Trends in UAV Propulsion

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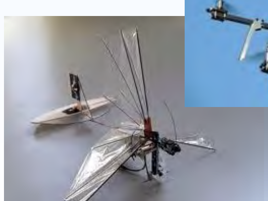
Trends in UAV Propulsion



UAV Propulsion Requirements

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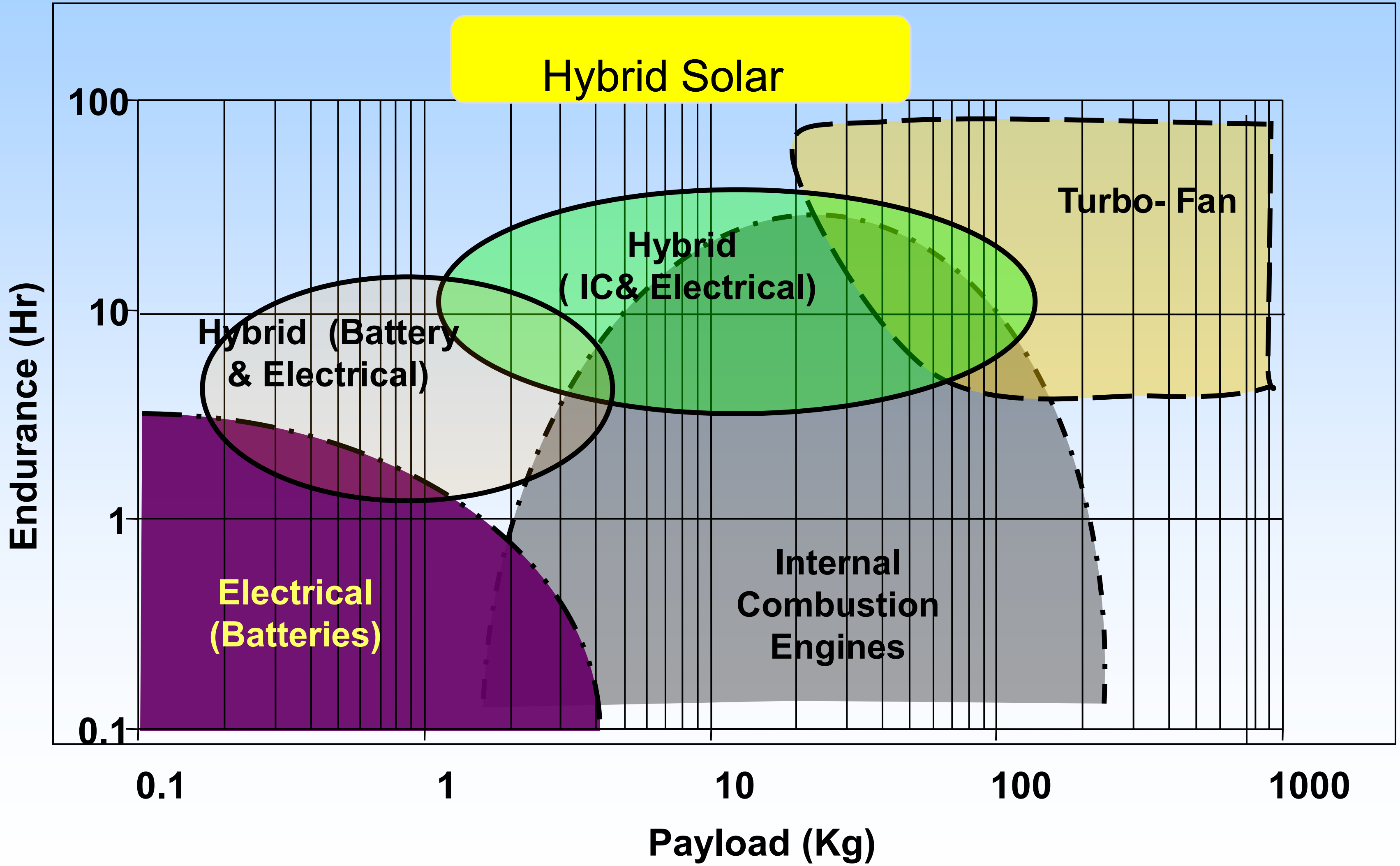
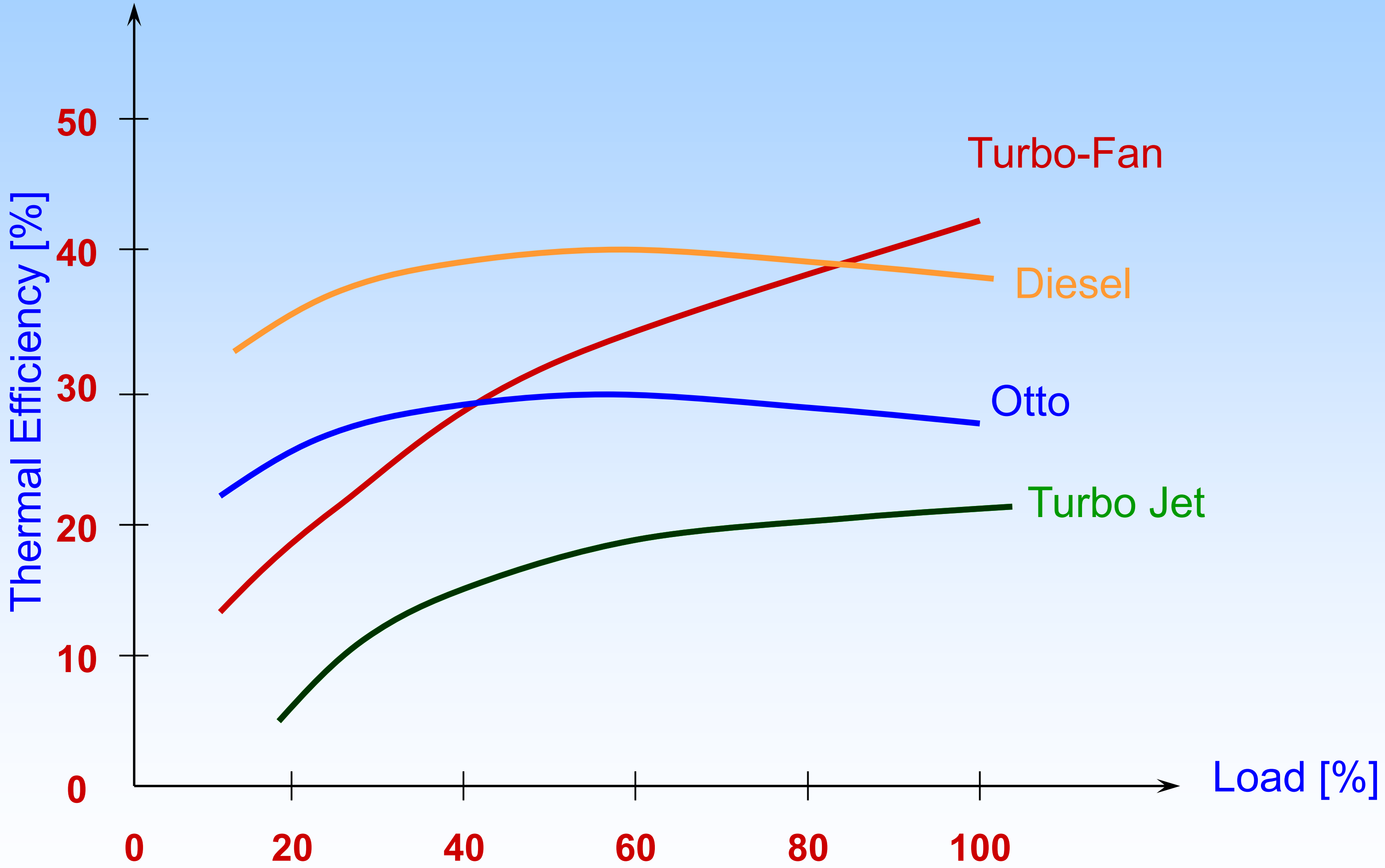
- Reliability
- High power to weight ratio
- High efficiency in the flight envelope
- Low emission of IR ,Radar and Noise signatures
- High Electrical Output for the UAV function and payloads
- Low LCC
- Complaince to Civil Aviation Regulation

