DESIGN OF ELECTRIC PROPELLED AIRCRAFT

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AEROSPACE TECHNOLOGY CONGRESS 2019

SUSTAINABLE AEROSPACE INNOVATION IN A GLOBALISED WORLD

FT2019

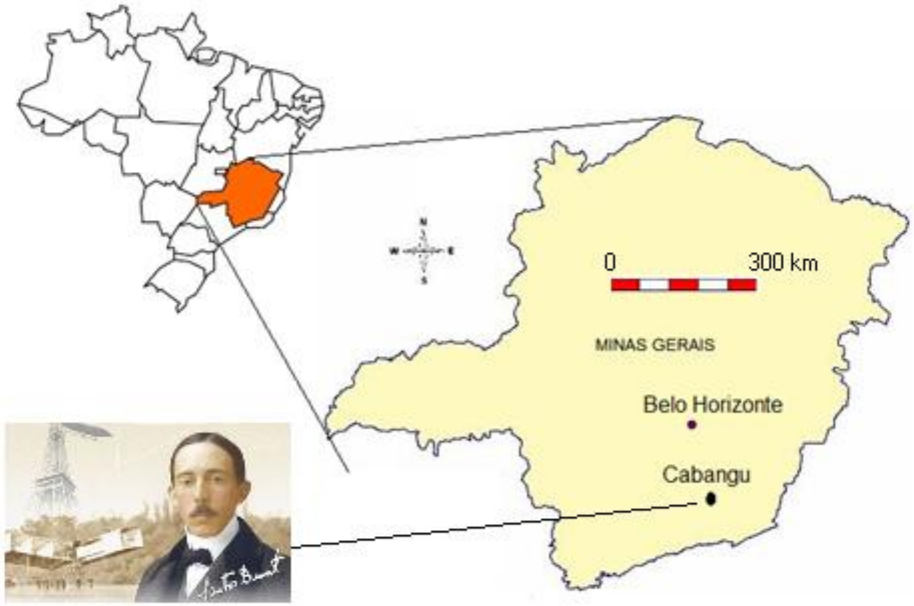
Overview

- About CEA and UFMG
- CEA´s projects and prototypes
- Introduction: The Electric Propelled Aircraft
- Electric Aircraft Main Issues
- Aerodynamic Efficiency using previous experience
- Structures
- Powerplant overview
- Related Research
- CEA Prototype solutions
- Main Conclusions

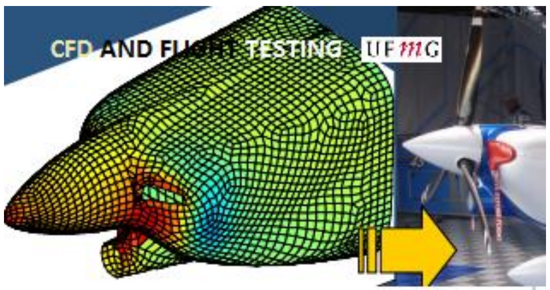
CEA and UFMG

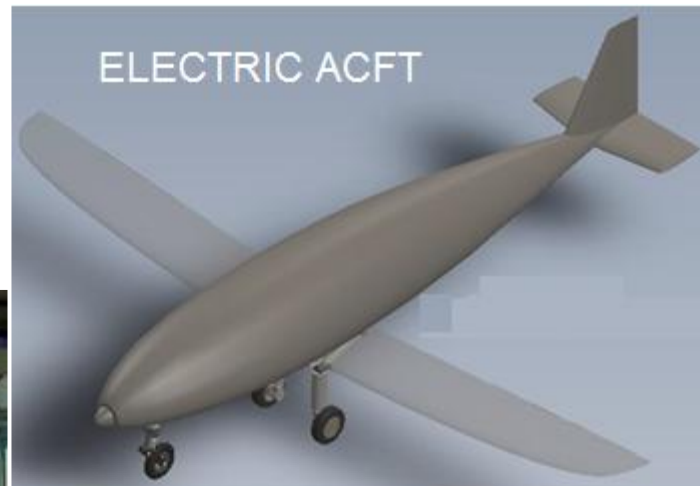
- Federal University of Minas Gerais (UFMG) (1927)
  - 50.000 Students,
  - 77 Undergraduate Courses
  - 140 Postgraduate Courses
- School of Engineering (1911)
  - 6.500 Students
  - 11 Undergraduate Courses
  - 20 PostGraduate Courses
- Aeronautical Studies Centre(CEA) 1962

