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Gerhard Sedlmayr Lecture

Urban Air Mobility: Safety Aspects for a New Era of Sustainable Aviation

Royal Aeronautical Society, Sept. 06, 2022

Dr. Joerg P Mueller, Head of Urban Air Mobility, Managing Director AUM GmbH

AIRBUS

Deutsche Gesellschaft für Luft- und Raumfahrt Lilienthal-Oberth e.V. Bezirksgruppe Hamburg

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HAW HAMBURG

RAeS Hamburg in cooperation with the DGLR, VDI, ZAL & HAW invites you to a lecture

Annual Gerhard Sedlmayr Lecture

"Safety Aspects for a New Era of Sustainable Aviation"

Dr. **Joerg P. Mueller**, Head of Urban Air Mobility, Managing Director,
Airbus Urban Mobility GmbH

Date: **Tuesday 06 September 2022, 18:30**
(light refreshments available from 18.00
and there will be a get-together with refreshments after the lecture)

Location: **ZAL TechCenter, Hein-Sass-Weg 22, 21129 Hamburg**

(If you wish to attend, please register online or send a mail to Susanne Altstaedt, susanne.altstaedt@airbus.com

Urban Air Mobility is at the juncture where the ever growing societal need for efficient and sustainable transport meets new solutions provided by emerging technology. The lecture provides the rationale for this new and sustainable way of flying in cities and beyond. It describes the state of the art, and in particular Airbus' positioning with CityAirbus NextGen. In that sense, UAM is much broader than just a flying vehicle. It requires infrastructure on the ground, an adapted airspace management, and an efficient integration with complementary means of transport.

Furthermore, the introduction of a new means of transport requires that highest safety standards are met. The new eVTOL architectures and mission profiles call for new approaches to safety of the vehicles in their operational environment. Therefore, the second part of the lecture provides an overview on Airbus' approach to safety and particular aspects concerning the distributed electric propulsion system, flight controls and aerostructures.

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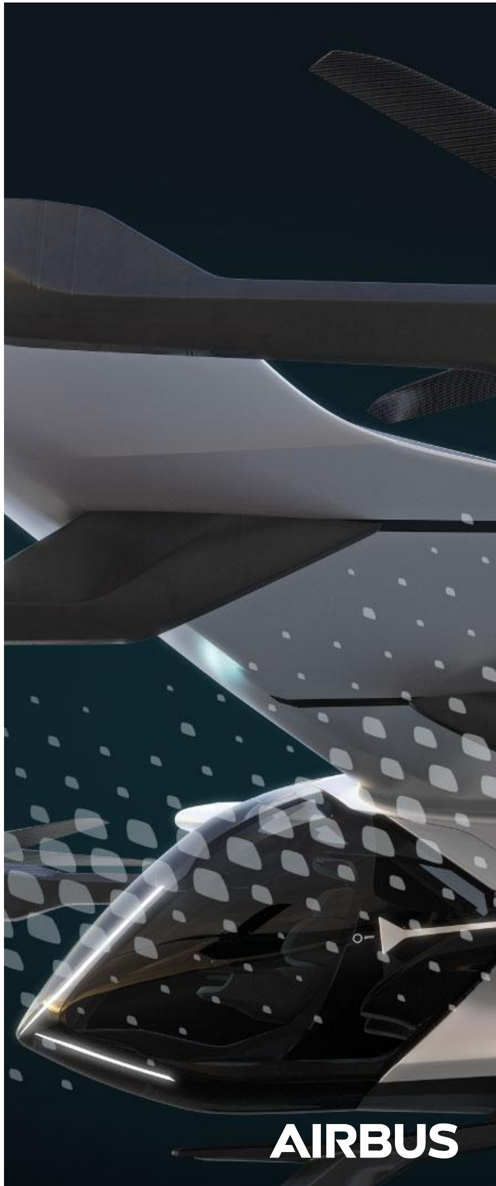
Agenda

- Advanced air mobility @ Airbus: where do we stand?
- The air mobility service of tomorrow: how will we maintain the highest safety standards with CityAirbus NextGen?



Why is Airbus developing an Urban Air Mobility aircraft?

01

Answer a societal need for alternative advanced air mobility services

From urban passenger transport, to medical services or eco friendly tourism, we intend to bring added value to communities' journeys.

02

Develop technology for sustainable aviation

Contribute to the Airbus-wide sustainability roadmap, by developing technological bricks for zero-emission flights.

03

Seize an opportunity to create a completely new market in aviation

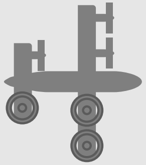
Co-create new ecosystems to deploy advanced air mobility services along with our wide range of partners around the world.

