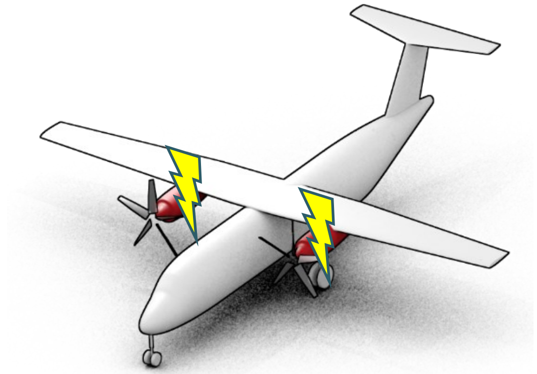
This project has received funding from the European Union’s Horizon 2020 research and innovation framework programme under grant agreement No 815122

WP7 Certification Driven Stream

T7.1 - AC 3 Systems Electrification
Results collection



MARCO FIORITI / T7.1 partners

Towards cyber-physical collaborative aircraft development

AC3 introduction and main objectives

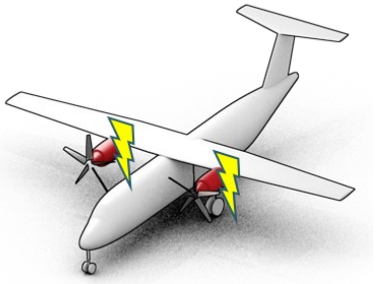
WP7 Certification Driven Stream - OBJECTIVES

"Electrify the aircraft safely"

App. Case 3

BOMBARDIER

Politecnico di Torino



- Integration of certification constraints for aircraft performance and safety for aircraft with conventional and innovative (different level of electrification) systems in the MDO process

AGILE4.0 → Perform **trade-off between design and certification objectives**

In the AC3&4 the following trade-off are addressed: **Systems Electrification** and **System Safety/Minimum Performance** - **Aircraft Maintainability** and **Aircraft performance**

AGILE4.0 → **Reduction of development time/cost** due to the virtual integration of design and certification aspects

The integration of **Safety/Minimum Performance** analyses and aircraft **Maintainability** on the MDO workflow will **reduce the need of modifications** during the certification phase reducing the aircraft development time and cost

AGILE4.0 → **Increase competitiveness of aeronautical products**

The AC3&4 are defining the optimal level of systems electrification and aircraft maintainability considering the **impact on aircraft LCC** (with special focus on certification and maintenance cost)

AC3 partners involved

Politecnico di Torino

BOMBARDIER

Application case owners
- TLARs
- Support and feedback on results

Deutsches Zentrum für Luft- und Raumfahrt (DLR)

Aircraft design

CFS Engineering — Computational Fluids & Structures Engineering

Aerodynamics

Politecnico di Torino 1859

AC3 Integrator and disciplinary expert
- MDAO framework
- Subsystems design
- Engine design

