IMOTHEP

GETTING HYBRID ELECTRIC

Key Technologies for hybrid electric flight

Dirk Zimmer – DLR

IMOTHEP First Technology Workshop

11/11/20 - On-line meeting

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 875006

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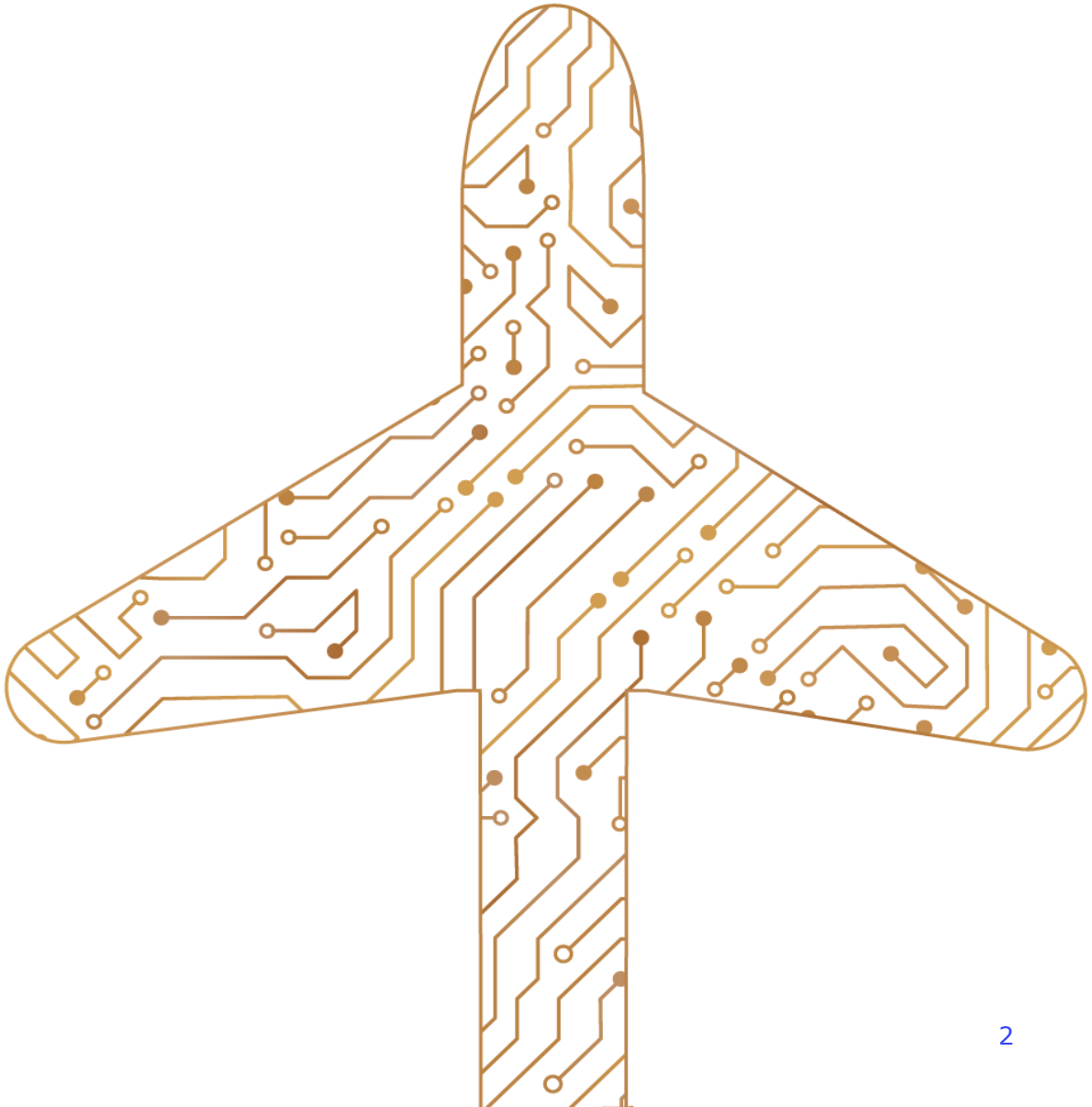
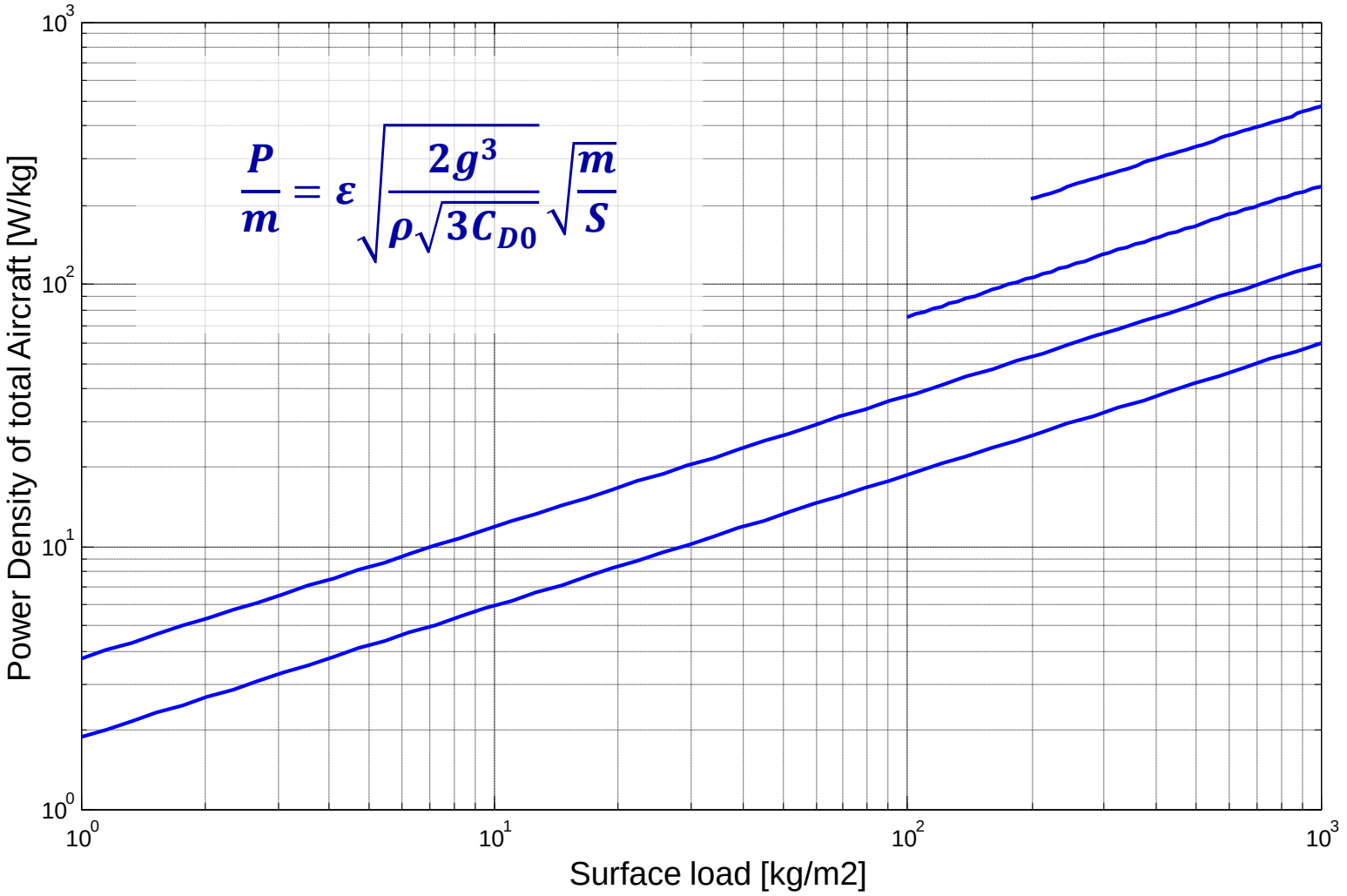