Domain of usage of different propulsion technologies



Relative efficiencies of different engines



IC Engines Benchmarking

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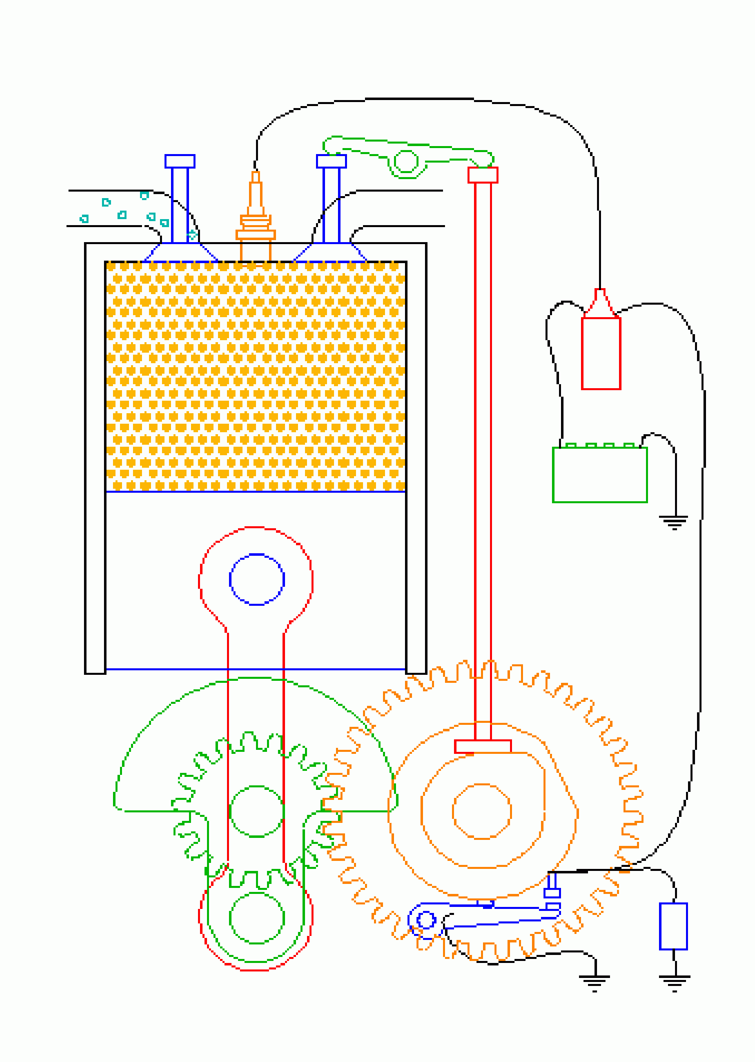
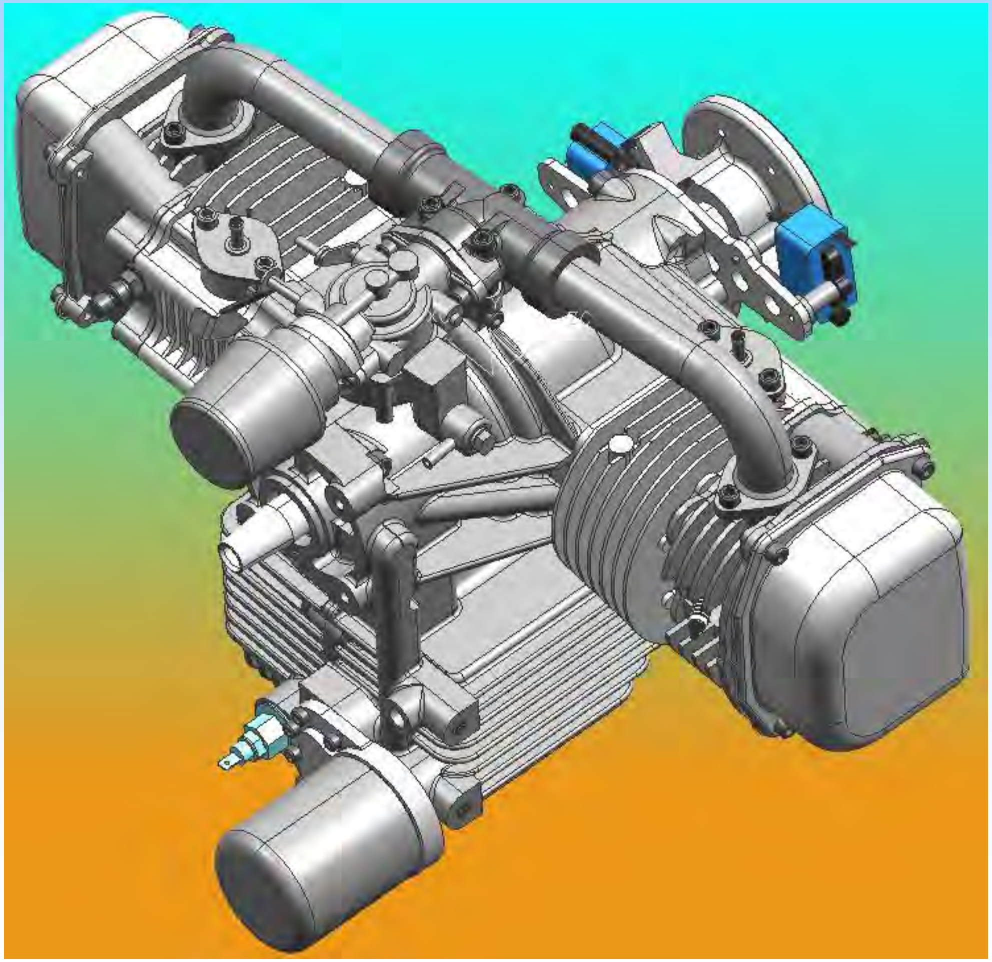
Feature	LCC	Noise	MTBF	Life	Fuel consumption	Power to weight Ratio	Weight	Instalation	Simple
Two Stroke (2)	++	++	++	++	+	++++	++++ (5)	++++ (5)	++++ (5)
Four Stroke	+++	++++	+++	+++	+++	++	++	+++	++
Wankel (1)	+	+	+	+	++	++++	+++	+++	++
Diesel (3)	+++	+++	++++	++++	++++	+	+	++	+

1. Expensive and unique parts
2. Simple and cheap
3. Expensive ,Exellent SFC &LCC,Heavy
4. Advantage for low HP and Air- Cooling.

