

Towards an all electrical Falcon

Cape Town – September 2nd 2013



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**The more electrical Aircraft – Achievements and perspective for the future –
ICAS Workhop - Cape Town 02/09/2013**

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Challenges

- **Improvement of energy management**
 - To reduce fuel consumption
 - To limit the installed power
- **Progress axes**
 - **Improve system efficiencies**
 - ◆ suppression of engine bleed
 - ◆ suppression of hydraulical circuits
 - **Control in a better way the thermal environment of the equipped airframe**
 - ◆ Use of optimized conditioning cycles
 - ◆ Use of adapted de-icing cycles
 - **Integrate systems more and more**
 - ◆ Put the resources of each system at the disposal of the others → rationalization of means
 - ◆ Bring the capacity of configurations on failure to increase the availability

➔ **A vehicle system architecture based on more electrical components is one of the most promising ones to reach the best trade-off considering this whole set of criteria**



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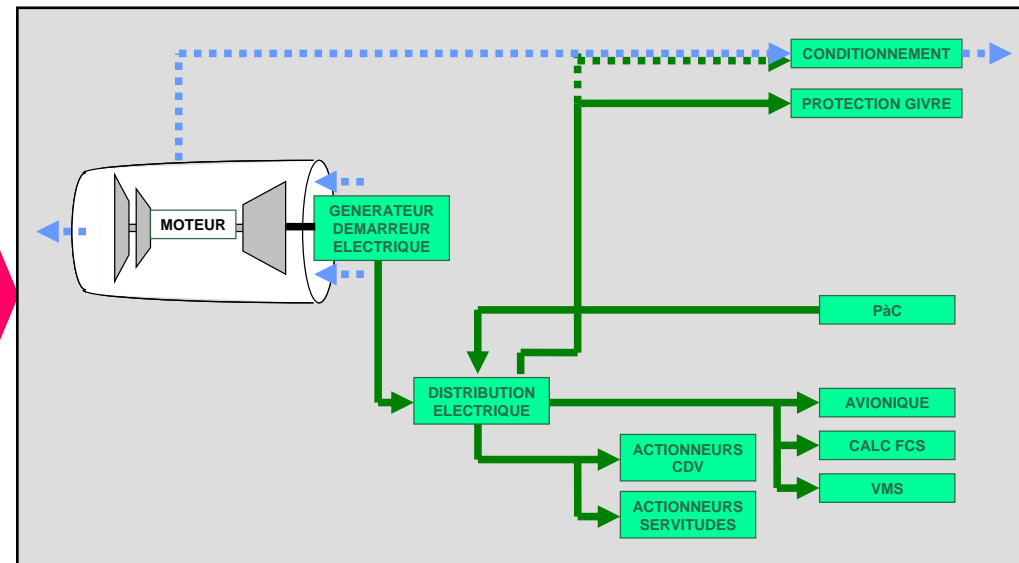
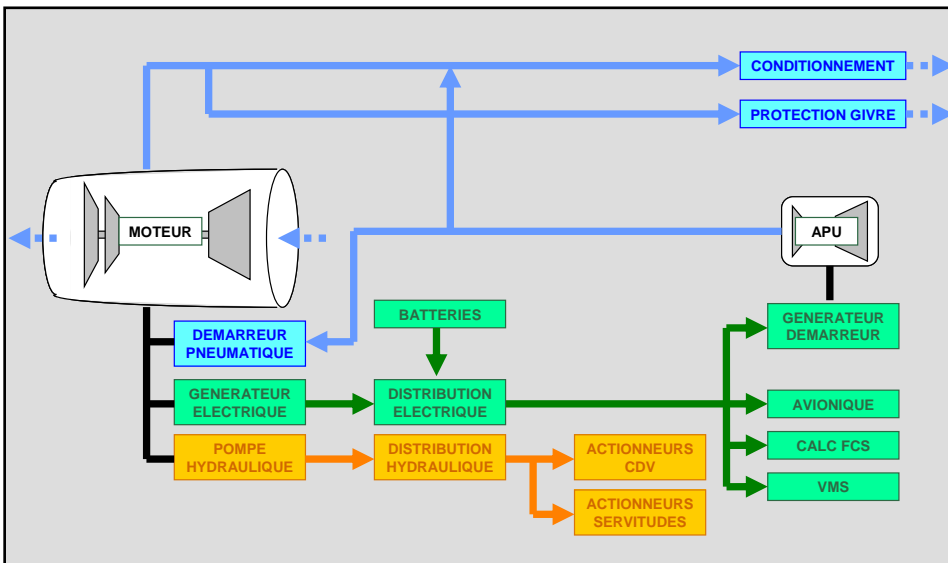
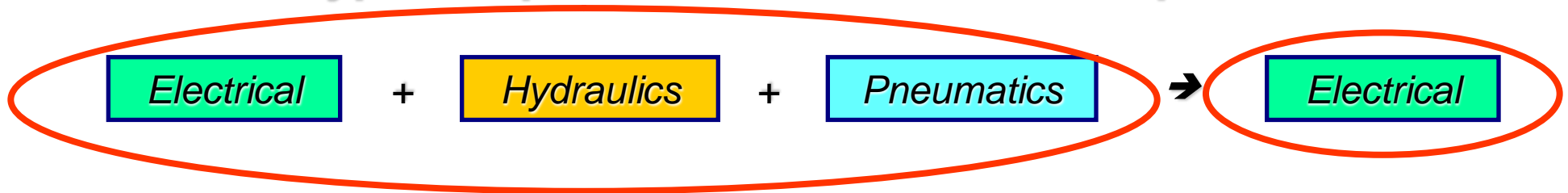
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All electrical Falcon concept: what is it about?

● From three types of power...

To a unique one



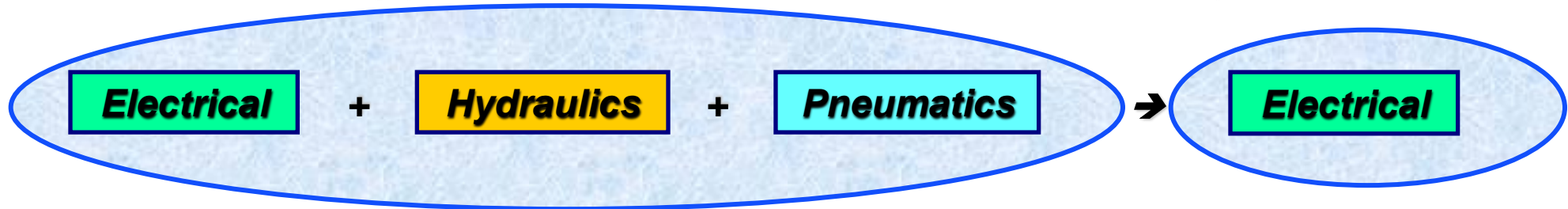
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All electrical aircraft: disruptive architecture concepts

From three types of power...

To a unique one



Installed Power in aircraft (type F2000):

33 kW **25 kW** **550 kW** → **195 kW**

Consumed Average Power:

15 kW **5 kW** **70 kW** → **85 kW**

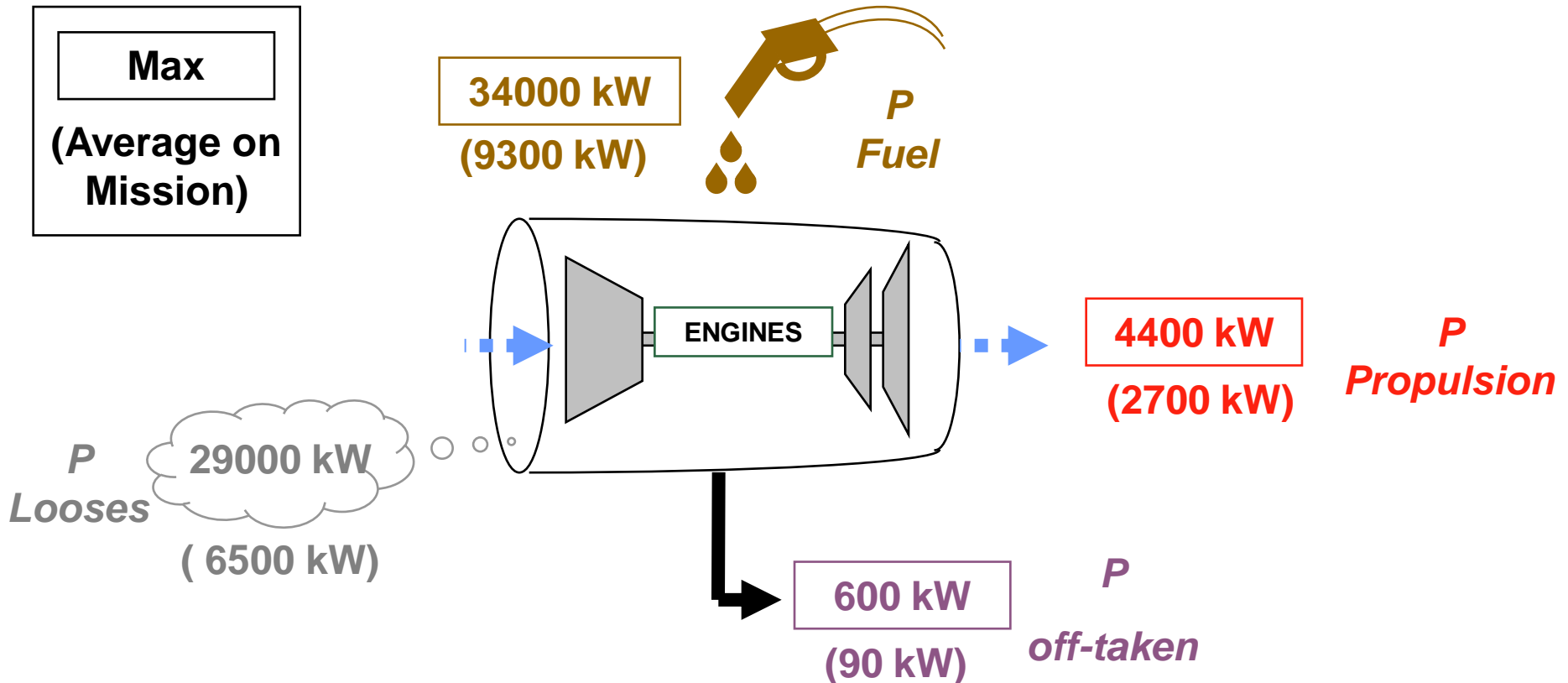
Voltage level:

28 VDC → **270 VDC**
& 28 VDC



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All electrical aircraft: order of magnitudes of involved power



For the extracted power:

The installed power is a significant fraction of the propulsive power: 14%

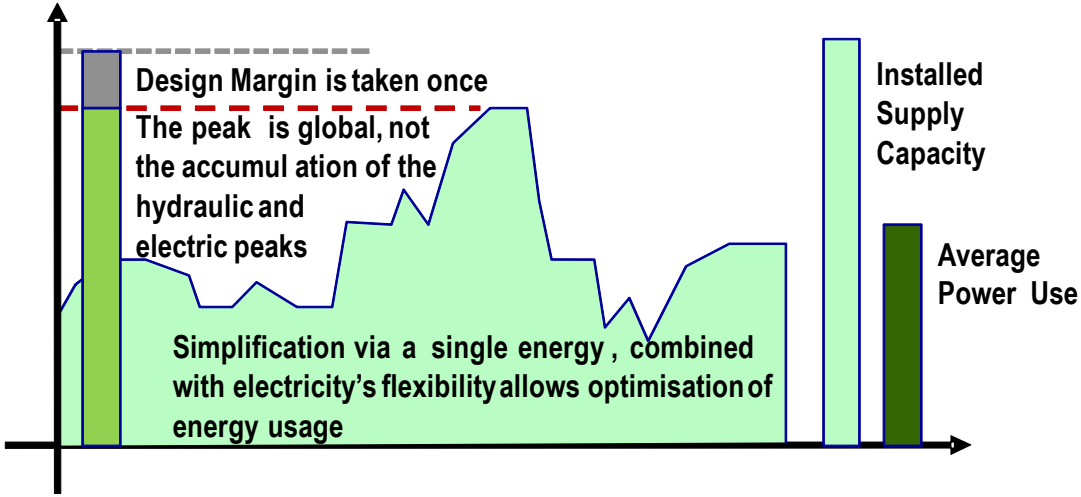
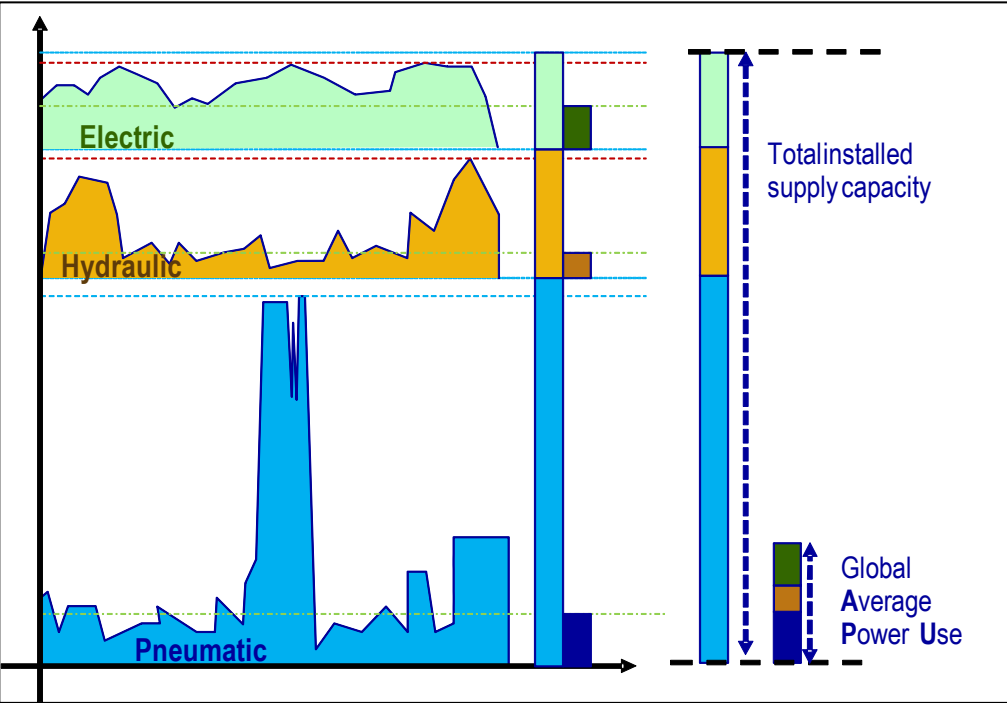
The consumed average power is a tiny fraction of the propulsive power: 3%



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More electrical Falcon



*In the conventional architecture the average power use is about **7 times** less than the total power supply capacity*