Technology Demand: Need for high power Density



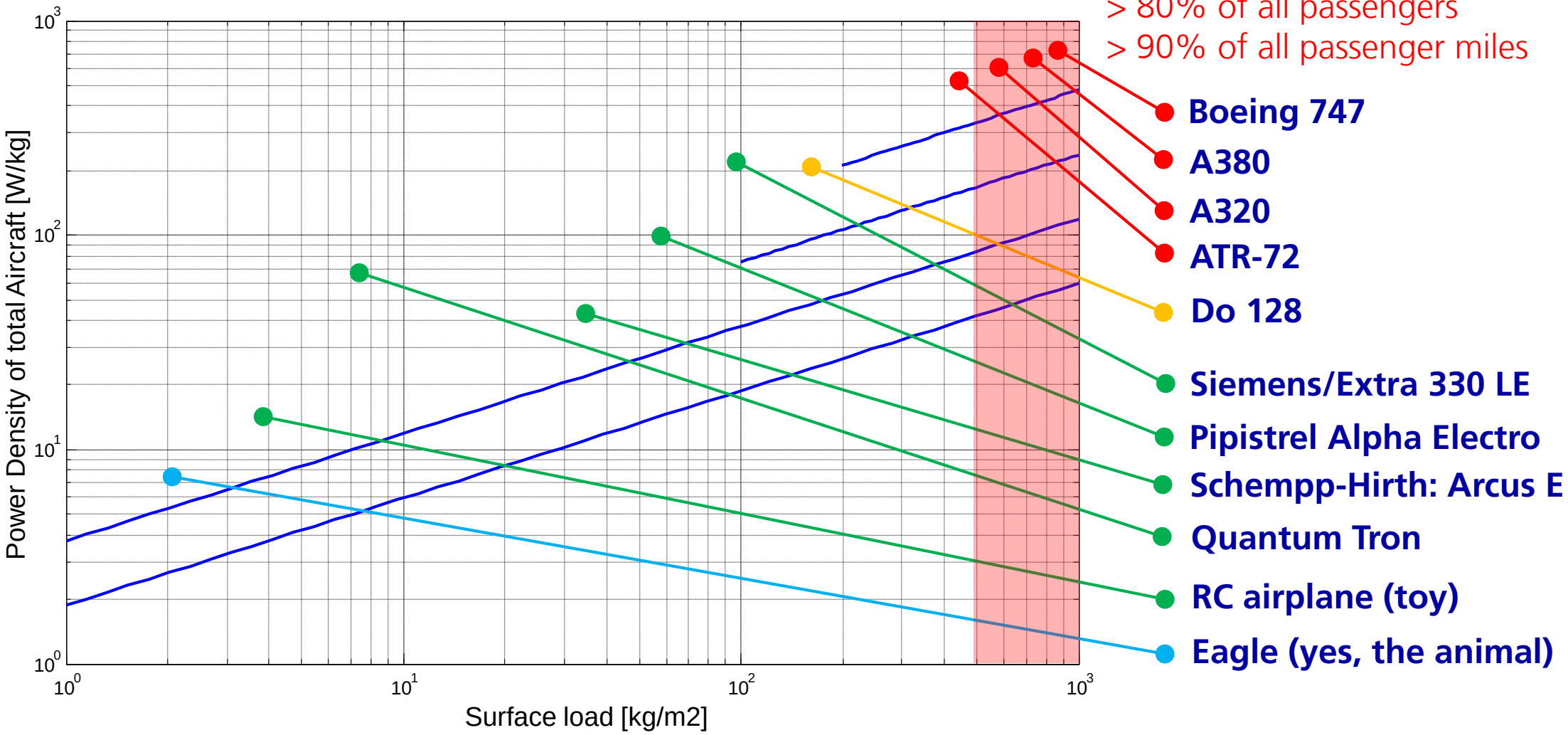
fast and high.