ILR Institute of Aerospace Systems | RWTH AACHEN UNIVERSITY

Cost estimation

Université Concordia University

MDO expert

ONERA THE FRENCH AEROSPACE LAB

Performance
Engine design

Università degli Studi di Napoli Federico II

Certification related disciplines

Safety assessment

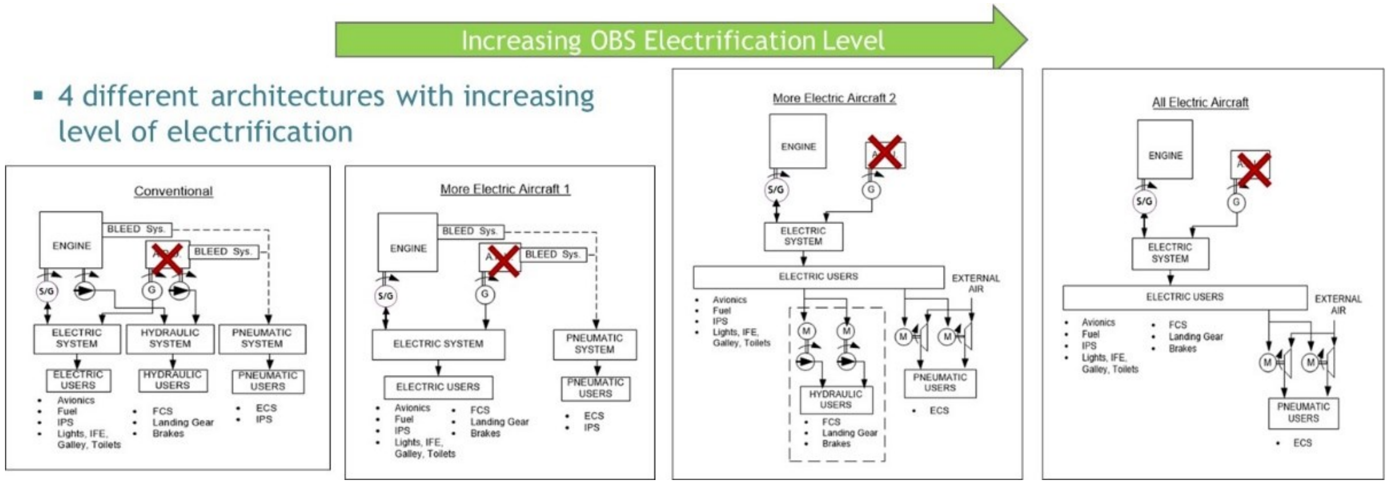
Minimum performance

External noise

AGILE 4.0

AC3 trade-off

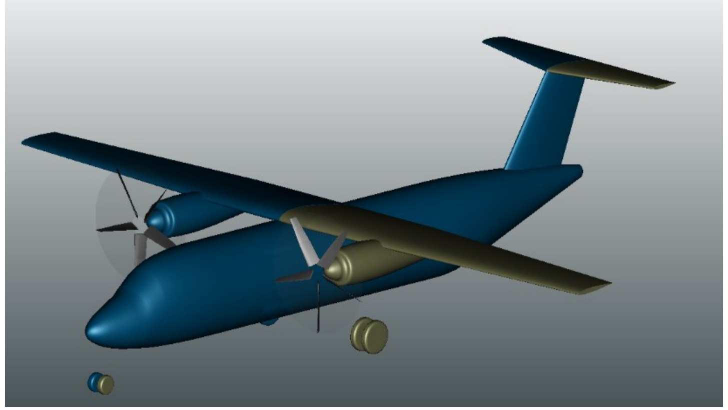
- Identify the best suitable systems electrification level vs certification margins and cost
- 4 different levels of systems electrification
- Certification → External noise, minimum performances, systems safety
- Detailed life cycle cost estimation



AC3 Baseline definition

- Specific aircraft baseline definition for certification study
  - Definition of specific aircraft baseline with a MTOM closes to Part 23 upper limit
  - Compatible with Part 23 and Part 25 regulations giving the opportunity of comparison studies
  - Baseline defined to be compatible with:
    - Systems electrification (new ECS and actuation system)
    - Different regulations

TLARc	Metric	Imperial	Rationale
MTOW	≤ 8600 KG	≤ 19000 LB	Per FAR 23
PAX	19	19	
Range	≤1500 KM	≤800 NM	Bombardier Requirement
Speed	0.45 M	0.45 M	Bombardier Requirement
Ceiling	7600 m	25000 FT	Benchmark
TOFL	<800 m	< 2600 FT	Embraer/Airport Data



ID	Requirement statement	Type	Parent/Source	Stakeholders
MR1	The standard mission shall be performed in 60 minutes	Performance	1.1, 2.2, 4.4, 5.1	ARL, OEM, SCT, PAX
MR2	The standard mission shall provide for the transport of 19 passengers at a distance of 370 km	Performance	1.1, 2.2, 4.4, 5.1	ARL, OEM, SCT, PAX
MR3	The standard mission shall be performed from airports with a minimum runway length of 800m	Performance	1.2, 4.4, 5.1	ARL, SCT, PAX
MR4	The standard mission shall be repeated after 20 minutes	Suitability	1.3, 1.11, 1.12, 1.13, 1.14, 2.10, 3.1, 3.2, 3.4, 3.5, 3.9, 3.10, 5.6, 5.7, 6.3, 6.5, 8.1, 8.2, 8.3, 8.4	ARL,OEM, MNT, PAX, ARP, PLT
MR5	The standard mission shall take place after a maximum delay of 60 minutes	Suitability	1.3, 1.11, 1.12, 1.13, 1.15, 2.10, 3.1, 3.2, 3.4, 3.5, 3.9, 3.10, 5.7, 6.3, 6.5, 8.1, 8.2, 8.3, 8.4	ARL, OEM, MNT, PAX, ARP, PLT
MR6	The standard mission shall be performed from year 2035 (Initial guess)	Design constraint	1.4, 2.7, 2.9, 7.1, 7.2, 7.3, 7.4	ARL, OEM, CRT
MR7	The standard mission shall be performed at a maximum total operating cost between 1781 and 4000 €	Performance	1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 2.1, 2.3, 2.4, 2.8, 2.10, 3.1, 3.2, 3.3, 3.4, 3.6, 3.7, 3.9, 4.1, 4.2, 5.2, 6.1, 6.2, 6.3, 6.4, 6.5, 8.5, 8.6	ARL, OEM, MNT, SCT, PAX, ARP, PLT
MR8	The standard mission cruise phase shall be performed at altitude greater than 7500 meters	Performance	1.5, 5.2	ARL, PAX
MR9	The standard mission shall be performed with a probability of catastrophic event not greater than 1/10^9 flight hours	Suitability	2.5, 2.6, 5.3, 7.3, 7.4, 8.1, 8.2, 8.3, 8.4, 8.5, 8.6	OEM, PAX, CRT, PLT
MR10	The standard mission shall be performed from airports provided with the reference hangar dimensions	Performance	1.2	ARL, SCT, PAX
MR11	The standard mission for electric variant of the aircraft shall provide for the transport of 9 passengers at a distance of 555 km	Performance	1.11,2.2, 4.4, 5.1	ARL, OEM, SCT, PAX

