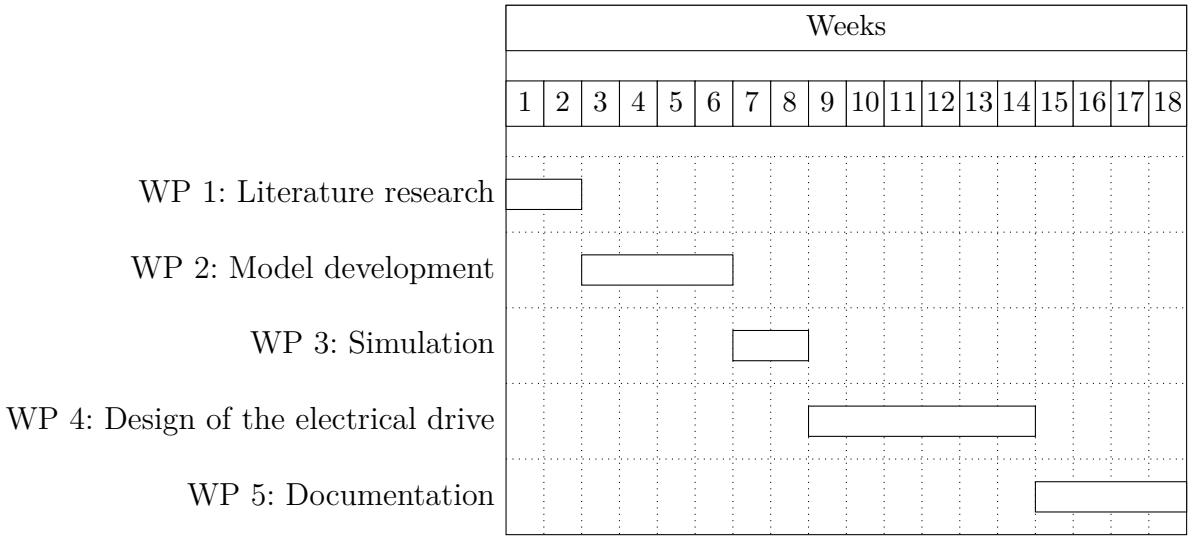


Figure 2: Gantt chart for the thesis.

References

[1] M. Doyle, D. Samuel, T. Conway, and R. Klimowski, "Electromagnetic aircraft launch system-EMALS," *IEEE Transactions on Magnetics*, vol. 31, no. 1, pp. 528–533, 1995.

[2] I.-M. Dobos, A. Munteanu, B. Virlan, I. Nacu, L. Livadaru, and A. Simion, "A Study on a Linear Actuator for the Electromagnetic Aircraft Launch System," in *Int. Conf. And Exposition On Electric And Power Engineering*, 2024, pp. 676–680.

[3] Mikiemike, *Linear motor U-tube*, Wikimedia commons, Feb. 2008.