ADENEAS
Public Workshop
22 February 2023

Presenter: Kees Nuyten - FE

Contributors: The Team

Advanced Data and power Electrical NEtwork Architectures and Systems

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006728.

Introduction

- The ADENEAS workshop is an interdisciplinary collaboration to expand, discuss and network on different topics related to H-2020 call MG-3-4-2020, part of 'Smart, green and integrated transport'

Innovative electric network architectures and systems, optimising global energy, electrical power, data and communication for aviation

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Participants

- Confirmed
  - A.D.S.E.
  - Airbus
  - ARTTIC
  - Collins
  - EASA
  - Evektor
  - GKN - Fokker Elmo
  - KLM
  - NLR
  - Ohmic
  - plc-tec
  - Synano
  - TU/e
  - University of Nottingham
- Invited
  - Benchmark
  - Bombardier
  - Brookx
  - Diehl Aerospace
  - DLR
  - Embraer
  - Honeywell
  - ONERA
  - MGM Compro
  - SAZ Aerospace
  - University of BRNO
  - University of Hamburg

Agenda

Time		Topic
Start	End	
10:00	10:05	**Welcome and introduction** *Presenter: Kees Nuyten, Coordinator of ADENEAS – Fokker Elmo*
		Project Presentation
11:05	10:25	**Project introduction** *Presenter: Kees Nuyten – Fokker Elmo*
		Work Package (WP) presentations
10:25	10:40	**WP2 – Wireless Technologies** *Presenter: Sonia Heemstra de Groot – Eindhoven University of Technology (TU/e)*
10:40	10:55	**WP3 – Power Line Communications** *Presenter: Stephen Dominiak – plc-tec*
10:55	11:10	**WP4 – Modular Distributed Power** *Presenter: Diarmaid Hogan – Collins Aerospace*
11:10	11:25	***Coffee Break***
11:25	11:40	**WP5 – Cooling Solutions** *Presenter: Johannes van Es – NLR*
11:40	11:55	**WP6 – Architectures & Topologies** *Presenters: Kees Nuyten – Fokker Elmo; Diarmaid Hogan – Collins Aerospace*
11:55	12:10	**WP7 – Technology impact Evaluation, Assessment & Optimization** *Presenter: Roland Furmanek – Evektor*
12:10	12:20	**Any other business**
12:20	12:30	**Summary of status and feedback**
12:30	13:30	***Lunch Break***
13:30	14:00	**Round table discussion**
		Related research project presentations
14:00	14:30	**ORCHESTRA project**
14:30	15:00	**3CCAR project**
15:00	15:15	**Ramp up**
15:15	-	***End of the Public Workshop***

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Project Introduction

Advanced Data and power Electrical NEtwork Architectures and Systems

Presenter: Kees Nuyten (Fokker Elmo)

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Safe, light, self-configuring, autonomous and modular power and data distribution network that is scalable to all aircraft sizes

- Hybrid data network envisioned
  - No single technology outperforms others under all circumstances – weight wise
    - Electrical cable for short distances (<1 m)
    - Wireless communication for wireless sensors
    - Electrical wire powered device do not prefer PLC or wireless communication in advance
  - Data network architecture behavior adds complexity to this simplified approach
- Modular power distribution will increase power equipment deployment and reduce weight
  - Power distribution network adds complexity to this simplified approach
  - Novel cooling system will reduce system weight

Project Vision Validation

Deliver a significant contribution to sustainability

- Weight reduction **WAS** an affordability driver (reduced fuel burn costs of ~1 k€/kg/aircraft lifecycle)

- Weight reduction **IS** a sustainability driver (reduced emissions by reduced fuel burn and enabler for More Electric and Connected Aircraft – MECA, reduced material consumption)

- Targeted weight reduction 400 kg for a 100-seater
  - Similar to 4 or 5 passengers
  - Weight reduction estimates vary but seems to be not overoptimistic
  - Emission reduction is TBD but substantial
  - At system level in scope ~20%

- Scalable solutions to maximize impact toward investor in climate and business

- Challenges
  - Complexity of the technology and the stakeholder landscape
  - Acceptance of initial increased costs leading to long term reduced costs by increased sustainability

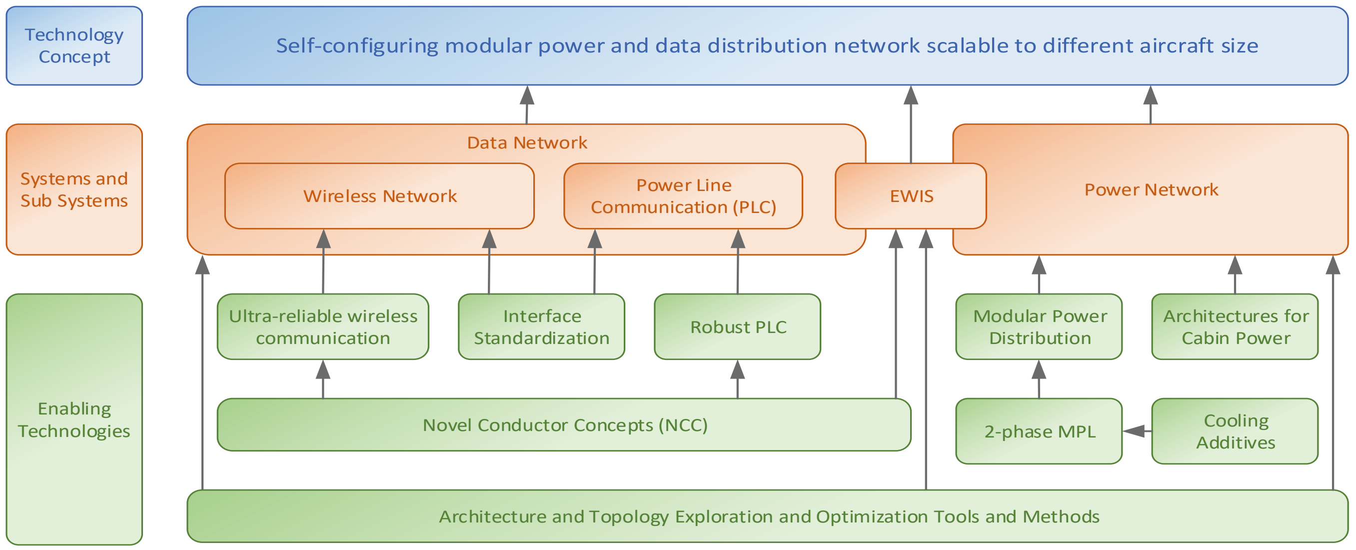
Project introduction
Project overview

Total EU contribution: 4.1 M€
Start date: 1 February 2021
End date: 1 February 2024

Key milestones
- Ultra-reliable wireless communication enablers
- Scalable and robust PLC
- Novel conductor concepts
- Architecture concepts
- Advance AI-based design tools
- Cooling system with increase performance/weight
- Demonstrators at different integration levels (TRL)

Consortium

Industrial Advisory Board



Project introduction
Rationale

Develop scalable solutions for

Large Passenger Aircraft

Regional Aircraft

Commuter Aircraft

Evaluate scalable solutions developed for

UAM

Cargo Aircraft

Rotorcraft

- More Electric and Connected Aircraft face ongoing trend of increase electrical wiring and power equipment weight
  - Current wiring weight 1200 kg for A220 / 5700 kg for A380
- ADENEAS will find and develop solutions to
  - Replace electrical wires by ultra-reliable substitutes for communication
  - Improve power network efficiency and effectiveness (including cooling solutions)

Project introduction
Objectives and targeted results

OBJ1: Develop enabling technologies for intra-aircraft data communication and power network
- Ultra-reliable wireless communication enablers
- Models for in-aircraft antenna to antenna signal transfer
- Scalable and robust Power Line Communication (PLC)
- Novel Conductor Concepts (NCC)

OBJ2: Develop new architecture concepts for advanced data and power networks
- Design criteria and architectures for integration of different communication technologies
- Multiplexed architectures for power distribution with PHM
- Optimized architectures for cabin power networks with high efficiency convertors

OBJ3: Develop advanced AI-based design tools which can facilitate the processing of new system requirements and architectures
- Tools and methods for architecture optimization and complexity reduction

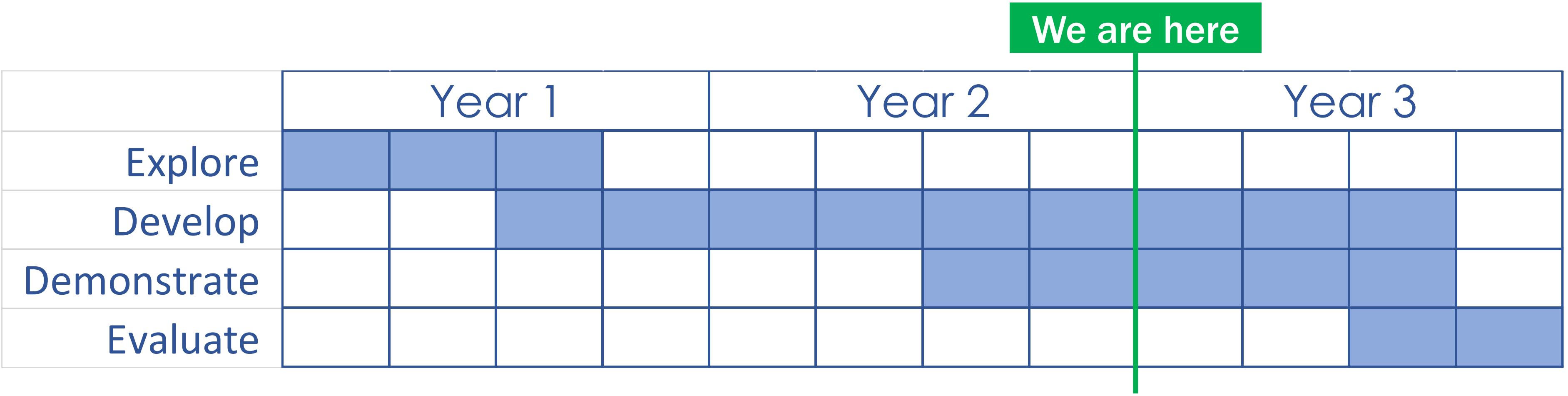
OBJ4: Develop a cooling system using a nano-fluid-based additive
- A 2-phase Mechanically Pumped Loop (MPL) cooling system with nano-fluids
- Nano-fluids for single and 2-phase cooling

OBJ5:Demonstrate at TRL3 to TRL5
- A Ground-Based Demonstrator (GBD)
- A flying testbed EVE Sportstar EPOS+ (Electric Powered Small aircraft)

OBJ6: Ensure the uptake of the ADENEAS technologies beyond the end of the project
- Standardization roadmap
- Business plan (technology roadmap)

Project introduction
Status

- Overview
  - Year 1: Context and size of the challenge explored defined and understood
  - Year 2: Developments took off, added focus to standardization
  - Year 3: Continue developments and evaluate, prepare exploitation plan
- Operation
  - Comparing status last year Public Workshop with current status
    - Vision and objectives are stable
    - Work packages show significant progress – all together quite well according plan
    - Awareness of need for standardization (interoperability and requirements) increased
  - Successor projects defined / took off (RHIADA, HECATE, NGF)



WP Achievements, Progress and Outlook

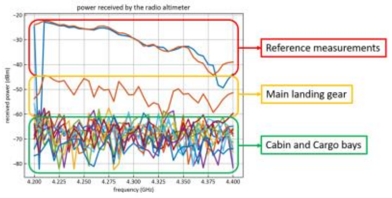
- WP1 – Requirements and System Specification
  - = Version 1 finished (D1.1/1.2)
  - + Extensions towards PHM
  - > Additional review upcoming IAB session

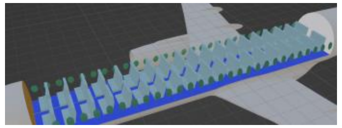
- WP2 – Wireless technologies
  - Antenna propagation
    - = Test campaign Fokker 100, (rapid) models developed
    - + Extension with relevant aircraft geometry details
    - > Finish at the appropriate level of fidelity
  - Wireless communication reliability enhancements
    - = Extensive survey of enablers performed
    - + Development selected enablers, test setup
    - > Test and evaluation
  - Software Defined Radio (SDR)
    - = Development cognitive radio techniques
    - + SDR first prototype design
    - > First prototype IC, prototype 2, test and evaluate

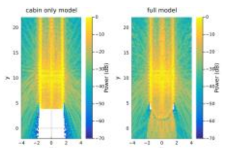
- WP3 – Power Line Communications
  - = EMC tests performed
  - = Prototypes PLC-modems +network configuration tool
  - + Tests setup preparation
  - > Test and evaluate PLC + with novel conductor concept

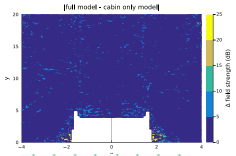
D1.1 - Systems Requirements and Spec
D1.2 - Reference Case Spec

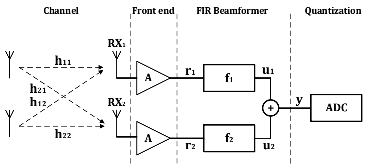
Grant agreement number:	101006728	Project start date:	1 February 2021
Project title:	ADENEAS	Duration:	36 months

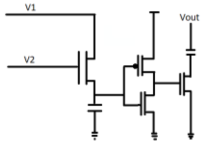


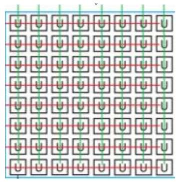










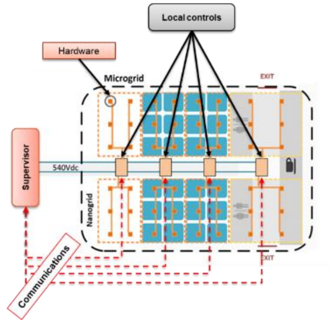


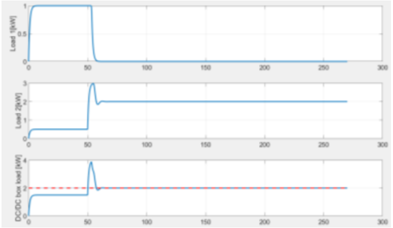
WP Achievements, Progress and Outlook

- WP4 – Modular Distributed Power
  - = Power network PHM viability analysis for multiplexed architectures
  - = Nano-grid power distribution network control designed + simulated
  - = Trade-off for power convertor concepts performed and 3 selected
  - \+ Development selected power convertor concepts
  - > Test and evaluate

- WP5 – Cooling Solutions
  - = 2-phase MPL cooling system designed + built
  - = Test methods for nano-fluids developed
  - \+ Test setup 2-phase MPL
  - > Test and evaluate

- WP6 – Architectures and Topologies
  - Power Network
    - = Power network topology exploration tool
    - \+ tools and methods for power network optimization
    - > Assessment of achievable weight gain
  - Data network design automation with AI
    - = Automatic position gateways for wireless communication
    - \+ Extension set of design constraints and PLC
    - > Tool and method to develop and trade-off architectural concepts
  - Novel Conductor Concepts:
    - = Concepts define, traded off and 2 selected, SE-model
    - \+ Production test samples
    - > Test and evaluation





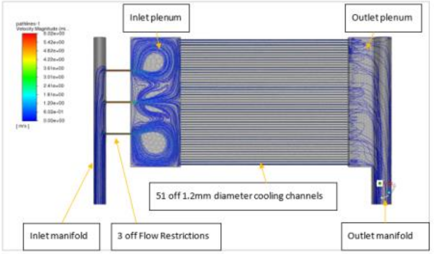
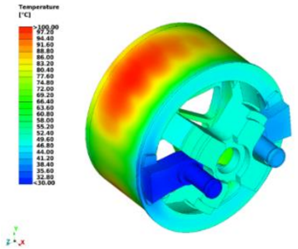
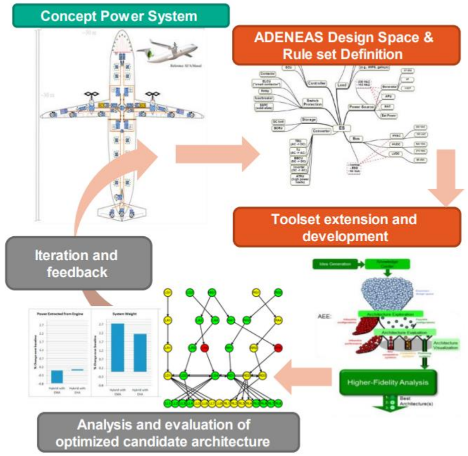
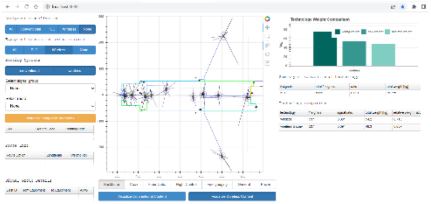
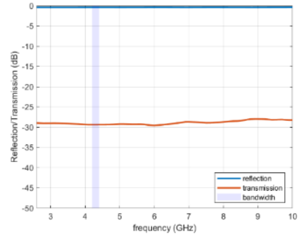


Figure 12 – CFD model of only 1 of the three cooling sections. Similar behaviour is expected for the other two cooling sections. Note that this single cooling section has 3 inlet ports (i.e. flow restrictions) into the inlet plenum.