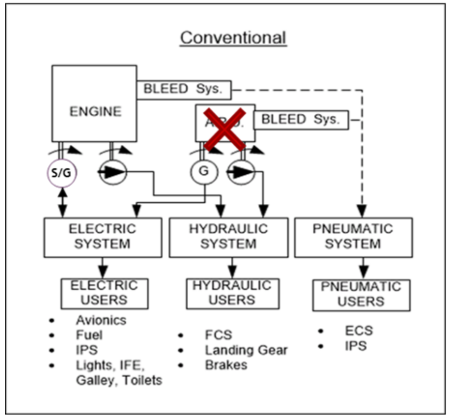
More than 300 stated requirements

All requirements are connected together with the stakeholders' needs

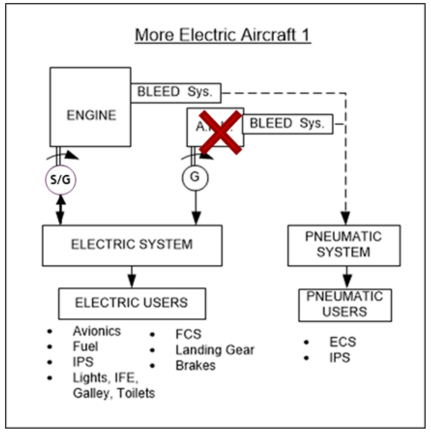
AC3 Baseline definition

- Systems architectures definition
  - Definition of 4 OBS architectures with different electrification level
  - The different architectures have been inspired by real industry trends

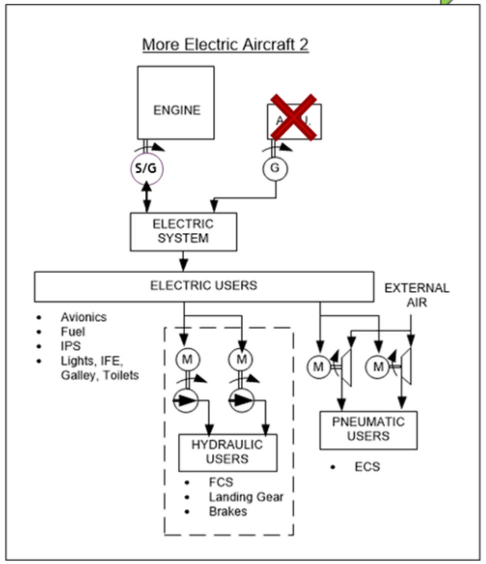
Increasing OBS Electrification Level



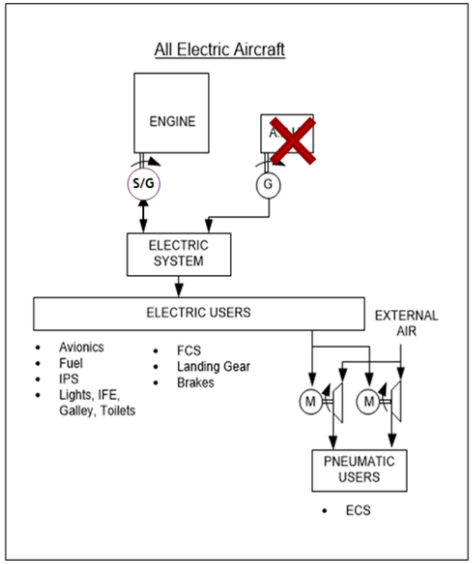
Conventional (hydraulic actuators, pneumatic IPS and ECS, low voltage)



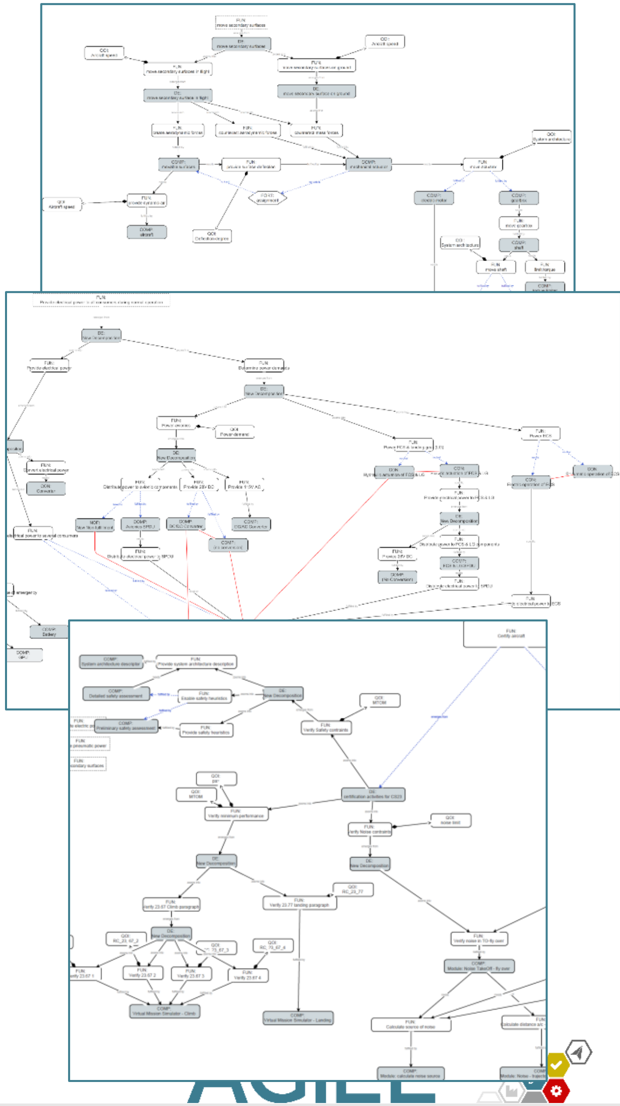
MEA1 (electric actuators, pneumatic IPS and ECS, high voltage)