Distributed electric propulsion opens a new design space

Lift- and cruise/winged

- ✔ Simplicity
- ✔ High reliability
- ✔ Easier to certify
- ✔ Quiet in operation
- ✔ Cost efficient maintenance
- ✔ Longer battery life-time

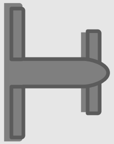
Tilt-X/convertible aircraft concepts



- ✔ High speed
- ✔ Long range

- − Complex design
- − Lower reliability
- − Complex certification
- − Challenging/ complex maintenance

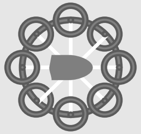
Fix-Winged vectored trust concepts



- ✔ Efficient cruise
- ✔ Long range

- − Energy-intensive hover
- − High noise levels
- − Low battery life-time
- − Challenging/ complex maintenance

Distributed propulsion/ Multicopter



- ✔ Efficient take off and landing
- ✔ Easier to certify

- − Less efficient cruise
- − Slower speed
- − Short range
- − Low battery life-time

Airbus has developed two demonstrators to explore the optimum aircraft architecture

Leveraging the Airbus expertise and experience on aircraft design, development and certification

Design for cruise

Vahana

Design for hover

CityAirbus

Key highlights:

- Experience of over 240 flight and ground tests conducted with around 1000 km flown
- >100 k engineering hours (incl. noise optimisation in real life testing)
- **CityAirbus NextGen** benefits from the best of both worlds: the simplicity of CityAirbus' RPM and the superior efficiency of Vahana's wing.

CityAirbus NextGen

- Optimum trade-off between design for cruise and hover
- Fulfilling all four design principles of Airbus for eVTOL vehicle
- Optimized for serving identified most promising three use cases

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CityAirbus NextGen, Airbus' eVTOL prototype

EASA SC-VTOL
Enhanced Category Certification Framework

Zero Local Emissions:
CO_2, NO_x free

Cabin size:
4 seats (incl. pilot)

Cruise Speed: 120 km/h

100% battery
and electric motor powertrain

Operational Range:
80 km

8 propellers (incl. 2 pushers on V- Tail)

Paving the way to autonomous operations
Piloted with simplified vehicle operation features

We are building on a set of simulations and testing to mature CityAirbus NextGen

CityAirbus NextGen’s components: a mix of in-house knowledge and partners’ expertise

- Structure - Cabin
- Propellers/ dynamic system
- EPU (electric propulsion unit)
- Batteries
- Flight control system

- Structure - Rear
- Structure - Wing
- Interior
- Avionics

Selected partners & suppliers

SPIRIT AEROSYSTEMS · DIEHL Aerosystems · THALES · MAGicALL · GERG M&F · KLK Motorsport

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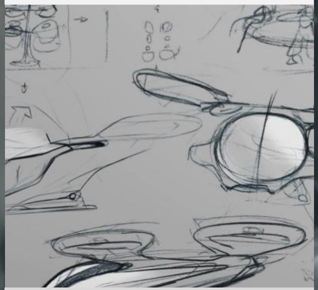
Airbus has built up expertise along the whole UAM ecosystem via demonstrators and prototypes as well as based on Airbus existing business

eVTOL vehicle



- eVTOL demonstrators (e.g., Vahana, City Airbus)
- Several demonstrators in the field of electrical propulsion

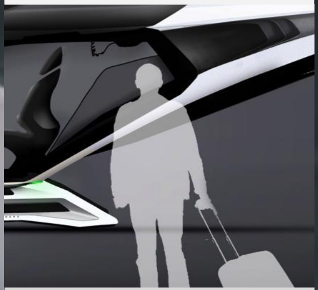
Support & Service

- Longstanding experience for Support & Service offerings across Airbus (e.g,, HCare) with global service and spare parts network
- Training of pilots to operate the aircraft safely

Airspace Management

- Prototypes for digital services at the intersection ATM/UTM for urban airspace management (e.g., via U-Space)

Flight Operations

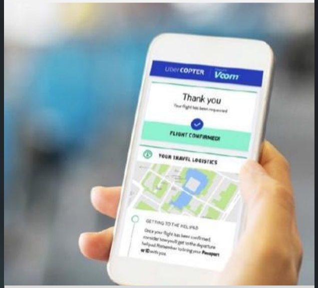


- Experience from operation of piloted and remotely controlled vehicles (e.g., Beluga Fleet Ops)

Ground Infrastructure

- Concepts and design studies for ground infrastructure for different use cases and locations globally (e.g., first projects in Paris and Bavaria)

Customer Integration



- Experience from Helicopter Services in 4 Mega-Cities with 120,000+ users, Flying 15,000+ pax
- Front-Face + Back-End digital platform and coordinating Ops, Heliport & PAX

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Building partnerships to drive the development of local UAM and AAM ecosystems

Expansion of our partnership with The Helicopter Company “THC”: focus on sustainability. Continue to develop helicopter activities with SAF and introduce UAM in Saudi Arabia.

Launch of the Air Mobility Initiative - a scalable AAM ecosystem - in Germany with around 30 partners to co-create a new mobility service.

April 2022, partnered with ITA Airways to identify strategic use cases for UAM in Italy and further progress on the definition of operational contexts for our eVTOL.