safely…

and fly…

Glide…

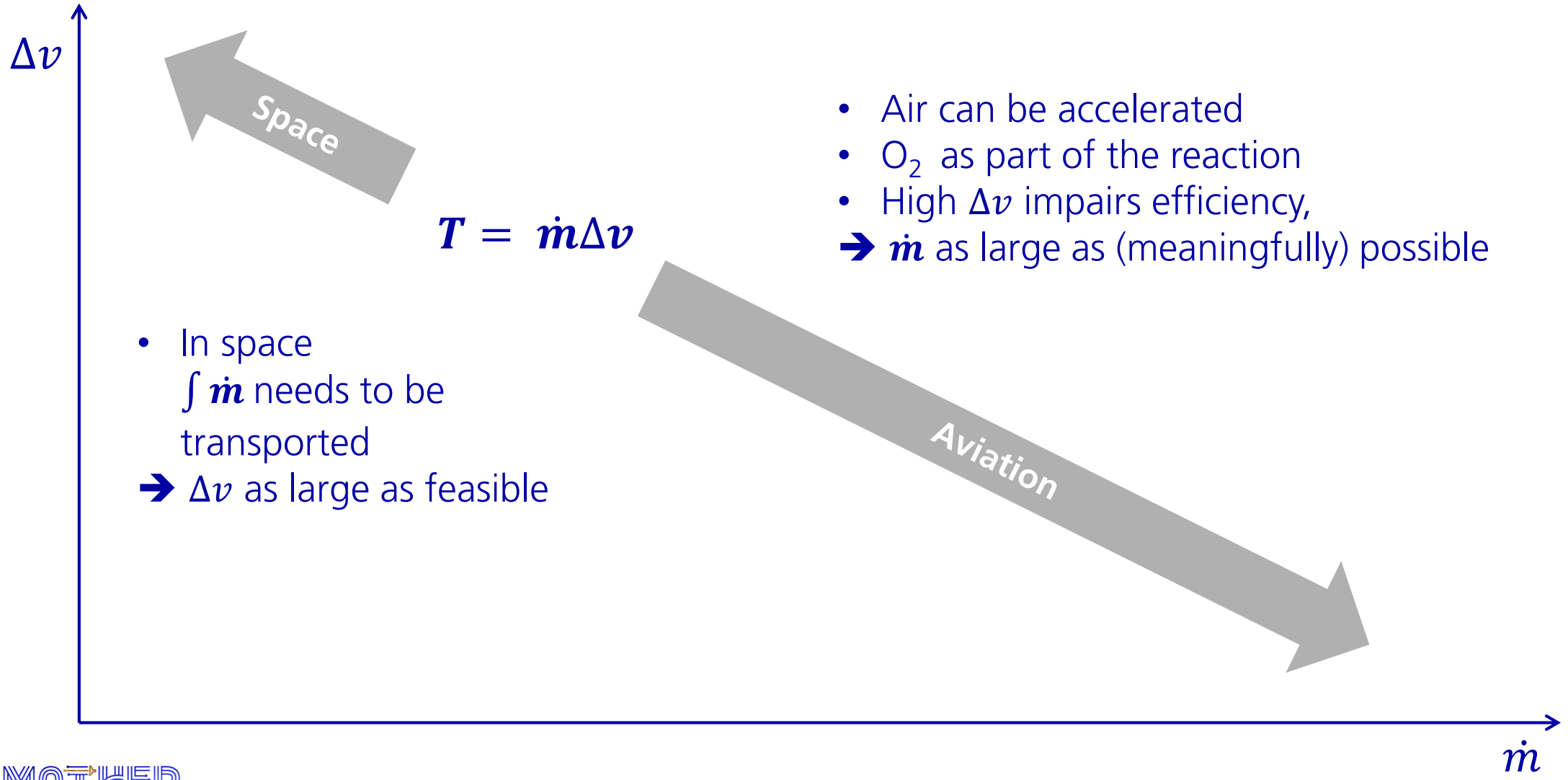
Technology Demand: Need for high power Density



