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Aircraft Technologies & Systems

Overview of Enabling Technologies for Regional Aircraft Electrification

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On-Board Systems

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Overview of Enabling Technologies for Regional Aircraft Electrification

- **From More-Electric to Hybrid-Electric**
- New scenarios for aeronautical propulsion
- Technological enablers
- Preliminary activities and results
- Future developments: projects and roadmaps
- Possible dual use applications

From More-Electric to Hybrid-Electric:
EU research on More/All-Electric

POA Project
(2006)

First work on MEA architectures, feasibility, main functional and certification issues

MOET Project
(2006-2009)

- New More Electric **"common"** EPS Architecture for small aircrafts
- Perimeter limited to electrical system
- Assessment limited to weight

Clean Sky
(2008-2016)

- New **270V DC Voltage Electrical Architecture**
- Innovative **Electrical Energy Management** algorithms (no generators overload)

Clean Sky 2
(2017-2022)

- New **Smart Grid Network** concept
- Centralized Primary Power Centre with **Decentralized Secondary Distribution** Network

Clean Aviation
(2022-30+)

- New **MW-class** Electric Power Systems for 2035+ **Hybrid-Electric** Regional A/C

Focus su trend tecnologico «Electrification»

- From Electric to Hybrid-Electric
- **New scenarios for aeronautical propulsion**
- Technological enablers
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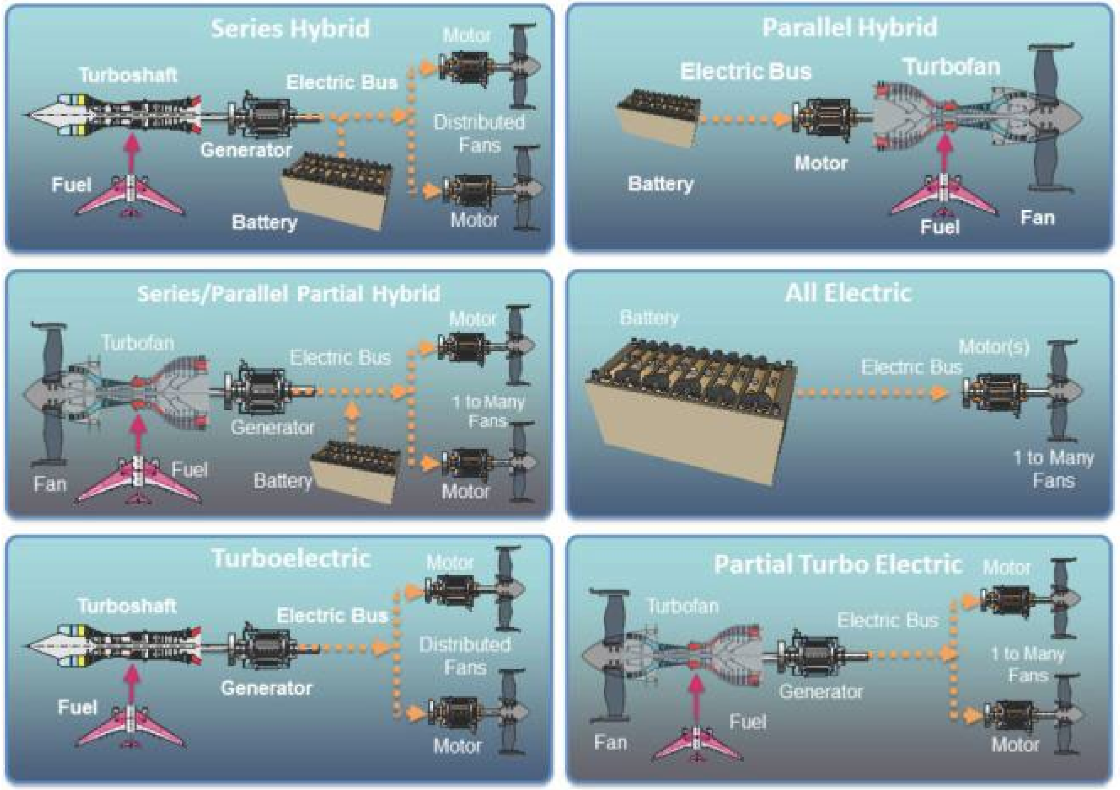
New scenarios for aeronautical propulsion
Hybrid-Electric Propulsion

Horizon Europe

- The ever-increasing push towards the reduction of polluting emissions produced by the aeronautical sector, together with the considerable improvements in the field of power conditioning, e-storage, e-machines, are making it possible to introduce electric propulsion also in the aviation sector.
- While *fully electric* propulsion suggests very high potential for reducing polluting emissions, the current limits on the energy density of batteries suggest, starting from regional class aircraft that require propulsive power in the **MW order**, a focus on the step intermediate of ***hybrid-electric propulsion***.
- In hybrid-electric architectures, the energy is stored on board (mainly) still in the form of fuel (kerosene or SAF), while the *propulsive power is also partially supplied by electric motors (powered by batteries)*, possibly also distributed along the wing.

Turbo-Electric, **Hybrid-Electric** and Full-Electric



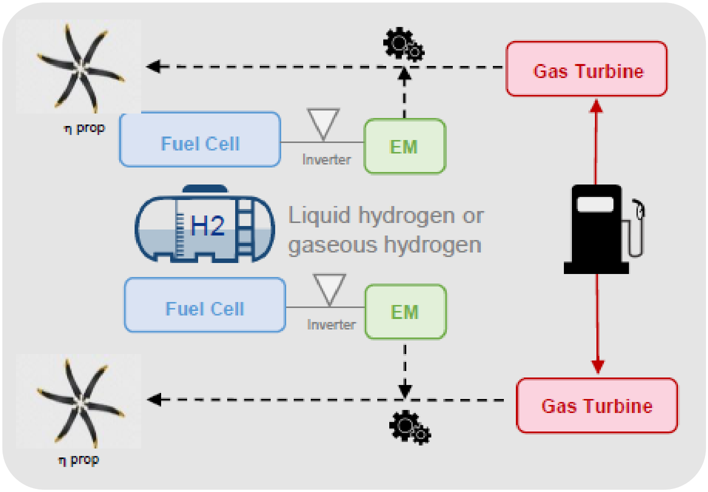
SOURCE: James L. Felder, NASA Glenn Research Center, "NASA Hybrid Electric Propulsion Systems Structures," presentation to the committee on September 1, 2015.

New scenarios for aeronautical propulsion

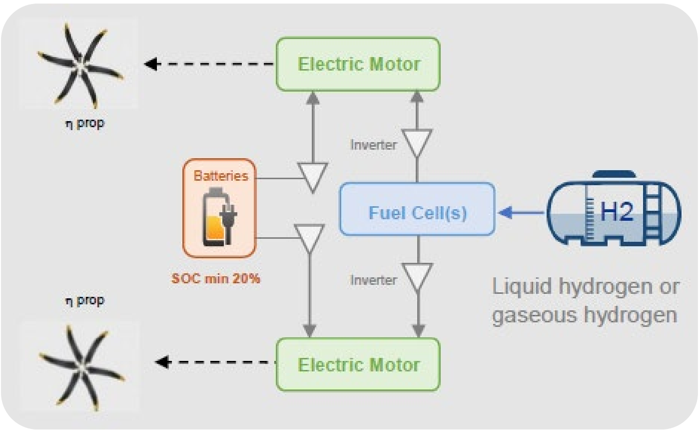
Hybrid hydrogen propulsion

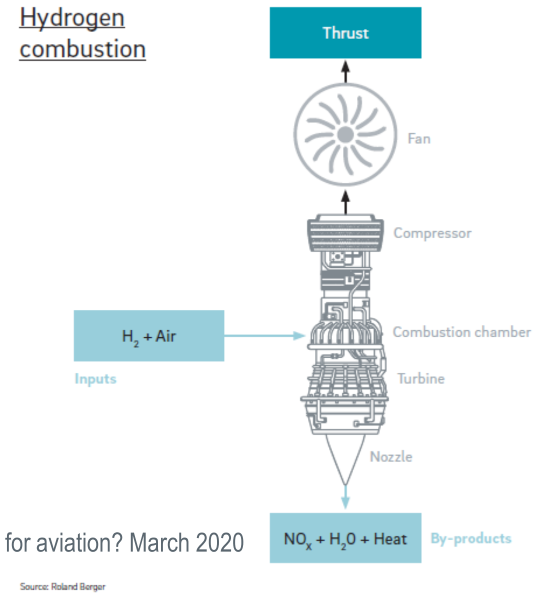
- In addition to hybrid-electric propulsion powered by batteries, another very promising solution in terms of environmental impact ("true zero" emissions) is (liquid) ***hydrogen propulsion***, both through direct combustion propulsion and through the use of fuel cells that supply engines driven by electric motors (also in hybrid combination with traditional thermal engines).
- Apart from the current technological and aircraft integration limitations (e.g. lower volumetric density than kerosene, thermal management), in this case it is also necessary to take into account the *significant infrastructural impacts*, relating to the production, distribution and refueling of hydrogen, as well as the *inevitable implications in terms of certification and safety*.