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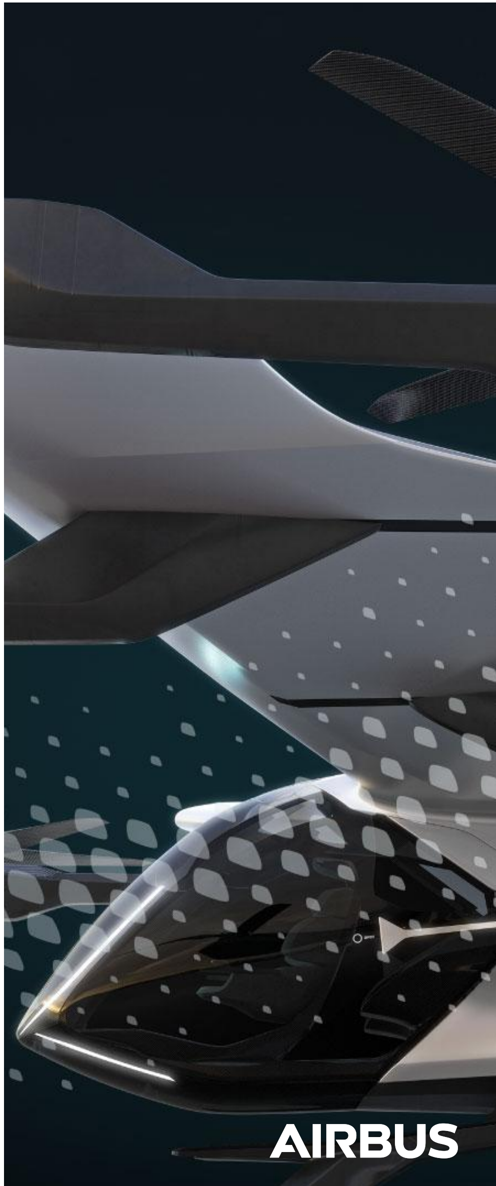
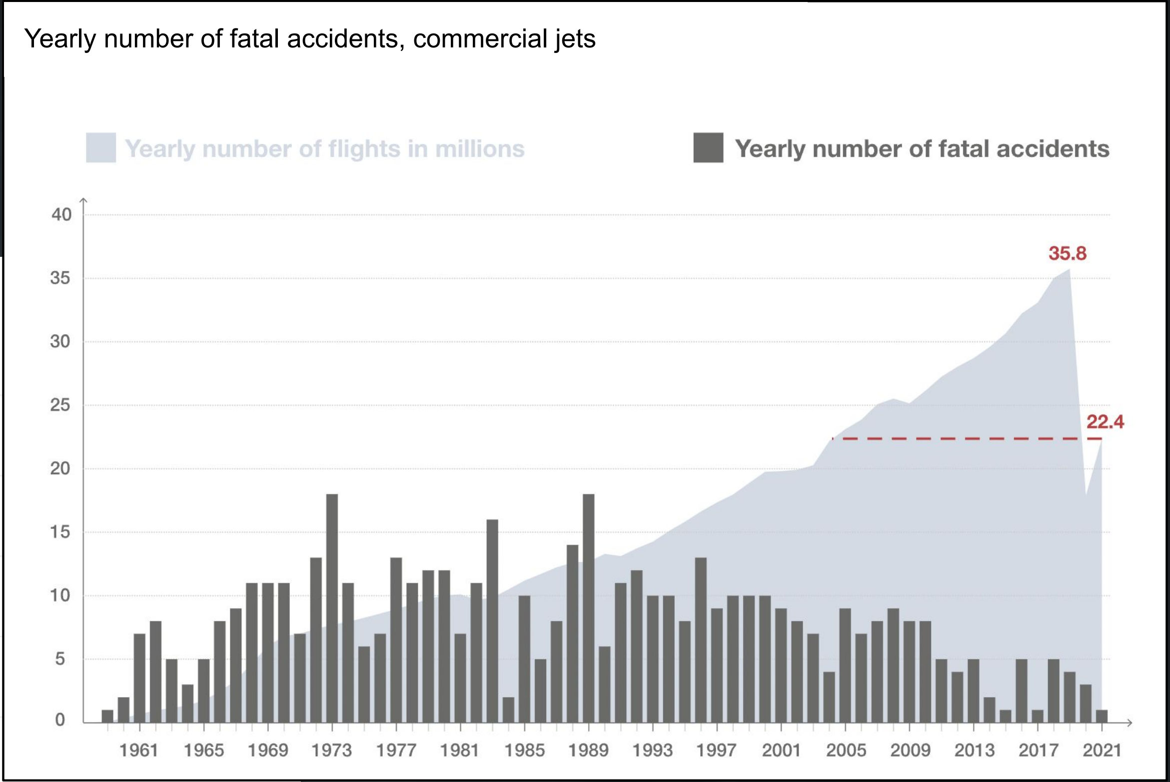
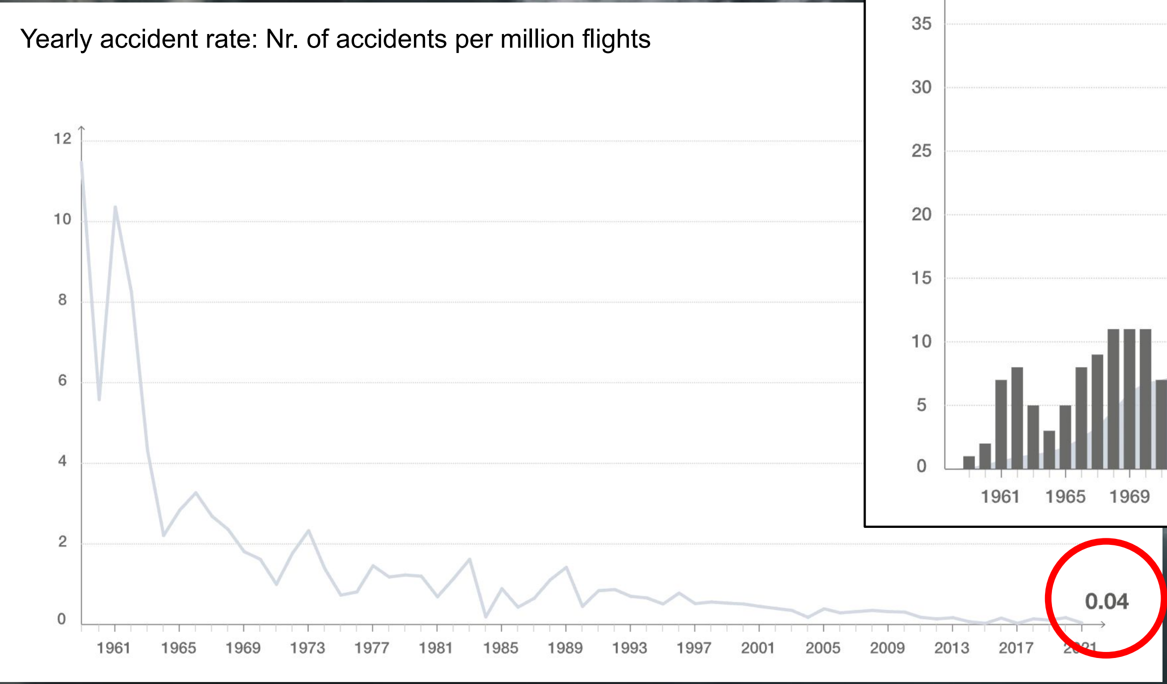