> 80% of all passengers
> 90% of all passenger miles

- Boeing 747
- A380
- A320
- ATR-72
- Do 128
- Siemens/Extra 330 LE
- Pipistrel Alpha Electro
- Schempp-Hirth: Arcus E
- Quantum Tron
- RC airplane (toy)
- Eagle (yes, the animal)

Technology Demand: Need for Power Distribution



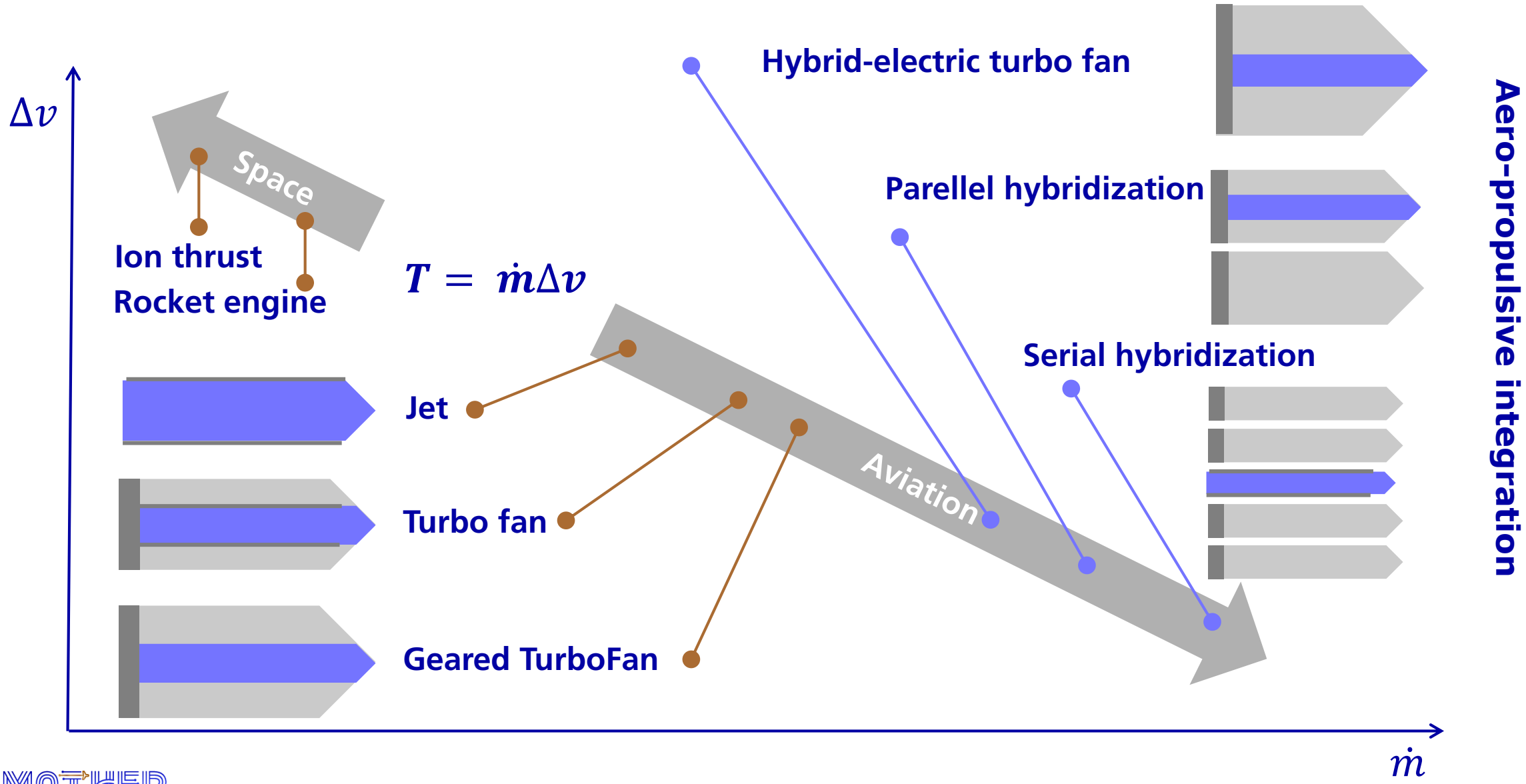
- In space
  $\int \dot{m}$ needs to be transported

➔ Δv as large as feasible

- Air can be accelerated
- O_2 as part of the reaction
- High Δv impairs efficiency,