Hybrid (Parallel Gas Turbine and Fuel Cell)



Full (Hydrogen Electric and Hydrogen Propulsion)



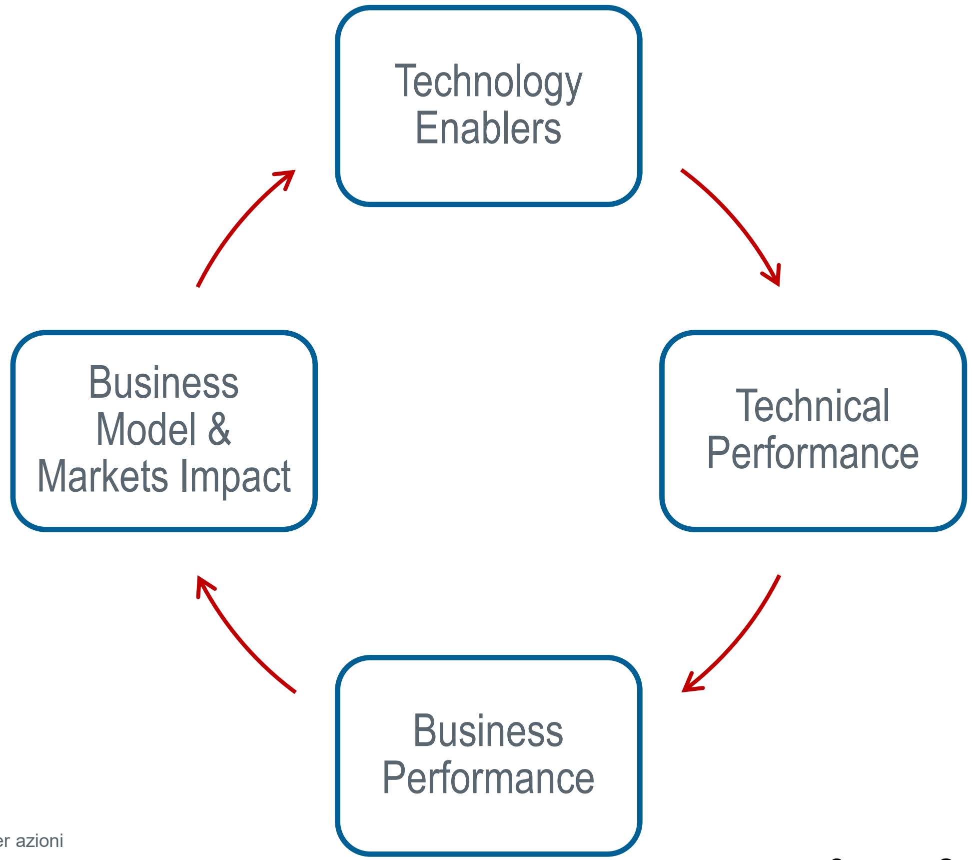


SOURCE: Roland Berger, Hydrogen | A future fuel for aviation? March 2020

New scenarios for aeronautical propulsion

Business Model

- The introduction of hybrid-electric propulsion and the evolution of technological enablers have the potential to *drastically change the operational performance and environmental sustainability* of aircraft and, consequently, the related business performance, enabling ***new markets and new business models***.



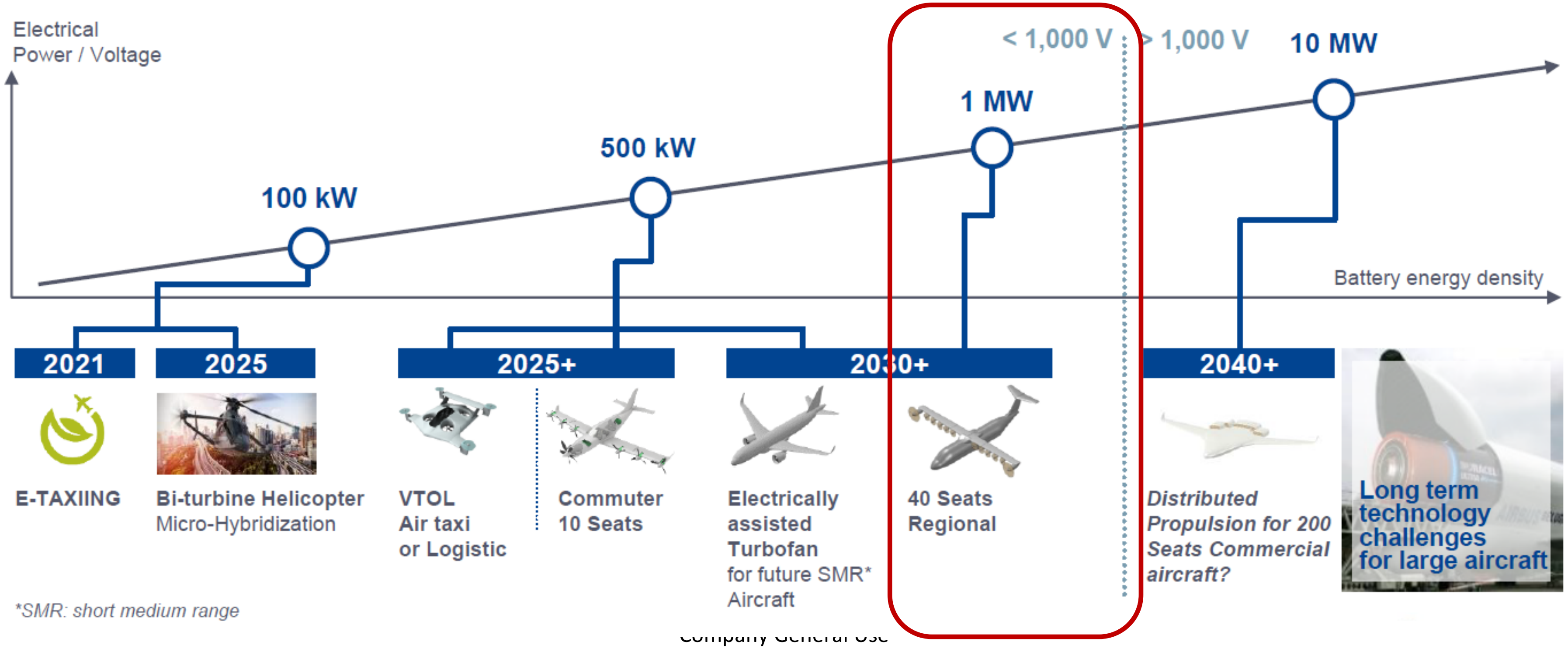
SOURCE: Leonardo Aircraft Preliminary Design

New scenarios for aeronautical propulsion

Roadmap for Electric Propulsion

- The concept of hybrid-electric propulsion is associated with the ***technological challenge*** of developing new electric power systems capable of managing powers in the **order of MW**.

- Leonardo Aircraft, as a major Regional A/C integrator, is more interested in the development of technologies in the **2÷5 MW** range (40÷70 pax) for application on future regional aircraft in the next 10-15 years.