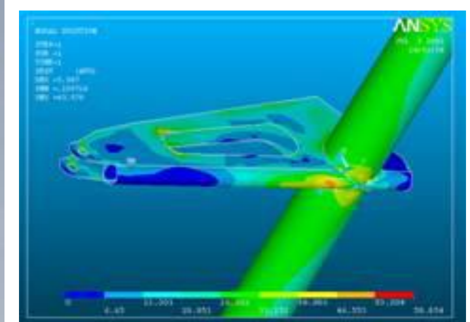
UFMG

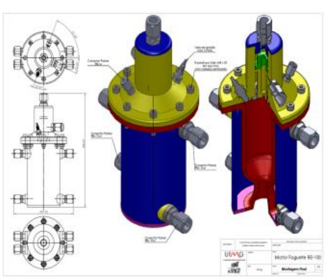


Typical CEA Research









Space Vehicles Simulation

CEA´S HIGH PERFORMANCE ACFT

ANEQUIM:

FIVE SPEED WORLD RECORDS (FAI)

Electric Propelled ACFT

- The first ever to fly in Brazil manned electric propelled aircraft used a CEA designed airframe with a power plant integration designed by a CEA graduate.

- The research is now concerned with highly efficient purpose designed aircraft.

ELECTRIC SORA

Introducing Electric Aircraft

Everyone knows that Electric Propulsion provides a sensible way to achieve innovative and Efficient Solutions for Future Aircraft

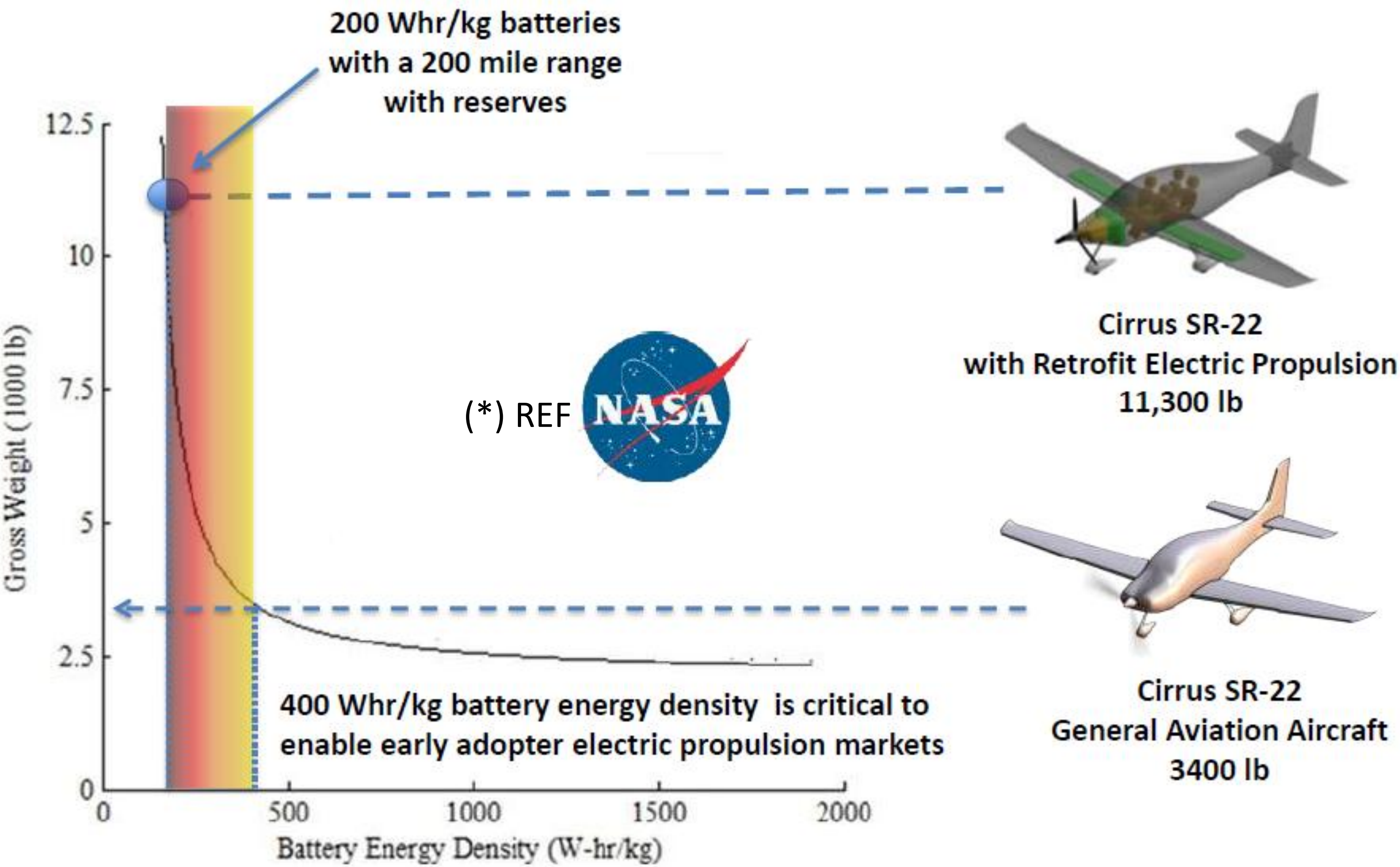
In fact ELECTRIC PROPELLED AIRCRAFT ARE ESSENTIALLY HIGHLY EFFICIENT VEHICLES!