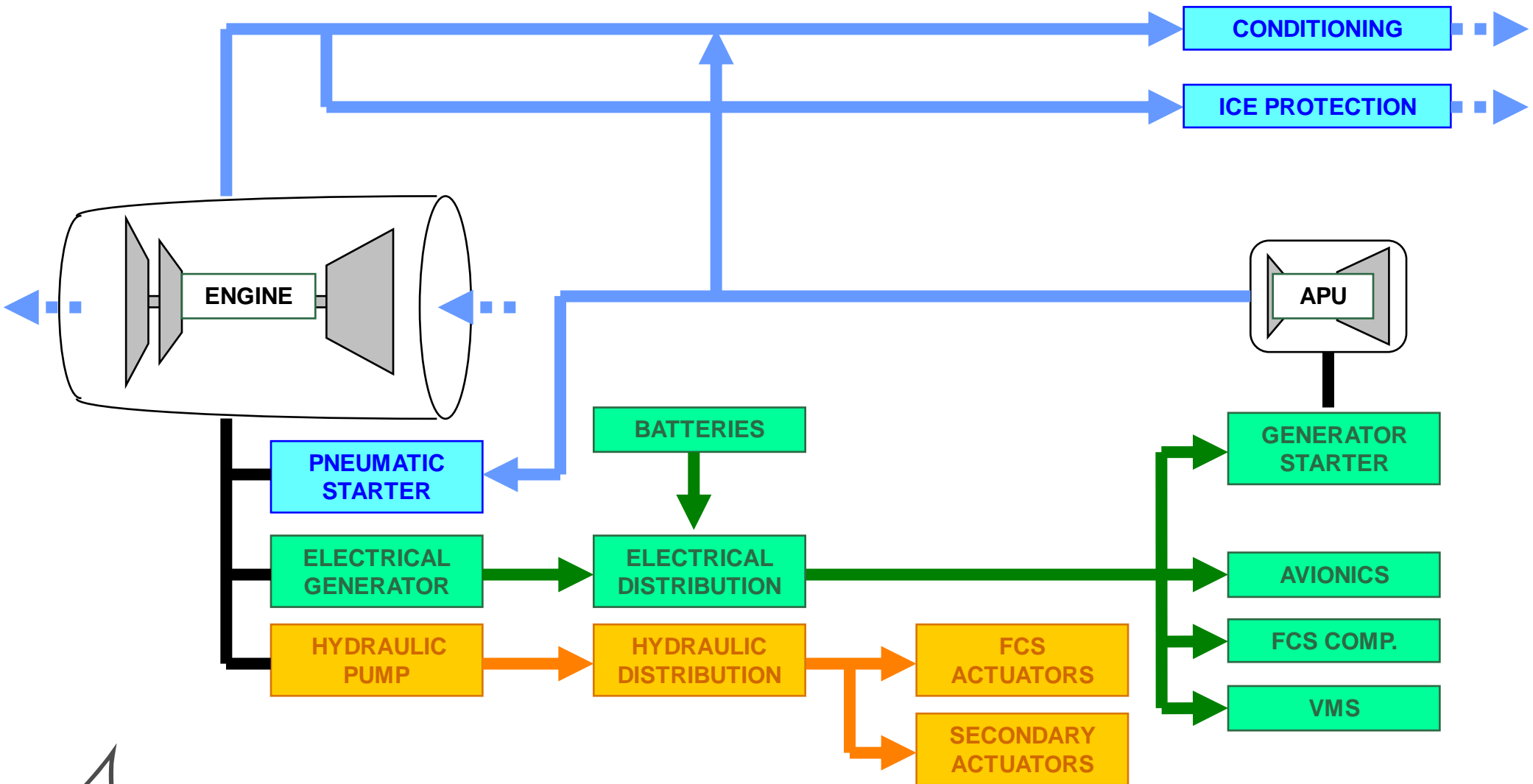
*In all electrical aircraft the ratio between installed power supply and average power use **drops to 2***