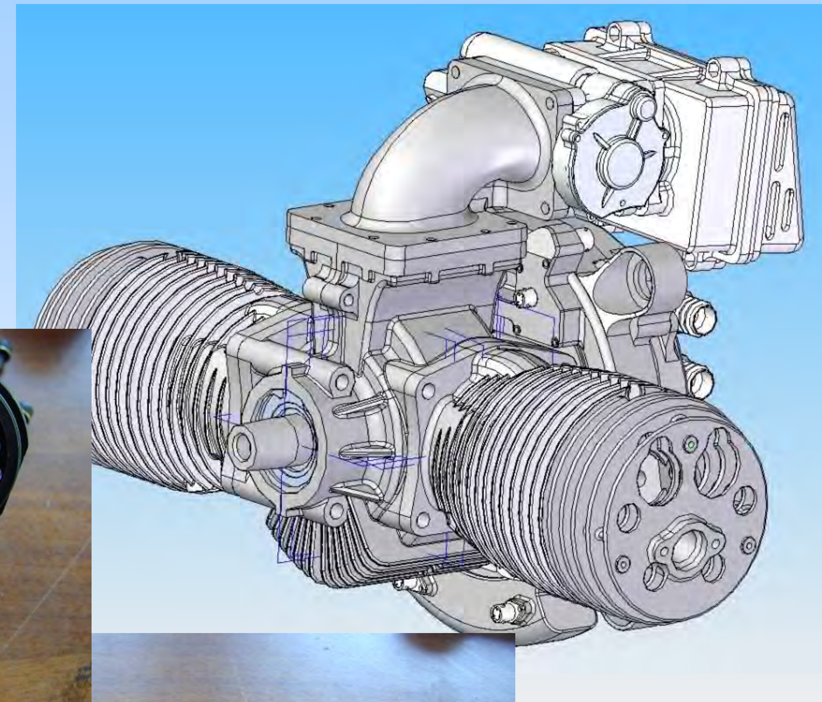
Legend: ++++ The best

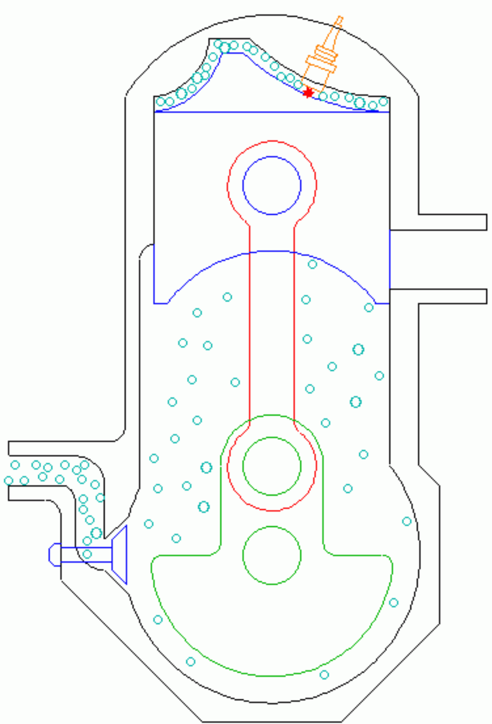
Four Stroke Engine



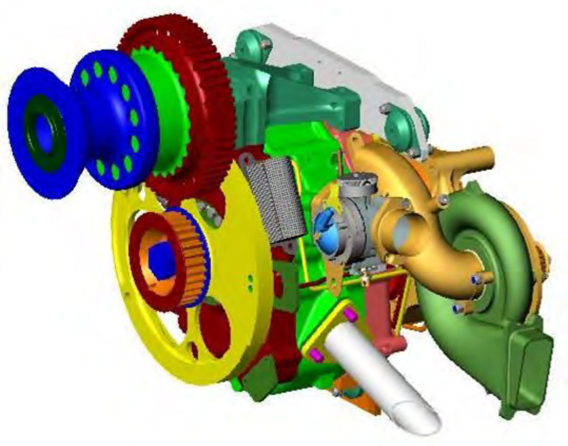


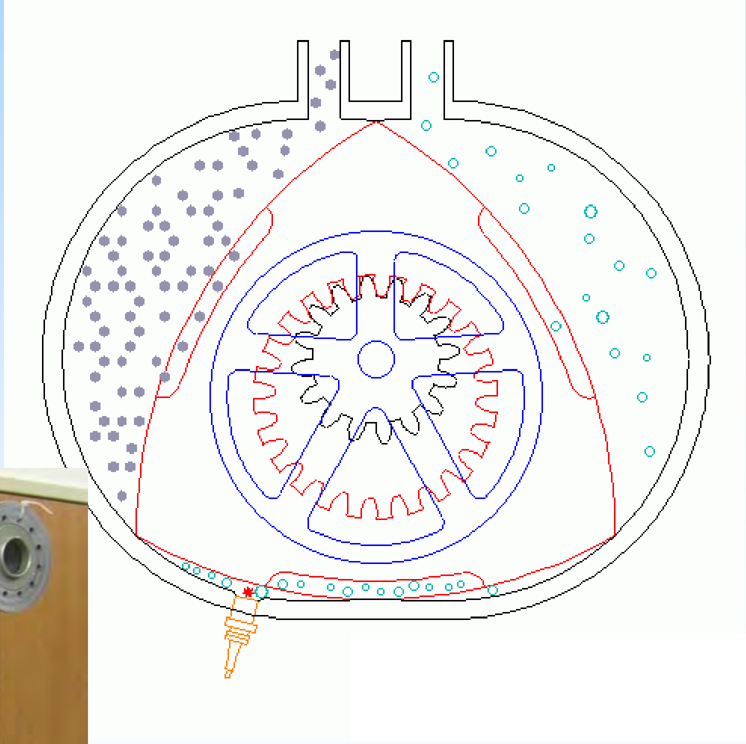
Two (2) stroke engine

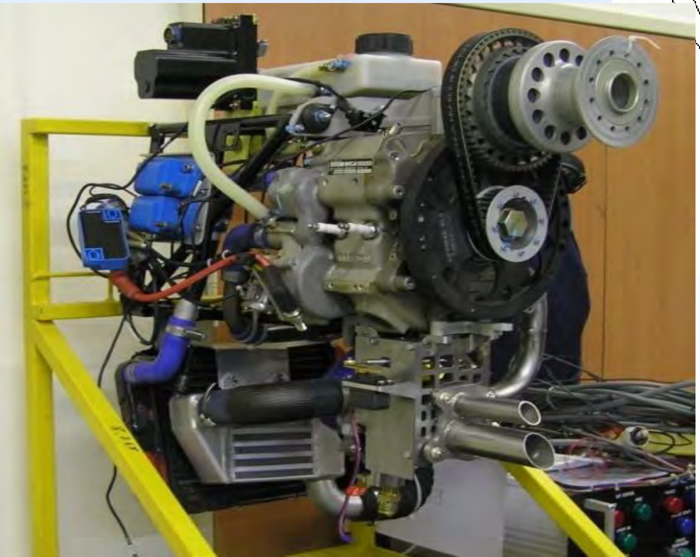




WANKEL Engine



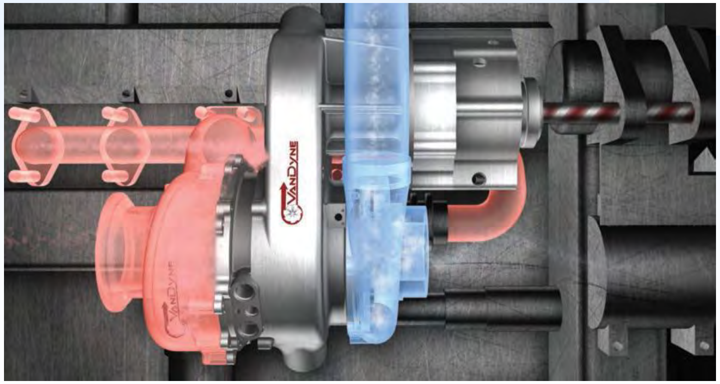




IC Turbo - charging

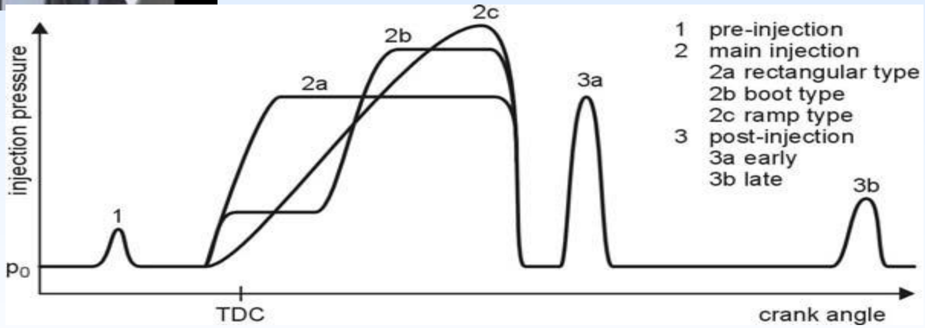
BMW- Tri Turbo Diesel engine

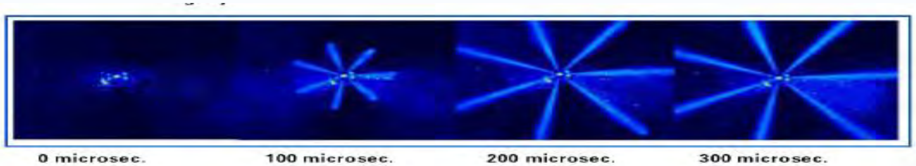
Volkswagen TSI engine



VanDyne- Turbo compound