THE DEMANDS

- Environmental Life Cycle Considerations
- Efficient Energy Use
- Enhanced Mobility
- Cost Effectiveness

Specific Energy Density(*)

VIABLE SOLUTION?: THE FIRST IDEA



What about large aircraft?

- Electric Propelled Aircraft are not at the moment suitable for large passenger aircraft
- Hybrid solutions will remain the only viable solution for a long time to come.
- However it must be emphasized that smaller aircraft do provide ideal test beds for developing and testing new technologies and innovation.

Batteries: Basic issues

- Low Energy Density(*), resulting in:
  - Limited Endurance and Range
  - Difficulties in Center of Gravity Positioning.
  - High and Concentrated Structural Loads, and:
  - Heavier structures? and problems with crash loads.
  - Efficiency versus constant weight during flight mission
- Batteries catch fire (+)
  - Fire Extinguishers are useless
  - Ejection of batteries: dangerous and change C.G.
  - Fire Containment Box: Weight and Insulation difficulties
- Battery type influences discharge rates considerably(+)
- Recharging Time: Slow (Not so Critical)
- Battery life cycle
- Recycling of Materials: not easy.

+Crucial but not always mentioned

Basic Guidelines *("Electric Breguet and efficiency")*

$$RANGE_{electric} = \frac{m_{battery}}{m} \cdot \frac{L}{D} \cdot \frac{1}{g} \cdot \mathrm{E} \cdot \eta_{systems}$$

Structures — Aerodynamics — Batteries

All the contributions are essential to the overall efficiency!