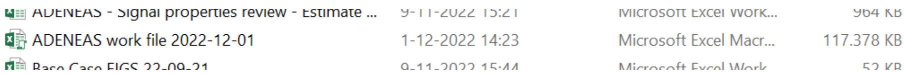




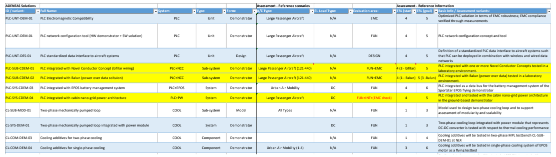


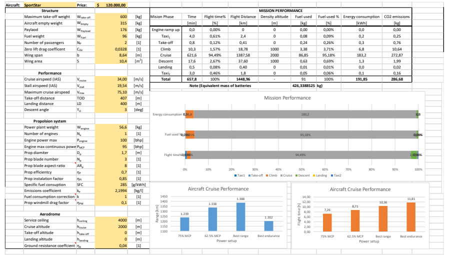
WP Achievements, Progress and Outlook

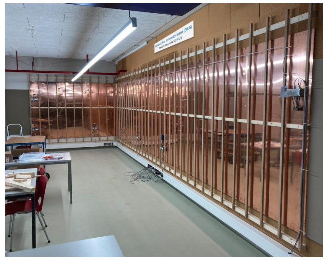
- WP6 Architectures and Topologies - reference cases
  = Extended reference cases
  > Case for commuter aircraft / UAM



- WP7 – Technology Impact Evaluation, Assessment & Optimization
  = Inventory of solutions to be evaluated provided with means of TRL evaluation
  = Aircraft Performance Model (APM)
  = Weight gain estimation made based upon link level
  + Test setups for ‘complex demonstrators’, APM
  > APM based impact evaluation







- WP8 – Management, Dissemination and Exploitation
  + EUROCAE/RTCA WAIC standardization group
  > WAIC requirements, MOPS and MASPS
  > Additional guidance for EMC, safety and security to prepare for
  > Exploitation plan including 3 successor projects

EUROCAE

ADENEAS
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22 February 2023

WP2:Wireless Technologies

Advanced Data and power Electrical NEtwork Architectures and Systems

Presenter: Sonia Heemstra de Groot (TU/e)

Contributors:
TU/e, NLR, Fokker Elmo

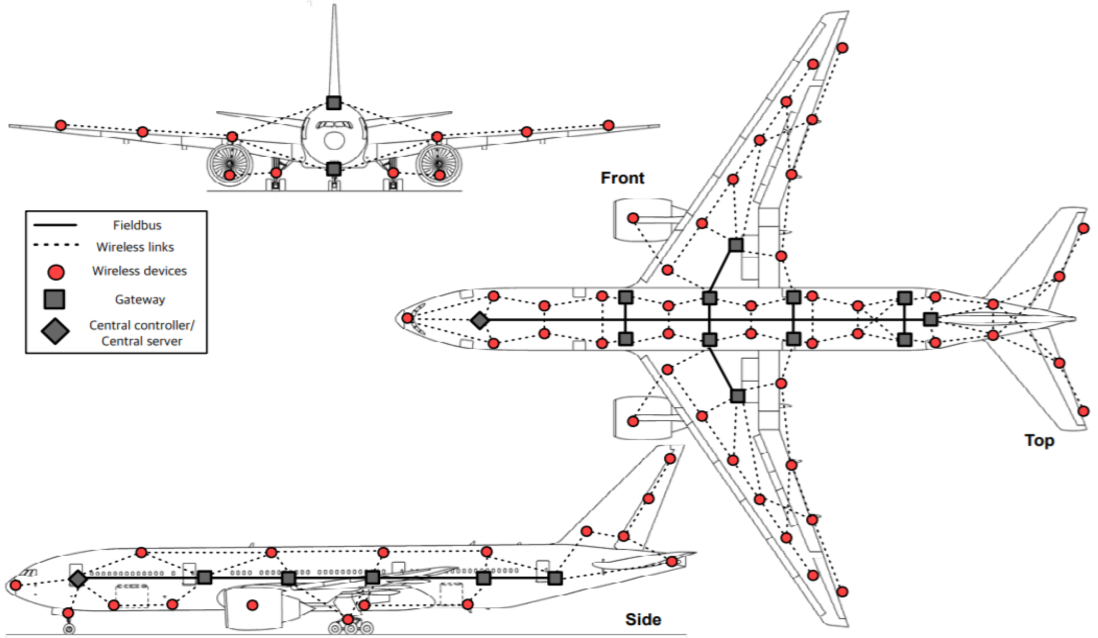
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006728.

Wireless intra-aircraft communication

Aiming at scalable and future-proof wireless communication techniques that can offer at least the same degree of robustness, safety and security as wired solutions

Challenges:

- Mission criticality
- Wireless channel
- Dynamic environment
- Low transmit power levels and limited frequency bands

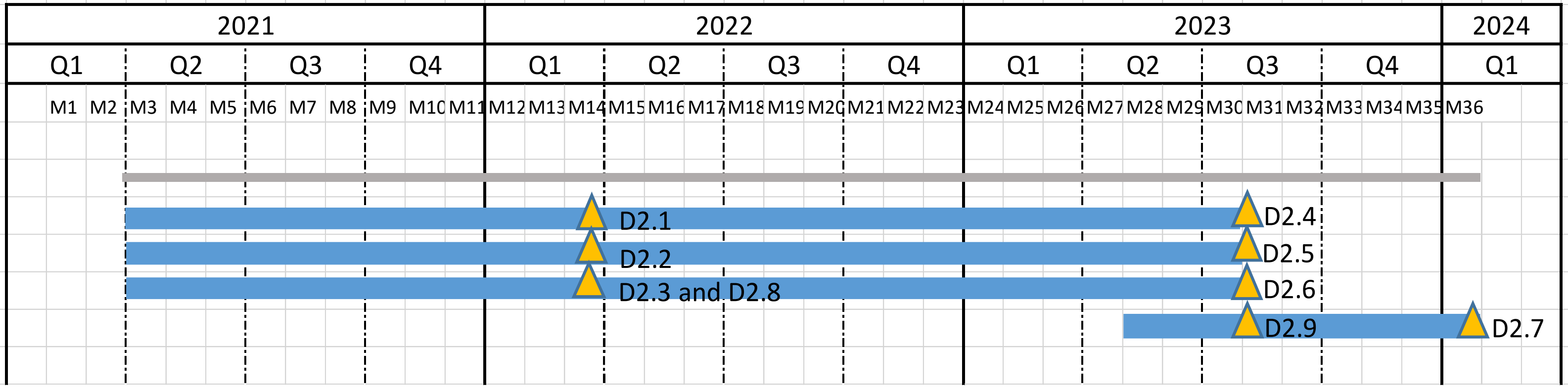


Wireless intra-aircraft communication network concept*

**Source: P. Park, P. Di Marco, J. Nah, and C. Fischione, "Wireless avionics intra-communications: A survey of benefits, challenges, and solutions," IEEE Internet of Things Journal, 2020.*

WP2 timeline

		Lead
WP2	**Wireless Technologies**	TU/e
T2.1	Ultra-reliable wireless communications	TU/e
T2.2	SDR-based cognitive radio techniques	TU/e
T2.3	EMC, antennas and propagation	NLR
T2.4	Experimental evaluation	TU/e



Task 2.1 Ultra-reliable wireless communications

Objectives:

- Research and develop techniques for high robustness to failure, interference and security attacks, very high availability and autonomous self-healing capabilities

Approach

- Reliability at several layers of the protocol stack
- Evaluation of candidate wireless standards
- Evaluation of some diversity techniques by analysis, simulation and implementation in COTS devices.

Techniques	Illustration	Example
Spatial		MIMO
Frequency	f_1 f_2	OFDM modulation
Time	coding	Channel coding
Polarization		
Channel	$path_1$ $path_2$	Combining techniques

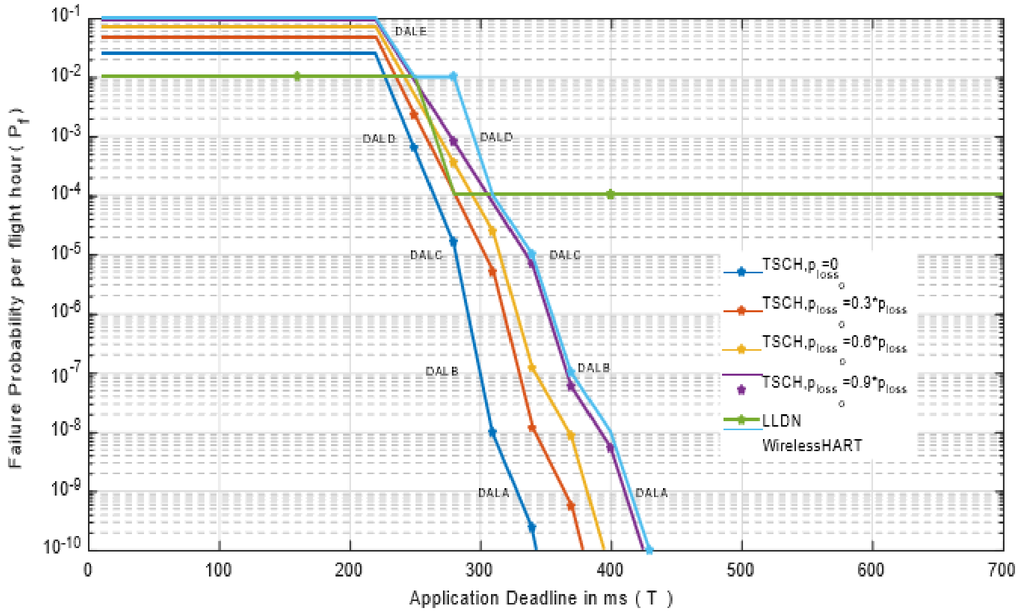
Physical layer of diversity techniques

Main achievements & technical highlights (1):

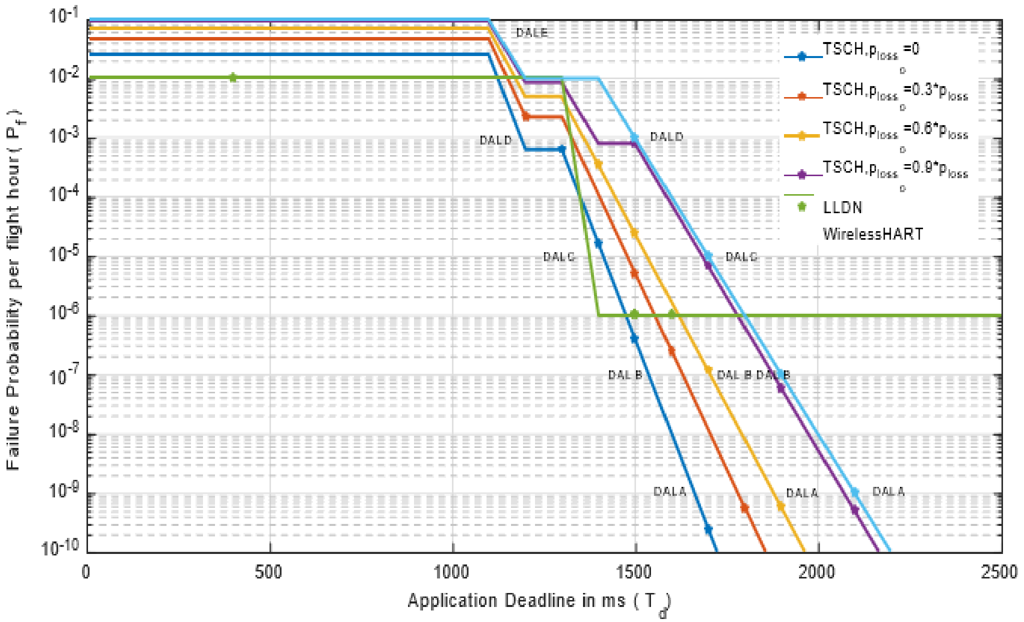
- Comparative analysis of reliability of IEEE802.15.4 protocols

  (presented at 42nd WIC Symposium on Information Theory and Signal Processing in the Benelux, June 1-2 20-2022 Louvain, Belgium)

24 sensors

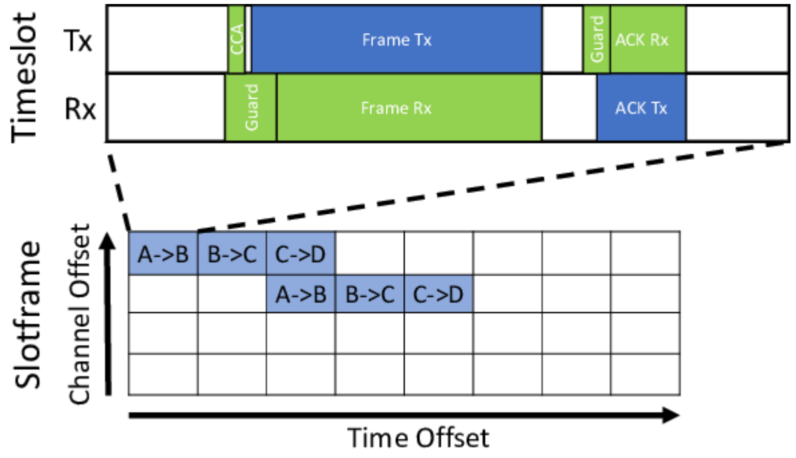


120 sensors



Main achievements & technical highlights (2):

- Implementation of path diversity techniques on top of IEEE 802.15.4 Time Slotted Channel Hopping (TSCH)
- TSCH and RPL are protocols designed for industrial IoT
  - Energy efficiency
  - Guaranteed channel access
  - Latency constraints
  - Channel diversity-> multi-path/fading mitigation

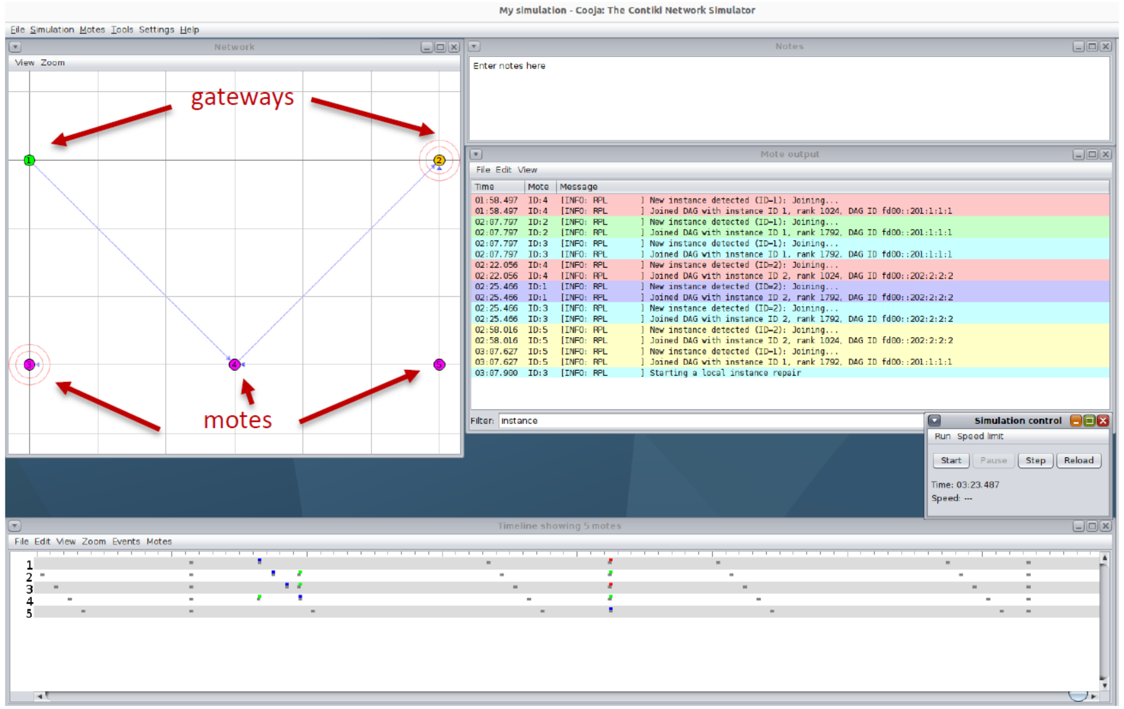


T2.1: Ultra-reliable wireless communications

Main achievements & technical highlights (3):

- Experimental set up complemented with network simulations
- Contiki-ng OS and Cooja simulator
- Path diversity: Several implementation options.
- Working on scheduling/priority techniques for different traffic classes
- Multicast techniques for resource efficient upstream traffic diversity
- Visualization of results

IEEE802.15.4 wireless radio modules



Example of Cooja simulator with 5 nodes and dual gateway diversity

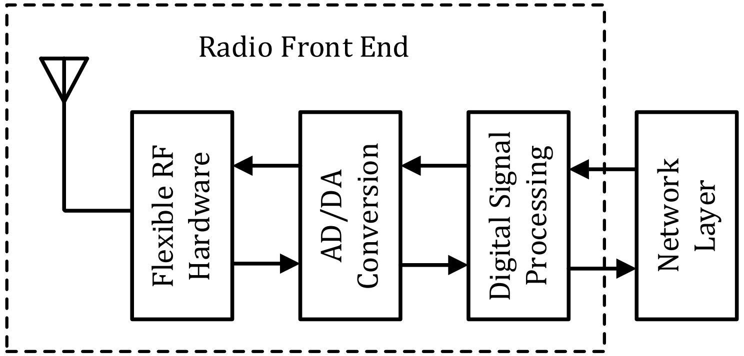
Task 2.2 SDR-based cognitive radio techniques

Objectives

- Investigation of radio techniques to achieve objectives of upgradability, flexibility, security and interoperability at the physical layer

Approach

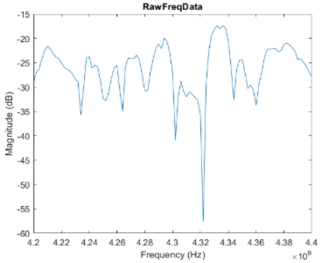
- Adaptive and software defined hardware, that can reduce dynamic range as early in the in the processing chain as possible

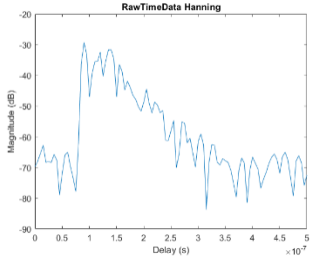


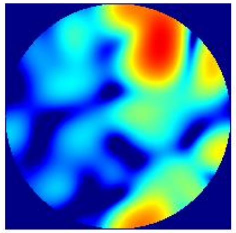
Task 2.2 SDR-based cognitive radio techniques

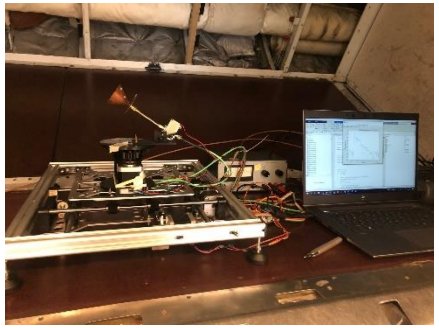
Main achievements & technical highlights (1):

- Carrying out measurements at the Aircraft Maintenance and Training School full week 1 (together with T2.3)
  - Measurement of the frequency response and power Delay Profile using Fieldfox VNA
  - Angle of arrival
    - Measure phase and amplitude in an array in the airplane

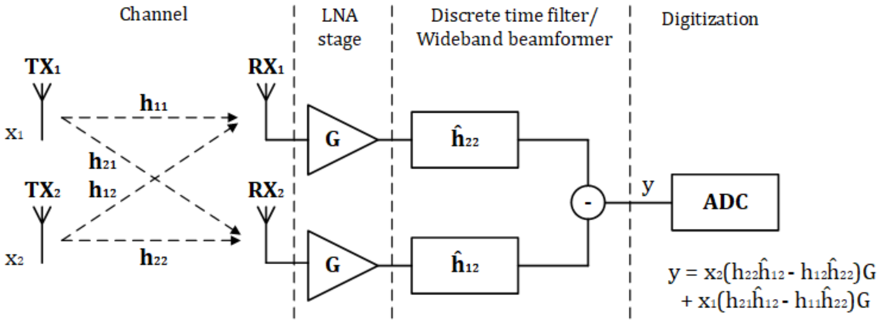








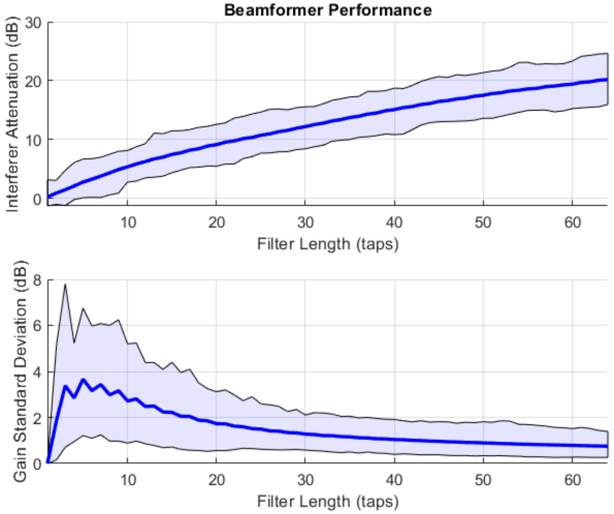
- Analog pre-filtering for wideband interference suppression
  - Wideband beamforming using FIR equalization
  - Eliminate interference early in the transceiver and reduce dynamic range requitements at the ADC