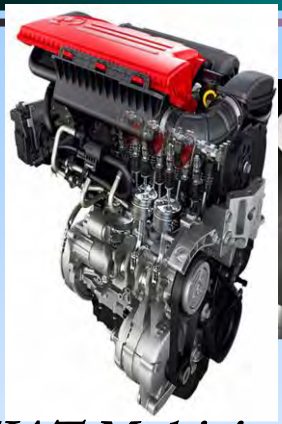
Direct Fuel Injection



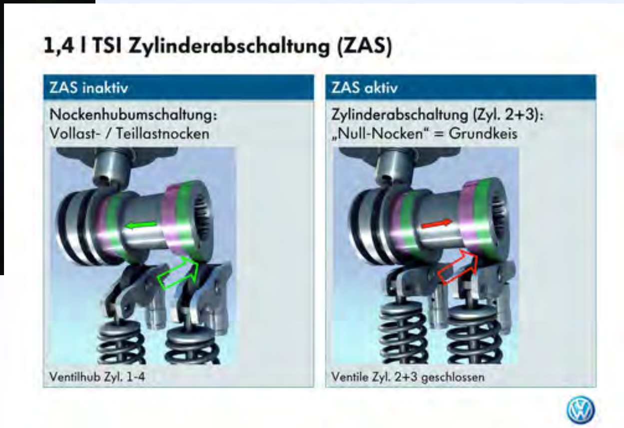


Very-High pressure fuel system

Valves control (Semi -Atkinson Cycle)

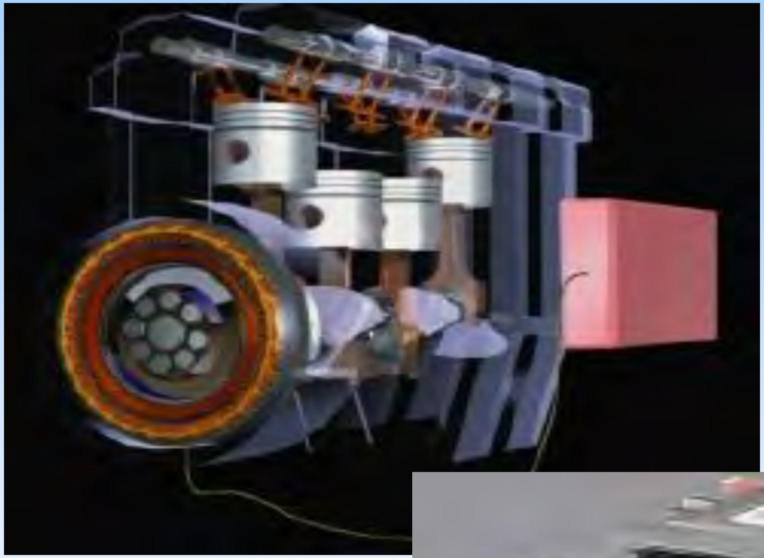


FIAT Multiair



- Active valve opening control (Atkinson cycle)
- Adaptation of thermo – cycle to loads and power needs.
- 5-15%Efficiency gain

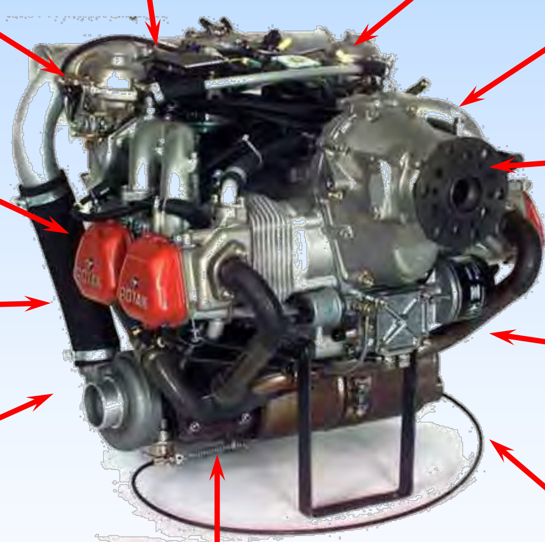
Starter - Alternator



- Efficient
- High Power and Moment
- “Built In“ structure
- Reliable
- Enables Hybrid Propulsion