MEA2 (hydraulic actuators, electro-pneumatic IPS and ECS, high voltage)



AEA (electric actuators, electro-pneumatic IPS and ECS, high voltage)



AC3 workflow development

11 Disciplines: Conceptual design, OBS design, Aerodynamics, Engine design, Performance, Engine SFC, Synthesis, Noise, Minimum Performance, Safety, Cost and Emissions

7 Partners: DLR, UNINA, ONERA, CFSE, CONU, RWTH and PoliTo

Converged MDA
- ✓ OBS mass and power variation
- ✓ Effect on engine power, engine SFC, airframe mass, geometry and aerodynamics

DOE/MDO

Aircraft conceptual design - initialization (DLR)

DLR Deutsches Zentrum für Luft- und Raumfahrt

4 OBS architectures
Wing surface 30-40 m^2

MDA

OBS design (PoliTo) — Politecnico di Torino

Engine offtakes sensitivity (PoliTo) — Politecnico di Torino

ONERA THE FRENCH AEROSPACE LAB — Aero-surrogate (CFSE-ONERA) — CFS Engineering Computational Fluids & Structures Engineering

Università degli Studi di Napoli Federico II — Performance (UNINA)

Università degli Studi di Napoli Federico II — Engine design (UNINA)

DLR Deutsches Zentrum für Luft- und Raumfahrt — Aircraft synthesis (DLR)

Virtual certification process
- ✓ External noise
- ✓ Minimum performance
- ✓ Safety assessment

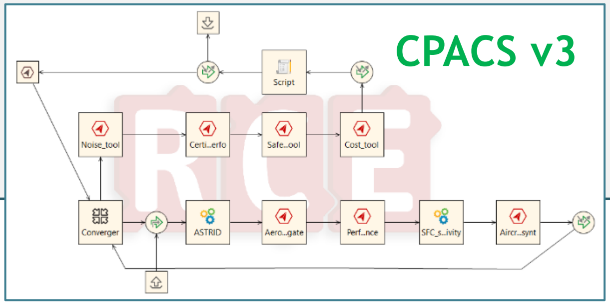
Università degli Studi di Napoli Federico II — Cert. NOISE (UNINA)

ONERA THE FRENCH AEROSPACE LAB — Cert. Minimum Performance (ONERA)

Concordia University — ASSESS (CONU)

ILR Institute of Aerospace Systems — RWTH Aachen University — Costs&Emissions (RWTH)