ENERGY and EFFICIENCY

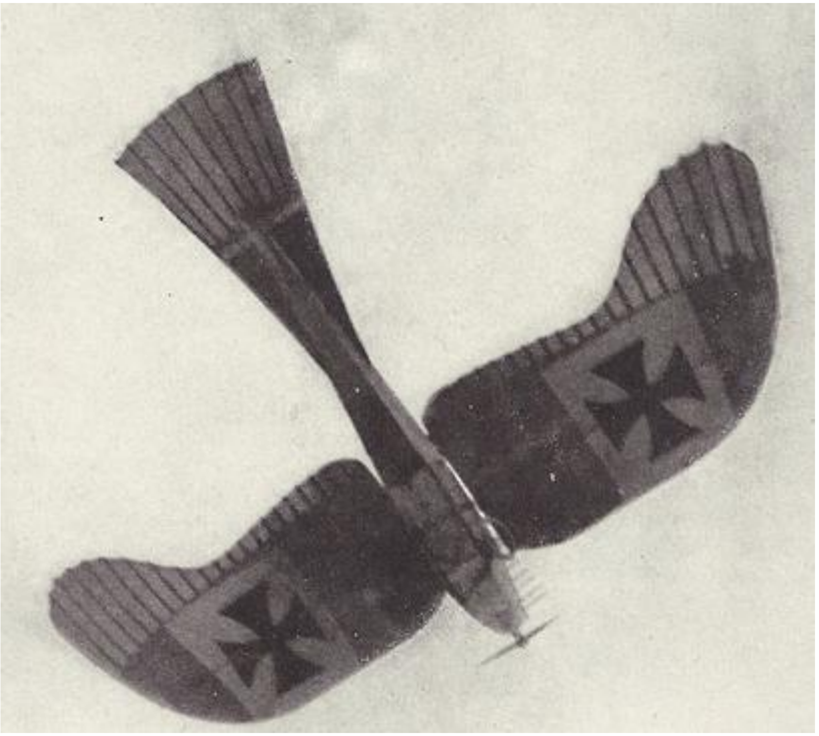
X AXIS ⇨ THRUST AND DRAG

- Geometry: PRESSURE GRADIENT CORRECTIONS
- Power plant set point (function of mission profile!)
- Drag fractions: According to speed adjustment
- Power/Weight Ratio
- Power plant efficiency and Airframe Matching

Z AXIS ⇨ LIFT AND WEIGHT

- Geometry: PRESSURE GRADIENT CORRECTIONS
- Materials and Structural Configuration
- Power plant and Airframe Matching
- Power/Weight Ratio
- Systems Consumption
- C.G. Positioning (also influences stability)

plus mission planning



Different birds ⇔ Different flight profiles

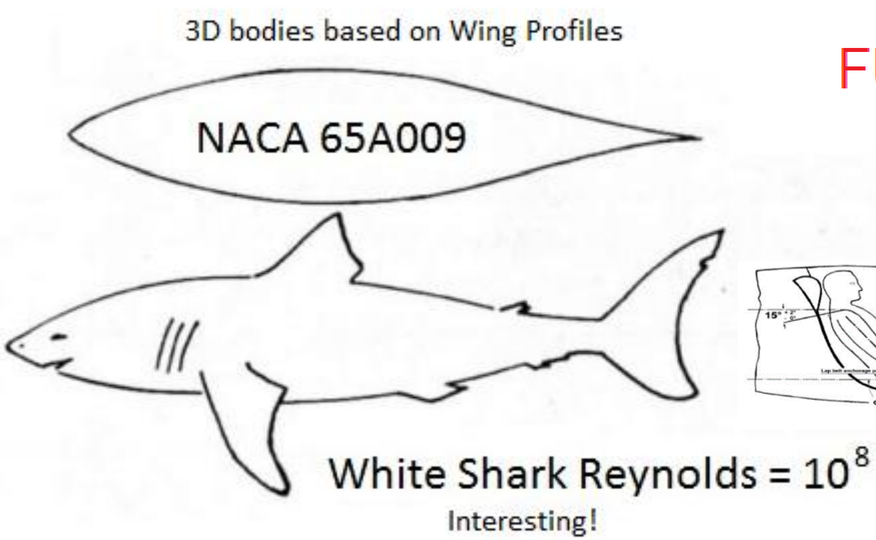
Different span/chord wise parameters

Etrich TAUBE based on a SEED shape (not a dove), was stable but had poor control response.