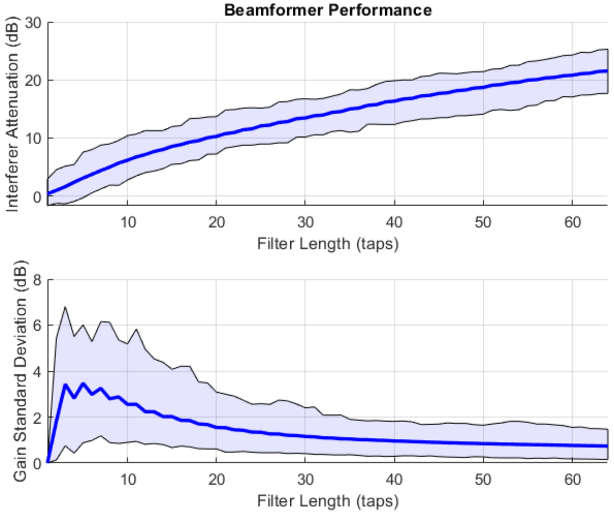
Main achievements & technical highlights (2):

- Analysis of optimal DT filter topologies:
- Filter performance in terms of filter length:
  - Attenuation of a Null steered signal
  - Flatness of the filter gain
  - Multiple Hoogerheide scenarios
- Filter performs well for reasonable filter length:
  - 12dB (2 bits) attenuation for 32 taps
  - Gain standard deviation of ~1dB/~12% for 32 taps
- This filter will be implemented as a bank of capacitors, that stores analog samples, which can then be combined at the output at a programmed delay
- Translation to actual electronics:
  - Circuit linearity/power consumption tradeoff
  - System level challenges for electronics

Intra Cabin ~8m



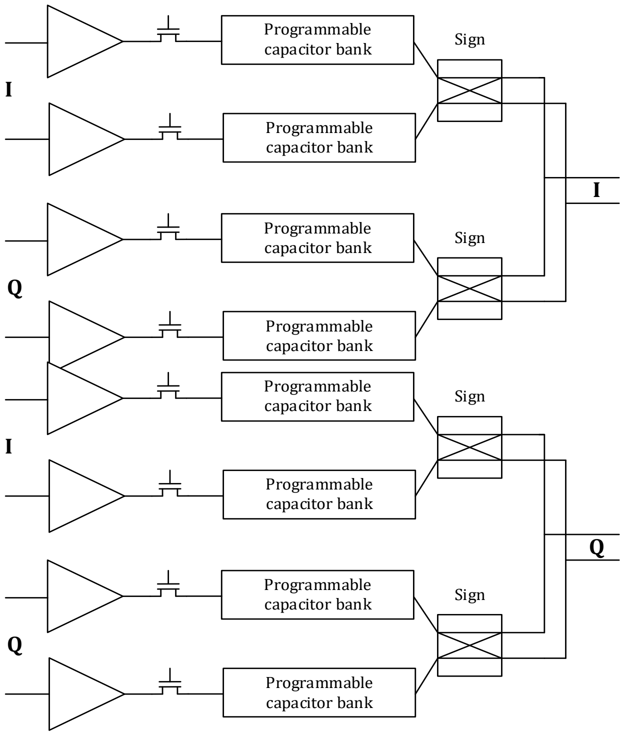
Cabin to Cargobay



Main achievements & technical highlights (3):

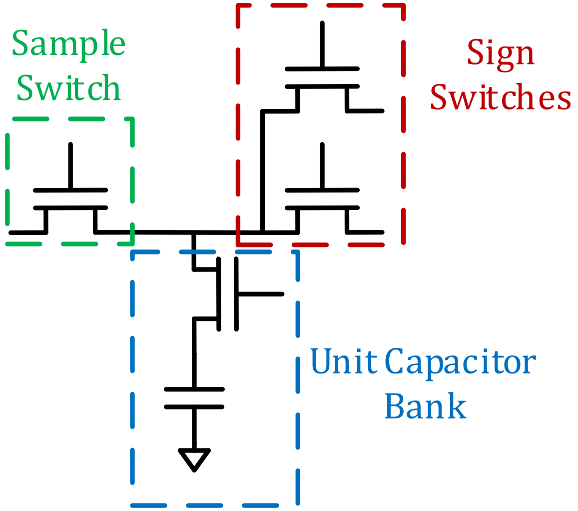
AFIR hardware implementation

- Each AFIR filter has 4 paths for in phase and quadrature signals



- Expected tape out 20 March

- The main component is a large capacitor bank, that stores and averages input samples with different delays
- This bank has three switches:
  - Sign switches that are used for charge sharing
  - Top plate switches that are used for programming the weight
  - Sample switches that are used to sample the input signal



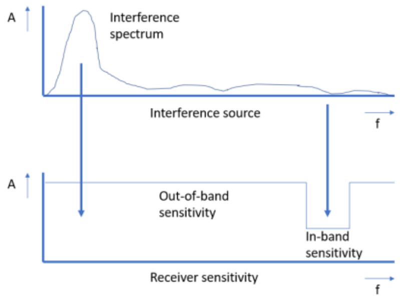
Task 2.3 EMC, antennas and propagation

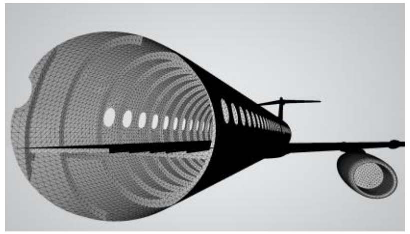
Objectives

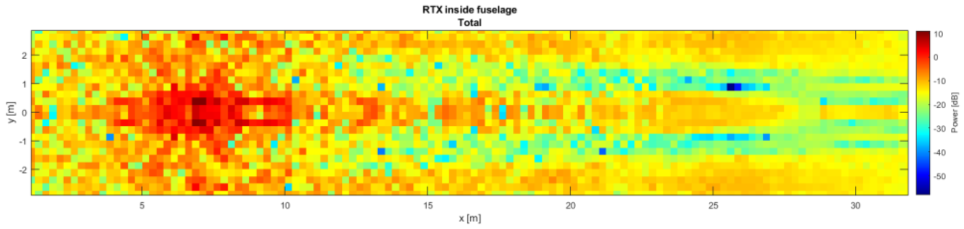
- Perform EMC and propagation analysis for ultra-reliable intra-aircraft wireless communications

Approach

- Compatibility (EMC&RFI) analysis between wireless networks and other aircraft systems (e.g., challenge with RA)
- Propagation measurements
- Simulation of propagation paths in the aircraft and minimisation of multipaths problems
- Development of (integrated) antennas that are suitable for wireless networks on-board aircraft



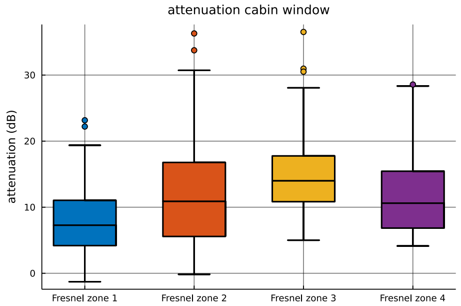




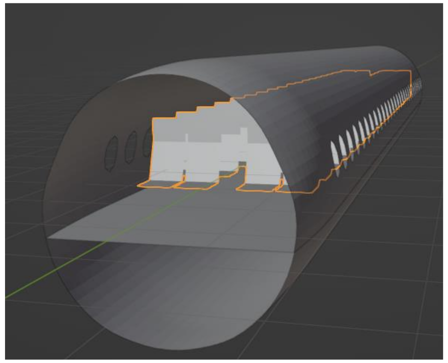
Task 2.3 EMC, antennas and propagation

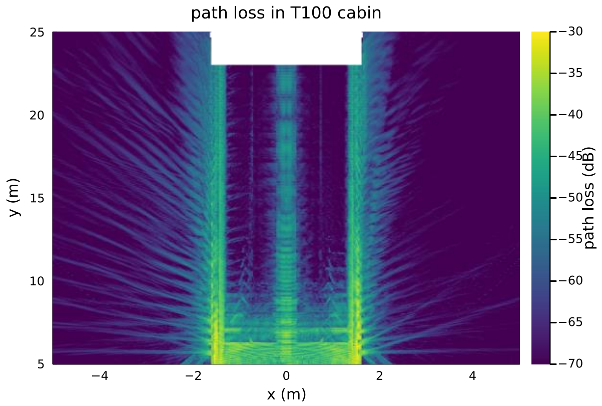
Main achievements & technical highlights (1):

- EIRP and propagation measurements of a Fokker 100
  - EIRP measurement
  - Effect of WAIC emitter on radio altimeter
  - Propagation measurements in cabin and front cargo bay
  - Isolation measurements



	Cabin	CF	CA	Cockpit	NLG	MLG
Cabin		-36	-34	-36	-69	-58
CF	-36		-57		-81	-41
CA	-34	-57			-84	-61
Cockpit	-36					
NLG	-69	-81	-84			
MLG	-58	-41	-61			

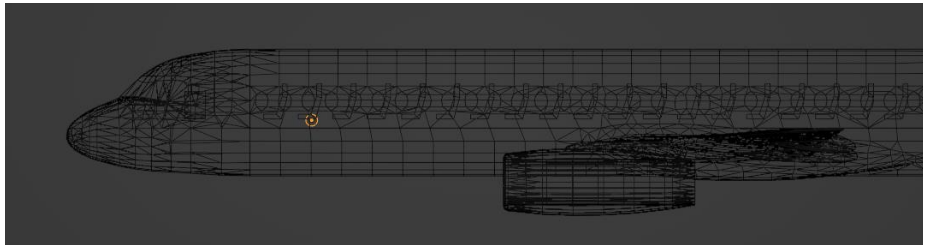




Simulated path loss for the T100 model, horizontal plane

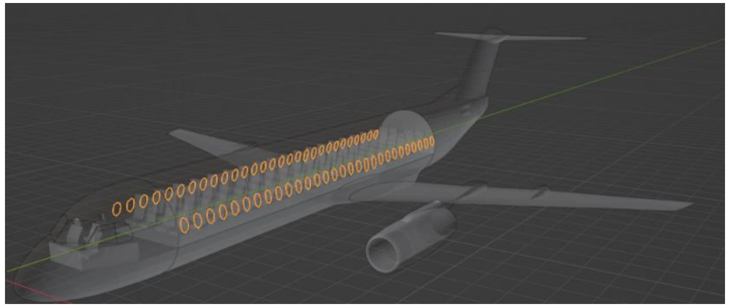
- Propagation simulations
  - Use fuselage 3D model for propagation simulations
    - Adapting the 3D model: rework mesh, add chairs/people inside, material electromagnetic properties
  - Substantial reduction of simulation time (from days to minutes)

Effect of aircraft fuselage on EIRP of a single transmitter

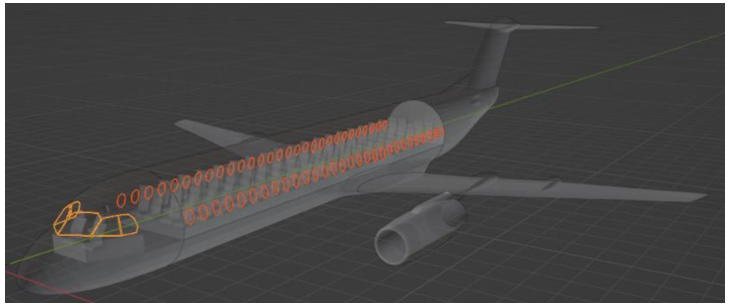


Transmitter location (0 dBm EIRP)