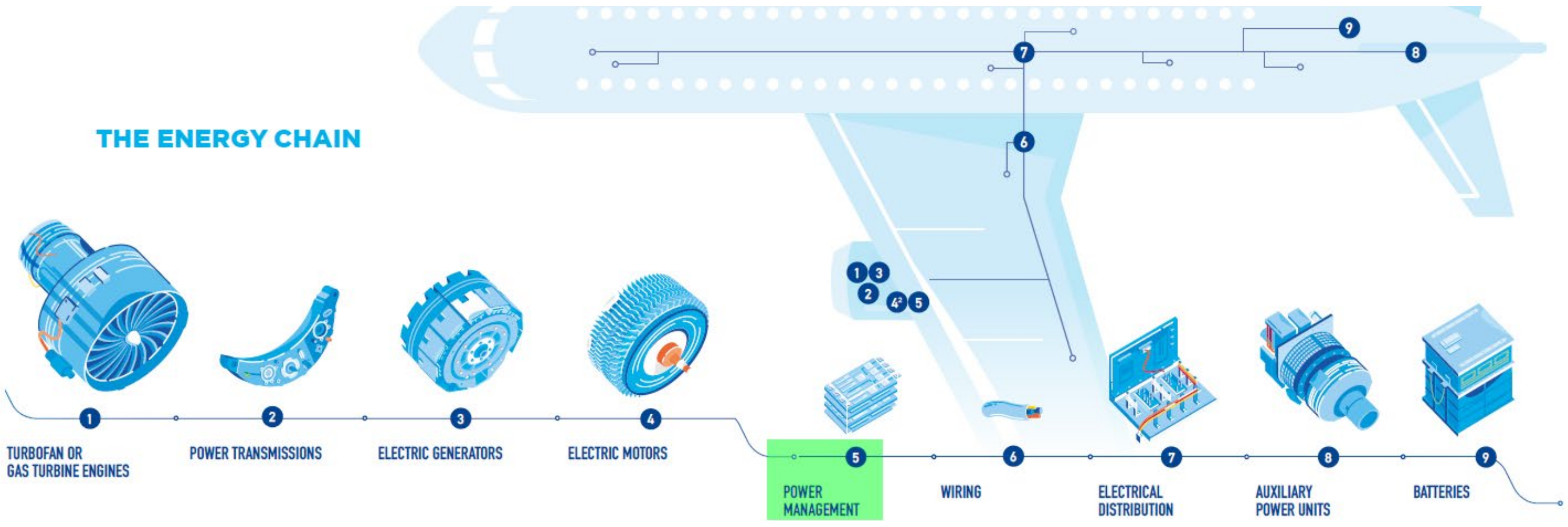


*SMR: short medium range

New scenarios for aeronautical propulsion

Technological Enablers

- While the technological enablers for **general aviation** are available **(tens kW class)**, those for the **Commuter / CS-23 (hundreds kW class)** appear to be under development.
- The enablers for the **CS-25 Regional product class (hundreds kW - MW class)**, for example Turboprop in the 2-5 MW power class, are instead in the development roadmaps of the main players.
- The enablers for the **Narrow Body and Wide body (tens MW) product classes** will probably require the development of technologies that currently have very low maturity (e.g. superconductivity).



Focus su trend tecnologico «Electrification»

- From Electric to Hybrid-Electric
- New scenarios for aeronautical propulsion
- **Technological enablers**
- Preliminary activities and results
- Future developments: projects and roadmaps
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Technological enablers

Overall spectrum of technologies and skills needed

- The control of the future hybrid-electric aircraft will depend on the ability to ***exercise a strong integrating*** role also with respect to new enabling technologies.
- It will be necessary not only to control the integration of the aircraft, but also the integration of the key technologies that qualify the hybrid-electric aircraft.

Below is the overall spectrum of key technological enablers (***Technological Building Blocks, TBBs***) for the hybrid-electric aircraft:

TLAR	gas turbine
configuration & integration	e.generator
safety, RMT, certification	e.motor
aerodynamic & flight control	power conditioning
power management	e.distribution
thermal management	e.storage

LDO Core Competence

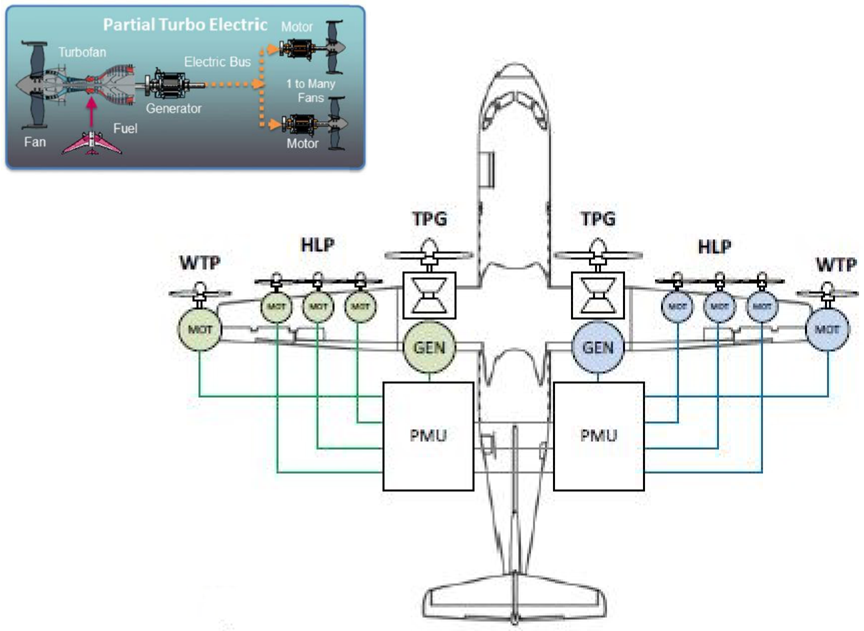
Partners Core Competence

Technological enablers

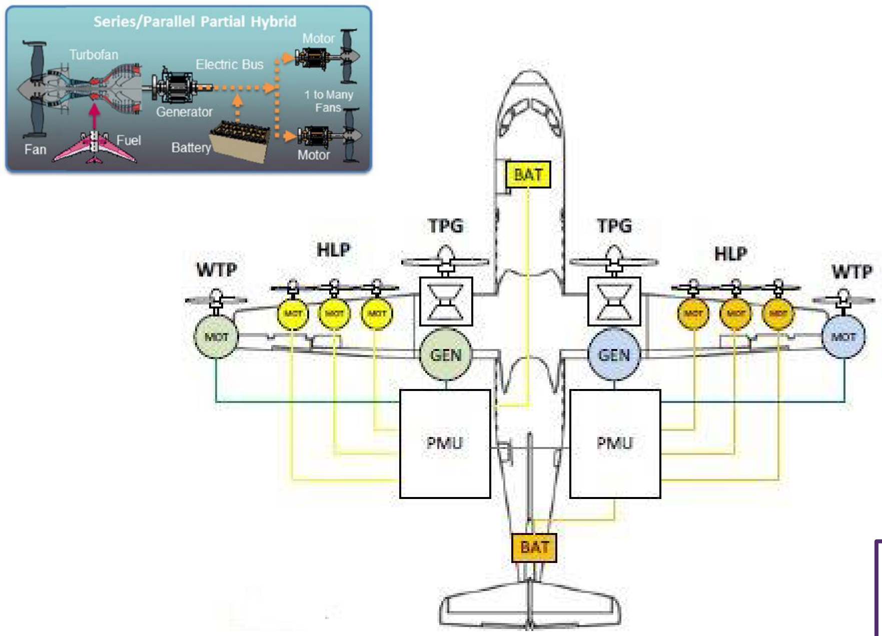
Example of propulsion architecture for a hybrid-electric aircraft

- Starting from the reference configuration, and in cooperation with the main engine/system engineering partners (GE Avio, Rolls Royce, Safran), **trade-off studies** have recently been conducted on new powertrain architectures, analyzing in particular two solutions for the future Regional Hybrid-Electric Turboprop aircraft (50 pax class).