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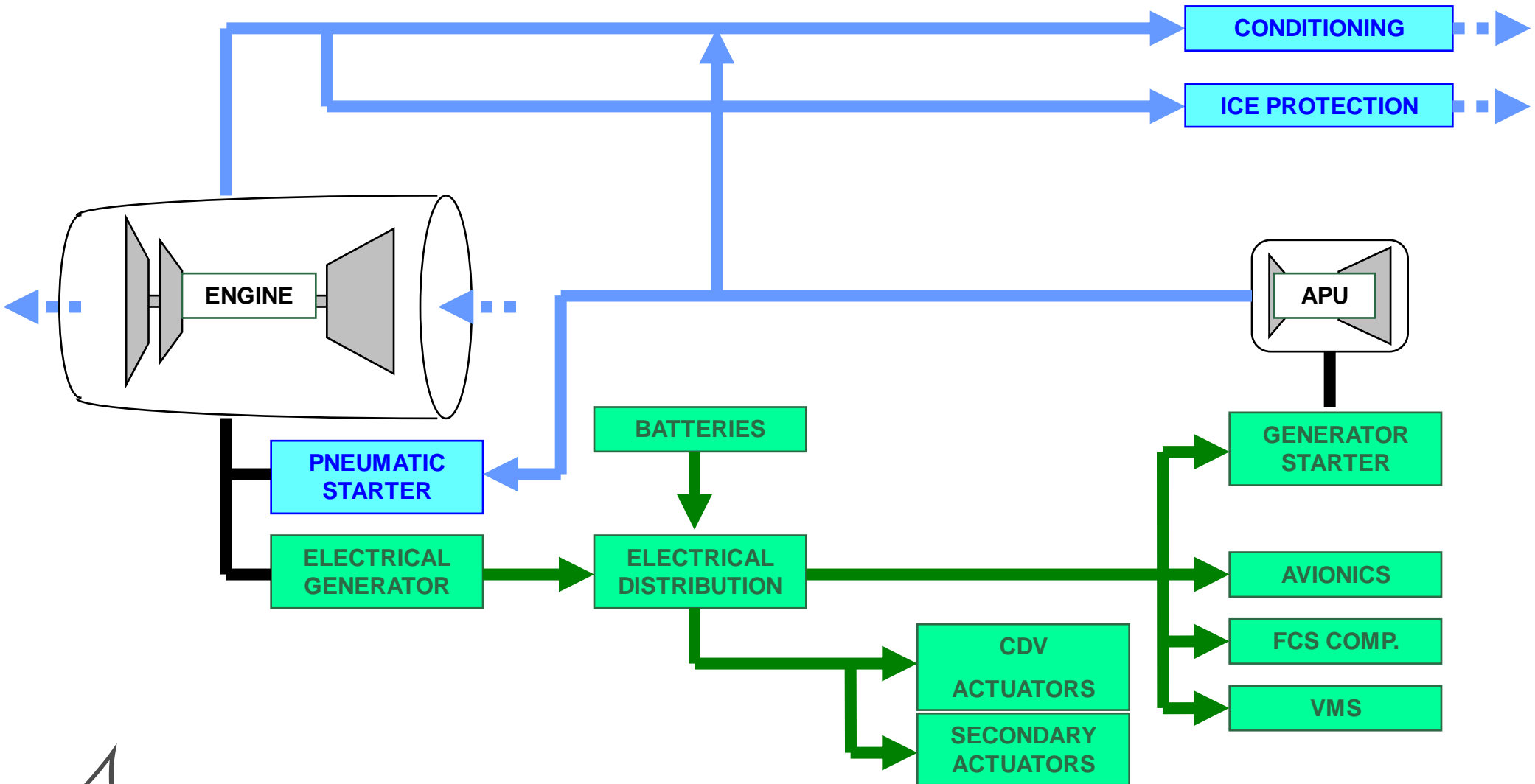
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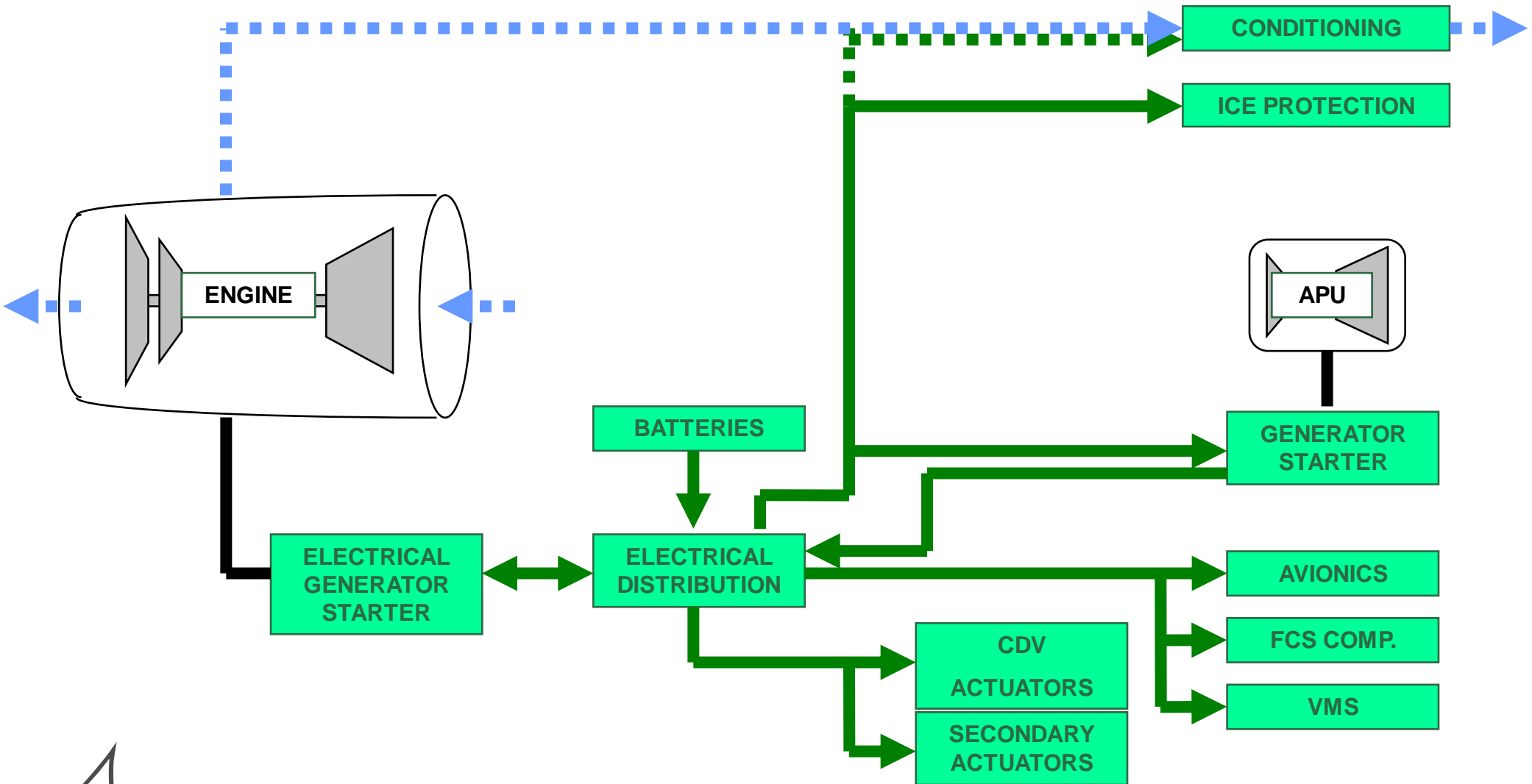
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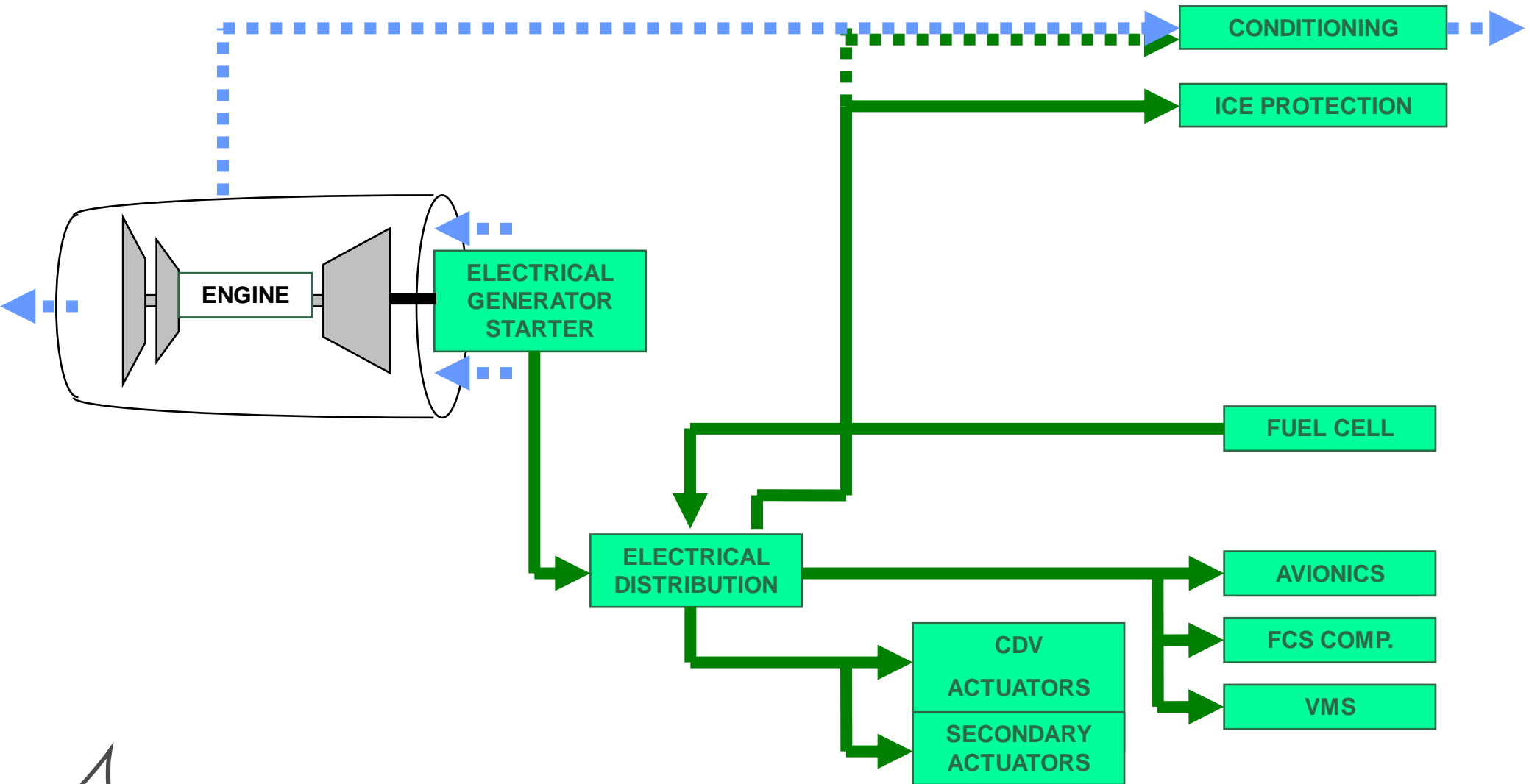
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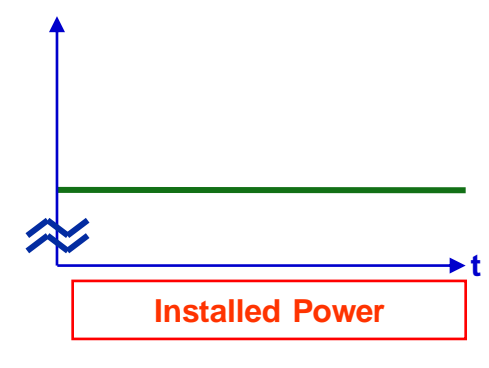
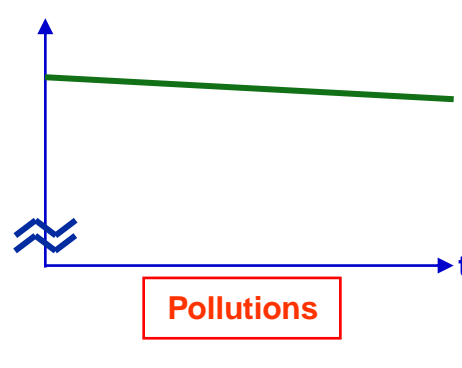
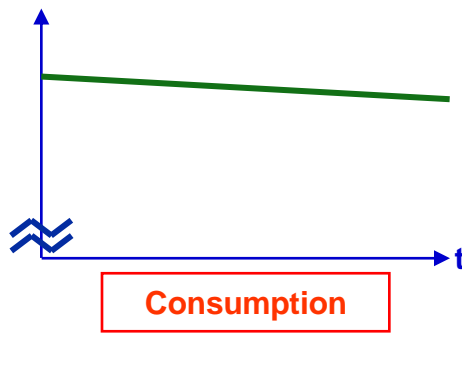
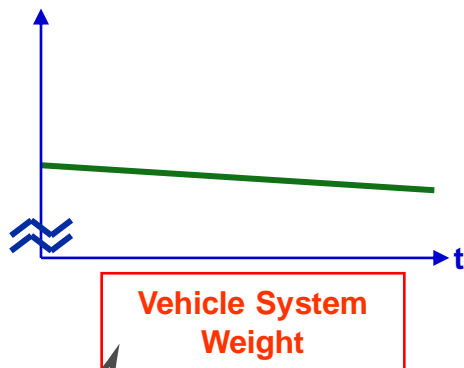
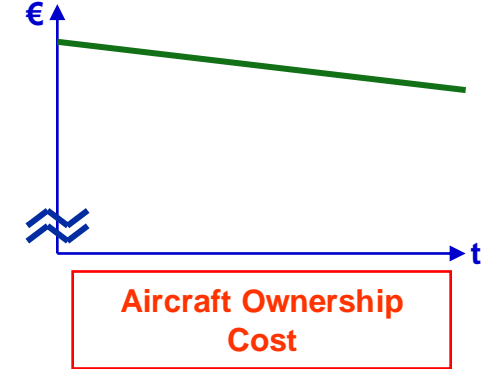
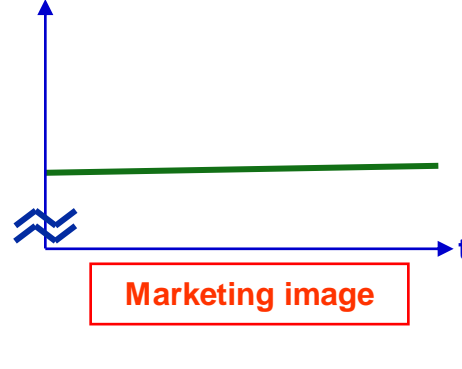
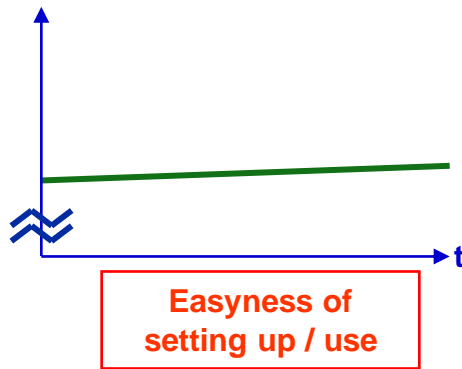
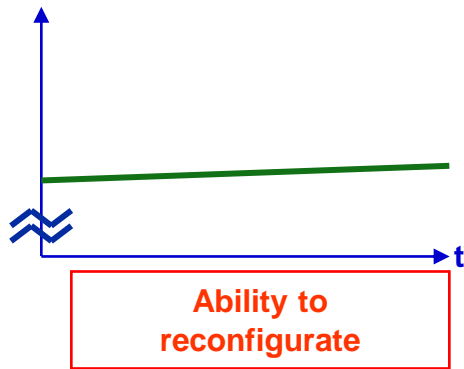