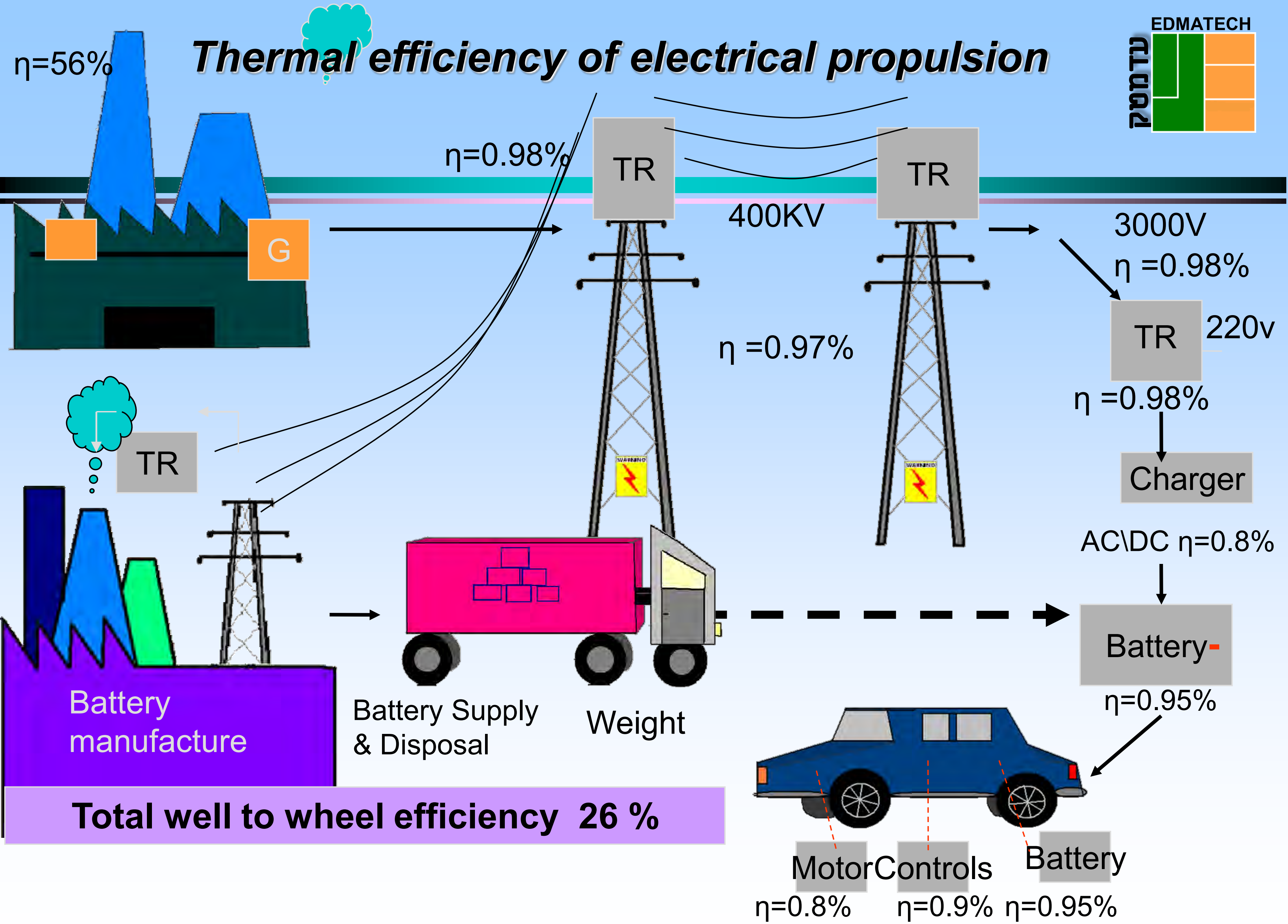
Electric Wheel Drive

IC – UAV Systems



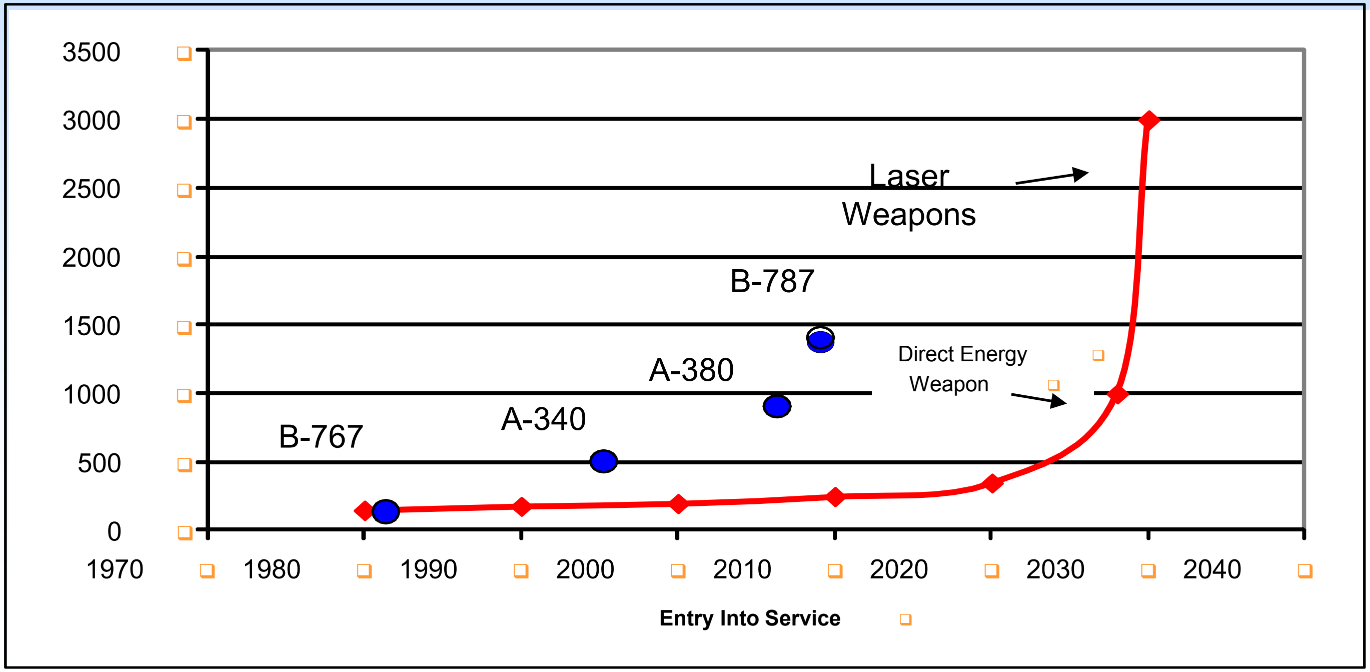
- Heat Exchangers Scoops
- EFI/ DFI
- Propellor (Noise & Efficiency)
- Health Monitoring Systems
- Transmission
- Fuel And Oil Systems
- Intake system
- Starter Alternator 1 L.fuel =Kwh
- Turbo-Charger
- Exhaust System
- Shock Mounts

Thermal efficiency of electrical propulsion



Trends – Electrical propulsion

- Efficient high -torque electrical motors with power to weight ratio of 8+
- Increased demand for a/c electrical consumption for payloads.
- "Intelligent" control of power sources and usage
- High voltage systems
- Batteries / Fuel cells with power to weigh ratio 300 --- 600 Watts/Kg



(KW)