Implementation in the MDO distributed environment



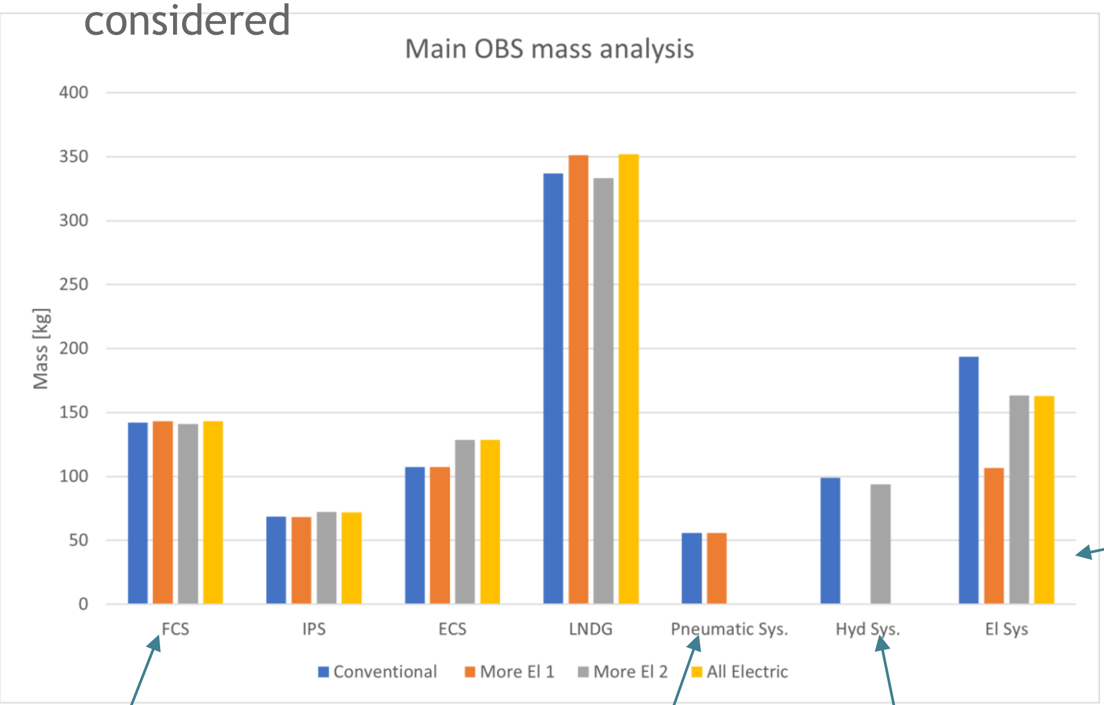
Final assessment

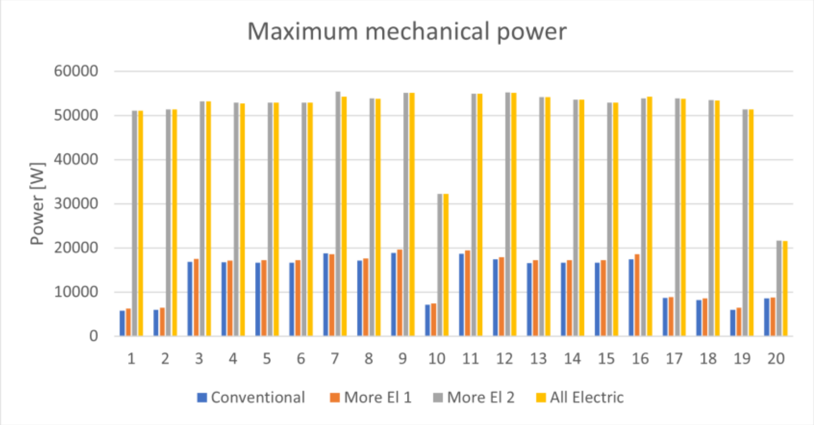
AGILE 4.0

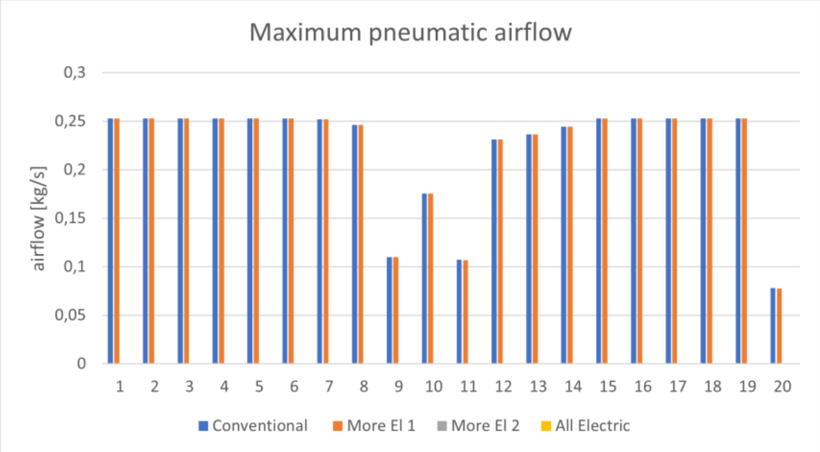
AC3 Achievements

▪ Systems electrification assessment (1 of 3)

- The different architectures have been designed and integrated with the aircraft and propulsion system
- Electric actuation, bleedless, high voltage, electric ECS and IPS technologies are considered







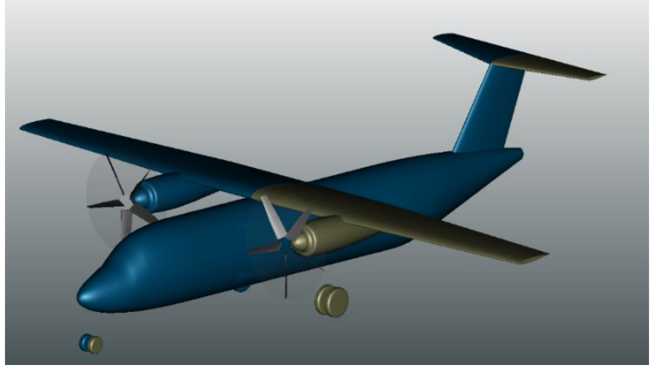
The increase of electric system mass is little for electrified architectures due to the use of **high voltage** (270 VDC instead of 28 VDC)