1. Partial Turbo Electric solution



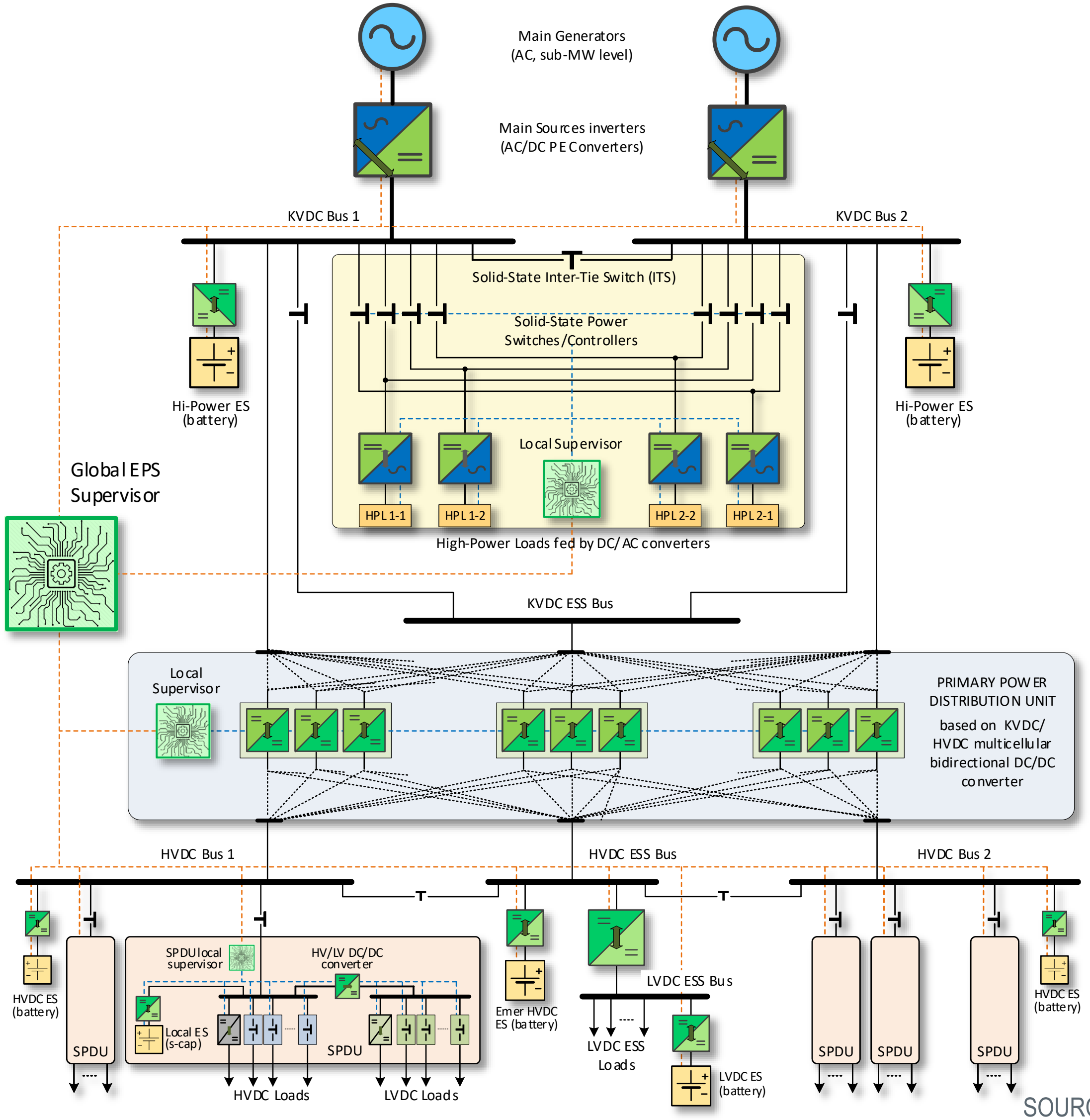
2. Series / Parallel Partial Hybrid



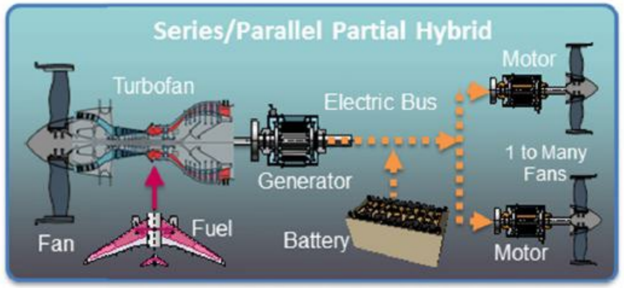
TPG : Turboprop + Generator
HLP: High Lift Propeller
WTP: Wing Tip Propeller

Technological enablers

Example of propulsion architecture for a hybrid-electric aircraft



- The global electrical architecture reflects the optimal configurations of the propulsion part (***series/parallel partial hybrid*** type) and non-propulsion part.



- For secondary (non-propulsion) on-board systems, the ***All/More-Electric Aircraft*** (AEA/MEA) assumption continues to apply, i.e.:
  - Heat engine without pneumatic extraction (bleed-less)
  - Electric Environmental Control System (ECS).
  - Electric de-icing system (wing and tailplanes)
  - Electric flight and landing gear controls (possibly with local hydraulics)
  - Electric APU → electric starting main combustion engine

SOURCE: H2020 ORCHESTRA Project

Focus su trend tecnologico «Electrification»

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- Technological enablers
- **Preliminary activities and results**
- Future developments: projects and roadmaps
- Possible dual use applications

Unione Europea

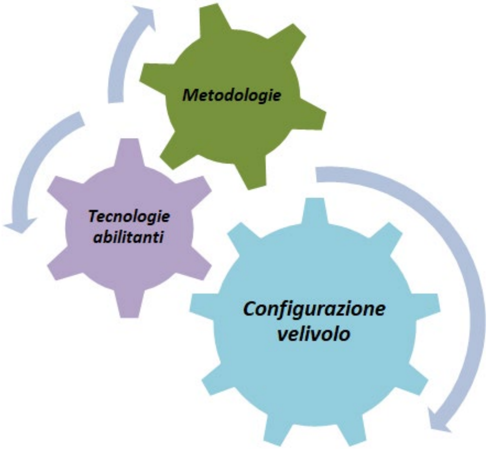
MINISTERO DELL' ISTRUZIONE, DELL'UNIVERSITÀ E DELLA RICERCA

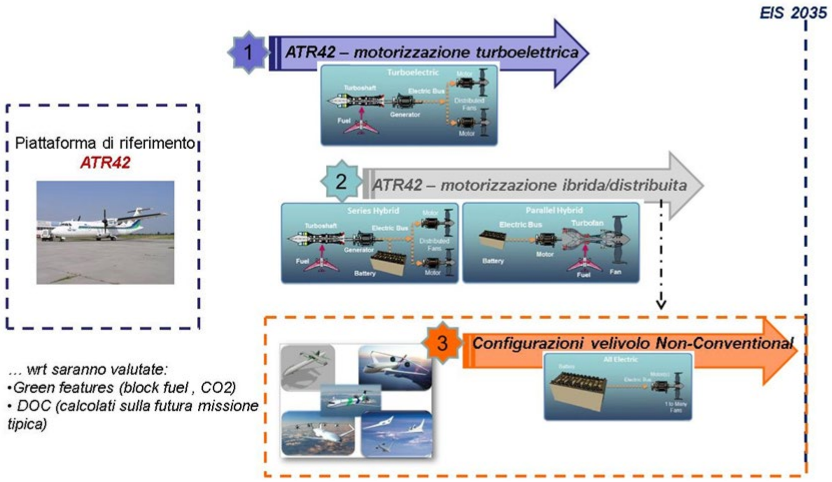
PON RICERCA E INNOVAZIONE 2014 - 2020

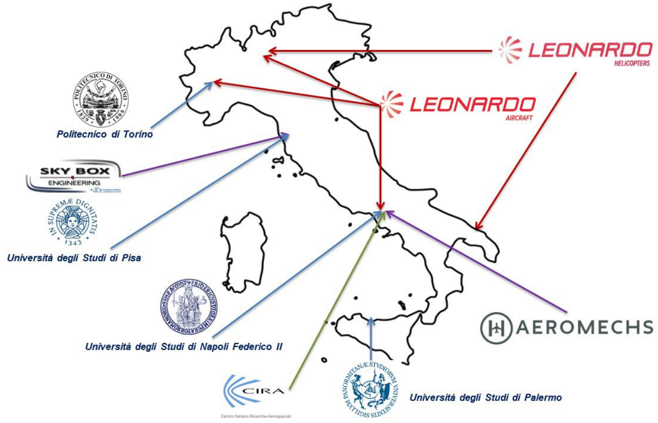
Preliminary activities and results

PROSIB project (PROpulsione e Sistemi IBridi per velivoli ad ala fissa e rotante)