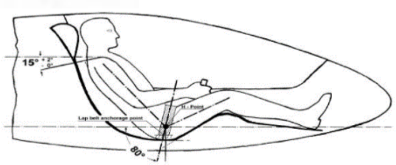
Aerodynamic Optimization

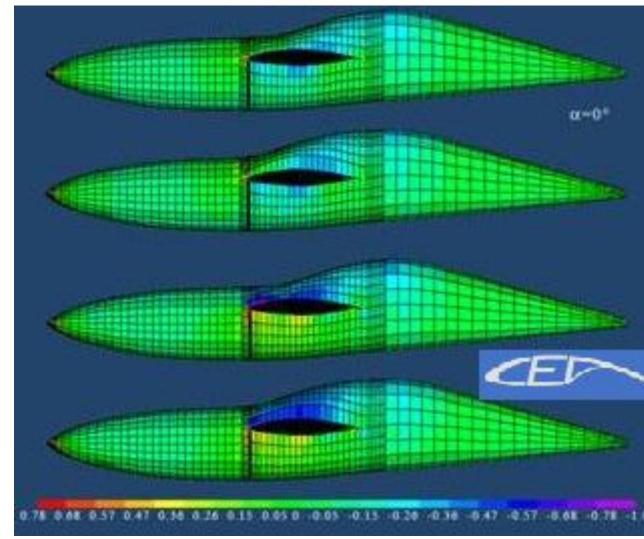
IDEALIZED INSPIRATIONS are useful but

require adjustments to become feasible.