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All electrical Falcon concept: anticipated implications

Hydromec

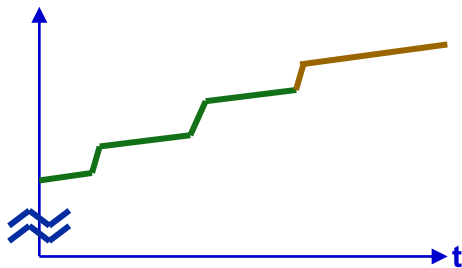


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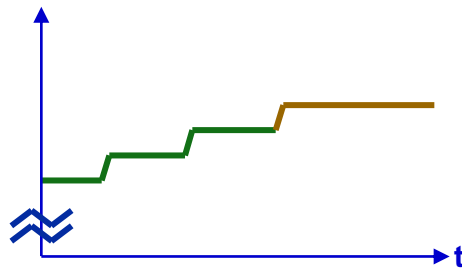
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All electrical Falcon concept: anticipated implications

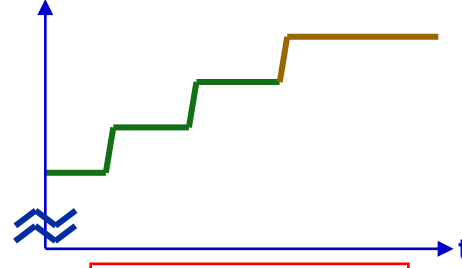
Hydromec → + FBW → + Electrical Actuators → + Electrical ECS



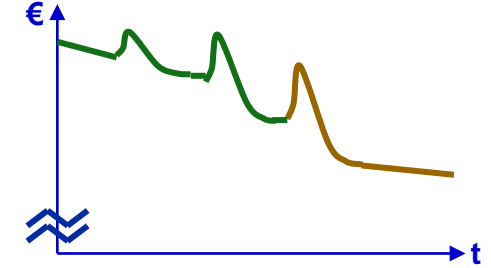
Ability to reconfigure



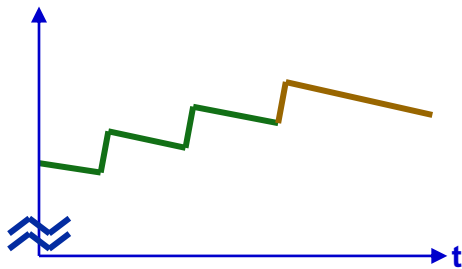
Easyness of setting up / use



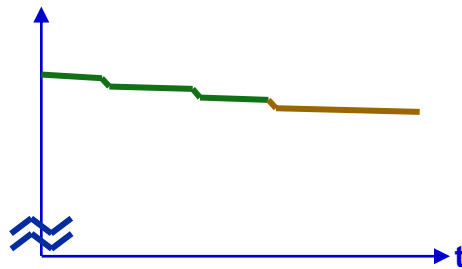
Marketing image



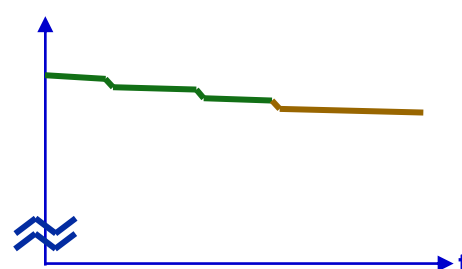
Aircraft Ownership Cost



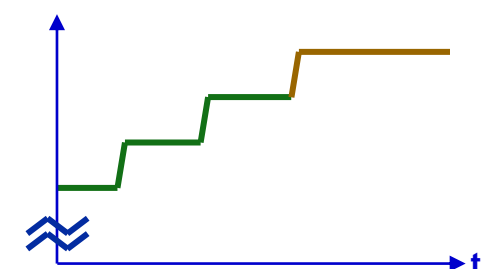
Vehicle System Weight



Consumption



Pollutions



Installed Power



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All electrical Falcon concept: expected advantages

- **Reduction of lay-out constraints / simplification of segregations**
- **Monitoring, detection et reconfiguration after failure**
 - → Simpler MMI / RHM
 - → Availability (daily maintenance and preventive maintenance)
- **Environment, safety (hydraulic fire, hot pipes)**
- **Setting up, easyness of use**
- **Reduction of ownership costs through:**
 - Simplification of the definition
 - Benefit in production cycle (installation and tests on chain)
 - Facilitated maintenance
- **Reduction of fuel consumption (« bleedless engine performance »)**



All electrical Falcon concept: risks

- **Some questions have to be consolidated:**
 - **Benefits on recurring costs ?**
 - **Global weight ?**
 - **Maturity of technologies**
 - **Risk mitigation on:**
 - ◆ Components selection (ex: EHA or EMA, rejection in network and regeneration, ...)
 - ◆ Quality of electrical network and maturity of high voltage networks
 - ◆ Thermal integration of actuators and high power electronics
 - ◆ Lightning and electromagnetic compatibility
 - ◆ ...

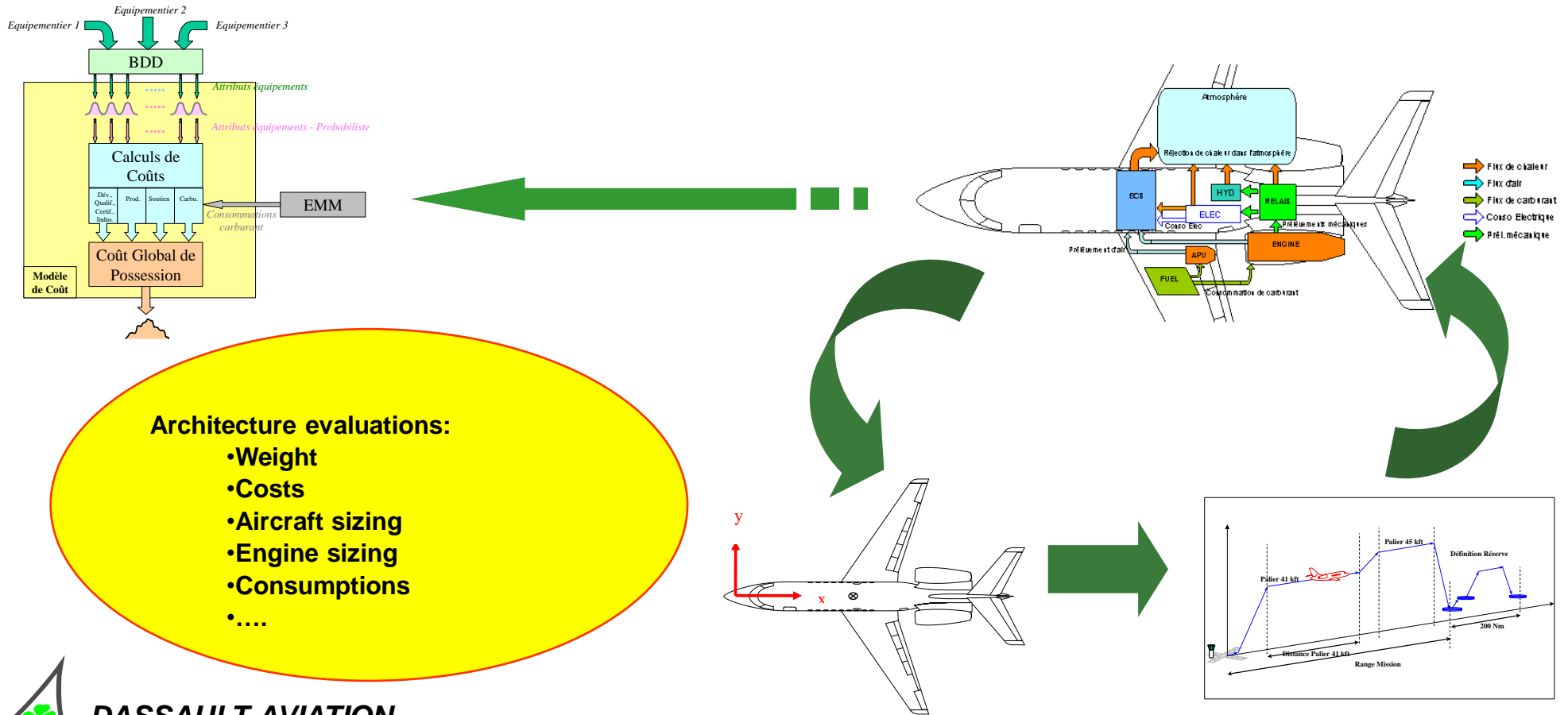
... which are the topics of a large amount of collaborative studies