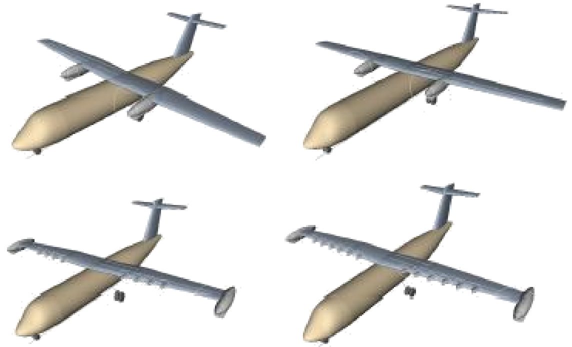
- Objective: carry out a quantitative exploration of the competitive advantages and critical issues arising from the adoption of hybrid-electric propulsion on regional transport & commuter aircraft (fixed wing) and VTOL (rotary wing) configurations through **configurational studies** supported by **trend analyzes of the main enabling technologies** complemented by the demonstration at **TRL 3** (**tunnel and laboratory tests**) of some significant technological enablers of a configurative and electrical nature.
- Start and end dates: 2018 – 2021 (closed)

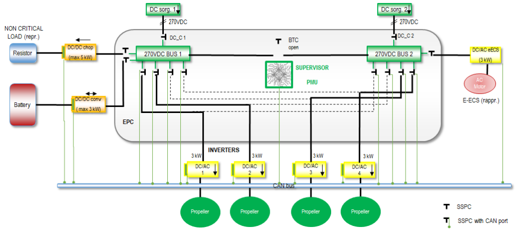




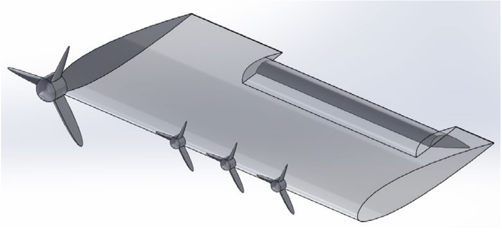


Aerodynamic parametric database for regional aircraft with application of DEP and WTP concepts





Electrical Network Demo



Wind Tunnel Test

Horizon2020
European Union Funding
for Research & Innovation

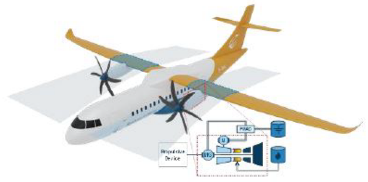
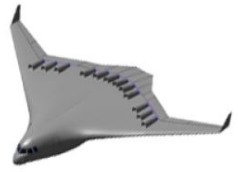
Preliminary activities and results

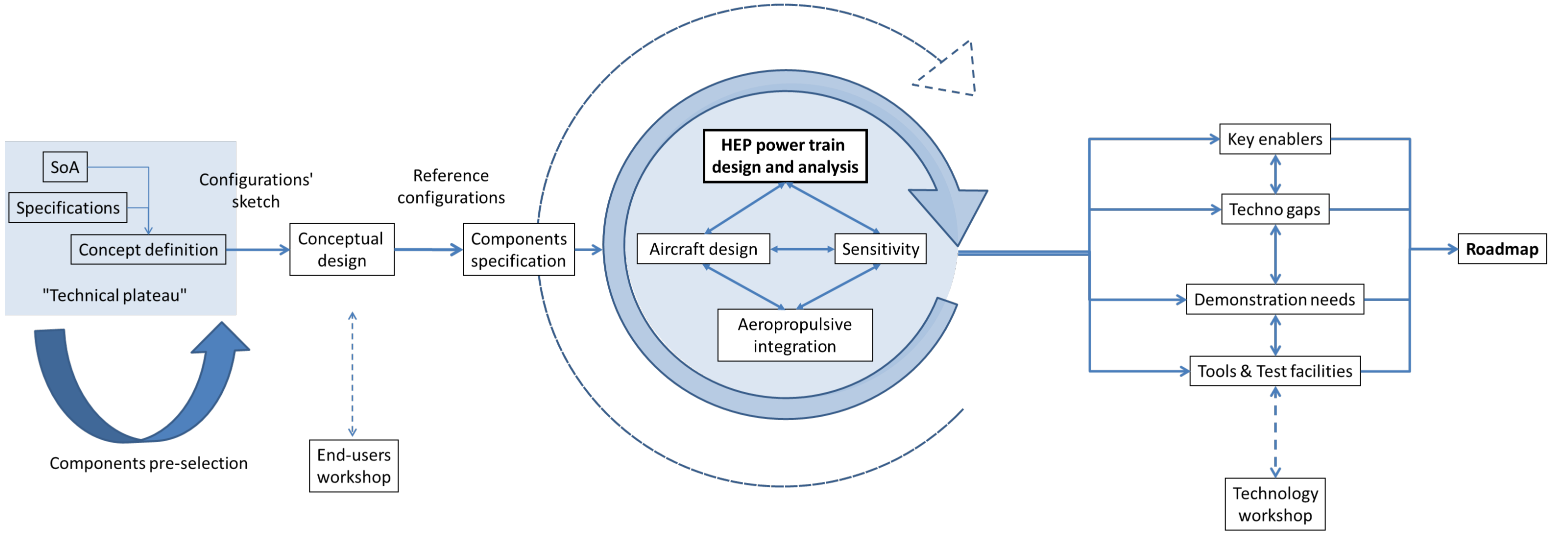
IMOTHEP project (Investigation and Maturation of Technologies for Hybrid Electric Propulsion)

- Objectives:
  - Identify promising **aircraft and propulsion architectures** to support hybrid-electric powertrain study
  - Investigate **technologies** for hybrid-electric powertrain components and architectures at relevant scale
  - Analysis of **methodologies and tools**, **infrastructures**, **demonstrations** and **regulatory adaptations** necessary for the development of hybrid-electric propulsion
  - Synthesis of the results through the development of a **development roadmap**
- Start and end dates: 2020 – 2023 (in progress)

Mission	PAX	Speed	Targeted range
Regional	50	[0.3 – 0.45]	≥ 300 nm
SMR	150 - 180	[0.6 – 0.8]	≥ 800 NM with 1200 NM as best option

LDO Vel focus

	Conservative	Radical
Regional	 Assisted turboshaft	 Turboelectric with DEP and wing-tip propeller
SMR	 Turboelectric with DEP	 Turboelectric BWB with DEP and BLI