Energy Density - Elec. Drive Vs. IC Engine

Battery





Fuel Tank

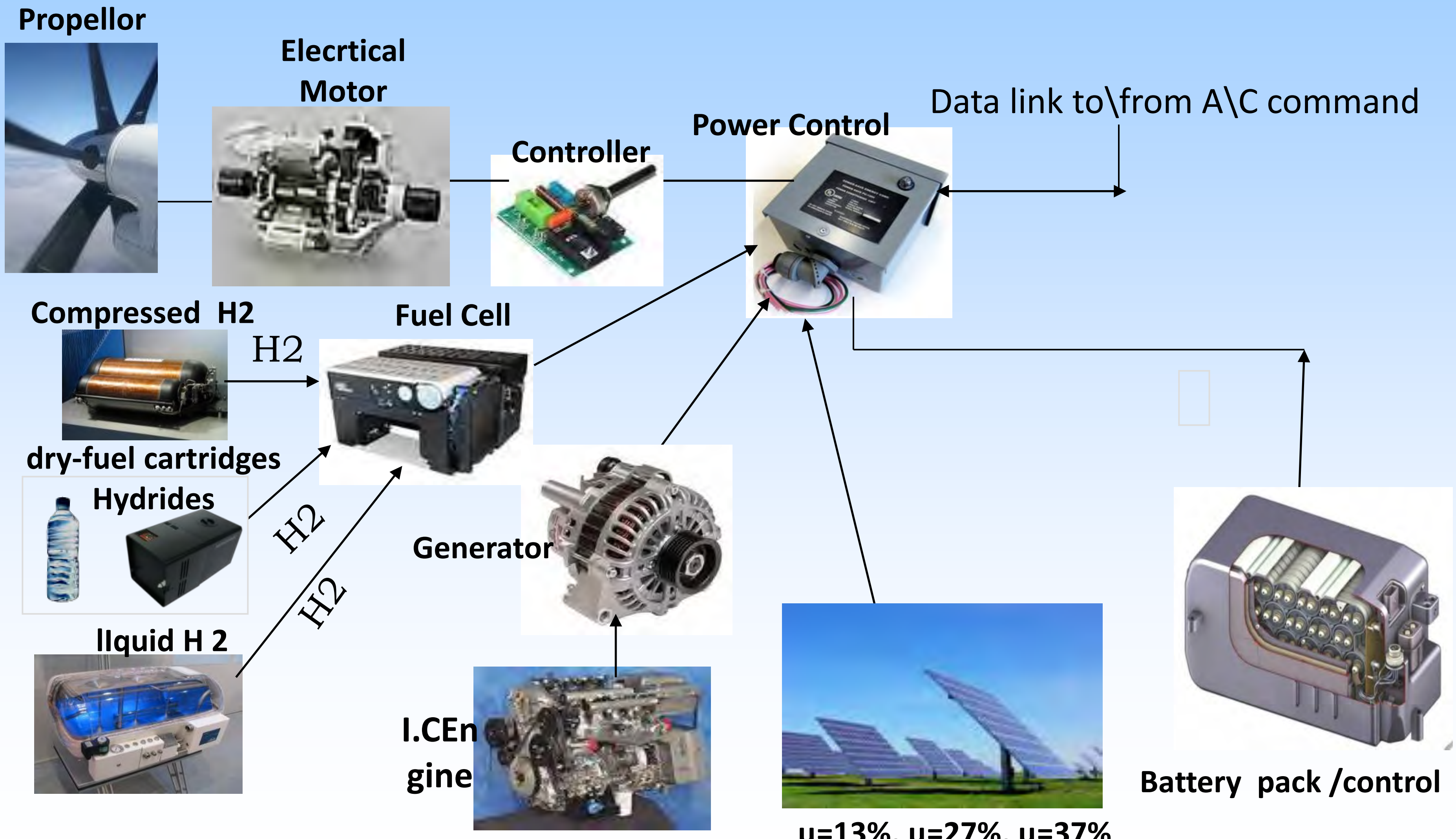
Electrical Propulsion

- Battery Energy density – 0.2 kwh/kg
- Controller Eff. = 0.9
- Motor eff. = 0.9
- Energy Output:
  0.2x0.9x0.9 = 0.16 kwh/kg

- **Fuel Energy Density - 12 kwh/kg**
- **Efficiency: Otto= 0.3**
- **Efficiency: Diesel= 0.4**
- **Energy output:**
  - **Otto - 12x0.3 =** 3.6 kwh/kg
  - **Diesel - 12x0.4 =** 4.8 kwh/kg

The ratio between Energy density of IC/ Fuel and Elec. Battery/Motor is 20–30 to 1 !!

UAV IC / Electrical hybrid



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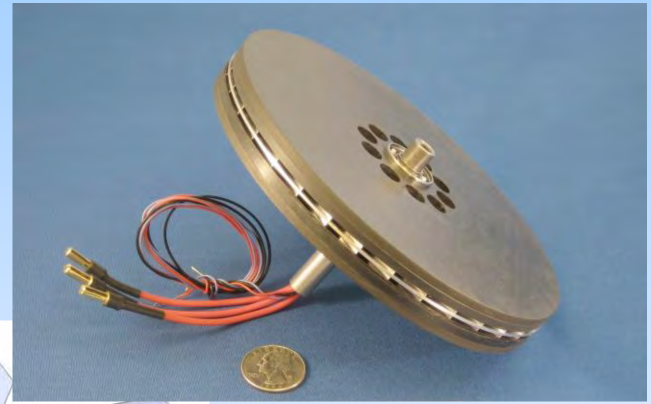
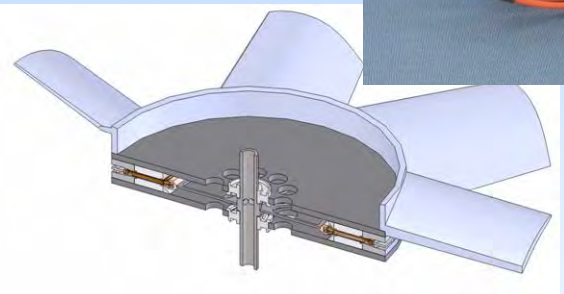
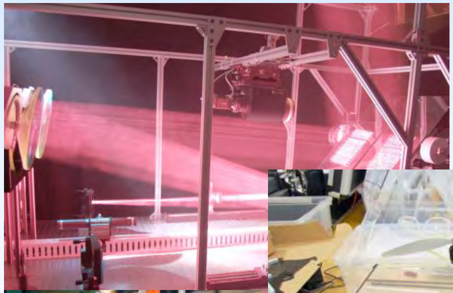
Electrical Propulsion