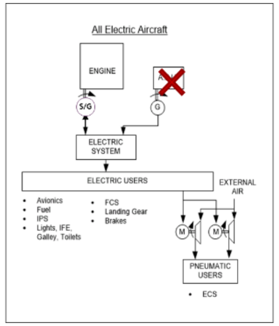
Practically **constant**. Only flap surfaces deflected with actuators

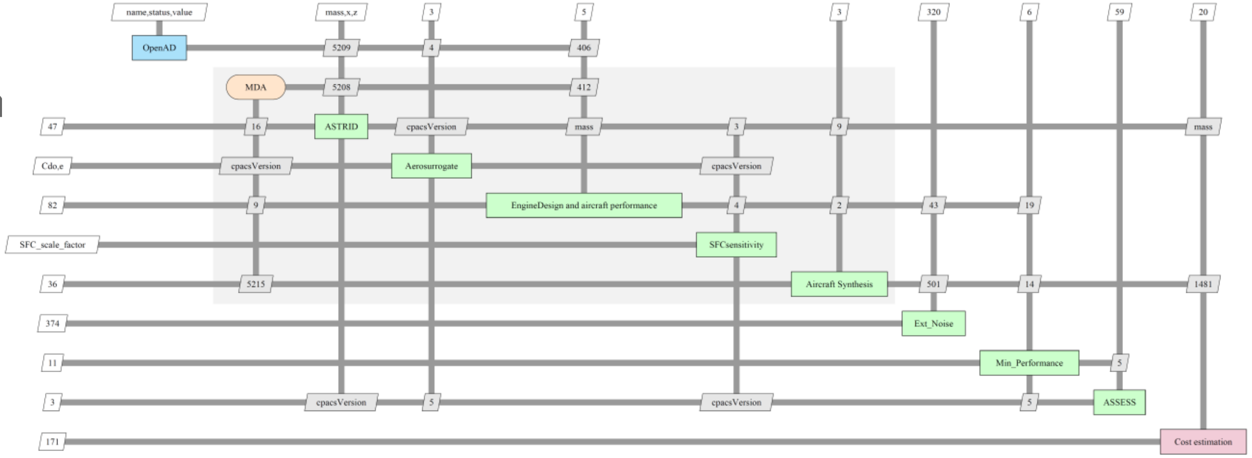
Notable **mass saving** when removing Hydraulic and Pneumatic systems (electric actuation and/or bleedless architecture)

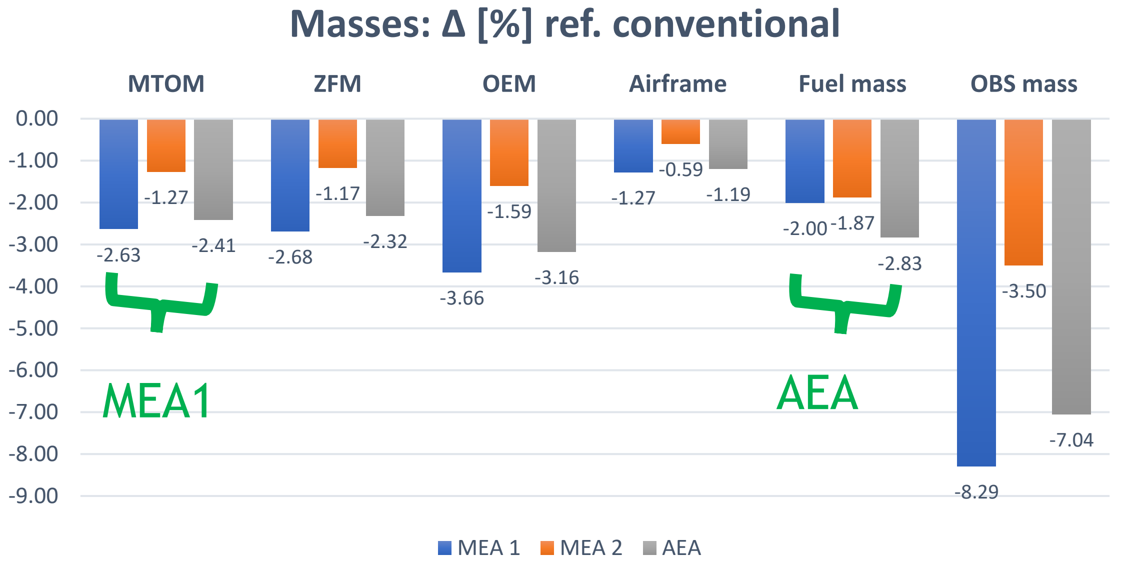
AC3 Results

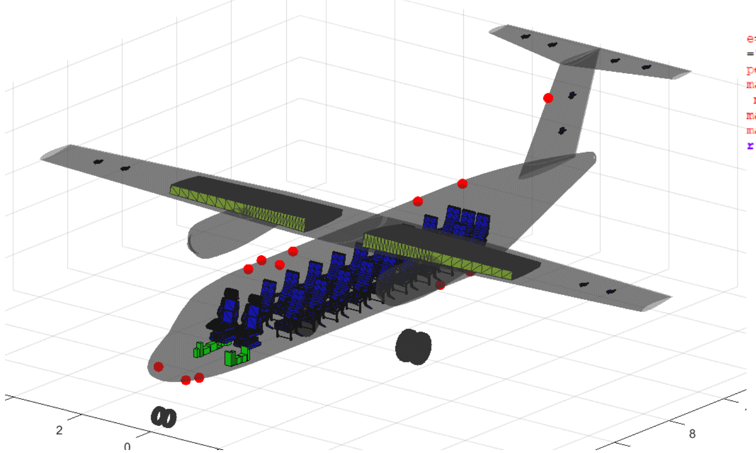
- Systems electrification assessment
  - The effect on aircraft mass and engine efficiency are both considered
  - For each OBS architecture, a new aircraft is designed