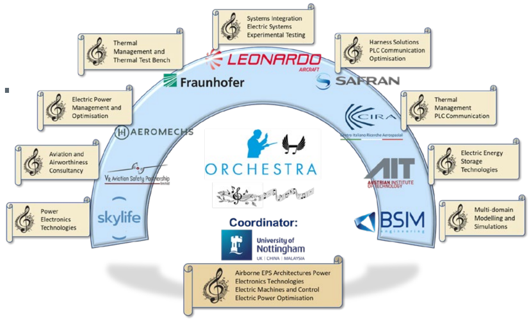


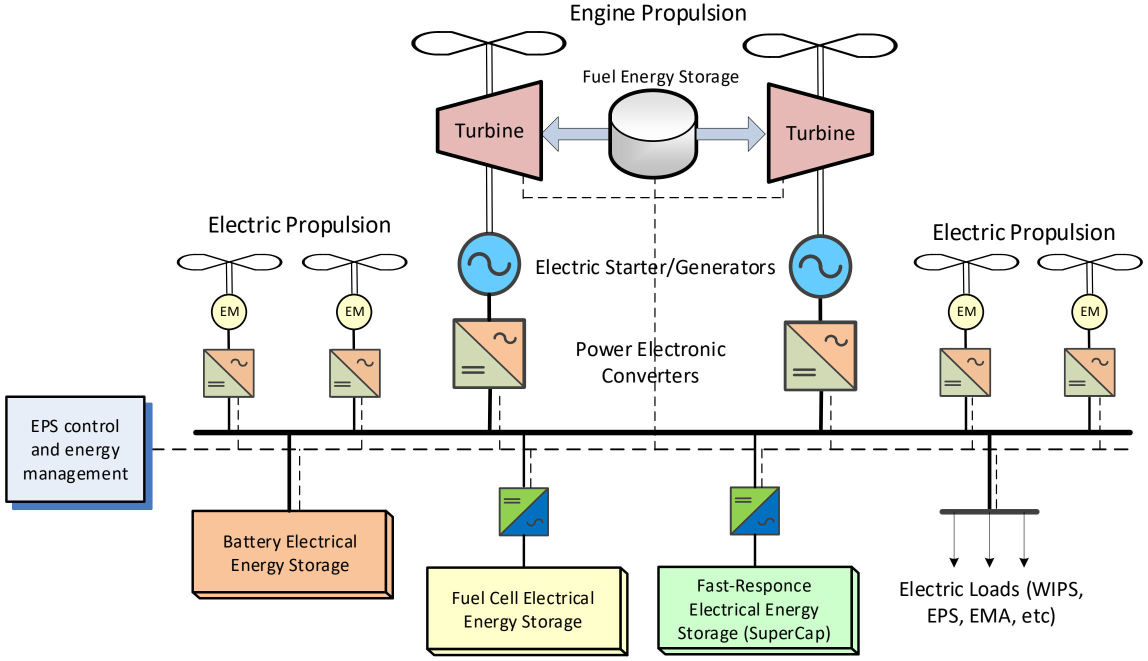
Horizon2020
European Union Funding
for Research & Innovation

Preliminary activities and results

ORCHESTRA project (Optimised Electric Network Architectures and Systems for More-Electric Aircraft)

- Objective: The project will focus on the main technological challenges of the **Electrical Power System (EPS)** to *enable the current and subsequent generations of electrification at powers in the MW range.*
- Leonardo Aircraft participates in the role of *end-user* with a focus on performance and certification aspects.
- Period: 2021 – 2024 (in progress)





Architettura EPS potenziale per propulsione ibrido-elettrica (Technological Building Blocks)

- **Modularity** as a key concept: building blocks designed and manufactured to operate at high voltage and high power levels will then be used as needed in future platforms.
- The project will also study cutting-edge **smart energy management** technologies to optimize electrical energy flows in response to flight conditions and load priorities.
- The project will develop technologies up to **TRL 3-4**.
- The developments will be followed by integrated tests of a representative EPS architecture (h-kW order) on a ground-based **electric rig** at Leonardo Aircraft.

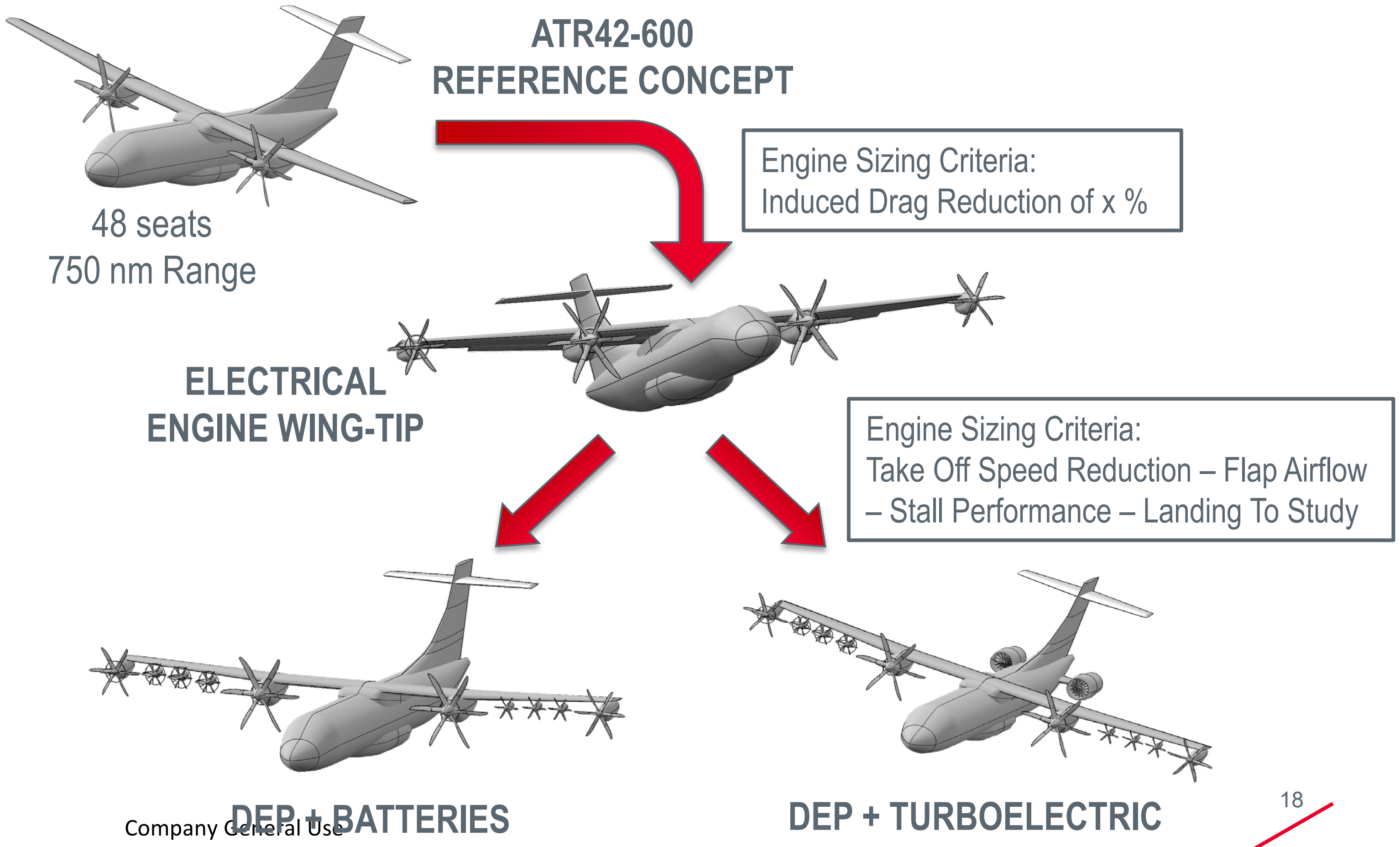
Preliminary activities and results

Clean-Sky 2 IRON program

- Objective: Starting from a reference aircraft configuration (ATR42-600), the study aims to analyze and understand the (cumulative) improvements due to the installation of a hybrid power train.
- Leonardo Aircraft coordinates the technical activity of the Core Partner IRON which is leading the aero-propulsive design of the platform.
- Period: 2014 – 2024 (ongoing)

Regional Hybrid Aircraft Preliminary TLAR:

- ATR42 class → 50 PAX
- Cruise speed → same of ATR42
- Same field length of the reference
- Turnaround time ≤ 20 min
- Design range → reduced to 600 nm (with no penalty on operational flexibility)



Preliminary activities and results

Preliminary Results

- The technologies considered preliminarily determine an **increase in MTOW** (structural reinforcement for wing, fuselage, landing gear, etc.).
- The **Partial Turbo-Electric** architecture does not appear to be advantageous for this type of configuration (substantial modifications are required, e.g. reduced wing surface area, advanced aerodynamic architectures).
- The **Series/Parallel Partial Hybrid** architecture allows carrying out a mission no higher than 200 NM, assuming a battery density of 250 Wh/kg. Higher energy density values for batteries are therefore necessary (**≥ 400 Wh/kg** to ensure enough operational flexibility).
- The **mission profile** must be reviewed in terms of *cruise altitude, cruise speed, thrust distribution philosophy and reserves*.
- **New Certification Rules** should be discussed due to the very different configuration compared to the conventional one (installation of multiple engines).
- In any case, architectures with distributed propulsion (multiple electric motors distributed along the wing) introduce various **constraints in terms of installation complexity and safety**.