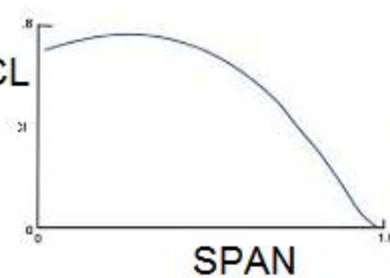
FUSELAGE

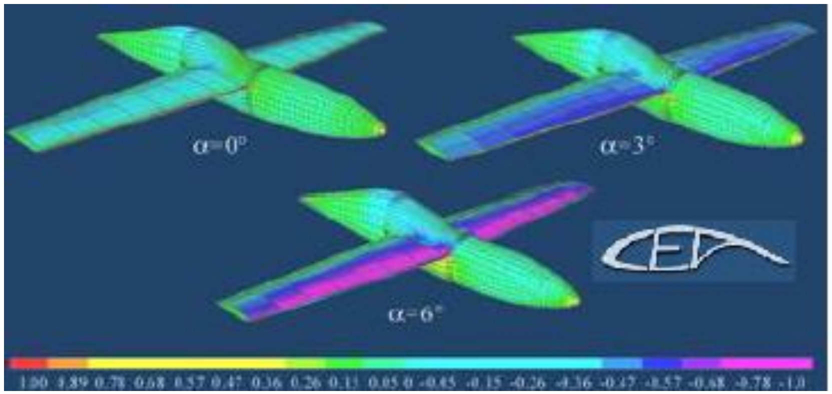


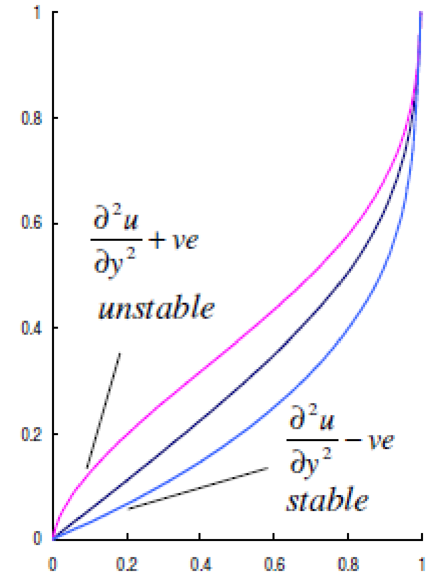


WINGS/TAIL

eg: reducing Induced Drag

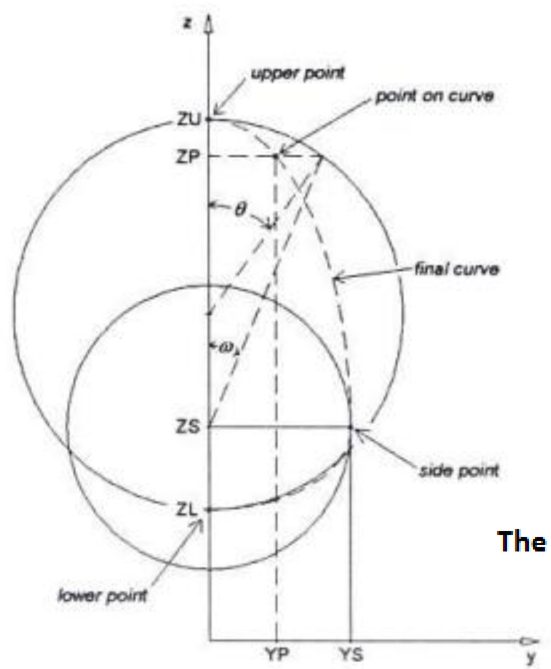






Boundary Layer Stability
Laminar Flow

Fuselage Cross Section

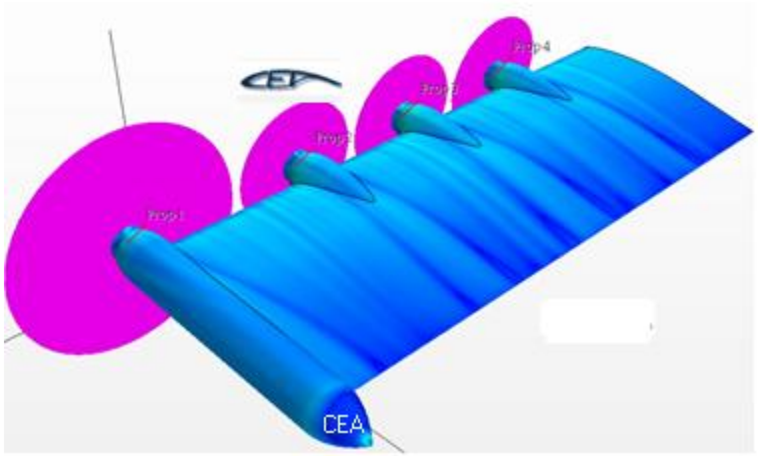


The "Hügelschäffer Egg"

Structures and weight

- **Structural Components are essentially the existing in highly efficient conventional aircraft, however**
  - **Composite Structure (Carbon Fibre)**
  - **Concentrated Masses and Mass distribution has to be taken into account**
  - **AEROELASTICITY: Different mass concentrations and distributed load, and slender geometry.**
  - **Electromagnetic compatibility issues and heat transfer issues have also an influence on airframe materials**
  - **Battery Safety Issues (structural loads and fire), fire containment metal boxes.**

Power Plant *(light aircraft)*



➢ Distributed Propulsion

(Current research at CEA)

- Optimal Efficiency in
- Aerodynamics and Control
- Structures & Aeroelasticity
- Fine Thrust adjustment, but
- Certification Issues!