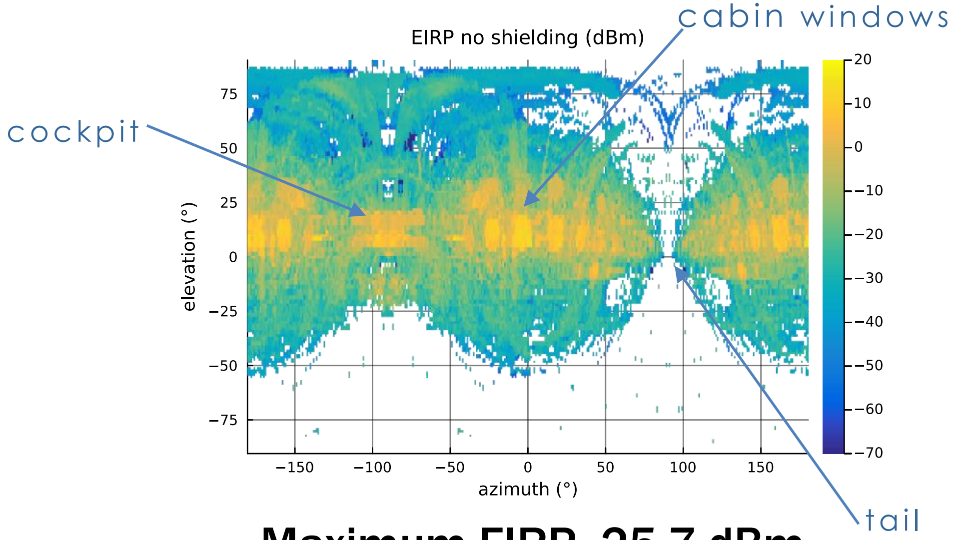
Shielded cabin windows



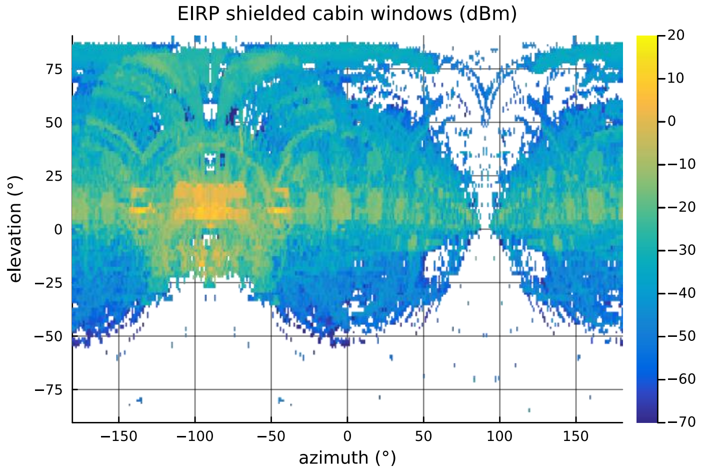
Shielded cabin and cockpit windows



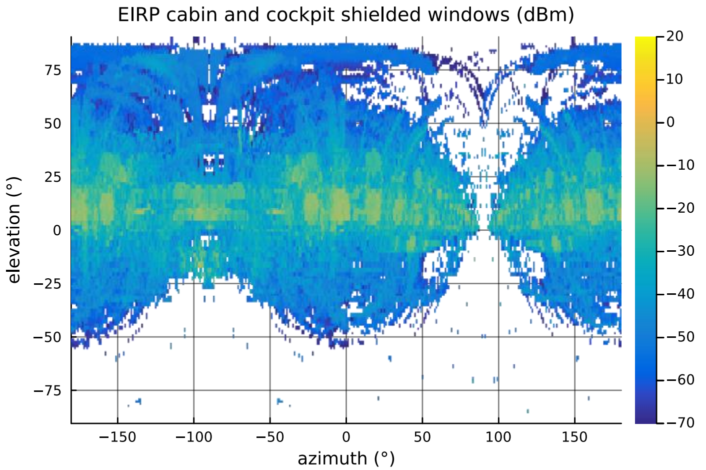
No shielding



Maximum EIRP 25.7 dBm



Maximum EIRP 25.6 dBm

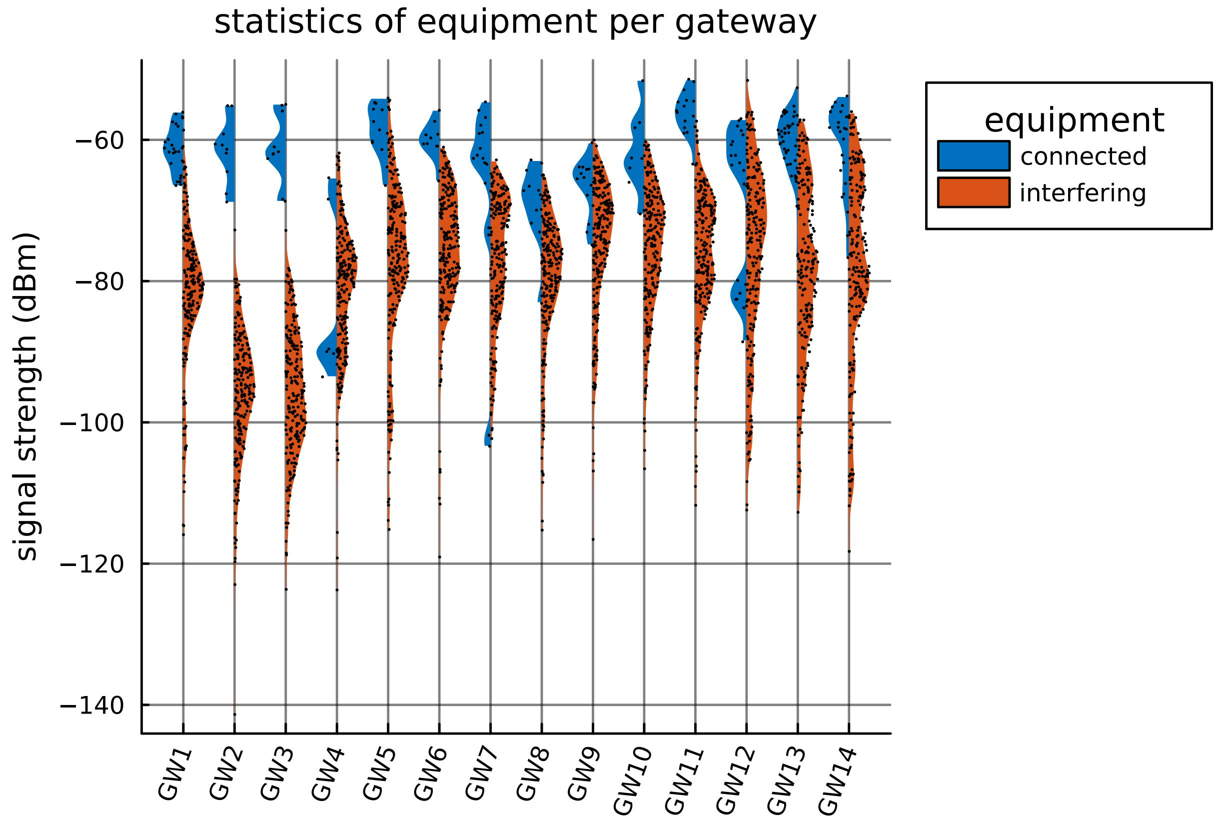


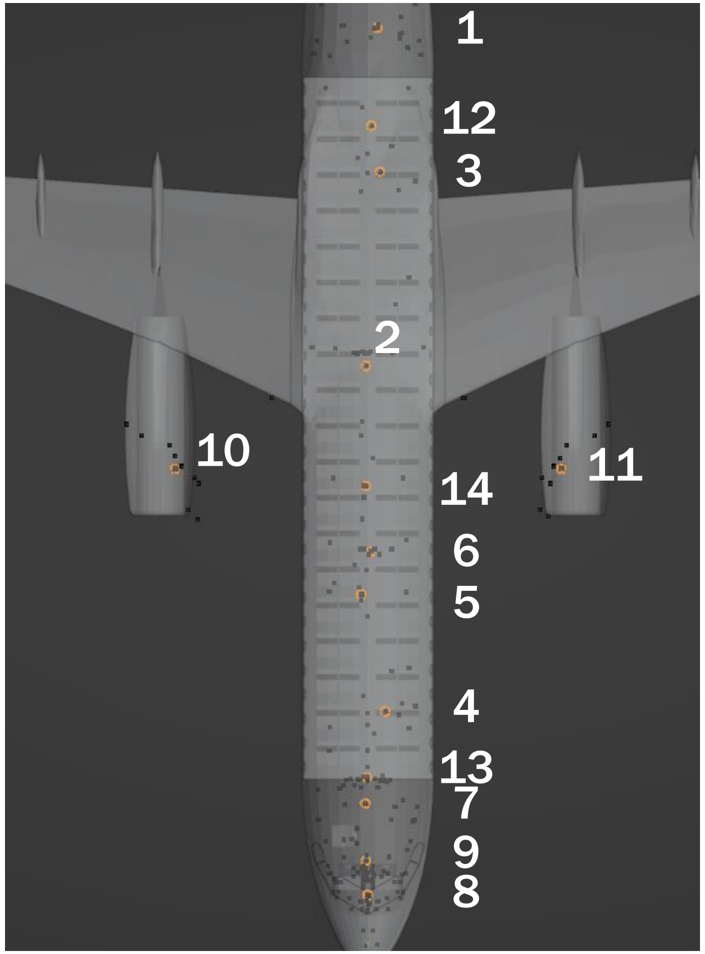
Maximum EIRP 4.2 dBm

Connectivity between gateway and nodes

Gateway and equipment locations modified from WP6 to fit the T100 model

- "connected" equipment
  - should communicate with gateway and
- "interfering" equipment
  - Belongs to different gateway, but still receives power from current gateway.





Gateway locations in the T100 model

Task 2.4 Experimental evaluation

Objective

- Integration ,validation and evaluation of a representative set of solutions developed in T2.1, T2.2, and T2.3 in experimental set up

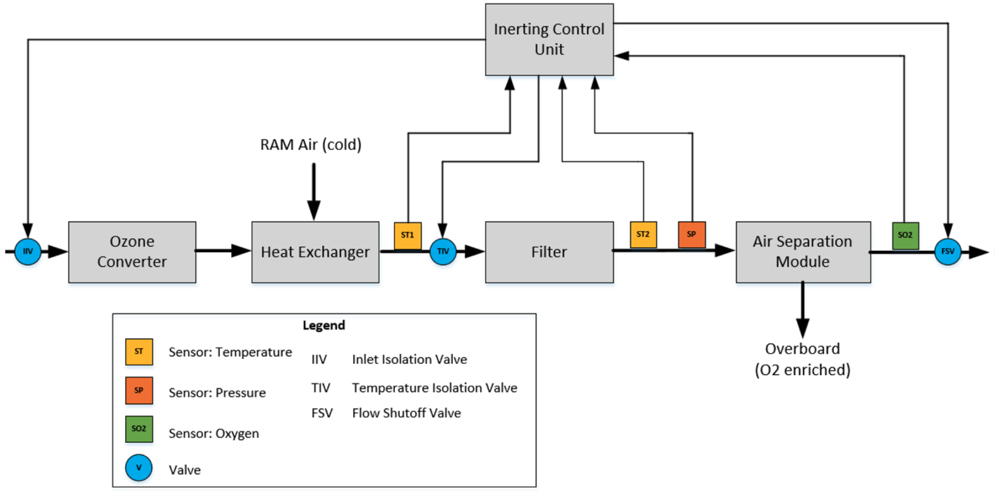
Approach

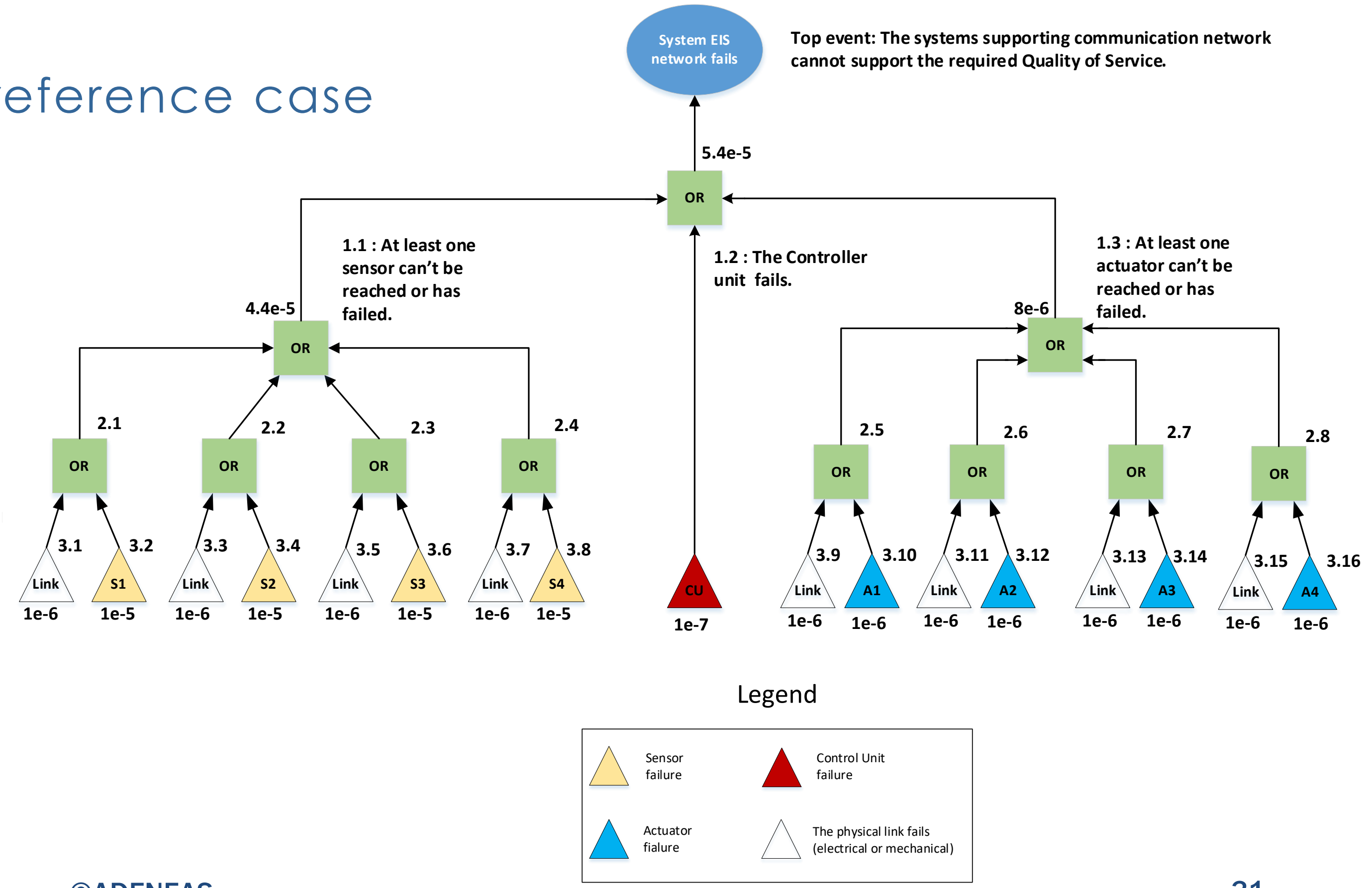
- Proof of concepts test bench
  - Representative subset of solutions
  - Complemented with simulations
  - Verify design
  - Assess performance
- Reliability model for wireless networks

Main achievements & technical highlights (1):

Reliability model for wireless networks

- Fault-tree analysis modified to suit ADENEAS needs (PLC and expansion to wireless)
  - Fault Hazard Analysis (FHA) to the reference case (Fuel Inert Gas System)



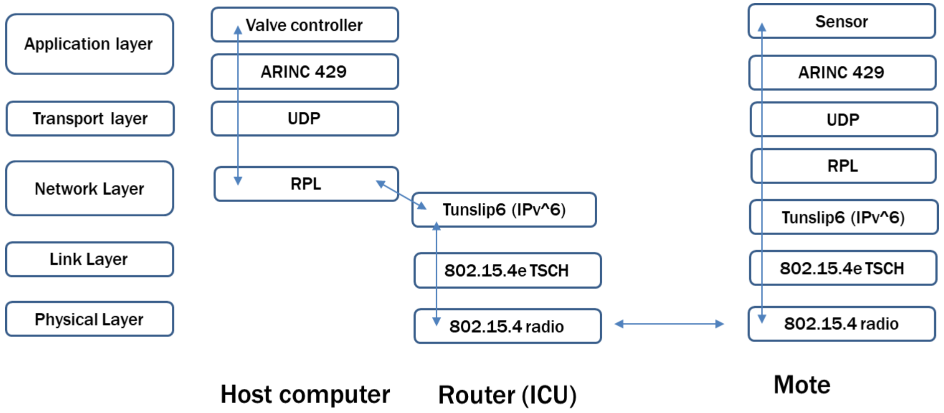


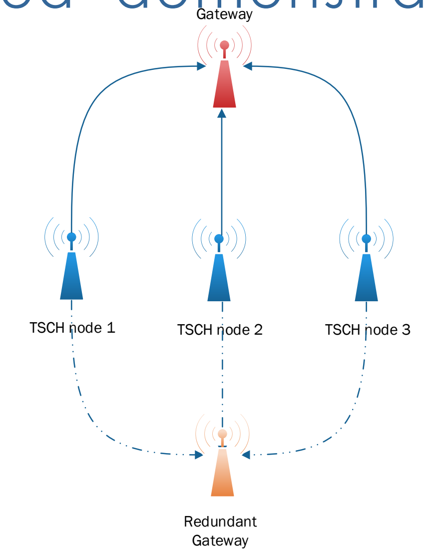
T2.4: Experimental evaluation

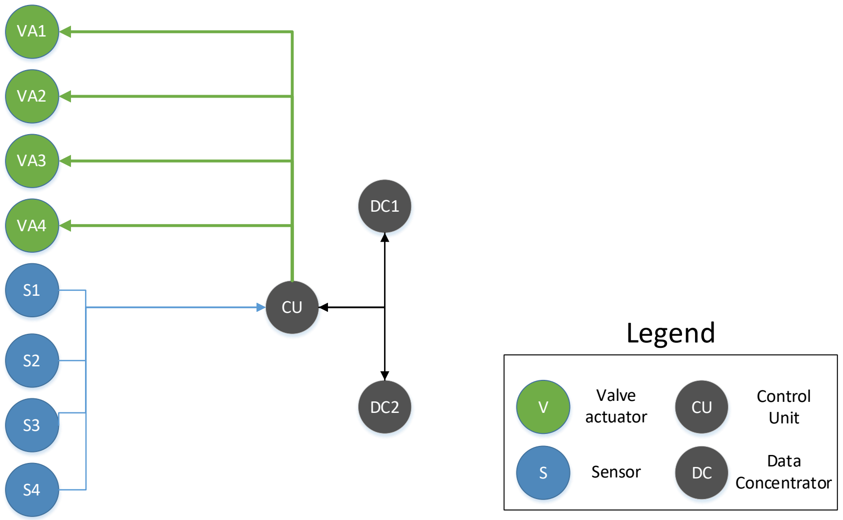
Main achievements & technical highlights (2):

First steps on experimental evaluation and demonstrator development

- Selection of 802.15.4e (TSCH) based network to model the A220 FIGS
  - Based on and combination of relevant reliability mitigation techniques
- Mapping Fuel Inert Gas System to the ground-based demonstrator network







ADENEAS
Public Workshop
22 February 2023

WP3 Power Line Communications

Advanced Data and power Electrical NEtwork Architectures and Systems

ADENEAS

Presenter:
Stephen Dominiak
plc-tec

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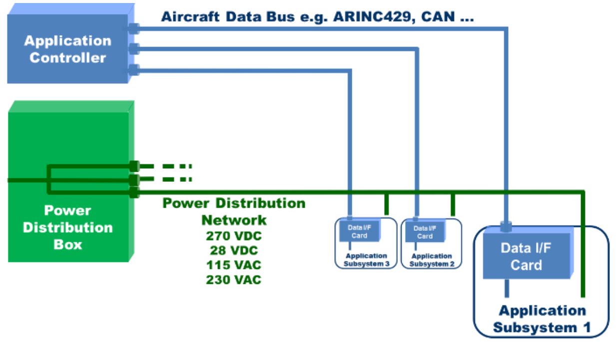
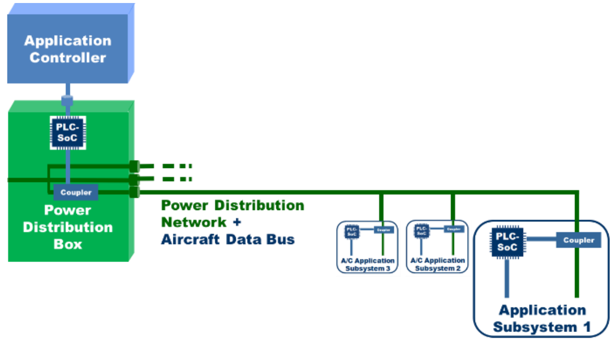
Power Line Communications (PLC)

- PLC Concept
  - Data transmission network completely removed
  - Single connector for power + data
  - Data transmission independent of the underlying power signal
  - Communications protocol designed for transmission in "harsh" environments
- PLC Advantages
  - Reduced wiring weight and volume
  - Reduced complexity which simplifies design
  - Reduced installation effort
  - Reduced maintenance
- **ADENEAS WP3 PLC**
  - ***Develop a scalable and robust data bus solution for communicating over the aircraft power distribution network using the PLC technology***
  - ***Develop a solution that can be applied to different aircraft sizes and a wide range of systems***



Traditional Avionics Architecture



PLC-Enabled Avionics Architecture

WP3 Power Line Communications objectives

Optimize the PLC technology in terms of EMC robustness and verify the EMC compliance

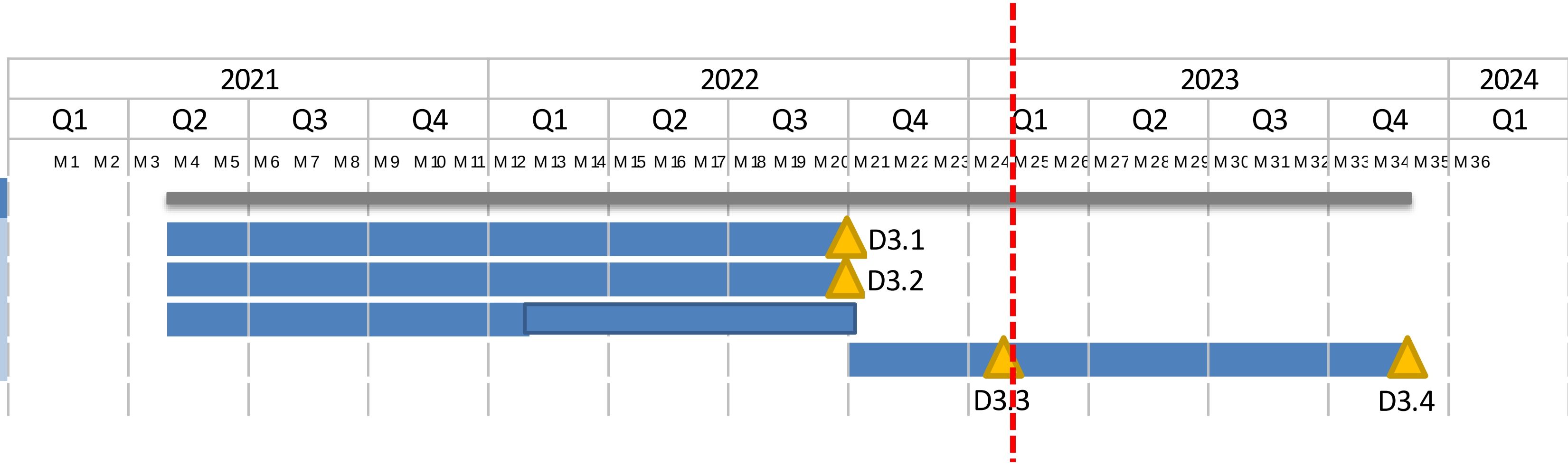
Develop a PLC network configuration concept and configuration tool for supporting an easy deployment of a PLC data bus to a wide range of aircraft systems

Define a standardized PLC data interface to aircraft systems such that PLC can deployed in combination with wireless and other wired data networks

Optimize the PLC coupling module and test the use of PLC on novel power distribution conductor concepts