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Future developments: projects and roadmaps

Roadmap TRL 3 → TRL 9

- **CLEAN AVIATION** PROGRAM (2022 – 2030)
  - TECHNOLOGICAL TARGET: **TRL 6** → 2030
  - EMISSIONS REDUCTION **30-50%**

CLEAN AVIATION

GREEN DEAL

- **NEW** HYBRID/ELECTRIC **PRODUCT**(**EIS 2035**)
  - TECHNOLOGICAL TARGET: **TRL 9** → 2035

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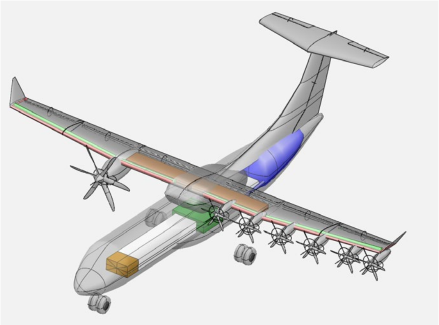
Future developments: projects and roadmaps
CLEAN AVIATION program

- The Strategic Research and Innovation Agenda (SRIA) contains ***a section entirely dedicated to regional hybrid-electric propulsion aircraft,*** including technological enablers, analysis methods and tools, advanced integration studies and demonstration.
- To date, **Call 1** has concluded with the assignment of the projects for phase 1 of the program. Collaborations with partners have been established for the technological development of the identified themes and their maturation up to demonstrations with **TRL 5** objective.
- Period: 2022 – 2025 (phase 1) / 2025 – 2028 (phase 2)



3 classes of solutions for the propulsion architecture:
- ***Traditional configuration***
- ***Distributed propulsion configuration***
- ***Disruptive configuration***

3 options for energy storage:
- ***Batteries***
- ***Fuel Cells***
- ***Combination of the two***

Targets

Aircraft Class	Key technologies and architectures to be validated at aircraft level in roadmaps	Earliest EIS Feasibility	Fuel burn reduction (technology based) [1]	Emissions reduction (net – i.e. including fuel effect) [2]	Current share of air transport system emissions
Regional Aircraft	Hybrid-electric, distributed propulsion coupled with highly efficient aircraft configuration	~2035	-50%	-90%	~5%

EUROPEAN UNION CLEAN AVIATION

Future developments: projects and roadmaps

CLEAN AVIATION program

HERA (Hybrid Electric Regional Architecture) Project

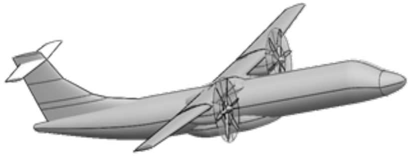
HERA main requirements:

Passenger number [50:100]

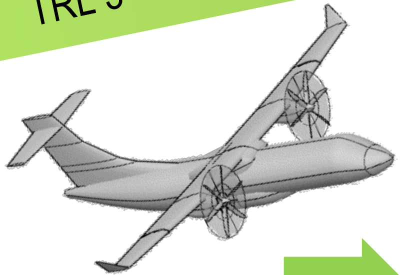
Design Range < 1000NM

Preparation | Phase 1 | Phase 2

START → TRL 3 → TRL 4 → TRL 5 → TRL 6 → TRL 7 → TRL 8 → **TRL 9**

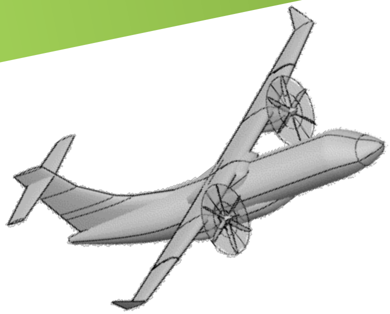


2020 Reference Gas-turbine



EIS 2035 Reference Gas-turbine

PROPULSION



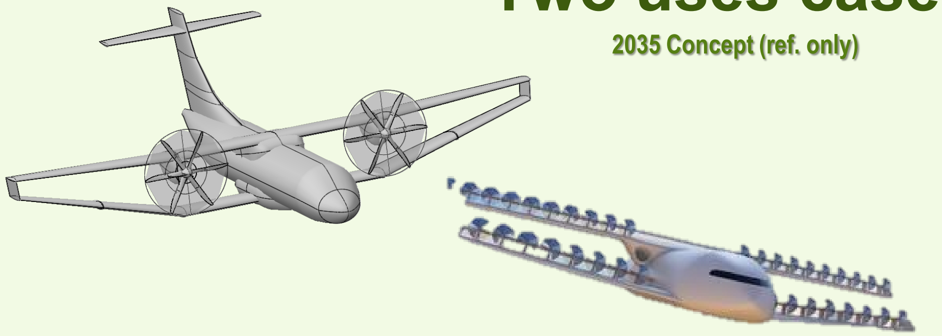
2035 Techno-trade
Wing integration
Fuselage and tail-plane integration
H2 Storage
H2 Fuel Cell
Electrical Distribution
Thermal Management
2035 Certification

2025+ Demos

2035 Concept (ref. only)

Two uses case

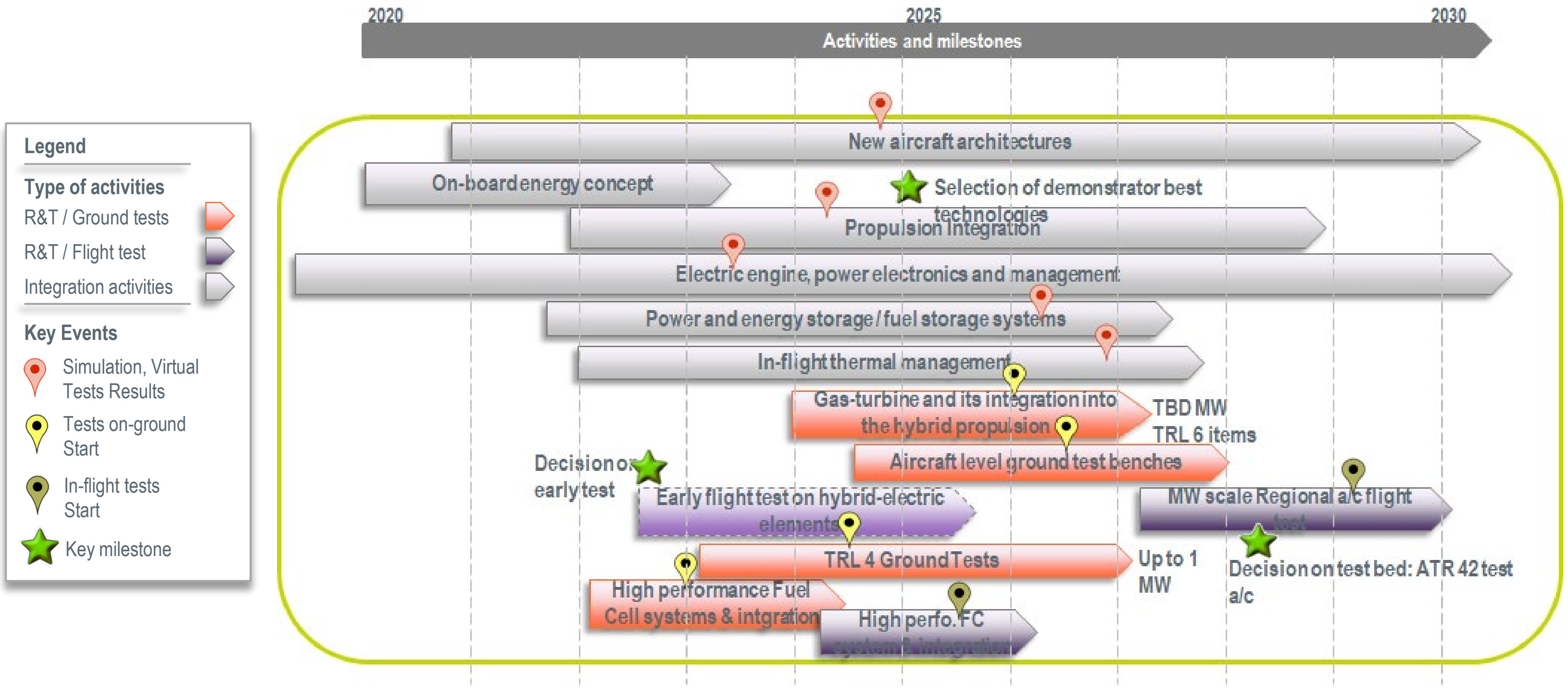
2035 Concept (ref. only)