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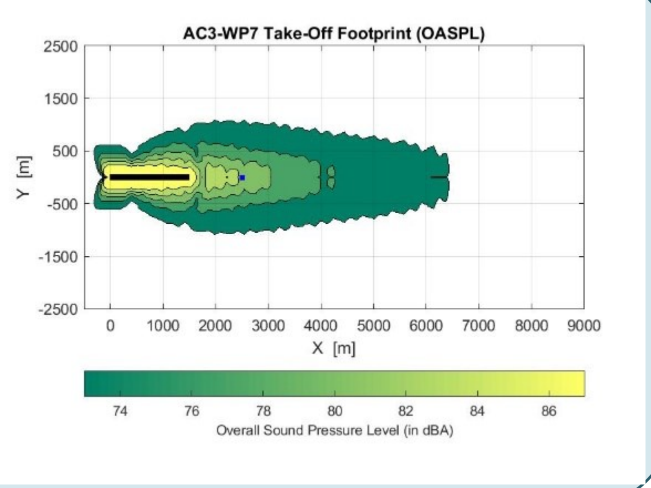
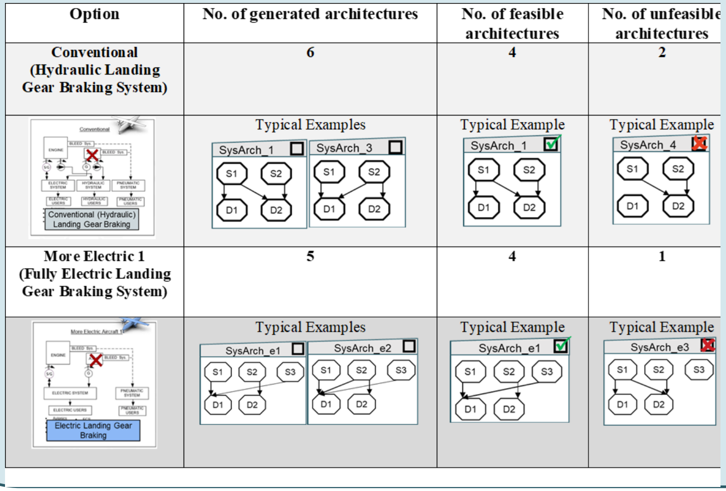
AGILE 4.0

AC3 Results

- *External Noise CS23 / CS25*
  - *CPACS file*
  - *Take-off trajectory computed (Fly-Over and Later noise analysis)*
  - *Approach trajectory computed (Approach noise analysis)*
  - *Airframe NOISE computed*
  - *Engine noise assumed*

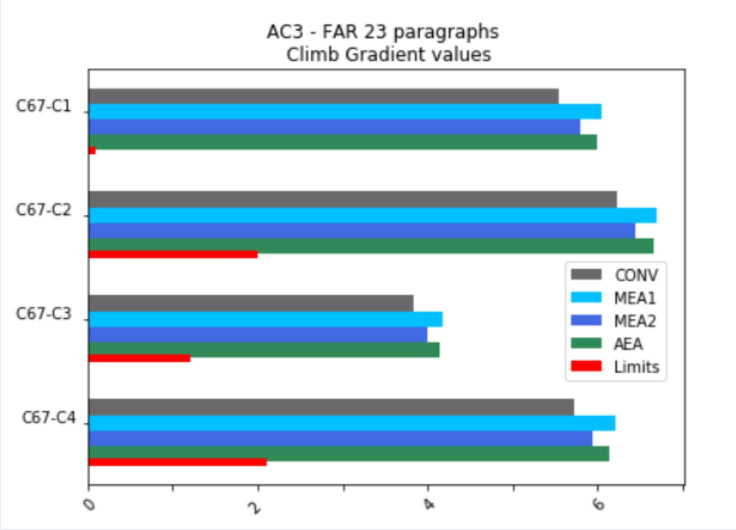




Option	No. of generated architectures	No. of feasible architectures	No. of unfeasible architectures
Conventional (Hydraulic Landing Gear Braking System)	6	4	2
Conventional (Hydraulic) Landing Gear Braking	Typical Examples: SysArch_1, SysArch_3	Typical Example: SysArch_1	Typical Example: SysArch_4
More Electric 1 (Fully Electric Landing Gear Braking System)	5	4	1
Electric Landing Gear Braking	Typical Examples: SysArch_e1, SysArch_e2	Typical Example: SysArch_e1	Typical Example: SysArch_e3