<u>Laser-- Radiated Energy ,HF</u>

- **Very low efficiency (3.5%)**
- **"At starting point"**

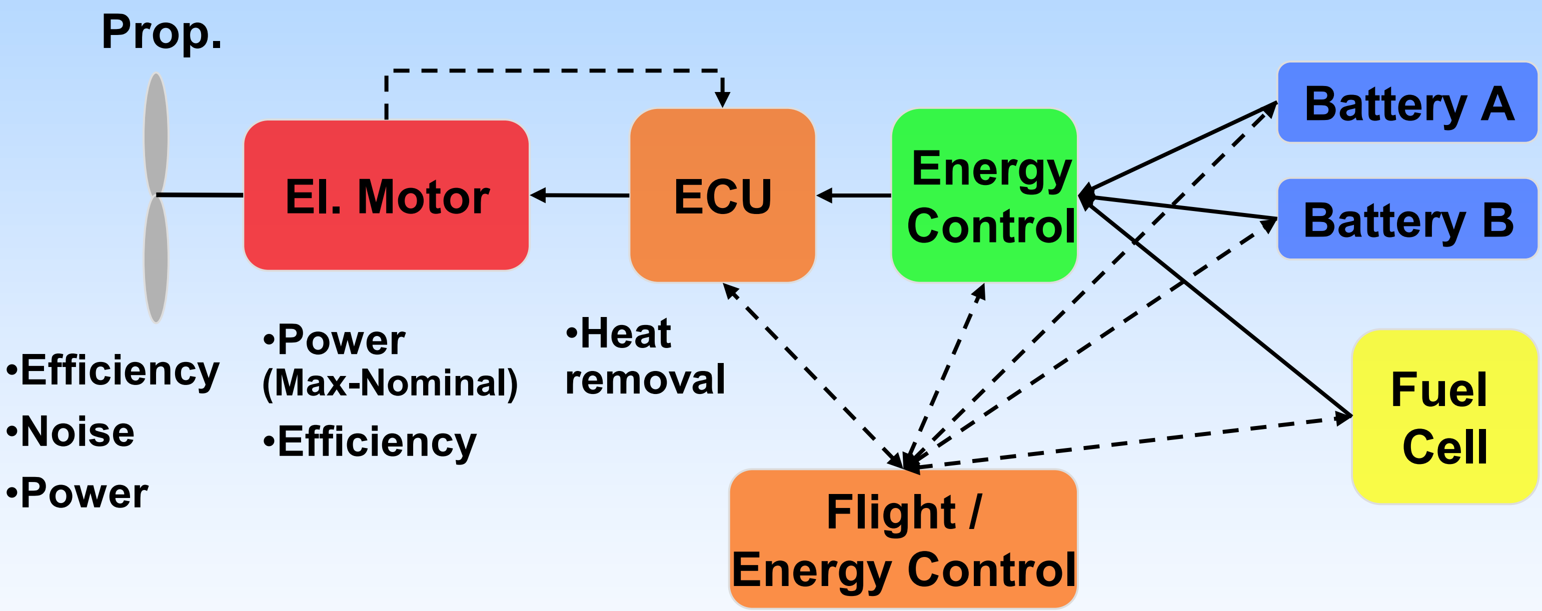


<u>Elec. Motors</u>

- **Weight to power ratio 1:8 Hp/Kg**
- **Efficiency (0.95)**
- **Axial Flux/ Halbach**

System Consideration

- Motor /Propellor optimisation
- Max. Efficiency @ Design point
- Optimal Useage and Control of Energy Sources



•Power Control
•Residual Energy
•Routing of energy Sources
•Energy Consumption optimisation

Fuel Cells for UAV 's

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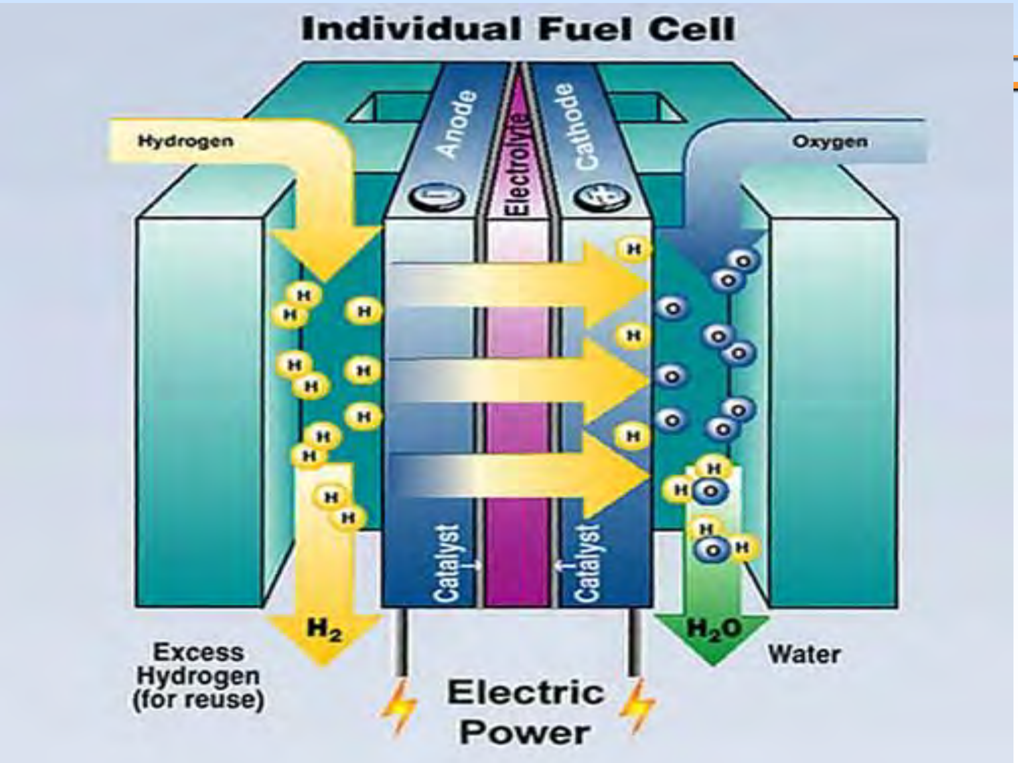
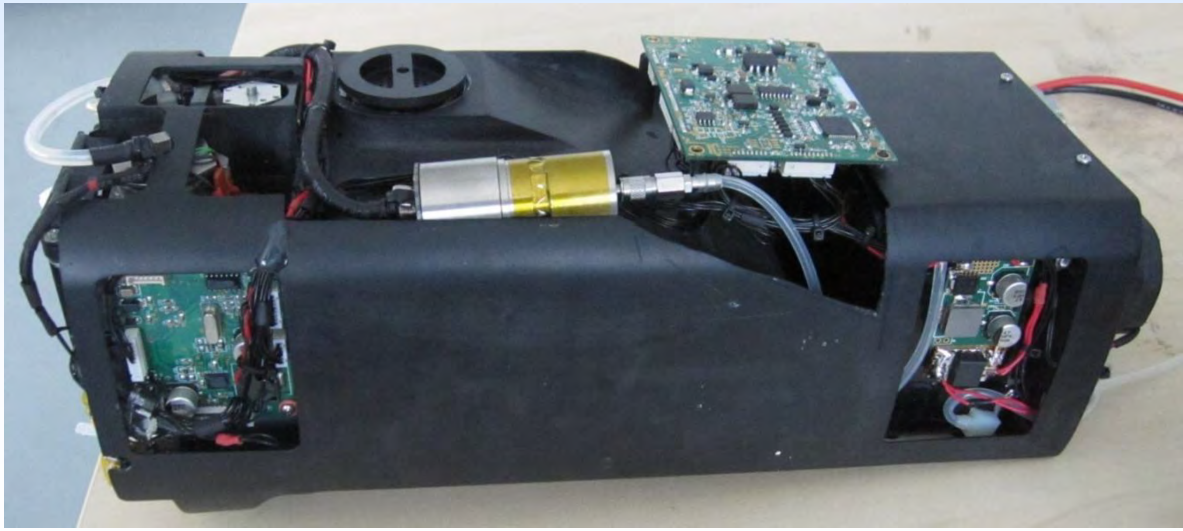
- **Trends**
  - Hydrogen storage improvements
  - Onboard Hyrogen generation
  - Use of Methanol
  - "Closed loop" water system

- **Advantages**
  - Higher Energy Density than battery
  - "Fuel Tank Concept "