The commercial aviation industry reached unprecedented safety levels in a collective effort





Airbus Analysis of Aviation Accidents 2021
https://accidentstats.airbus.com/statistics/fatal-accidents

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Technology progress is a main driver in increasing safety

1

Early Commercial Jets

From 1952

Dials and gauges in cockpit, early autoflight systems

Comet, Caravelle, BAC-111, Trident, VC-10, B707, B720, DC-8, Convair 880/990

2

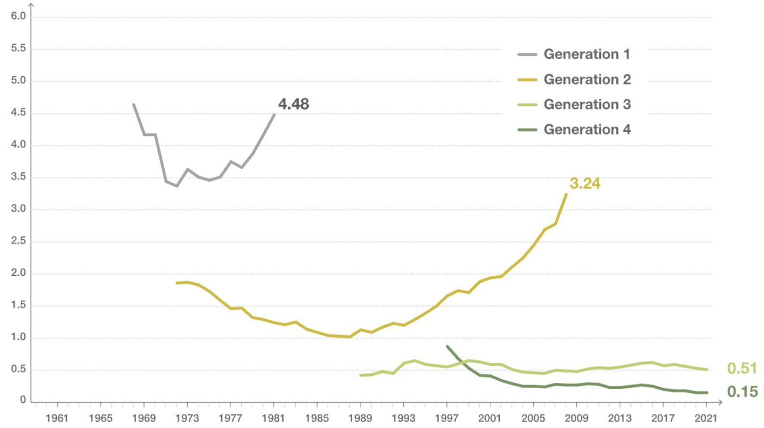
More Integrated Autoflight

From 1964

More elaborate autopilot and autothrottle systems

Concorde, A300, Mercure, F28, BAe146, VFW 614, B727, B737-100/-200, B747-100/-200/-300/SP, L-1011, DC-9, DC-10

10 year moving average hull loss rate (per million flights) per aircraft generation



3

Glass Cockpit, FMS & TAWS

From 1980

Electronic displays, Flight Management System (FMS), and Terrain Awareness and Warning System (TAWS) reduced CFIT accidents

A300-600, A310, Avro RJ, F70, F100, B717, B737 Classic, B737 NG, B737 MAX, B757, B767, B747- 400/-8, Bombardier CRJ, Embraer ERJ, MD-11, MD-80, MD-90

Fly-By-Wire

From 1988

Flight envelope protection enabled by fly-by-wire technology reduced LOC-I accidents

A220, A318/A319/A320/A321, A330, A340, A350, A380, B777, B787, Embraer E-Jets, Sukhoi Superjet