➔ $\dot{m}$ as large as (meaningfully) possible

Technology Demand: Need for Power Distribution



Technology Assumptions: Electric Components

Device Type	Conservative 2035	Aggressive >2035
Electric Machine: • Power Density [kW/kg] • Efficiency [1] • Power Factor [kW/kVA]	 11 kg/kW 96% 0.95	 17 kg/kW 97-98% 0.95
Electric Power Converters • Power Density [kW/kg] • Efficiency [1]	 20 kg/kW 99%	 30kg/ kW 99%
Circuit Breakers DC or **AC** • Power Density [kW/kg] • Efficiency [1]	 93 or 260 kg/kW 99.5%	 200 or 350 kg/kW 99.5%
Main Voltage Level	1kV DC	3kV DC
Cable Weight and Losses	subject to consolidation	subject to consolidation

based on various literature

Technology Assumptions: Energy Storage

Device Type	Conservative 2035	Aggressive >2035
Battery: • Energy Density [Wh/kg] • Energy Density [Wh/l] • Power Density [C-Rate] • Battery Efficiency [1] • Discharge Depth [1]	310 Wh/kg (pack-level) 800Wh/l (cell-level) <8C 90% (discharge) 80%	450 Wh/kg (pack-level) 1000Wh/l (cell-level) 10C >93% (discharge) >80%
Fuel Cell • Power Density [kW/kg] • Efficiency [1]	subject to consolidation 2kW/kg 40-60%	subject to consolidation up to 8kW/kg? 65%?
H2 Tank and Fuel System • Volumetric Density • Gravimetric index • System Energy Density	subject to consolidation	subject to consolidation

based on various literature

Technologies for Thermal Management

Overall challenges:

- Large amounts of thermal power [MW]
- Small temperature gradients
- Strict requirements for inverters, batteries, etc.

Potential Energy Sinks:

- Near the engines (GKN, CHAL)
- on Wings and Fuselage (BHL, MTU)
- Fuel (BHL, MTU)
- Recovery by Peltier effect or Stirling converter (Safran)

Transport by

- by Pumps (SAFRAN)
- Heat pipes (SAFRAN)

Lumped Estimation for power-specific weight penalty for cooling:

0.68 kW Cooling / kg

Technologies for Thermal Management

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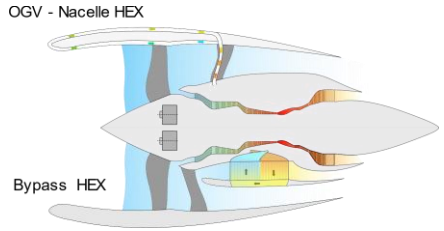
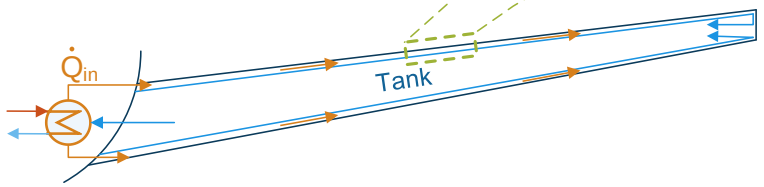
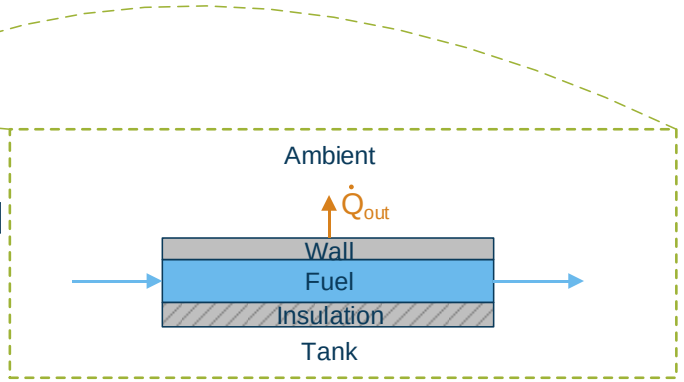
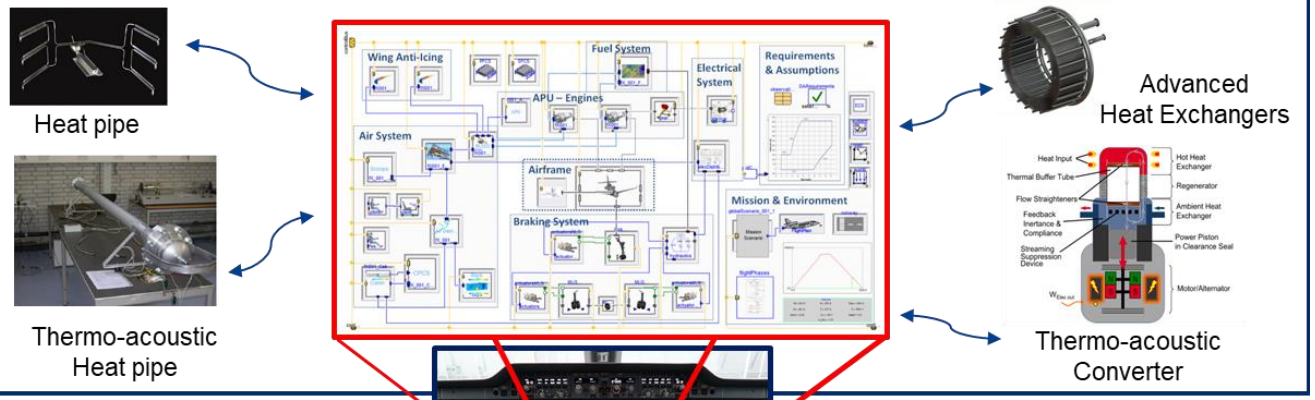