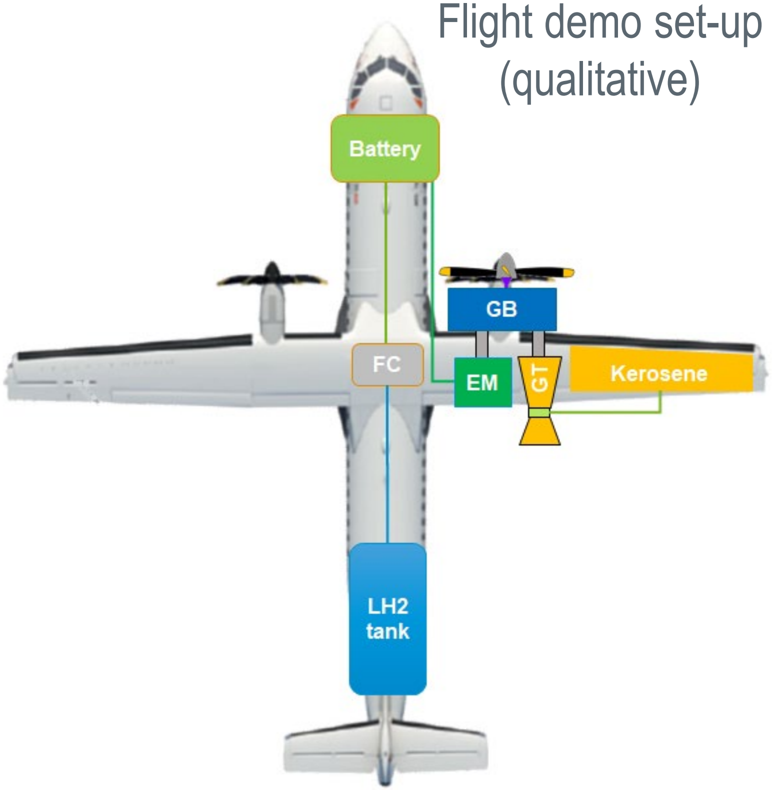
Future developments: projects and roadmaps

CLEAN AVIATION program

- The purpose of the **in-flight demonstrator**, with limited impact on the existing ATR-42 configuration, is the **functional validation of the new powertrain** in real operating conditions.
- In parallel, the theoretical optimized configuration will be sized and tested in a **wind tunnel**.



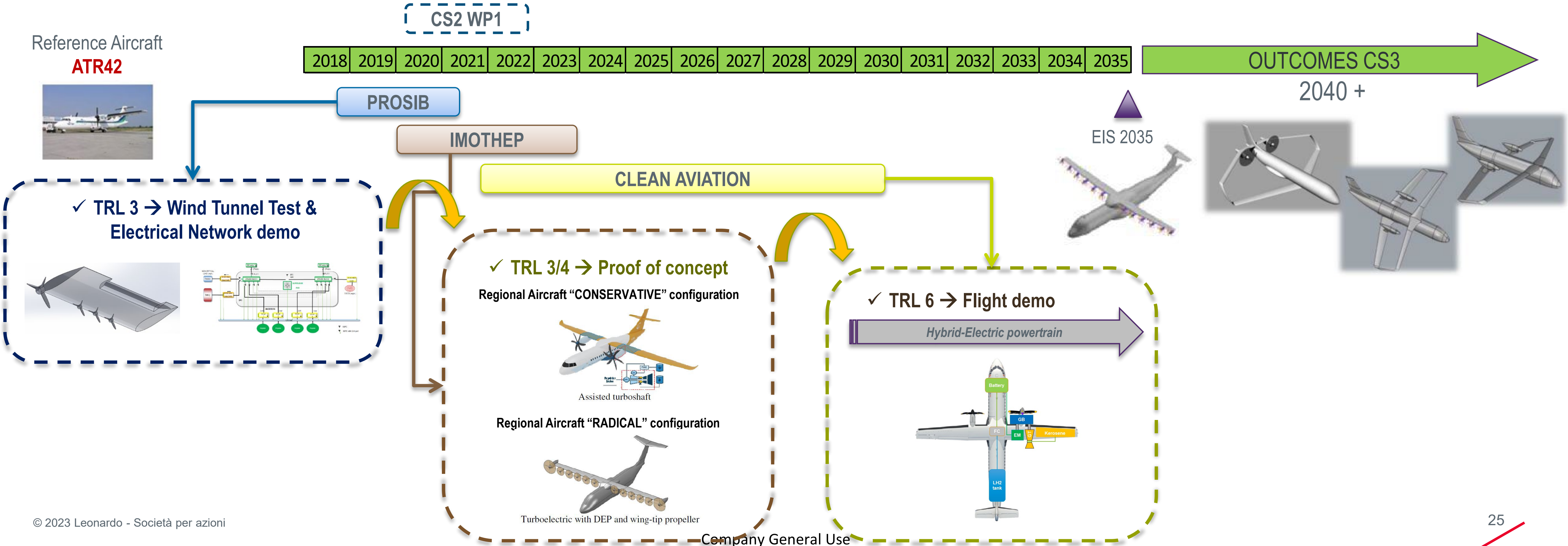
Flight demo set-up (qualitative)



Future developments: projects and roadmaps

Global roadmap

- The development of a hybrid-electric propulsion aircraft progresses in parallel with the evolution of enabling technologies in the field of electrical systems.
- In a phased approach, Leonardo Aircraft's target hybrid-electric product is in the class of 50-100 pax.



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Possible dual use applications

Considerations

- Hybrid propulsion can bring about ***various advantages*** compared to conventional solutions: *greater operational flexibility, greater performance, greater safety, reduced life-cycle costs, high reliability*.
- The use of these technologies could also find application in a ***military context*** which will presumably concern *highly autonomous platforms:* ***military transport, unmanned****.*
- For example, the adoption of distributed propulsion ("blown wing") will be able to significantly improve *tactical use* (short take-offs and landings planned with military criteria), and also the effectiveness of certain *platforms that need to reach low speeds* (typically firefighting aircraft) or *reduce thermal signatures*.
- Future high-performance aircraft (6th generation fighters) will have to manage installed power on board in the order of MW and will be able to benefit, for example, from *electrical distribution and thermal management* solutions developed to support hybrid propulsion.
- In the face of potential benefits, there are ***additional complexities and costs*** that have not yet been explored, with impact both on the architecture of the aircraft and on their logistics (e.g. even in the military field it will be necessary for airports to be able to equip themselves with the *infrastructure necessary* for the management of hybrid platforms).

THANK **YOU**
FOR YOUR ATTENTION

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