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The unprecedented traffic forecasts for UAM require to put safety at the heart of all we are doing in order to further improve accident rates

Hypothetical accident numbers, illustrated based on traffic forecast of Roland Berger

Year	Estimated # of air taxi Vehicles (Roland Berger*)	Estimated # of flights [per million landing, per year]	hypothetical # of fatal accidents [per year] (Note 3)
2050 (Note 1)	160000	480	19
2040 (Note 2)	16000	256	1
2030 (Note 2)	1600	144	0
2025	160	0,08	0

Not acceptable (2050, 2040)

⇨ **Strong further safety improvements are needed to avoid accidents**

Note 1: A dynamic growth between 2030 and 2050 is expected.* "The market will grow 10 times every 10 years starting from 2030 until 2050."
Note 2: Estimation of number of fatal accidents is performed assuming at least the same accident rate will be achieved as of today (0,04 per million landings**)

* (Urban Air Mobility | USD 90 billion of potential: How to capture a share of the passenger drone market; Roland Berger, November 2020)
** Airbus Analysis of Aviation Accidents 2021 - Accident rate achieved by commercial jets

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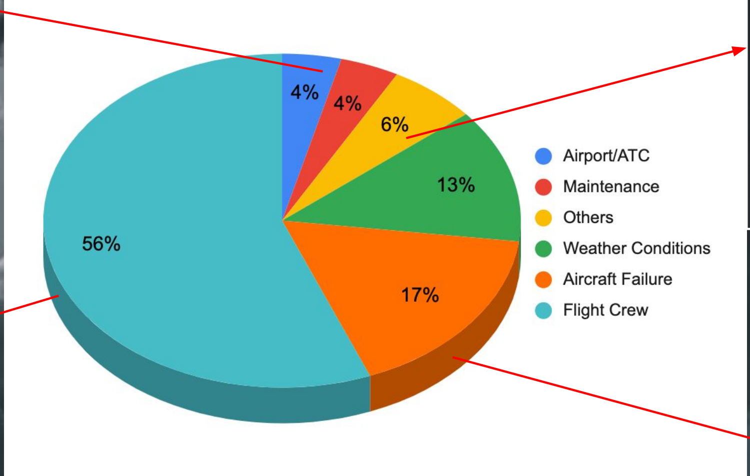
Based on the various root causes for accidents, we take a holistic approach to safety

ATM & U-Space Enablers

- Develop & Deploy UTM Digital Services
- Develop UTM digital twin
- Support other Airbus Programs for non-segregated airspace integration

Autonomy Enablers & AI

- Reduce pilot workload
- Minimize and eliminate crew errors
- Decrease operating and training costs
- Increase power savings



Operation and Maintenance

- New operational environment considerations
- Airspace and Operational Requirements
- Detect & Avoid Technology, Visual Flight Rules
- Adaptive Condition Based Maintenance Strategy

AW requirements Certification:

- SC/MOC VTOL
- SC E19 (EHPS)

➔ Vehicle certification and System Safety Assessment only deals with 17% of the accidents.

➔ A mitigation for the remaining 83% will push the safety of operations of UAM further.

1001 Crash Database "Commercial Aviation Accidents Statistics"
https://www.1001crash.com/index-page-statistique-lg-2.html