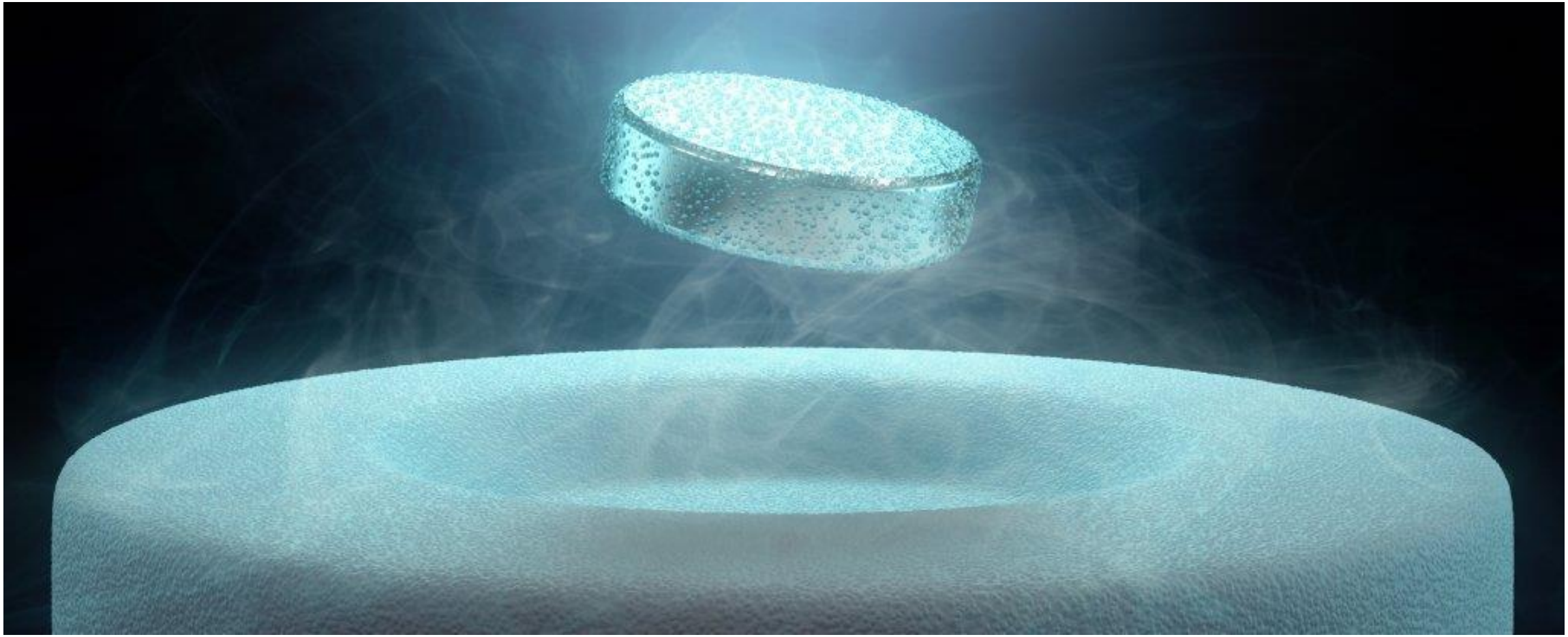




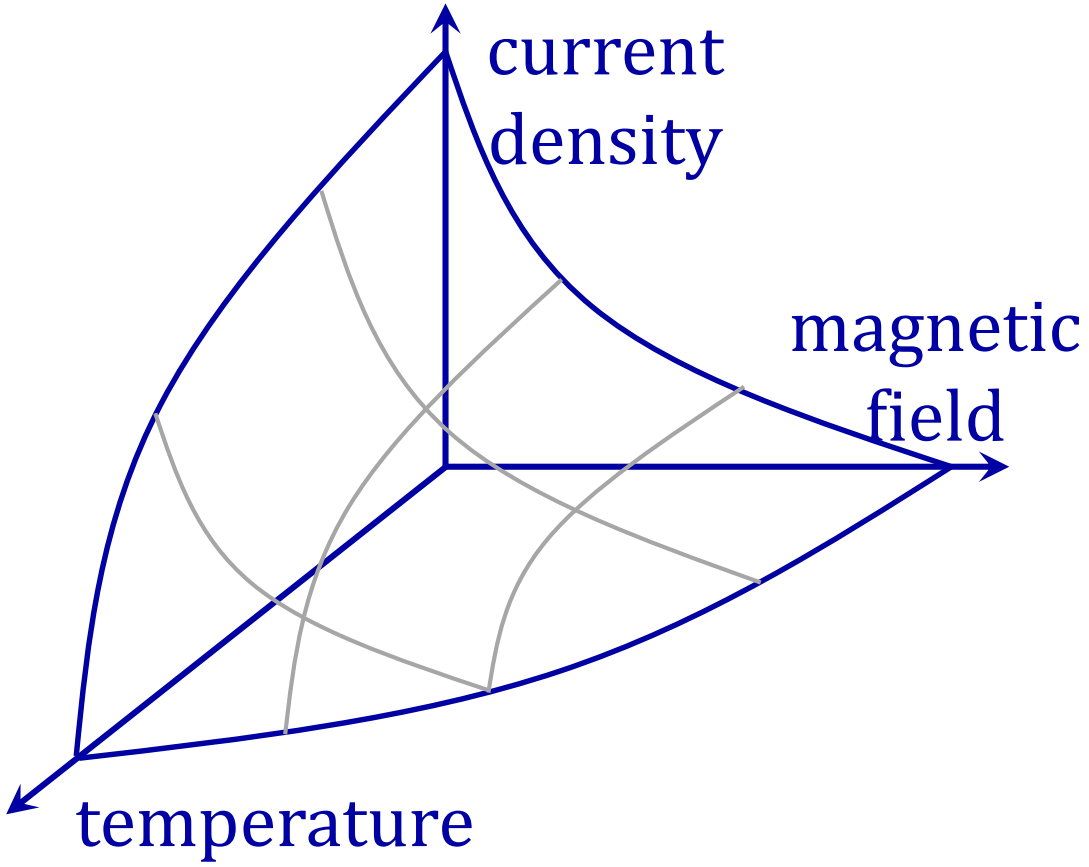


AIRCRAFT ARCHITECT COCKPIT

Potential Disruptor: Superconductivity



Potential Disruptor: Superconductivity



Extremely high power density

- >20kW/kg feasible. Potential to beat classic propulsion.
- Low losses on electric side (however, current lead and mechanic losses still must be regarded)

Resolves key conflict of thermal management

- High Power leads to high voltage