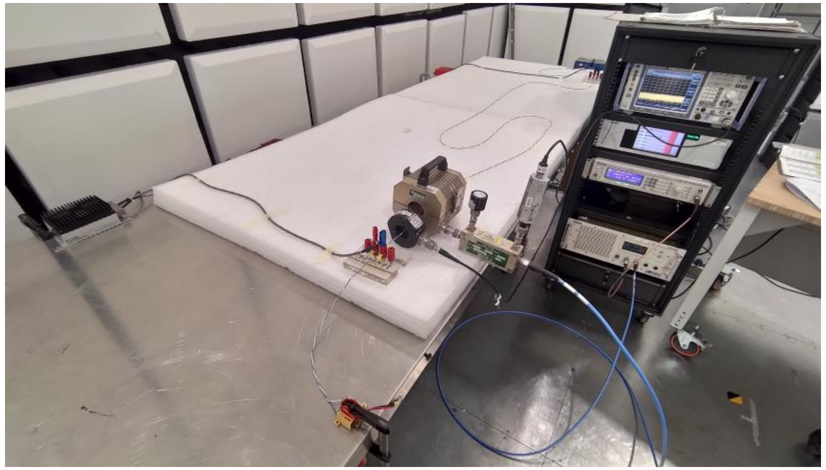
WP3 PLC Timeline

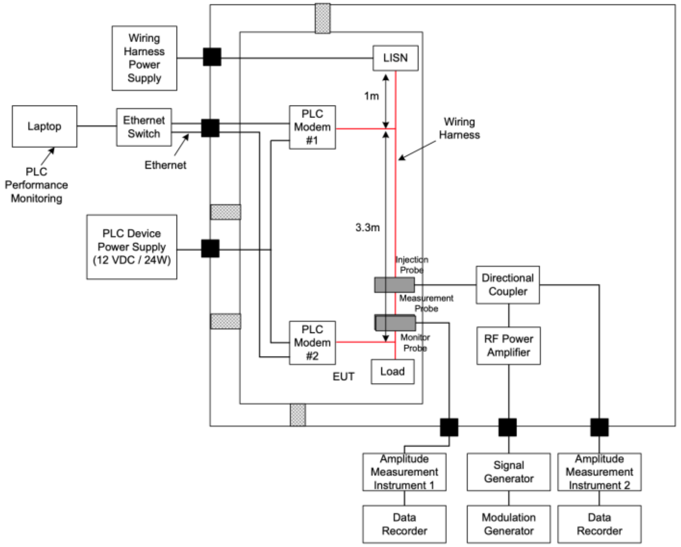
WP/Task		Lead
WP3	**Power Line Communications**	**PLC-TEC**
T3.1	PLC EMC	NLR
T3.2	PLC Network Configuration Concept and Tool	plc-tec
T3.3	PLC Interface Standardization	plc-tec
T3.4	PLC Testing on Novel Power Distrib. Cond. Concepts	plc-tec



T3.1: PLC EMC - Overview

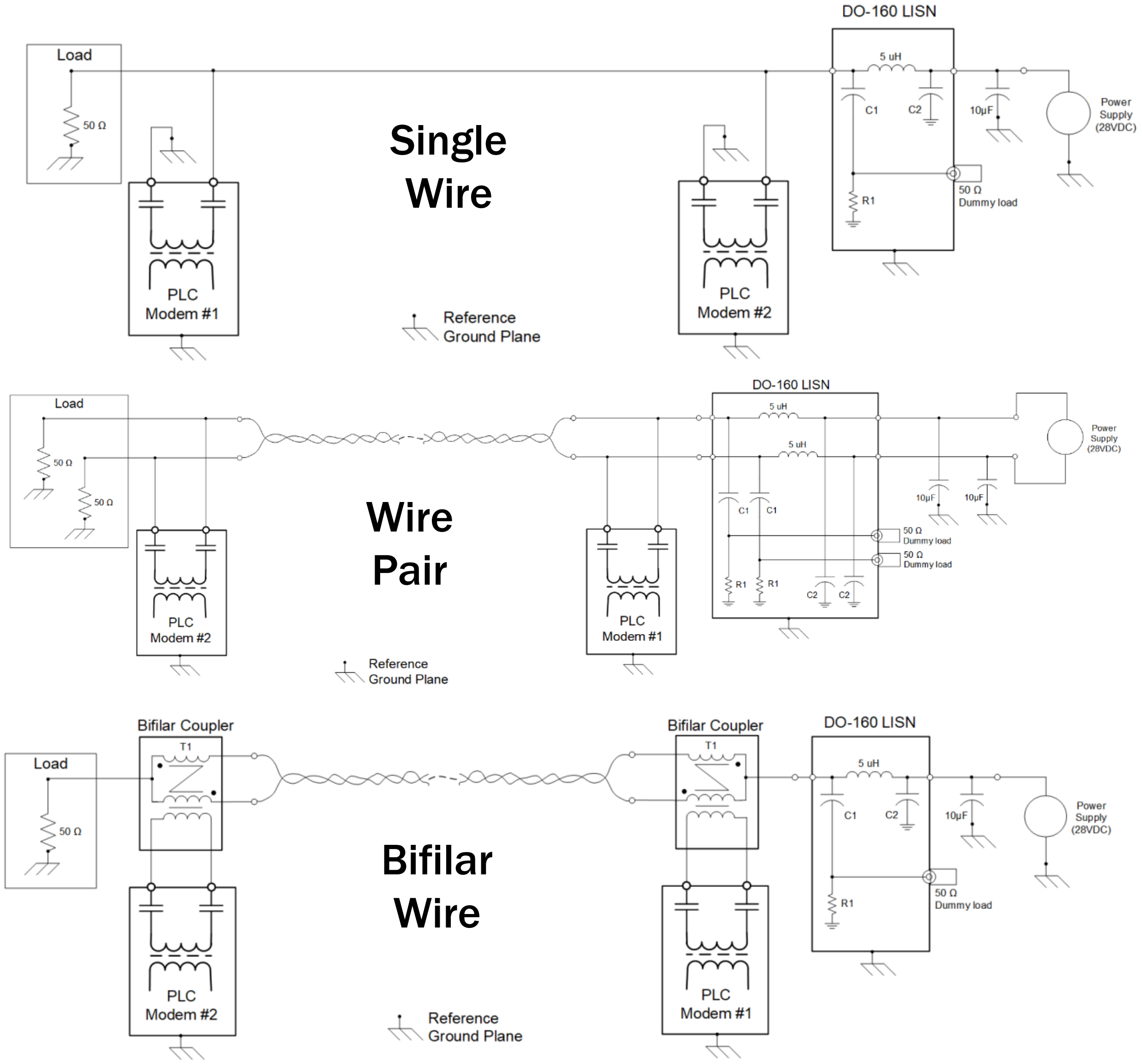
- PLC EMC measurements performed at NLR
  - March – May 2022
- Measurements:
  - Conducted Susceptibility
  - Conducted Emissions
  - Radiated Emissions
  - Crosstalk
- Additionally, crosstalk simulations have been performed
- Much work has been done to define test setups for applying ED-14G/DO-160 to PLC





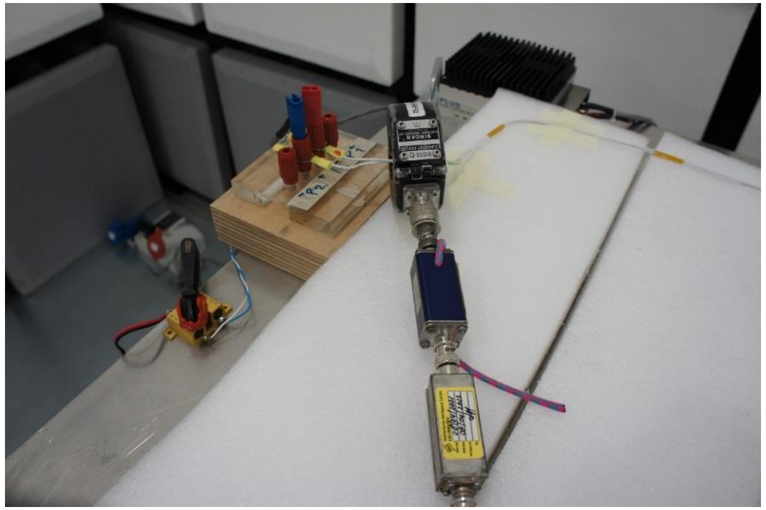
T3.1: PLC EMC – Wiring Architectures

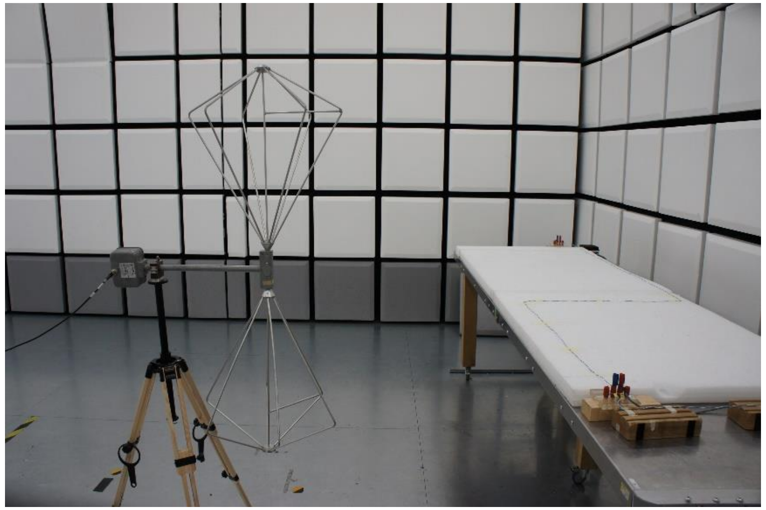
- The impact of different aircraft wiring architectures on EMC was investigated
- Single wire with ground return – typical power cabling for DC power
- Wire pair – typical power cabling for AC power
- Bifilar wire with ground return – replacement of the single wires by two cores with are in common-mode for power while PLC is used in differential-mode



WP3 – T3.1 PLC EMC – Summary EMC Measurements

- Measurements performed on different wiring architectures:
  - Conducted Susceptibility
  - Conducted Emissions
  - Radiated Emissions
- Test result summary



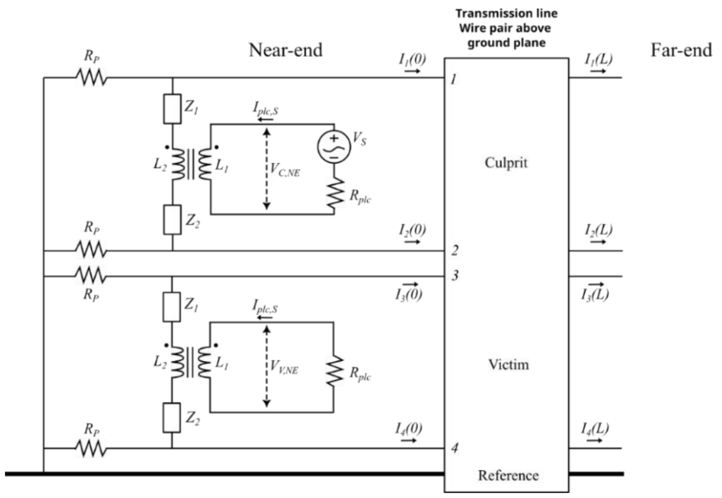


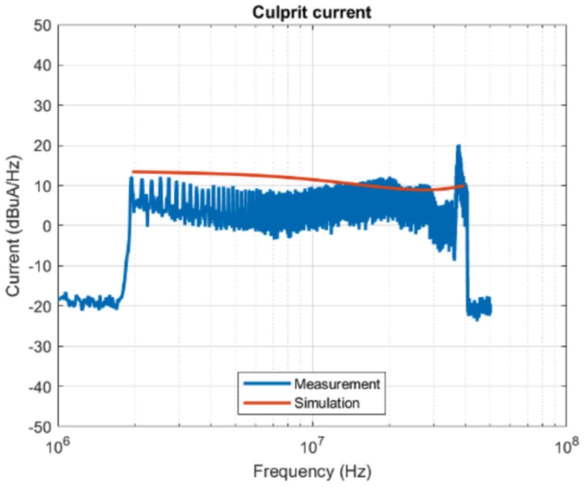
	STP	UTP	UUP	Bifilar (NCC)	SW
Conducted Susceptibility	PASS (up to Cat Y)	PASS (up to Cat W)	PASS (up to Cat W)	PASS (up to Cat W)	FAIL
Conducted Emissions	PASS (cat L/M/H powerline)	PASS[1] (cat L/M/H powerline)	PASS[1] (cat L/M/H powerline)	PASS (cat L/M/H powerline)	FAIL
Radiated Emissions	CONDITIONAL[2]	CONDITIONAL[2]	CONDITIONAL[2]	PASS (cat M)	FAIL

1) Emissions peak around 40MHz has been attributed to cable resonances through simulations and additional measurements – results to be published
2) Certain frequencies slightly (ca. 5dB) above the limits

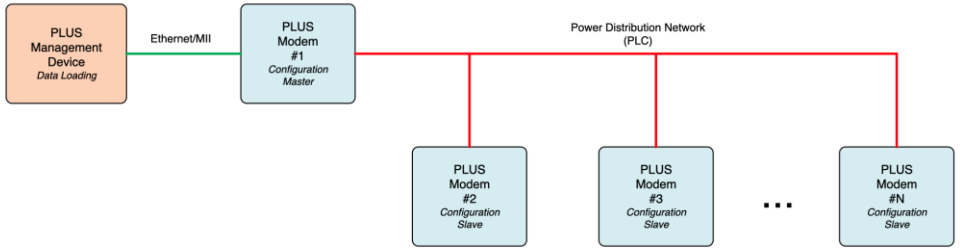
Crosstalk

- Two different types of crosstalk analyses have been performed:
  - Crosstalk between multiple PLC systems within a single bundle
    - Goal: determine the number of PLC signals that can be applied in a single bundle
    - Conclusions:
      - PLC in the single wire configuration will be disturbed already with more than 2 culprit systems
      - PLC with other cabling types will not disturb itself even in the worst-case situation (single victim surrounded by 6 culprit signals)
  - Crosstalk between PLC signals and other cables in the same bundle such as power signals, data signal and sensitive signals
    - Goal: Determine how PLC and other systems can co-exist in a single bundle
    - Conclusions:
      - Data signals are not interfered by PLC signals for wire-pair wiring (single-wire requires twisting of the data signal)
      - Power signals do not interfere with PLC signals for all configurations
      - Shielded high-speed signals (ARINC 664) do not interfere with PLC signals for all configurations





- PLC Network Configuration Concept and Tool
  - A concept for remote configuration of the PLC network has been designed
    - Based on the exchange of Ethernet frames for the remote configuration/management of all PLC modems
    - Supports PLC multi-channel configuration



- PLC Management Tool in ADENEAS
  - For the ADENEAS project, the PLUS Management Device (PMD) will be realized on a MOXA UC-8112-LX embedded PC with Linux OS
  - A web-based user interface for the PLC network configuration has been developed

T3.4: PLC Testing on NCC

- PLC modem prototypes
  - plc-tec has developed a PLC solution dedicated for safety-critical applications
    - Power Line data bUS (PLUS)
  - Next generation PLC modem prototypes (PLUS-V2) have been developed for ADENEAS demonstrators
    - Flying demonstrator on Evektor EPOS platform
    - Ground-based demonstrator with power components
- Novel conductor concept testing
  - Avionics wiring testbench with bifilar wiring harness has been constructed
  - Testing with PLC to begin April 2023

PLUS-V2 Housing	Aluminum housing Screw mount with mounting feet Dimensions (incl. mounting feet): 109 mm (L) x 78 mm (W) x 43.2 mm (H)
PLUS-V2 Weight	Complete PLUS-V2 Prototype: 342g PLUS-V2 PCB Only: 70g
PLUS-V2 Power Supply	Input voltage: 9-36VDC Power consumption: 7W nominal Power supply input available on connector X1 Protection: 1.5kV isolated supply
Data Connectors	Data Connector (X1) 30-pin Deutsch DMC-M DMC-LPR 30-23 P
Ethernet	ETH 100BASE-TX
CAN	CAN Up to 1Mbps
Other Interfaces	One (1) 5V GPIO Six (6) Digital Signal Input (DSI) Eleven (11) Pin Programming GPIO UART
Power/PLC Interface	Power Connector (X2) 8-pin Deutsch DMC-M DMC-LP 08-16P
Supported Voltage Ranges	DC Voltage Range: 0-540VDC AC Voltage Range: 0-480VAC
Surge Voltage	Differential (1.2/50us): 2 kV, Z_src = 2 Ohm Common Mode (1.2/50us): 4kV, Z_src = 12 Ohm
Supported Current Range	N/A – current on the power line is not relevant due to the use of a capacitive coupler

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WP4 – Modular Distributed Power

Advanced Data and power Electrical NEtwork Architectures and Systems

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WP4 Objectives

Energy and power management controls for future power architectures and distributed systems

Investigate and test circuit topologies for 540/28Vdc conversion to achieve modular and very high-power density conversion stages.

Demonstrate and characterize controls and hardware performance in a laboratory grid

Development and demonstration of PHM methodologies for modular power systems

- Research focus for future power architectures
  - HVDC primary power – localized secondary distribution – cabin systems focus
  - Power conversion topologies and techniques for localized LVDC cabin distribution to achieve modular and very high-power density conversion stages.
  - Power and energy management supervisory controls for reconfigurable systems to optimize power demand
  - PHM techniques to develop predictive analytics for failure detection of passive and active components

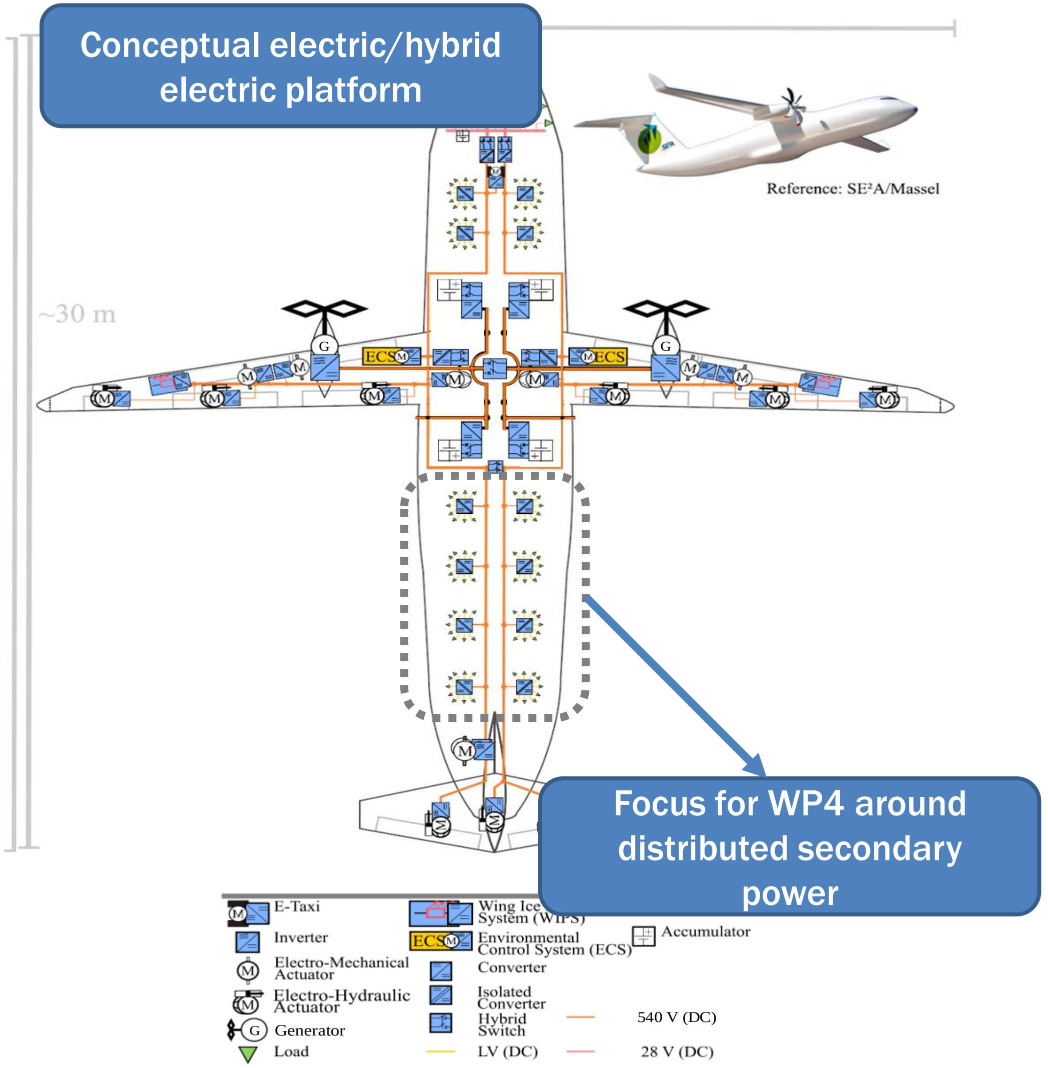


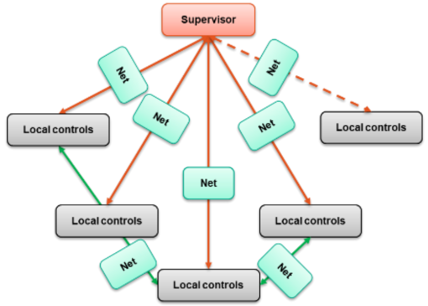
FIGURE 5. Electric schematic of AEA.