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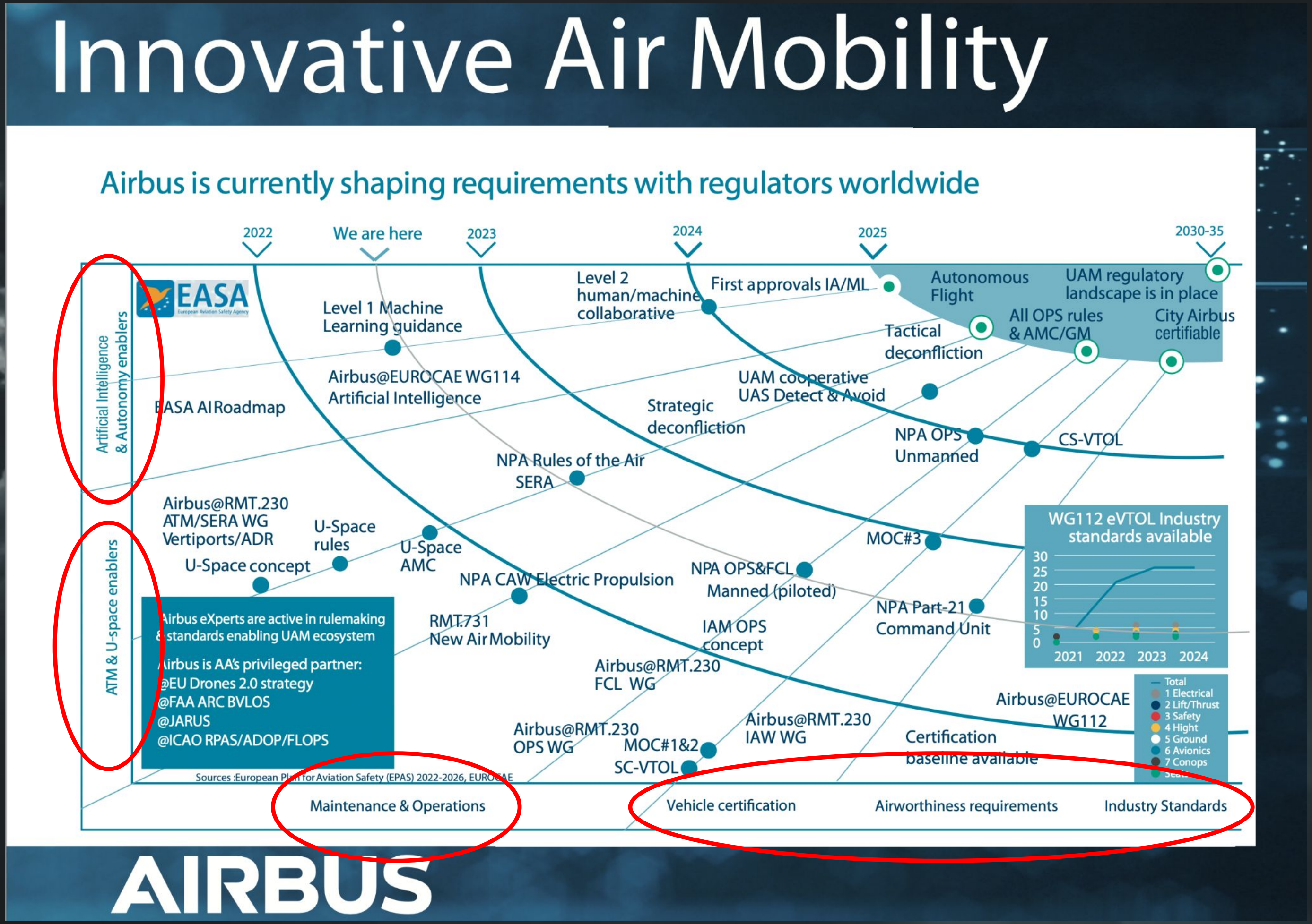
We are engaging with the regulator and industry to mature the safety frameworks



SC VTOL is a Performance Based Regulation, facilitates innovation and design of integrated and complex systems

Certification according to the specific type of operation

- ❑ Category Enhanced (commercial flights and flights over congested areas)
- ❑ Category Basic (non-commercial flights outside of the congested areas)

Proportionality in Performance Objectives According to the Type of Operation

- ❑ Continued Safe Flight and Landing (CSFL) for Category Enhanced: An aircraft is capable of continue controlled flight and landing to a vertiport, possibly using emergency procedures, without requiring exceptional piloting skill or strength
- ❑ Controlled Emergency Landing (CEL) for Category Basic: Aircraft is capable of performing a controlled landing, possibly using emergency procedures, without requiring exceptional piloting skill or strength. Upon landing, some aircraft damage may occur.