➢ OneThrust Axis

- Same axle multimotor
- Concentric axles c.r. propellers

➢ Torque/RPM Inverter Control

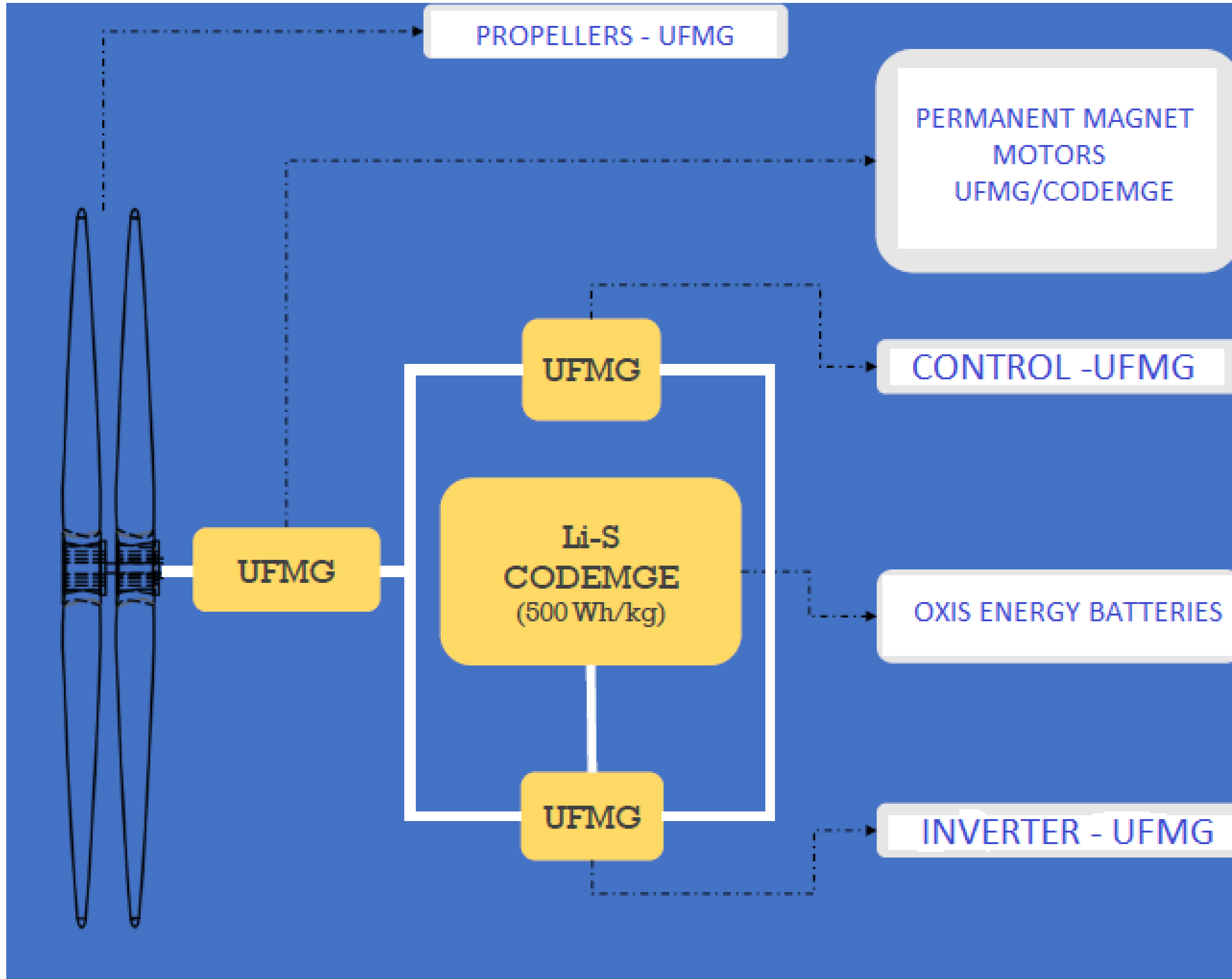
- Without Conventional Pitch Control
- With Propeller Pitch control

Power Unit Project Design

PROPOSED TO CODEMGE(*)

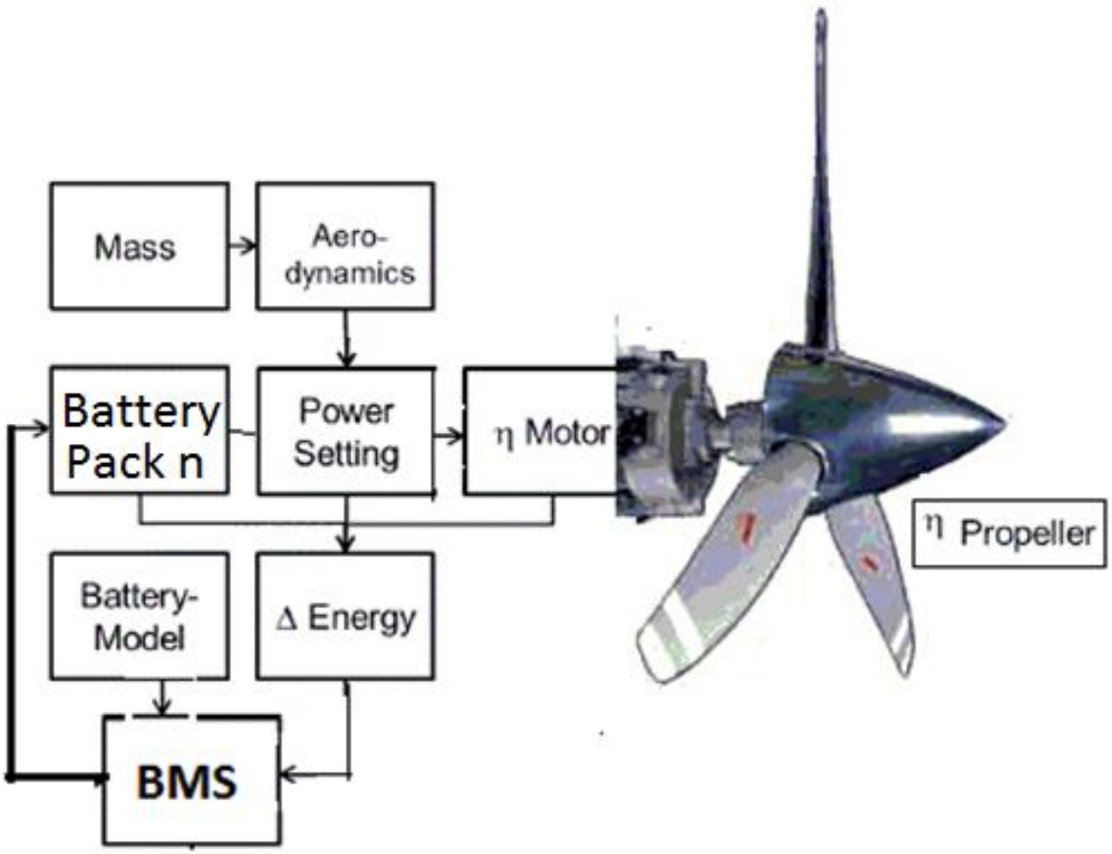
Existing motors are mostly automotive conversions and not completely optimized for aeronautical applications.