Modular & Distributed Aircraft Power – Controls, Conversion and PHM

ADENEAS

WP4.1 – Power and Energy Management for Cabin Systems

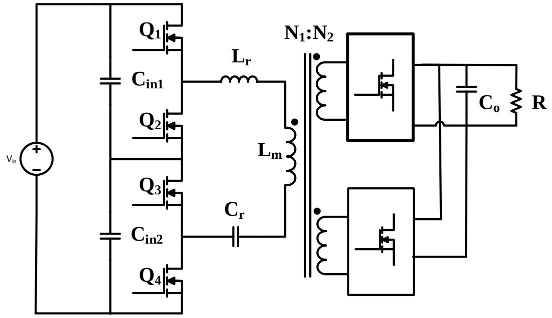
- **Problem statement:**
  - Power & Energy Management supervisory controls often re-developed using diverse approaches
  - This results in inefficiencies, misalignments, and lack of robustness along the process
- **Project objectives:**
  - Develop a generic framework that allows the easy implementation and deployment of PEMS for aircraft



Framework capable of adapting to changes in the network

WP4.2 – Modular Power Conversion

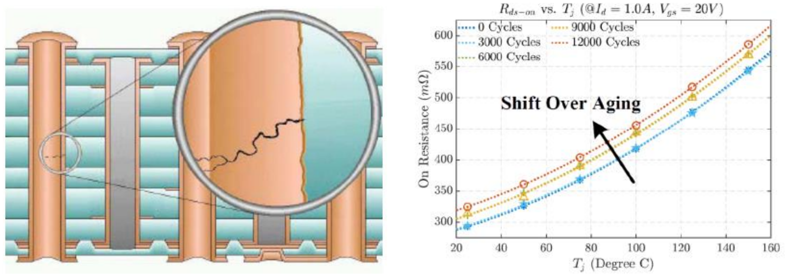
- **Problem statement:**
  - Power conversion topologies and techniques for localized HVDC-LVDC cabin distribution to achieve modular and very high-power density conversion stages.
- **Project objectives:**
  - Optimized topology for 540 Vdc to 28 Vdc.
  - High switching frequency
  - Highly integrated – passive cooling



Advanced topologies for high-density power conversion

WP4.3 – PHM Techniques for Power Electronics

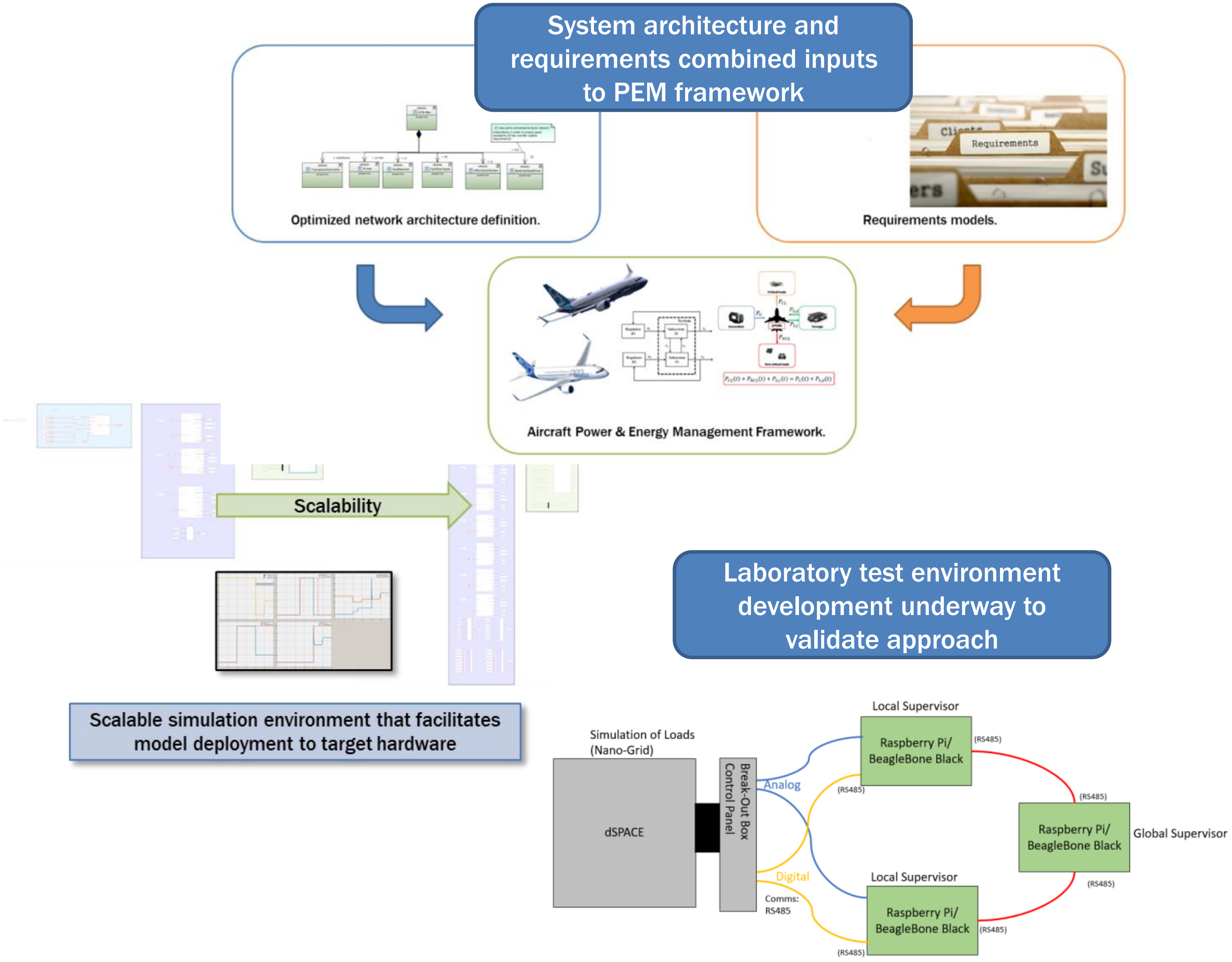
- **Problem statement:**
  - Product failure mode and effect analysis & machine learning approaches for predictive analysis of capacitor and other passive and/or active component failure effects
- **Project objectives:**
  - Study of physics of failure for key components & benchmark of diagnostic and prognostic methods
  - Testing feature extraction, diagnostic, and prognostic algorithms



Physics of failure and feature extraction for prognostic detection

WP4.1 – Power and Energy Management for Cabin Systems

- **Benefits:**
  - Scalable and replicable solution across different platforms and use cases.
  - Reduction of development times and increased re-usability of artifacts.
- **Completed Activities:**
  - Simulation validation of control framework complete
  - Library developed of components for loads, storage, local controllers and supervisory controller
- **Current tasks**
  - Experimental validation through the use of development controller boards and hardware-in-the-loop emulation of aircraft electrical loads
  - Completion of WP4.1 through validation and reporting



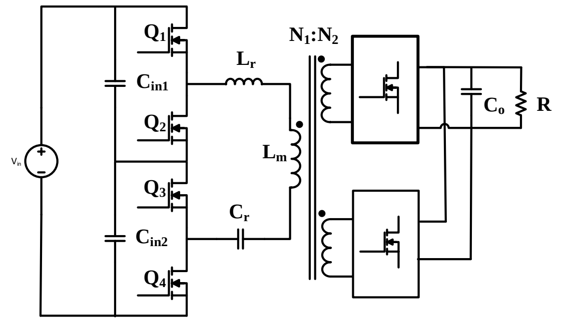
WP4.2 – Modular Power Conversion

- **Benefits:**
  - Weight saving potential vs. centralized approach
- **Completed Activities:**
  - Trade-space study completed to downselect suitable candidate topologies
- **Current tasks**
  - Detailed design of chosen converter design – LLC converter
  - Preparation for hardware design, build and test through laboratory validation

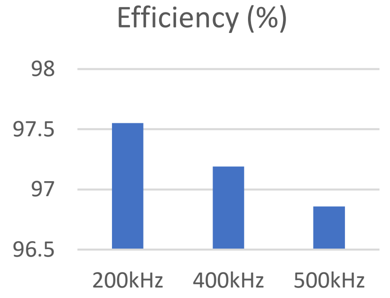
Trade-Off Study

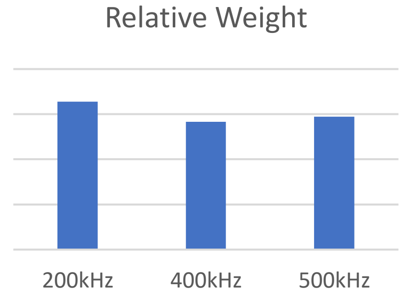
	Efficiency	Soft-switching	Power density	Design complexity	Control complexity	Breakdown voltage
2-L: LLC	🟢	🟢	🟢	🟡	🟡	🔴
3-L: LLC	🟢	🟢	🟢	🟡	🟡	🟢
4-L: LLC	🟢	🟢	🟢	🔴	🔴	🟢
2-L: DAB	🟡	🟢	🟢	🟢	🔴	🔴
2-L: AHB	🟢	🟢	🔴	🟢	🟢	🔴
2-L: ZAHB	🟢	🟢	🟡	🟡	🟢	🔴

Candidate 3L-LLC Topology



Preliminary Design Optimization





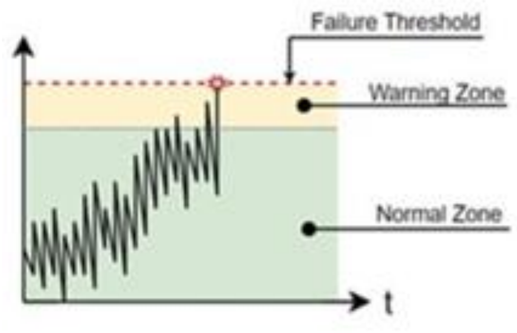
WP4.3 – PHM Techniques for Power Electronics

- **Benefits:**
  - Groundwork for development of PHM for modular power systems
  - Increase time out service for equipment

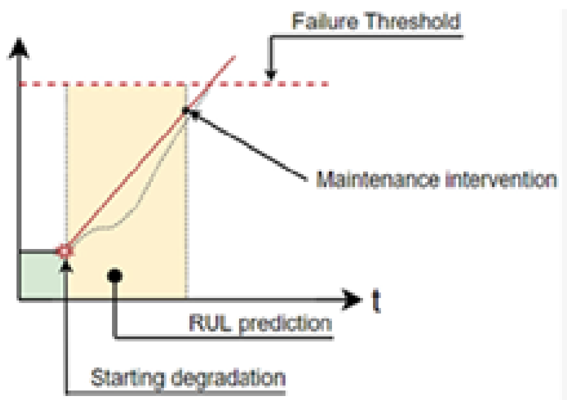
- **Completed Activities:**
  - Conducted review of existing research and identified candidate component failure case to be studied
  - Design and procurement of materials to develop test-bench for materials testing and data capture

- **Current tasks**
  - Test bench under construction
  - Aging tests to be conducted in coming months to generate training data
  - Development of machine learning approaches to provide prognostic detection of failure mechanisms

Diagnostic



Prognostic



PHM Testbench under development

Modular & Distributed Aircraft Power – Conclusions

- ADENEAS will facilitate future concepts for highly efficient and modular solutions for aircraft power systems
  - Cabin systems provide interesting opportunities to evaluate and certify controls approaches that may have broader impact
  - Modular and highly integrated power electronics will save weight through local conversion and support EWIS optimization for the aircraft
  - PHM techniques will support diagnostics and prognostic capabilities for the electric system to ensure reliable operation of critical systems

ADENEAS
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22 February 2023

WP5 – Cooling Solutions

ADENEAS

Advanced Data and power Electrical NEtwork Architectures and Systems

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Presenter:
Sana Fateh - Synano

Contents

- WP5 “Cooling Solutions” objectives
- WP5 “WP 5.3 ADENEAS Nano-fluids R&D objectives”
- WP5 “WP 5.3 Main achievements and technical highlights”
- WP5 “WP 5.3 Single-Phase cooling and EPOS mini-demonstrator next steps”
- WP5 “WP 5.3 Two-Phase boiling Nano-fluids & Nano-fluid deposition results”

- Partners involved inWP5

WP5 "Cooling Solutions" objectives

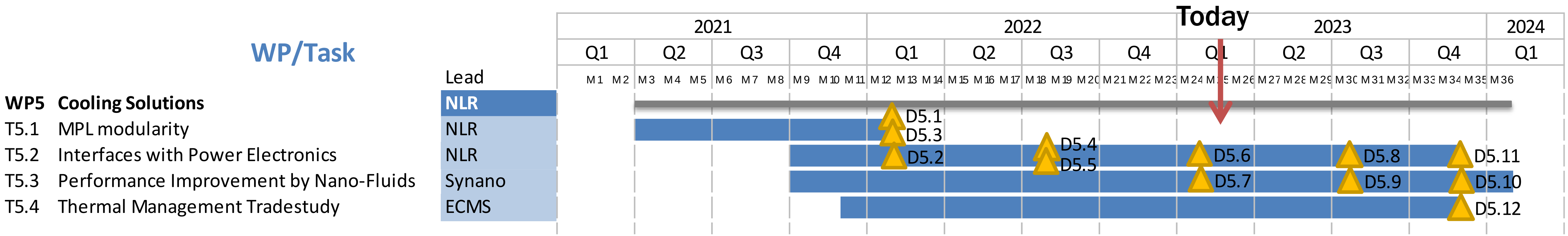
Define architectural designs compatible with MEA aircraft and subsystems (T5.1)

Develop an MPL demonstrator which demonstrates MPL's modularity, scalability and MPL's standardization aspects for implementation in MEA (T5.2)

Demonstrate and quantify the performance improvement of nano-fluids in both single-phase and 2-phase MPL's (T5.3)

Analyse the performance improvement for electric systems as a consequence of MPL systems (T5.4) (just started)

WP5 timeline



Ref	Title	Leader	Due date	Comment
D5.1	Architectural design analyses and trade-off study for 2-phase MPL's in MEA	NLR	M12	Delivered
D5.2	Preliminary MPL evaporator design and electronics interface	NLR	M12	Delivered
D5.3	Preliminary 2-phase MPL demonstrator design	NLR	M12	Delivered
D5.4	Detailed 2-phase MPL evaporator design & electronics interface	NLR	M18	Delivered
D5.5	Detailed 2-phase MPL demonstrator design	NLR	M18	Delivered
D5.6	*2-phase MPL demonstrator Test Plan*	*NLR*	*M24*	Delivered
D5.7	*Performance improvement by nano-fluids*	*Synano*	*M24*	Delivered
D5.8	*2-phase MPL demonstrator Test Report*	*NLR*	*M30*	
D5.9	*Performance improvement by nano-fluids: proof of concept*	*Synano*	*M30*	
D5.10	*Performance improvement by nano-fluids: standardisation and safety Document*	*Synano*	*M34*	
D5.11	*Final Report 2-phase MPL demonstrator*	*NLR*	*M34*	
D5.12	*Thermal management trade-study Report*	*ECMS*	*M34*	

WP 5.3 ADENEAS Nano-fluids R&D objectives

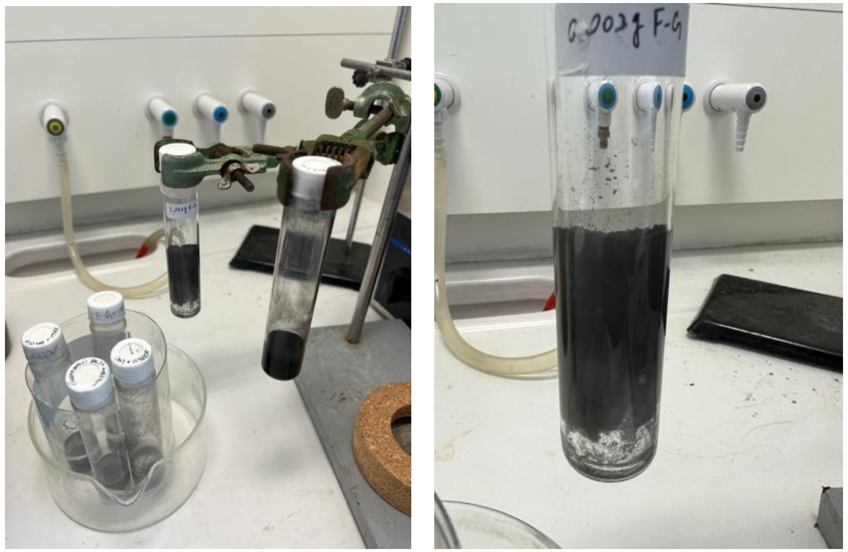
- Main aim: To show effect of nanoparticles on heat transfer improvement in single and two phase cooling systems

- Research questions to be answered:
  - What is the change in heat transfer with and without nanoparticles in single and two phase heat transfer?
  - What are the relevant parameters affecting boiling heat transfer and how are they affected by the presence of nanoparticles?
  - Are nanofluids more effective as boiling heat transfer media or nanoparticle coating on the surface provides a better alternative and why?
  - Are the results repeatable and reproducible?