- High voltage leads to electric insulation
- Electric insulation leads to thermal insulation
- Thermal insulation is good for super-conducting systems but bad for conventional systems.

Missing technologies

- Inverter technology still subject to lot of research
- Scalability and price of material is key.

THANK YOU !

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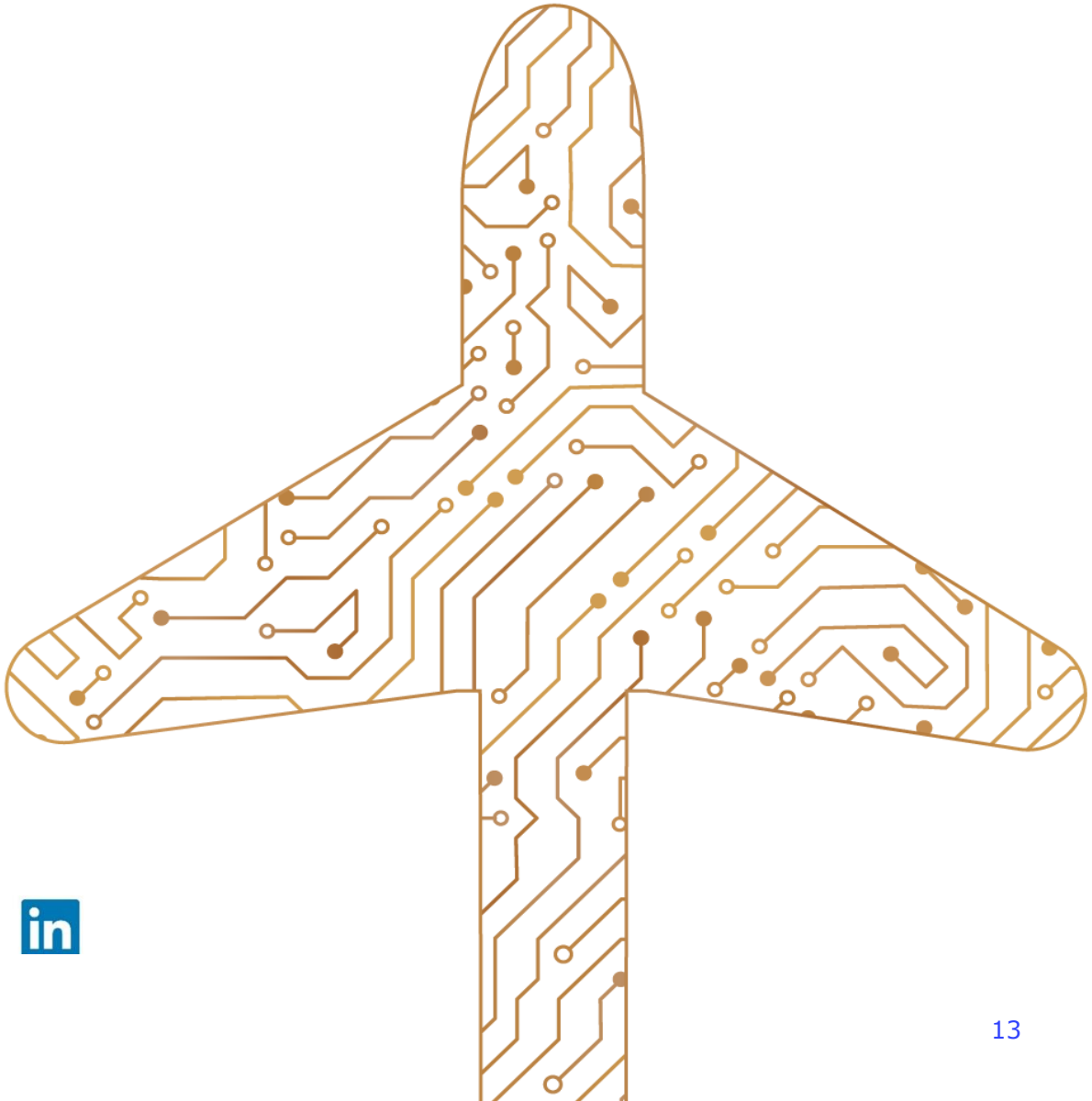
https://www.linkedin.com/company/h2020-imothep/