- **Shortcomings**
  - Complexity
  - Price.
  - Technology not yet mature

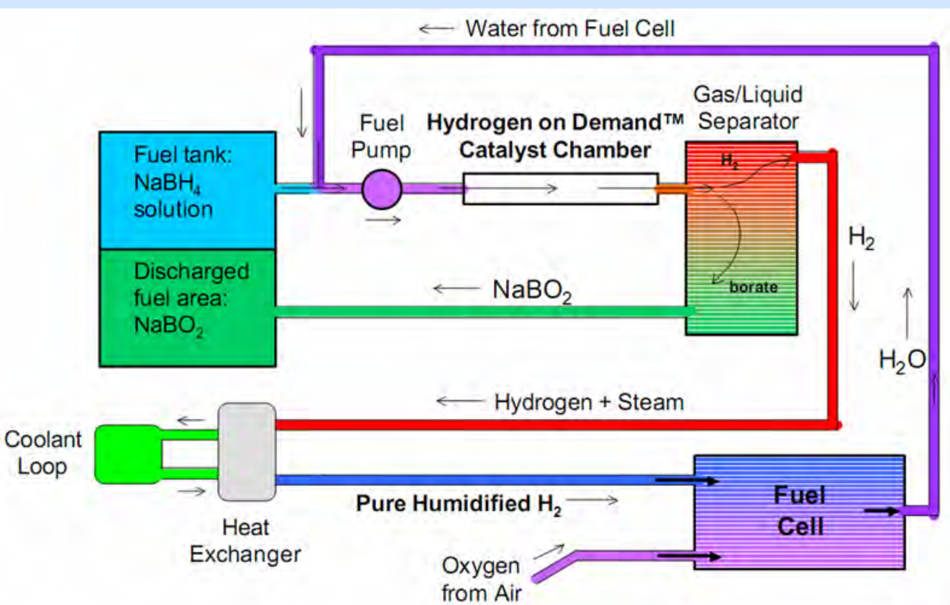
UAV - Airborne Fuel Cell



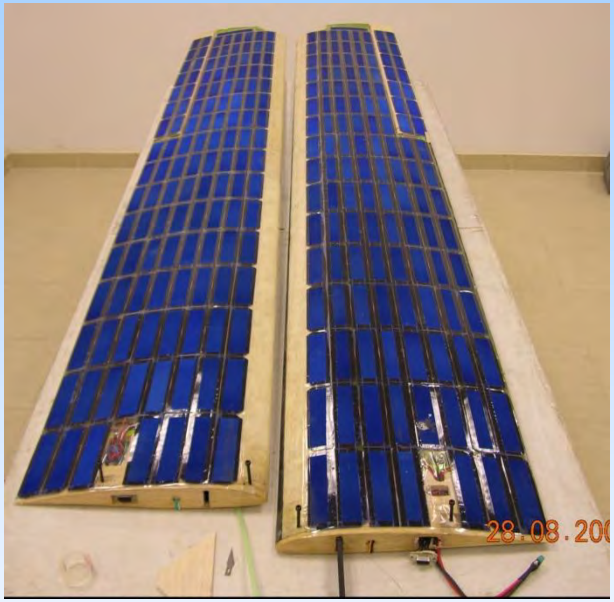
Fuel Cells Application

Technologies

- PEM
- Hydrides/PEM
- Methanol DMFC
- Propane /SOFC



Photovoltaic hybrid propulsion



Hybrid Propulsion

PV Propulsion

- High Altitude Application
- Unlimited Time on station
- Technology of PV cells and batteries are not yet mature for this application

Bio Propulsion

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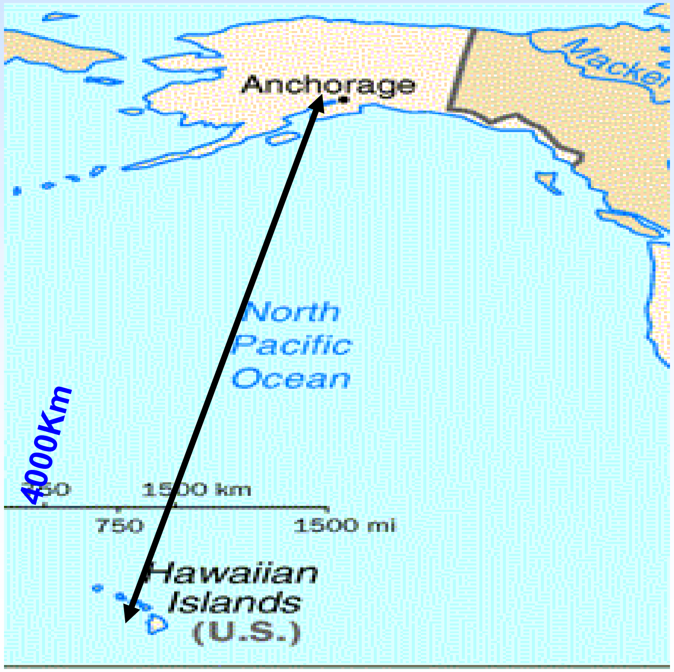
Golden Plover UAV

Consumption - 70 gr. of Fat = Fuel

Flight of 4000 km non- stop 88 hrs / 250,000 Wing Flaps



Take-off weight – 200 gr

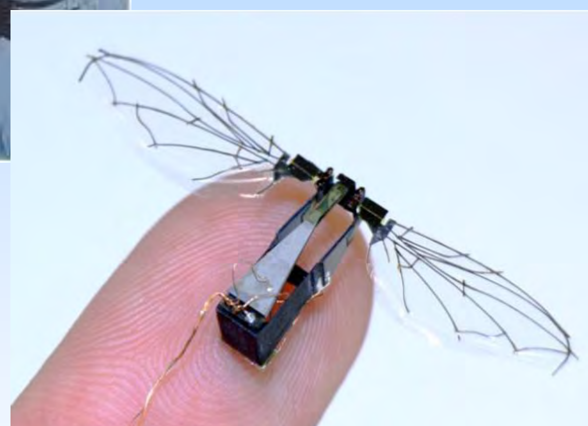
Landing weight – 130 gr.

Future Trends

Albatros

"Bio" - Propulsion

We try to understand and learn?



Low Reynolds Aerodynamics

Airfoils

Materials

Smart structures

Summary of trends IC Engines

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- I.C Engines will continue to dominate UAV Propulsion due to the high energy density/content of the HydrocarbonFuel.
- UAV Engines benefit from the developments in Automotive Industries.
- More and more UAV'S will require Heavy Fuel capability.

Summary of trends Electrical Propulsion

- "Break Through" in Energy capacity and power to weight ratio of batteries is needed .
- The portable I.T. devices as well as automotive applications are taking the lead.
- Usage for small UAV'S with limited flight duration.
- Important achievements in Electrical Motors and Generators.

Summary of trends Fuel Cells

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- Promising technology with higher energy density than batteries
  (600 wh/kg. and up)
- Bottled high pressure hydrogen with PM are practical solution for small long–range UAV'S.
- Cryogene-hydrogen systems can increase range and payload.
- Other Fuel- Cell systems are complex and require considerable effort to mature and to reach reliability.
- In next year or two we shall see Automotive Fuel cells on the market and maybe these technologies can be used in UAV propulsion.

Summary of trends -Photovoltaic Propulsion

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- Need further advances in:
  - Lighter structures.
  - Lighter and higher efficiency of P.V cells.
  - Batteries or Fuel- Cells back-up need much higher power density.
  - Flexible wing flight controls.
  - Efficient Low-speed Propellers.

Summary of trends Hybrid Systems (I.C and Electrical)

- Important load fluctuations.
- Big difference between the requirement for duration of High- Power (T.O) and the cruise power.
- The A/C design and structure dictates distributed electrical propulsion.
- Automotive Industry is leading.

The dream

Summary

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We still have a lot to learn …

Thank You