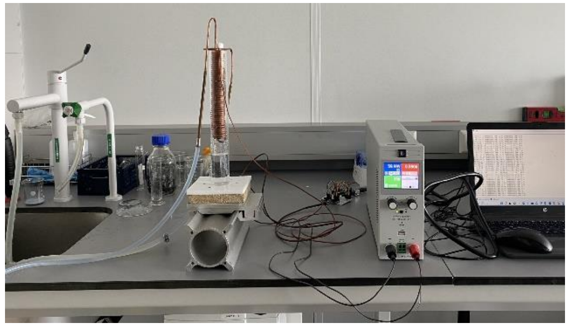
Main achievements & technical highlights

WP5.3 Main achievements & technical highlights

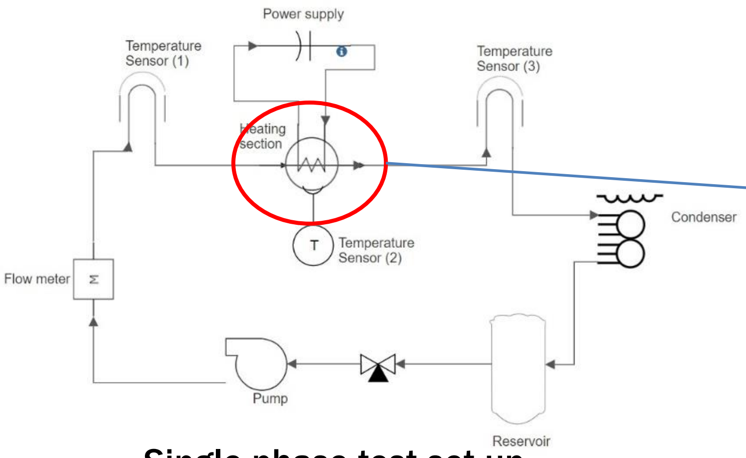
- Synthesis of stable nanofluids/refrigerants and nanoparticle coatings
- Single-phase cooling test facility
  - Tests with nano-fluids performed and reported
  - Tests with nanoparticle deposition performed and reported
- Two-phase pool boiling test facility
  - Tests with nano-fluids performed and reported
  - Tests with nanoparticle deposition performed and reported



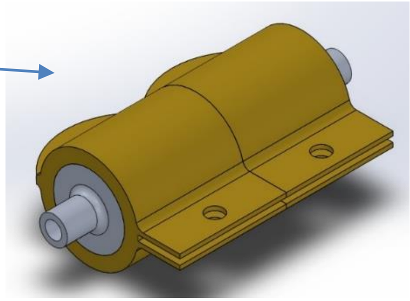
Nano-refrigerant samples & deposition of F-G as result of ultrasonication



Two-phase boiling test set-up



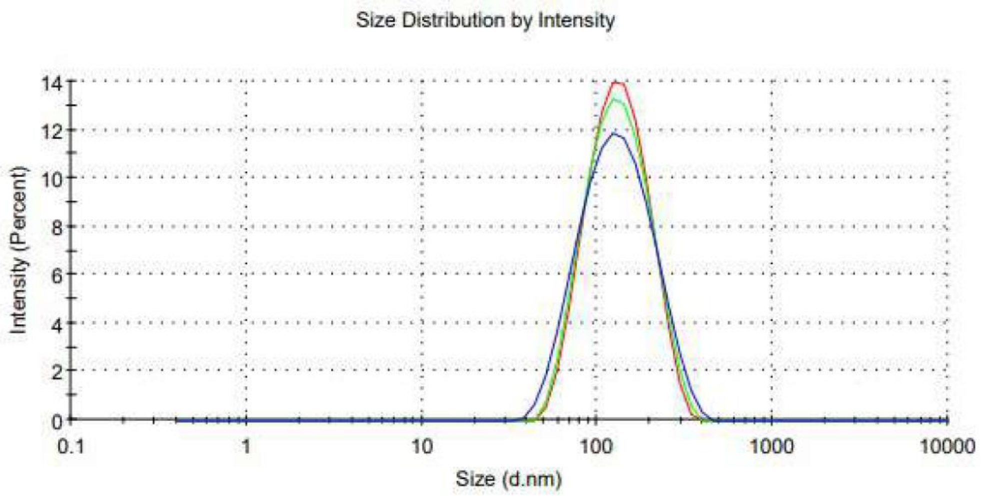
Single-phase test set-up



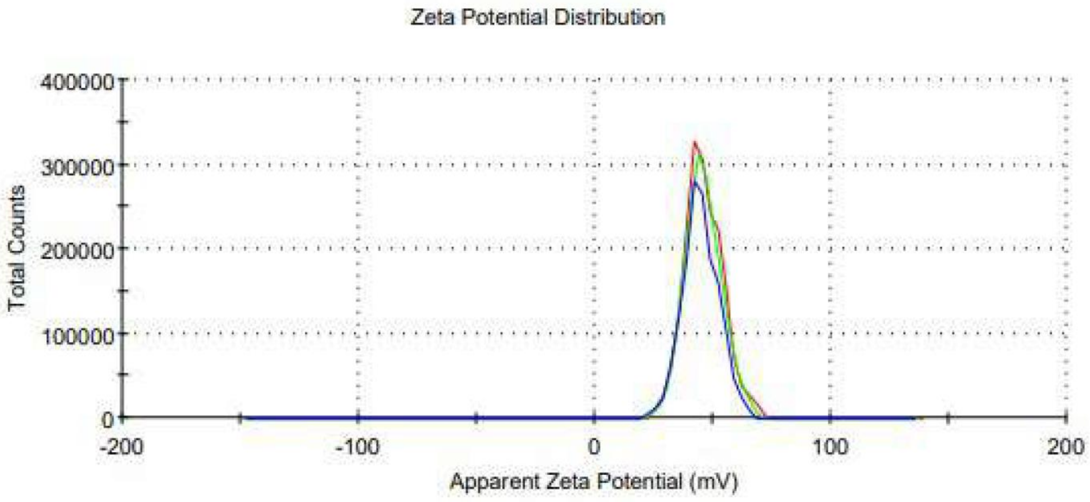
Heating section

- Nanofluids are suspensions of nanoparticles (metal, metal oxide, carbon) in base-fluids like water, glycol, refrigerants and oils.
  - Nanofluids created to improve the thermal conductivity of traditional heat transfer media.
  - In boiling heat transfer, nanoparticles interact with bubbles and form highly conductive porous layer on the heater surface.

- For ADENEAS project, SYN has developed water and acetone based nanofluids/ nano-coatings using Alumina nanoparticles.
  - Average diameter of $Dp = 115\ nm$
  - Zeta potential $\zeta = 46\ mV$, confirming the stability of the nanofluid.



Alumina nanoparticles size distribution in water-based 0.1% *wt* nanofluid



Zeta potential of water-based 0.1% *wt* nanofluid

Single phase cooling system

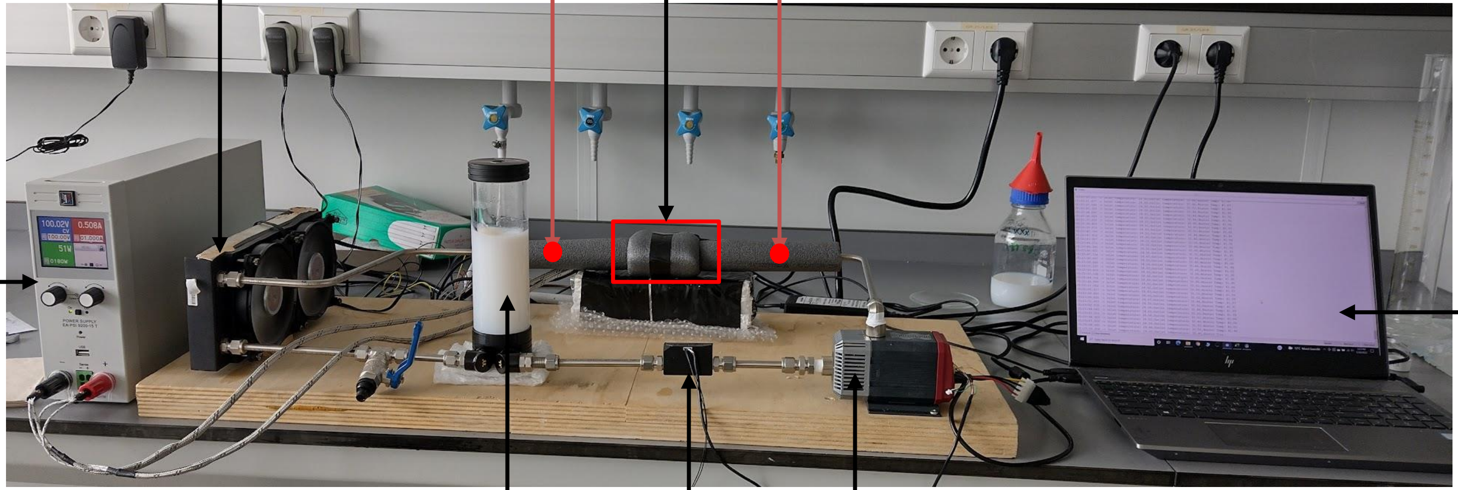
Power supply unit

Condenser with fans

Outlet liquid temperature- TC

Heating section- TC on surface

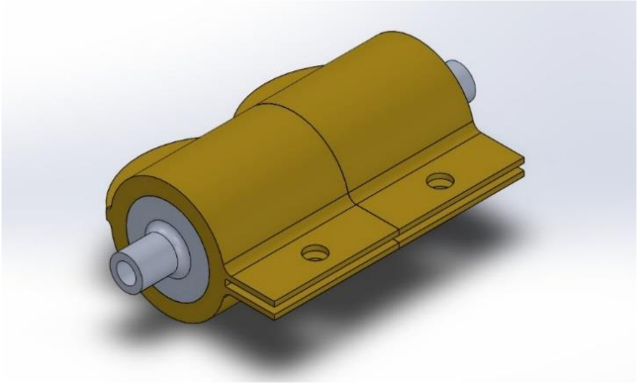
Inlet liquid temperature- TC



Reservoir with nano-coolant

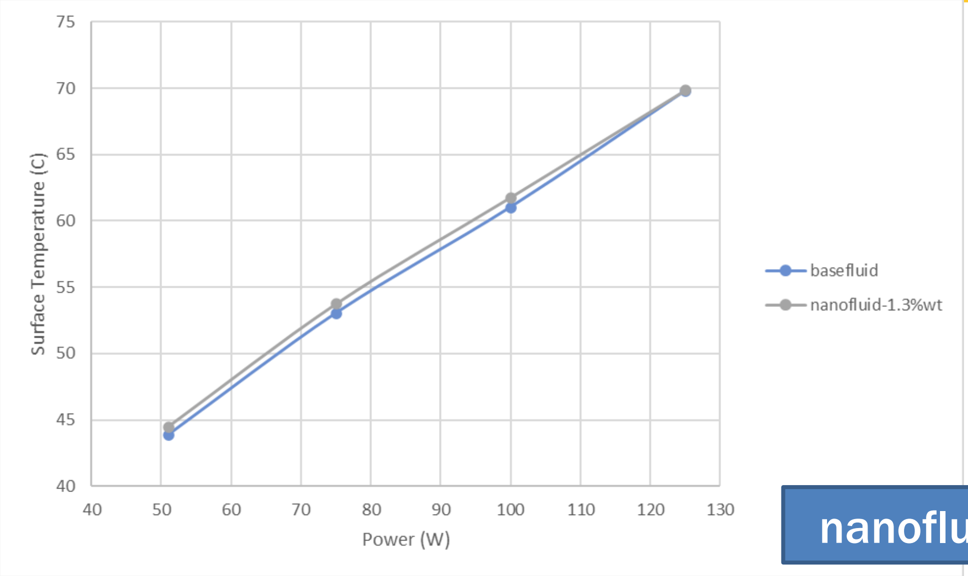
Flow meter

Pump

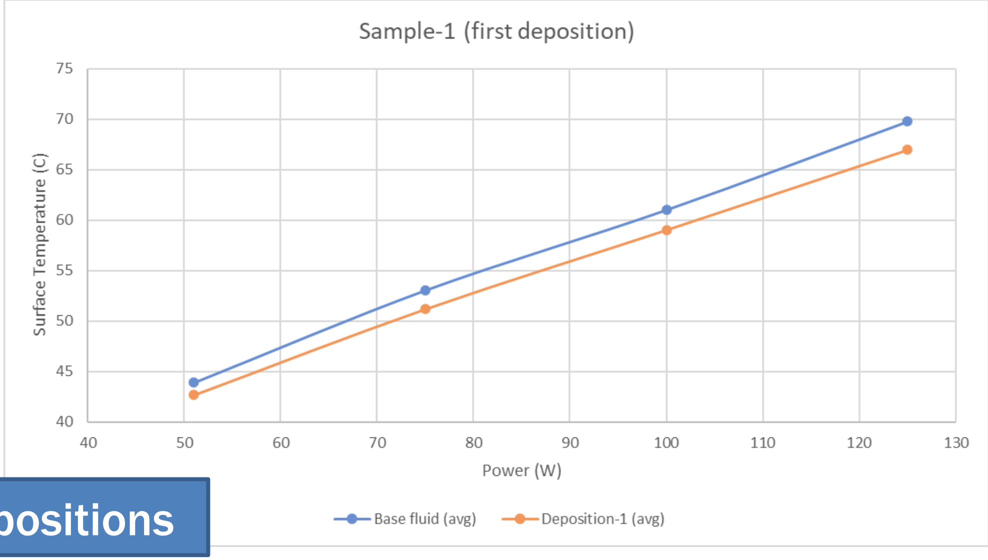


Data logging

Single phase cooling system- results



nanofluids



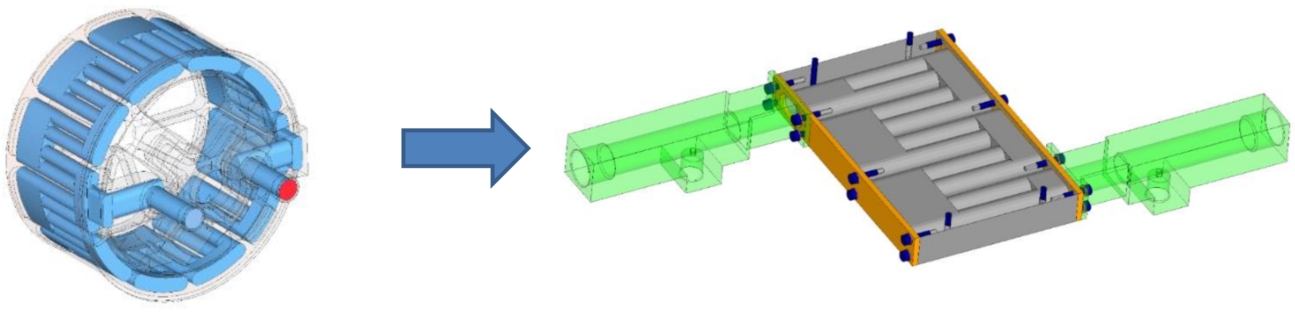
Nano-depositions

Nanoparticle depositions give better results compared to nanofluids.

- Improvement seen with depositions. Higher the power, more the temperature reduction. **~2.5^{0}C reduction in surface temperatures observed for 125W (**heat flux of 13.27 W/cm^2)
- More depositions create thermal resistance and makes heat transfer worse leading to similar or slightly better performance than base surface
- Way forward
  - Further nanoparticle deposition tests with different particle types and sizes.
  - Surface study is also needed before and after making depositions.

EPOS mini-demonstrator

- The temperature of the stator needs to be maintained within acceptable limits otherwise the efficiency is deteriorated.
- Nanoparticles will be used to improve heat transfer of single phase cooling system employed in the EPOS stator and compare it with the results of base fluid tests



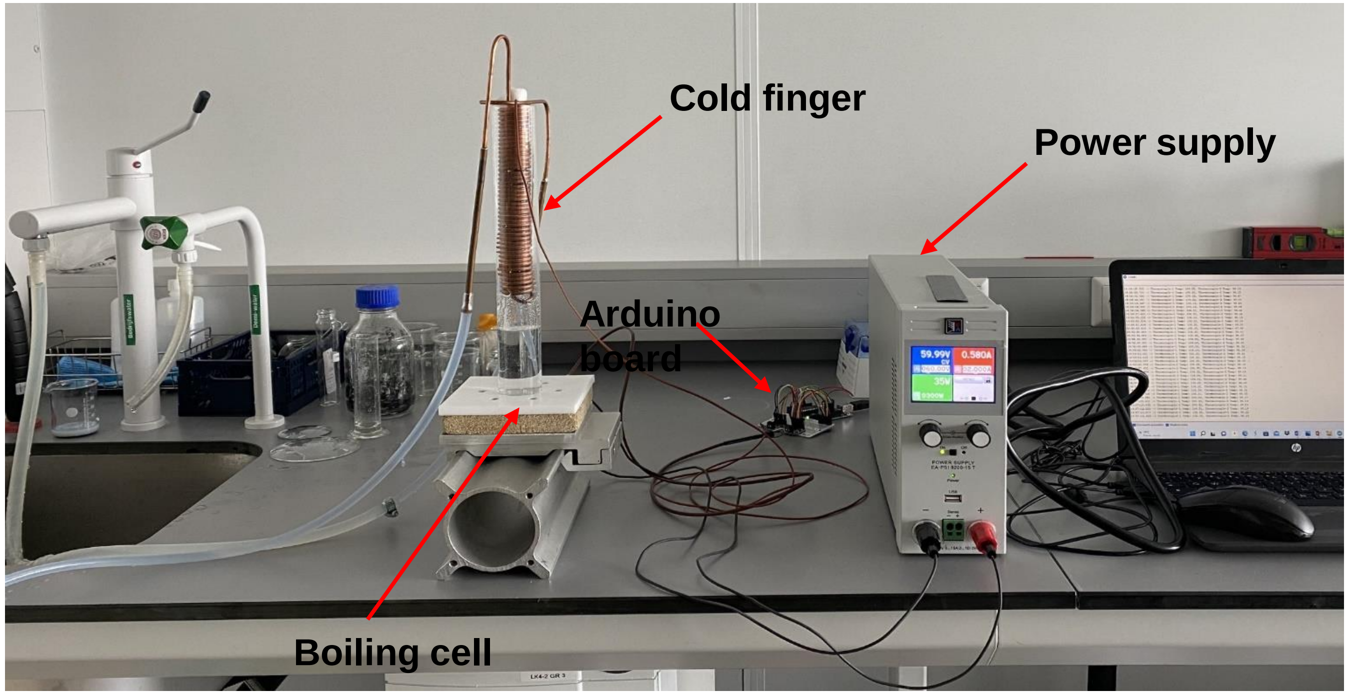
Demonstrator design

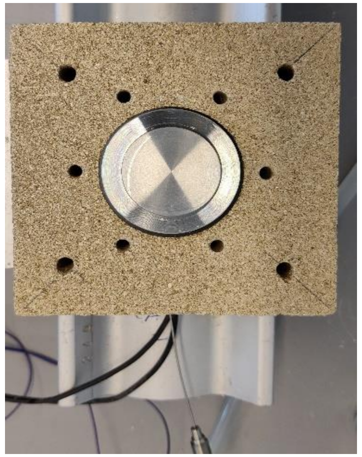
- Quarter of the cylinder of the stator was extracted and redesigned to the planar one (3 pieces manufactured)
- Two sections to determine coating method at Synano
- Third section tested with base fluid to get baseline data by EVEKTOR and sent to SYN for coating
- At EVE, the same tests will be repeated with the new surface treatment
- The result can be extrapolated to the whole assembly of stator heat exchanger and this representation of the system will be shown as a demonstrator for EU deliverables
- Parts under manufacturing