All electrical Falcon concept: today outputs

● Evaluation methodology:

Snowball effect to be accounted for at aircraft level considering energetic rendements and system weights



Architecture evaluations:

- Weight
- Costs
- Aircraft sizing
- Engine sizing
- Consumptions
-



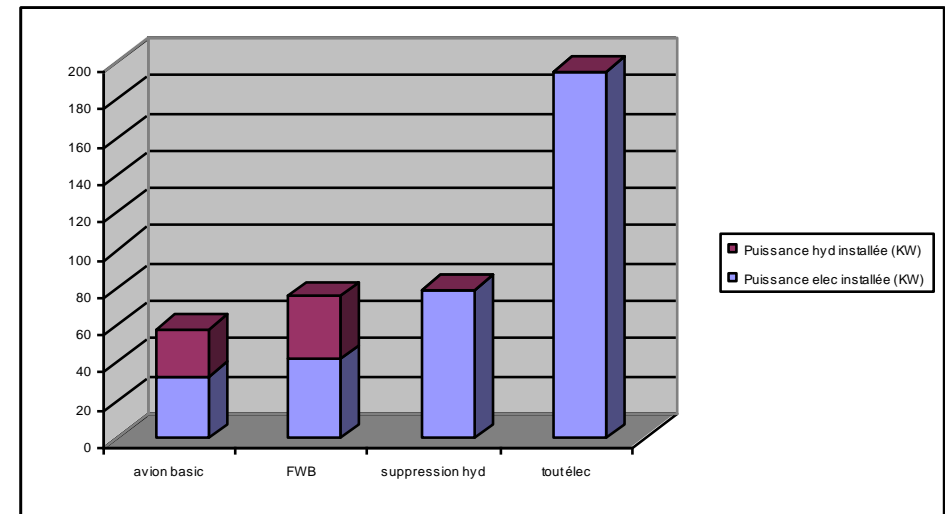
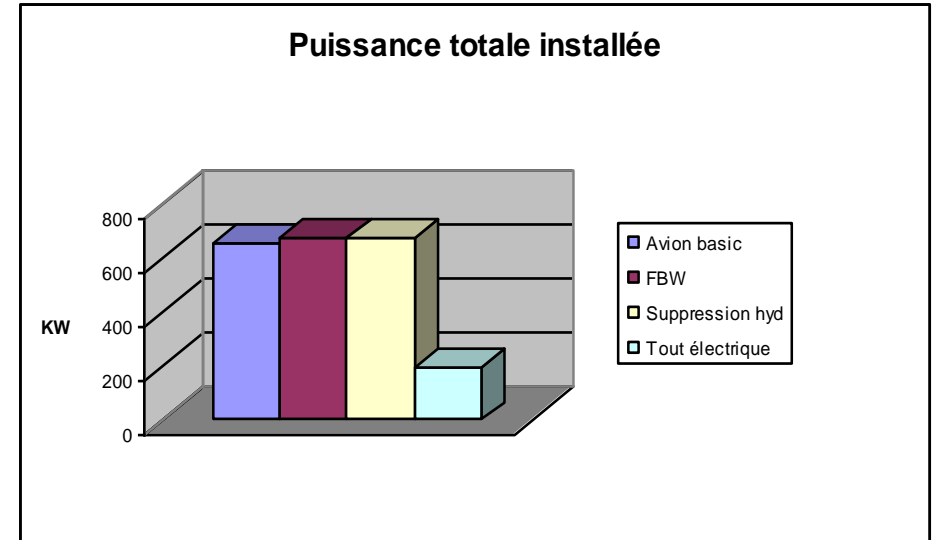
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All electrical Falcon concept: today outputs

● Installed Power

- The global installed power of more electrical aircraft is significantly reduced
- The suppression of hydraulic circuits allow to stay in electrical power ranges which are usual for business jets. The mechanical off-take on engine is nearly unchanged
- On the contrary, the all electrical concept leads to installed electrical powers which are disruptive compared to existing ones. The mechanical off-take on engine is more than doubled



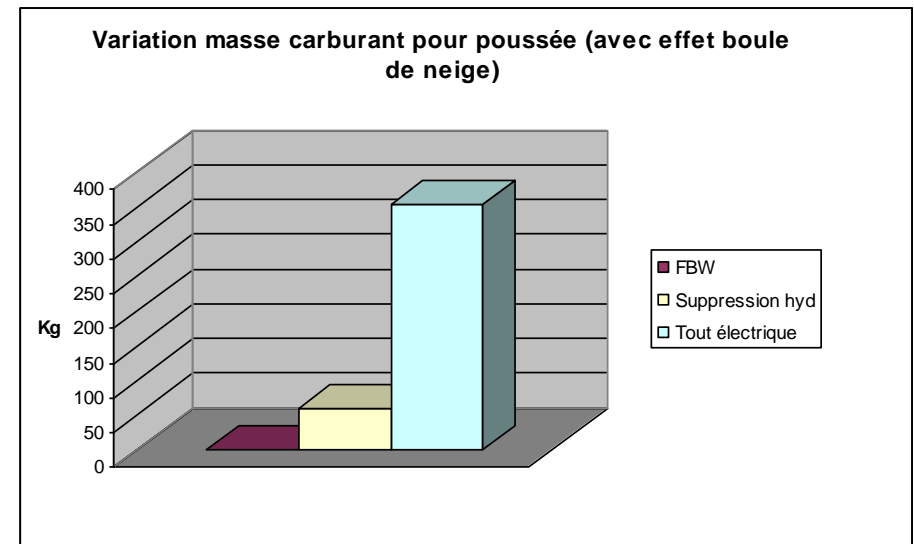
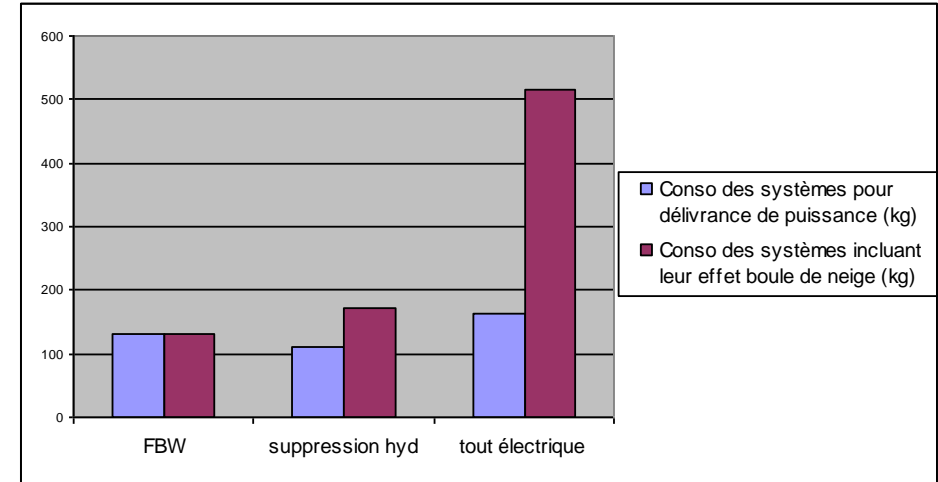
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All electrical Falcon concept: today outputs