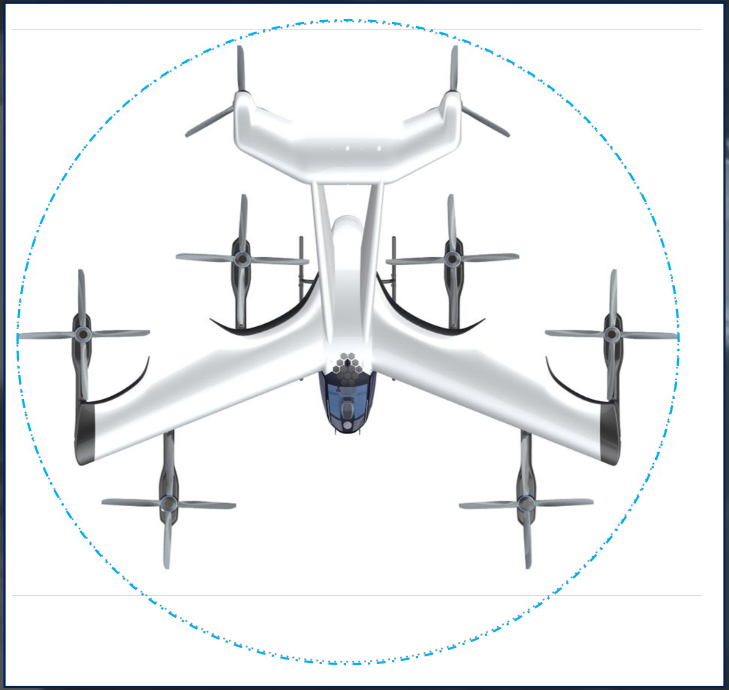
Table 1: Safety Objectives

	Maximum Passenger Seating Configuration	Failure Condition Classifications			
		Minor	**Major**	**Hazardous**	**Catastrophic**
		Allowable Qualitative Probability			
		Probable	Remote	Extremely Remote	Extremely Improbable
		Allowable Quantitative Probability (Note C and D) Development Assurance Level			
Category Enhanced	-	$\leq 10^{-3}$ FDAL D (see Note B)	$\leq 10^{-5}$ FDAL C	$\leq 10^{-7}$ FDAL B	$\leq 10^{-9}$ FDAL A
Category Basic	**7 to 9 passengers (Basic 3)**	$\leq 10^{-3}$ FDAL D (see Note B)	$\leq 10^{-5}$ FDAL C	$\leq 10^{-7}$ FDAL B	$\leq 10^{-9}$ FDAL A
	2 to 6 passengers (Basic 2)	$\leq 10^{-3}$ FDAL D (see Note B)	$\leq 10^{-5}$ FDAL C	$\leq 10^{-7}$ FDAL C (see Note A)	$\leq 10^{-8}$ FDAL B (see Note A)
	0 to 1 passenger (Basic 1)	$\leq 10^{-3}$ FDAL D (see Note B)	$\leq 10^{-5}$ FDAL C	$\leq 10^{-6}$ FDAL C (see Note A)	$\leq 10^{-7}$ FDAL C (see Note A)

[Quantitative safety objectives are expressed per flight hour]

Note A: no considerations of the system architecture for a DAL reduction are acceptable, as the FDAL classification already constitute a proportionate approach.
Note B: Alleviation in software development assurance for IDAL D as per section 9(c) is possible.
Note C: It is recognised that, for various reasons, component failure rate data may not be precise enough to enable accurate estimates of the probabilities of Failure Conditions. This results in some degree of uncertainty. When calculating the estimated probability of each Failure Condition, this uncertainty should be accounted for in a way that does not compromise safety.
Note D: The applicant is not expected to perform a quantitative analysis for minor failure conditions.
Note E: An average flight profile (including flight phases duration) and an average flight duration should be defined.

There are three Novel and Key Aspects of SC-VTOL that we focus on particularly



1) Lift/Thrust Considerations in Flight Controls
   - Distributed propulsion system directly contributes to the controllability of the aircraft (Integrated Flight Control Function)
   - Integrated Flight Control Function is designed for FDAL-A*
   - The relevant safety objectives are determined at aircraft level
   - Derating and multiplexing to comply with quantitative requirements
2) Considerations for Highly Integrated Systems (V&V and Testing Strategy)
3) No single failure criteria in Structures.

*Functional Development Assurance Level

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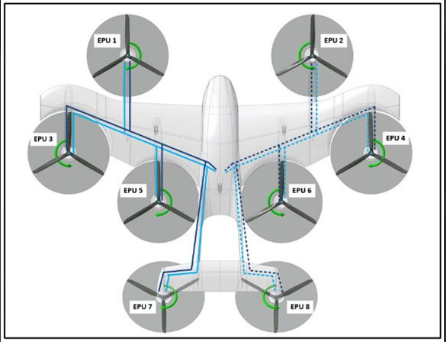
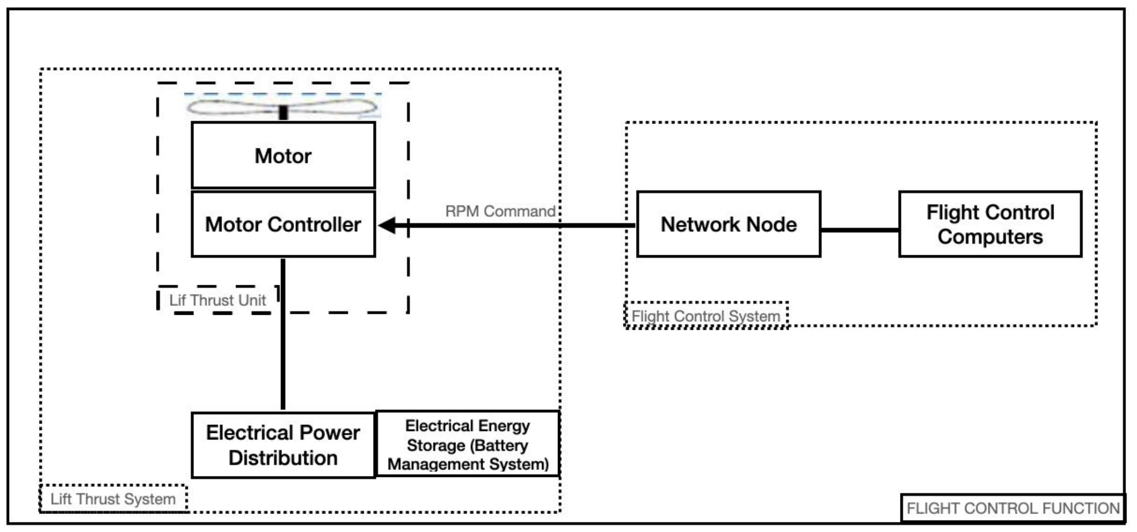
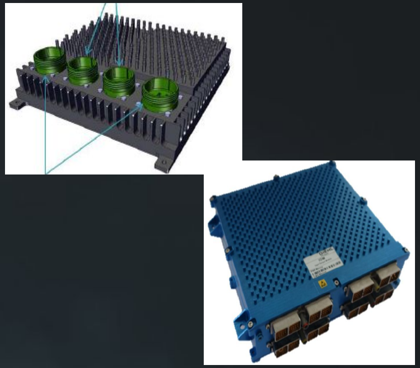
Novel and Key Aspect 1: Lift/thrust Units are part of Flight Controls