The complete aircraft and electric motor developments are intended, together with control and systems, all purpose-designed to comply with aeronautical technology



* Minas Gerais Development Company

BMS,Power Control,Performance



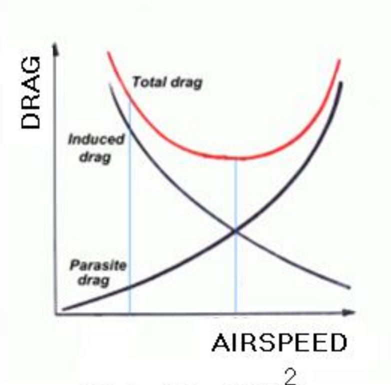
Pack n: Battery Type and Number of Cells require optimization

Related and Current Research Issues

- Electric Motor : Permanent Magnet Axial Flow
  - 3 Phase and Inverter
  - Brushless DC (potential use for some applications)
  - Magnet Geometry
  - Temperature Control: Motor, Inverter, Batteries

- Noise related issues
  - Environmental Noise: gains will tend to be more related to the resulting improved Aerodynamics
  - Cabin Noise: Structure borne excitations important gains to be achieved without a reciprocating engine.
  - Psychoacoustic perception, different motor/propeller speeds demand intensive research.

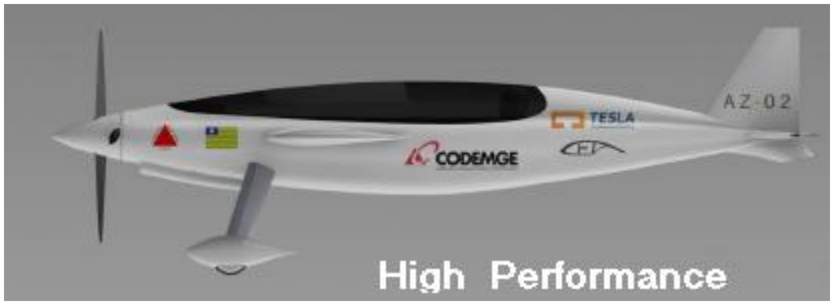
Mission Planning



$$C_D = C_{Do} + k\,C_L^2$$

- FLIGHT REGIMES
- Different power settings for each mission phase
- Evasive and/or emergency manouvres
- Temperature Control and minimizing of fire risks
- Control of Motor Operational Point matched to propeller pitch control.
- Pwavailable curves: changes due to electric motor behaviour, marked influence of props.

CEA High Performance Electric Designs



High Performance Trainer

Main Conclusions

- Electric propelled aircraft are essentially extremely efficient aircraft, all aspects considered.
- As such this development will provide an additional bonus in solutions for many other applications.
- Electric Propulsion is already a viable solution for G.A. aircraft, and a promising concept for other classes of aircraft.
- Electric Propelled Aircraft Design high efficiency approach provides an ideal opportunity for innovative research and development in all concepts of Aeronautical Engineering.

Thank you for the privilege!

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