● Consumption

- Suppression of hydraulics reduces fuel consumption needed for system power delivery
- But the benefit is insufficient to compensate the overconsumption due to weight increase
- For a given « engine cycle », the all electrical aircraft does not bring efficiency improvements and therefore do lead to an impressive consumption increase



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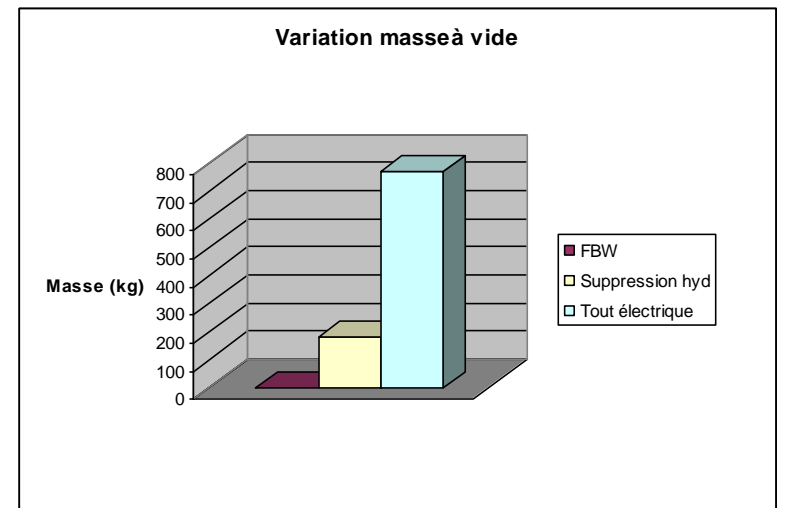
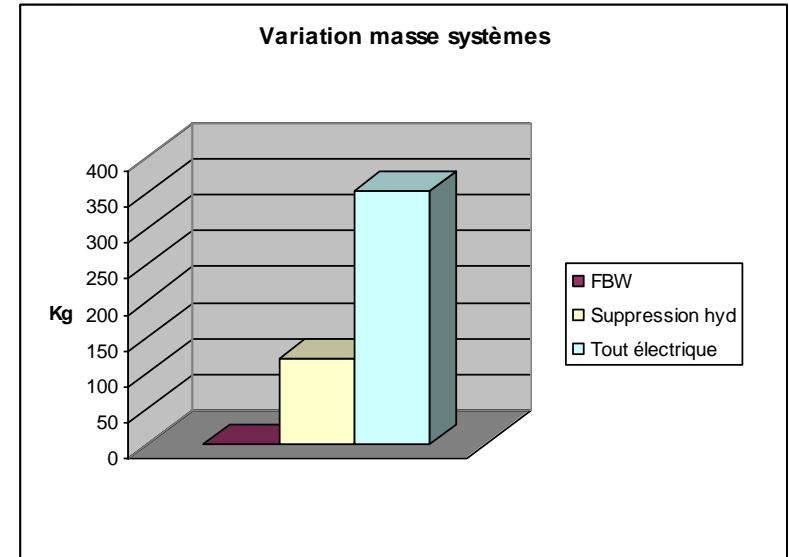
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All electrical Falcon concept: today outputs

● Weights

- With today assumptions, aircraft electrification increases aircraft empty weight
- System weight penalty for the Aircraft without hydraulics (« oilless ») is low
- Suppression of air off-take will be an attractive concept if and only if solutions to reduce electrical ECS packs weight emerge



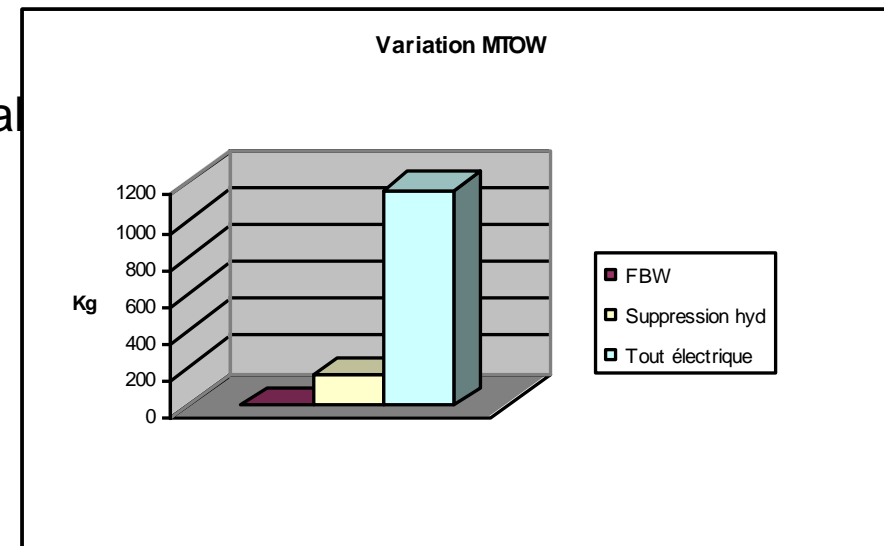
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All electrical Falcon concept: today outputs

- **Aircraft Weight**

- The equipped airframe of the aircraft without hydraulics (« oilless ») is close to the conventional one
- The all electrical aircraft leads to a drastically different one



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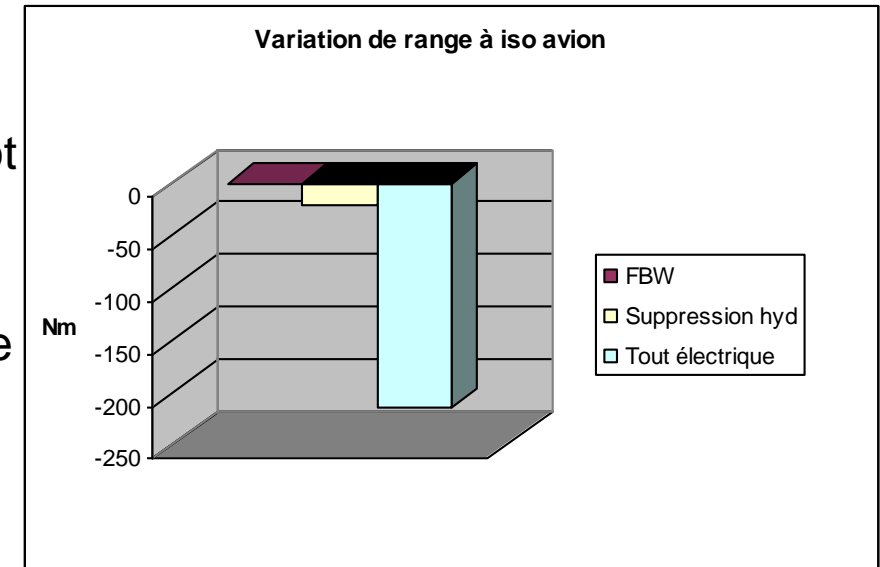
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All electrical Falcon concept: today outputs