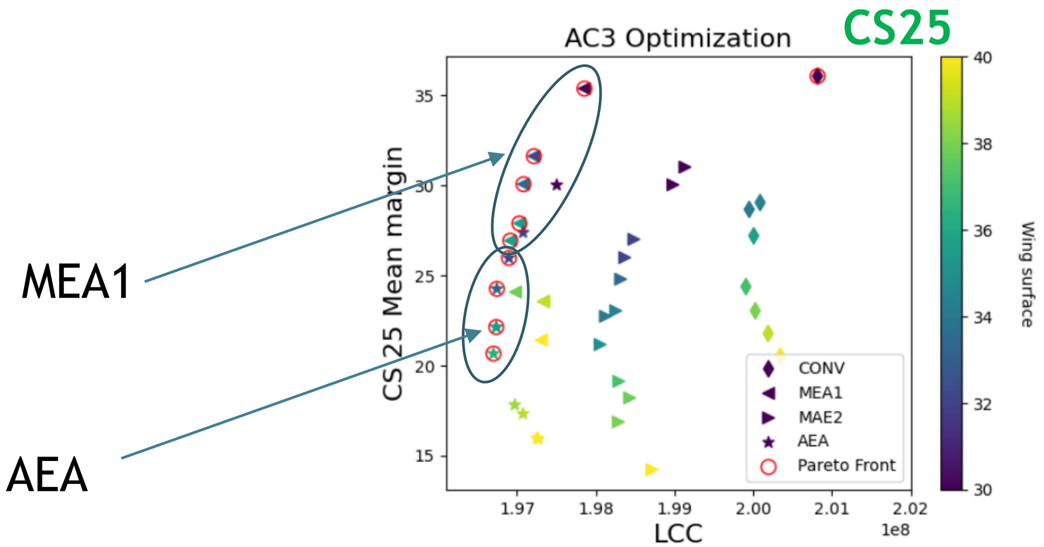
- *Safety Assessment*
  - *Systems architecture (braking system)*
  - *Main requirement: at least 2 independent power lines*
  - *Different electrification levels → different architectures*

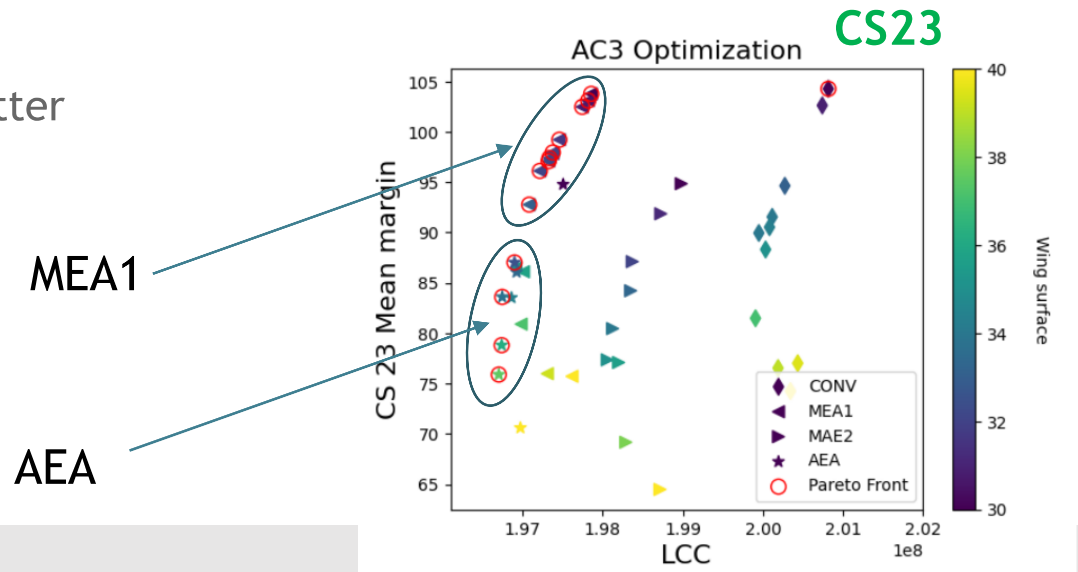
- *Minimum Performance CS23 / CS25*
  - *Min. climb gradient*
  - *Performance simulation*
  - *Different aircraft configurations (clean, TO, LND condition)*
  - *Different mission phases (TO, climb, Landing)*



AC3 MDO results

- Systems electrification assessment with certification constraints
  - **Variables**: systems electrification level, wing surface
  - **Objectives**: minimum LCC and maximum Certification Margins
- Results
  - All electric (AEA) and More electric 1 (MEA1) are the best electrification level
  - AEA achieved minimum LCC, MEA1 achieved maximum Certification margins
  - Aircraft with small wing surface perform better





Towards cyber-physical collaborative aircraft development

Thank You !

AGILE 4.0

HORIZON 2020

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