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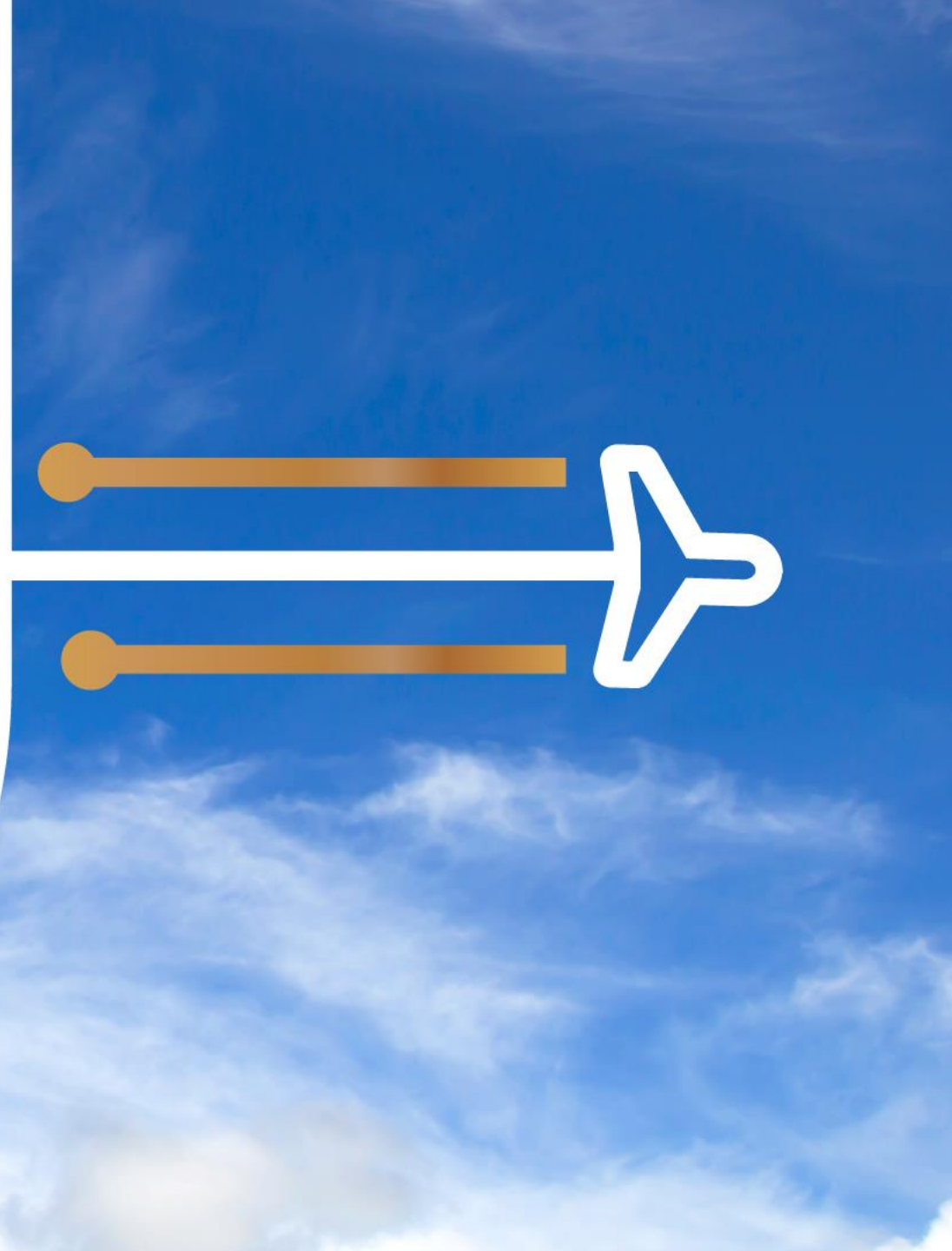

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