● Range

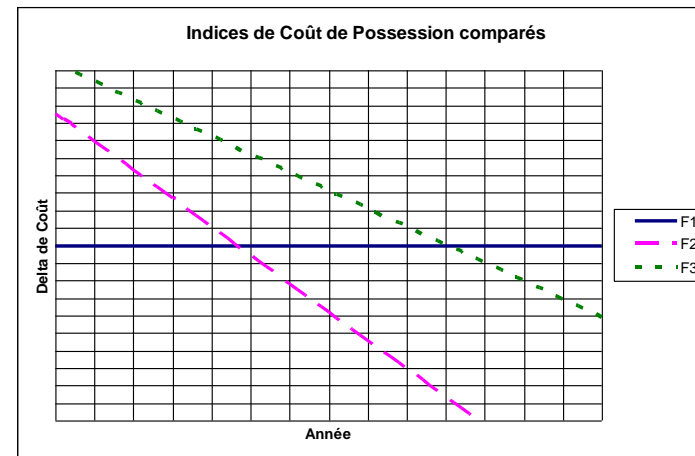
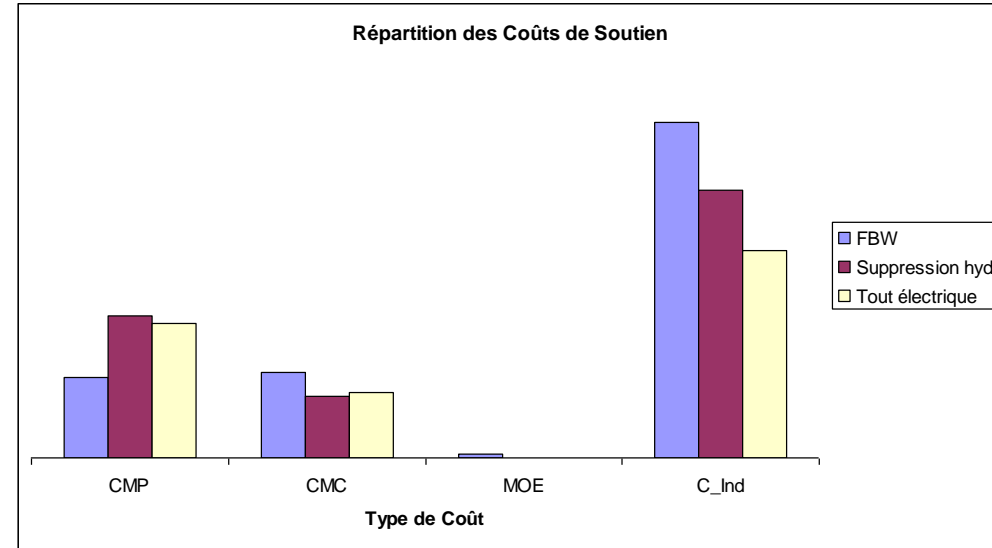
- For a given set of specifications (size and MTOW), with drag, thrust and empty weight corrections, suppression of hydraulics does not lead to a significant range penalty.
- All electrical aircraft range is penalized. Engine is not adapted and must be optimized.



All electrical Falcon concept: today outputs

- **Cost evaluation**

- Globally, the more the aircraft is « electrified », the more support costs are improved
- Of course, a certain learning period must be let past to envisage an improvement of global ownership costs
- Benefits on industrialization costs should be key to reduce its duration



CMP = coût de maintenance préventive
 CMC = coût de maintenance corrective
 MOE = coût de mise en œuvre
 C_Ind = coût d'indisponibilité



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The roadmap to More electrical Falcon

■ Step by step introduction of technologies

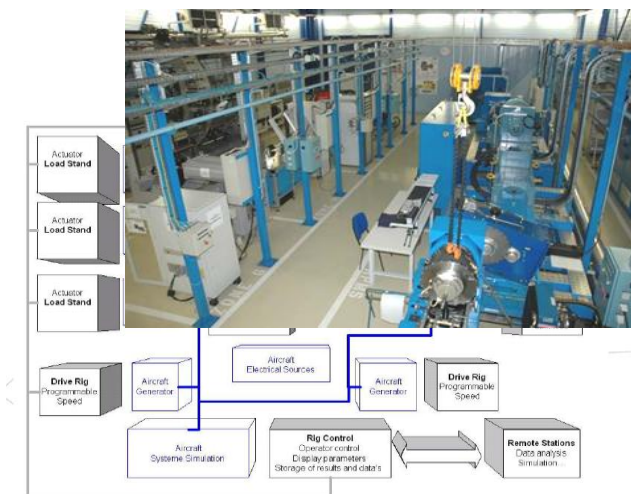


■ Design Drivers

- ◆ Weight (benefit expected in 2025 horizon)
- ◆ Dispatch ratio, reliability

■ Design and development capabilities

- ◆ Modelling and technological tests
- ◆ Electrical and thermal benches



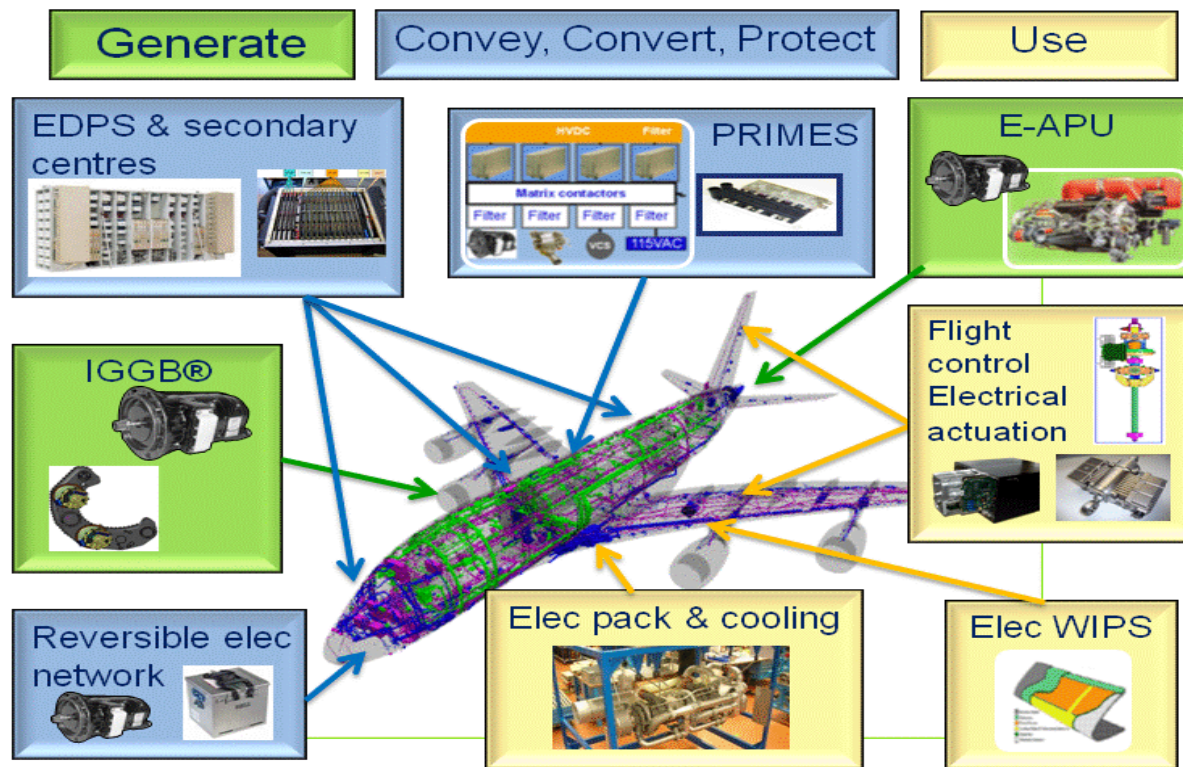
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Two main collaborative studies: Clean Sky & GENOME

- **CleanSky** is an European Joint Technology Initiative
 - Aim is to bring validation of architectures based on TRL 5 technologies up to a representative level of power network systems (electrical network, electrical conditioning and de-icing)
- **GENOME** is a French project funded by national aerospace R&T support
 - Devoted to disruptive technologies to reach additional performances which are required to propose attractive architectures as mature technologies have limited evolution perspectives
 - High density generators, High power electronics, System in severe environment
 - Storage and high voltage control, diphasic cooling,



A complete new energy chain



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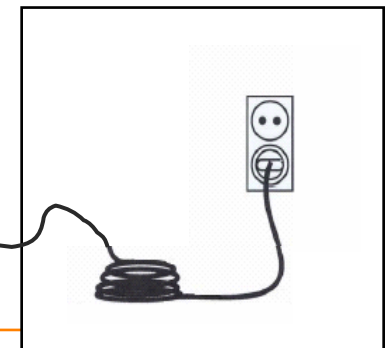
The key technological challenges

- **Optimization of bleedless or « less bleed » engines to optimize the sizing of the whole electrical generation system**
- **Development and integration of a e-APU (ground & flight) which participates to the electrical generation (for instance, to give the capacity of a sufficient electrical generation in the case of a one-engine failure to reconfigure the de-icing system on an emergency source)**
- **Development of de-icing procedures (modularity) acceptable from certification standpoint in order to limit the required power (class 50kW)**
- **Development and integration of modular and mutualized high power electronics**



All electrical Falcon concept

We have still to work on technologies !



Questions ...?



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