Lift Thrust System

- Distributed electrical propulsion bringing significant advantage for redundancy and failure accommodation. Aircraft is tolerant to the loss of one of its LTUs.
- Identical LTUs have dissimilar redundant architecture internally to cope with common mode failures.
- Simple, no tilting mechanisms, no significant transition phase between hover and cruise
- No flammable fluids, containment of electrical fire
- Batteries: Multiple battery packs, tolerant to the loss of single battery pack. Containment of the battery thermal runaway.

Flight Control System

- System Architecture and Integration designed from Airbus long experience since 80s.
- Advanced Flight Control/Autonomy to reduce pilot workload
- Advanced Control Laws algorithms hosting piloting concept & envelope protection
- Redundancy and dissimilarity in Flight Control; no single error/failure causes catastrophic consequences.
- Two different manufacturers for FCCs

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Novel and Key Aspect 2 : Validation of end-to-end function (highly integrated system)

MOC VTOL 2510

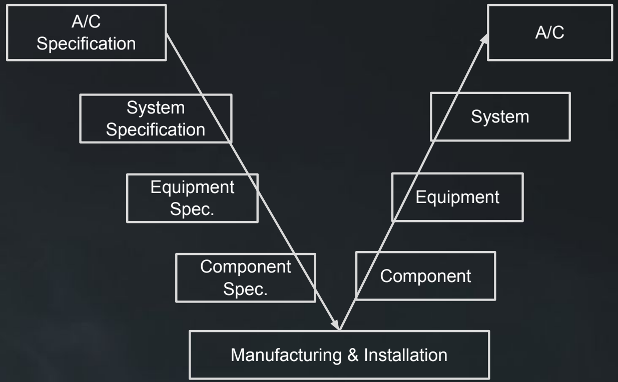
11. Considerations for highly integrated systems

(a) Generic guidance

(1) When aircraft functions are provided by a combination of systems, the relevant requirements of those systems should be validated together, including the following activities:

(i) Analysis of the potential interactions and interferences between systems,

(ii) Planning of dedicated activities at system and aircraft levels to ensure validation of those requirements that are affected by interactions or interference.



Simulations to validate the aircraft behaviour in different failure scenarios for the end-to-end function

- Vehicle Aeromechanical Modeling based on several complementary modeling tools (CFD, Wind tunnel data, Rotors computations)
- Handling Qualities evaluation covering the full flight envelope
- Piloting concept validation with several pilots
- Vehicle System Modeling (VTOL Flight Lab)
- Desktop simulations
- Flight Simulator

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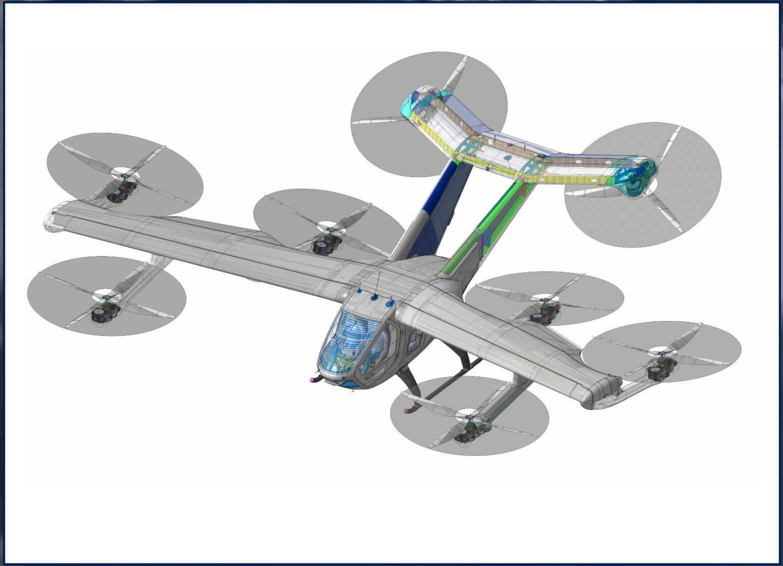
Novel and Key Aspect 3: No single failure requirements applied to Airframe Structure

Airframe Structure



- Structural Durability
  - Dual load path to avoid single failures (MOC)
  - Fail-safe critical attachments
  - No critical part
- Particular Risks
  - Compliance to Bird Impact, flocking bird requirement
  - Cascading Failure Analysis for High Energy Fragments
  - Explosive Fire Zone and Fire Withstanding Zone Approach for Fire Protection
  - HV effects

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Building together a viable solution for an urban air mobility transport system

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