Two phase MPL cooling system with nano-fluids

Objectives:

- To show improvement with nanoparticles in two phase heat transfer performance
  - Pool boiling tests with alumina nanofluids
  - Pool boiling tests with nanoparticle coatings
- Implement the best option on a flow boiling demonstrator (with 2-phase MPL)





Pool boiling- nanofluids

PRELIMINARY ACTIVITY:
Synthesis & characterization of the nanofluid

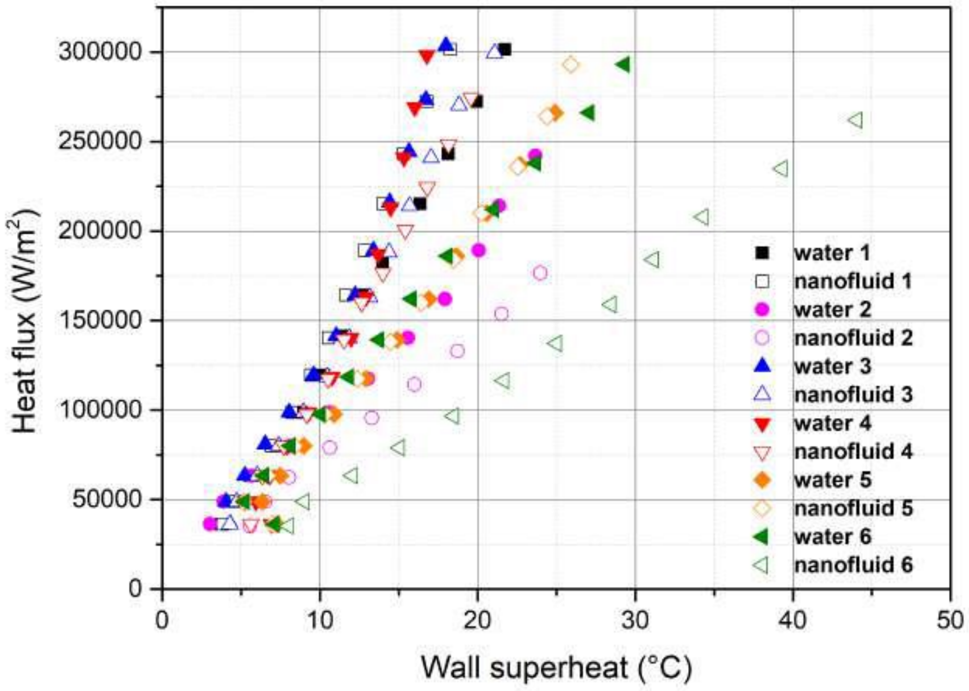
BEFORE BOILING:
Surface analysis of original boiling surface (SEM & WLI)

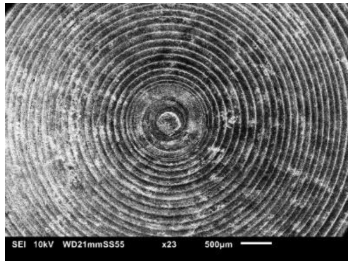
2 BOILING RUNS FOR EACH SAMPLE:

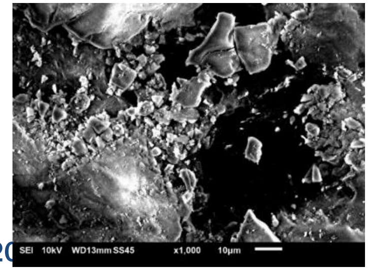
- Pure fluid on original surface
- Nanofluid on original surface

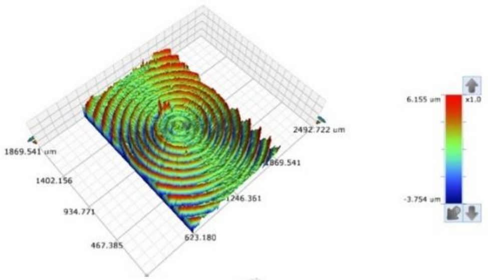
OUTPUT:
Boiling curves

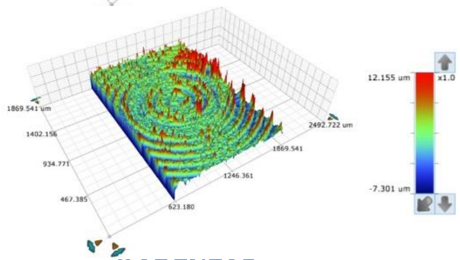
AFTER BOILING:
Surface analysis of nanoparticles-deposited surface (SEM & WLI)











- Inconsistent results from nanofluid boiling- not repeatable
- Sample-1 (good), Sample-5 (same), all other samples (worse)

Pool boiling- nano-depositions

3 boiling runs on base surface with pure water (establish baseline)

↓

Synthesis of the nanofluid
Use of nanofluid to create nanoparticle depositions by either boiling or evaporation

↓

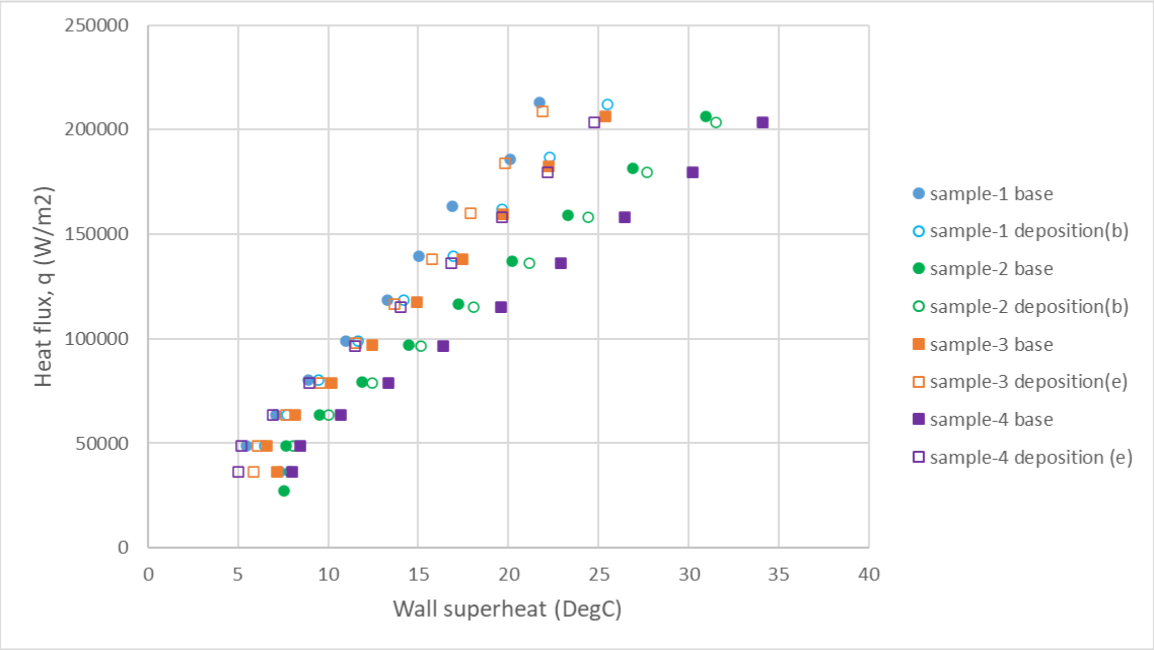
3 BOILING RUNS after depositions using pure water

↓

OUTPUT:
Boiling curves

	Water-alumina	Acetone-alumina	Deposition technique
Sample-1	0.1%wt		Boiling
Sample-2	0.01%wt		Boiling
Sample-3	0.01%wt		Evaporation
Sample-4		0.01%wt	Evaporation

- Low conc. deposition preferred, high conc deteriorates heat transfer
- Evaporation depositions more homogeneous than boiling
- **With (evaporative) deposition using acetone nanofluid, wall superheat reduced by ~9^{0}C.**

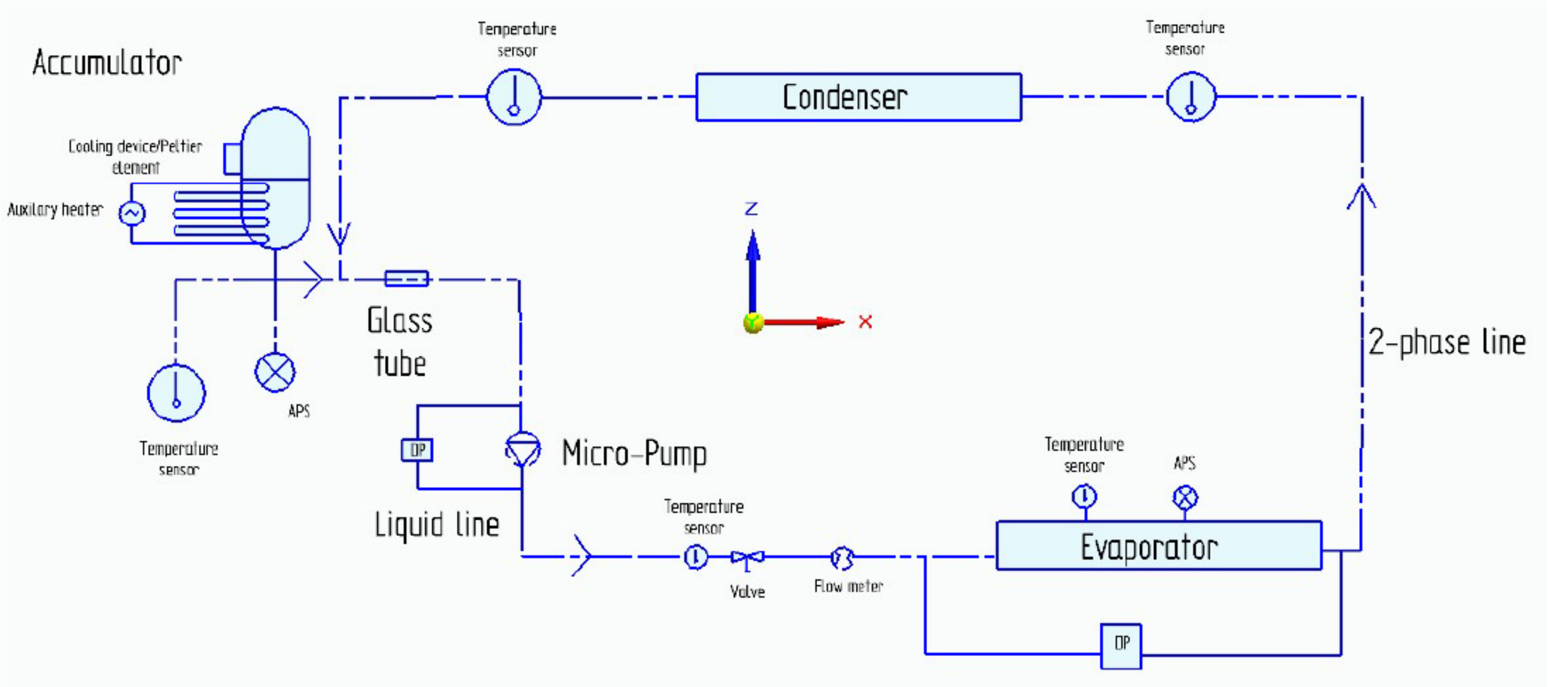


Nanoparticle deposition to be used for 2-phase MPL demonstrator

Next steps:

- Multiple runs show reduced performance, more robust depositions methods needed
- Modifications to the apparatus might be required so that the setup reaches critical heat flux point

Flow boiling setup



- Flow boiling setup will represent 2-phase MPL demonstrator at NLR
- Aim: To show nanoparticle depositions can improve boiling heat transfer in flow boiling conditions
- Schematic and setup requirements are done

Outlet vapor fraction= 0.5 (to avoid dry-outs in the channels)
Maximum heat flux = 25W/cm^2

SPECIFICATIONS	REQUIREMENTS
Fluid	$R1233zd(E)$
Saturation temperature	$70°C$
Saturation pressure	$5.1bar$
Temperature at evaporator inlet	$70°C$
Temperature at the condenser outlet	$50°C$
Maximum vapor fraction at the evaporator outlet	0.5

Flow boiling setup- challenges and next steps

- Design of cooling plate to study the surface and make depositions non-destructively
- Maintaining proper seal and pressure conditions during operation
- Starting procedure
- Draining and cleaning the system without causing pressure loss
- Avoiding dry-outs in evaporator
- Saturated liquid entering into the channels to ensure uniform flow in all channels
- Ensuring proper sealing when dissembling and assembling the setup after depositions are made

Next steps:

- Finalising deposition method of nano-particles in the mini-channels;
- Finalising specifications of other components of the setup;
- Building the setup and performing test runs with pure fluids to validate the setup;
- Experiments to study the effect of nanoparticle depositions on heat transfer performance

ADENEAS
Public Workshop
22nd February 2023

WP6: Architectures and Topologies

Advanced Data and power Electrical NEtwork Architectures and Systems

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006728.

Presenters:

Diarmaid Hogan – CA

Asterios Souftas - FE

WP6 Architectures and Topologies

Develop a system exploration toolset for distributed modular power systems

Analyze and optimize power system architectures

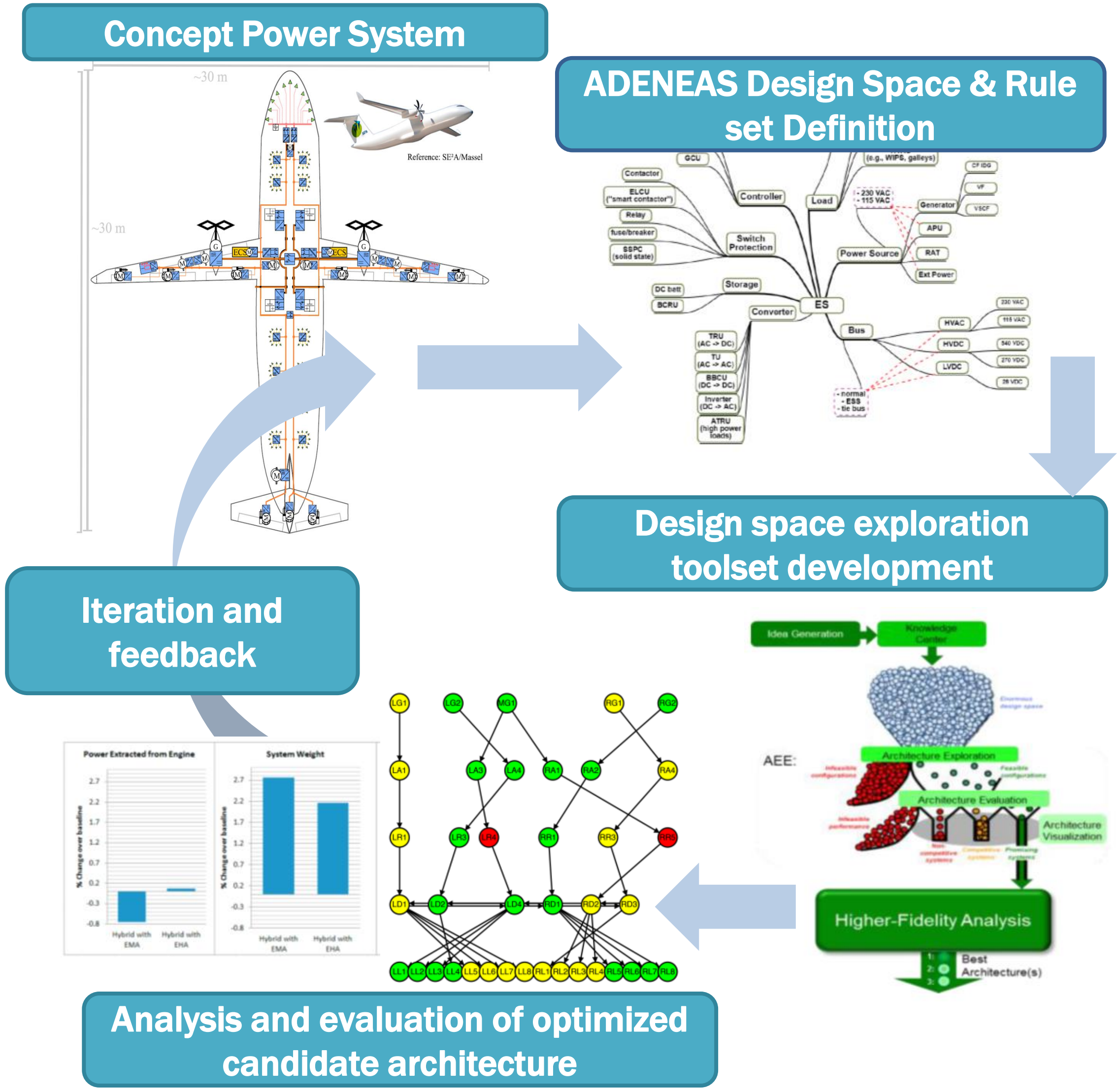
Develop methods and tools to optimize hybrid data networks with wireless communication and PLC

Develop Novel Conductor Concepts to increase data network capacity and improve EMC

Power System Architecture Exploration – WP6.1 / 6.2

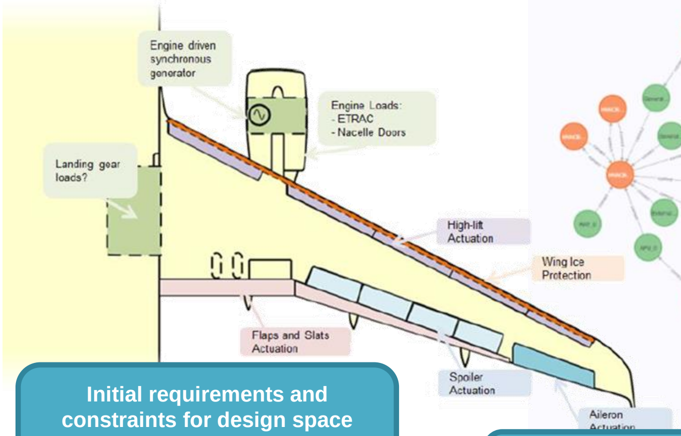
- **Objective**:
  - Automate design of complex aircraft power systems
  - Satisfy design requirements, e.g. reliability redundancy
  - Reduce system mass
  - Enable complex system design for highly reconfigurable systems

- **Approach:**
  - Development and extension of design space exploration tool for next generation aircraft power systems – HVDC, Distributed, Modular
  - Enhance in-house toolsets, solvers, libraries, and methods to provide rapid comprehensive exploration of architectural design spaces
  - Utilize system validation capabilities from other EU programs such as Clean Sky - MISSION to evaluate outputs against key metrics such as system weight

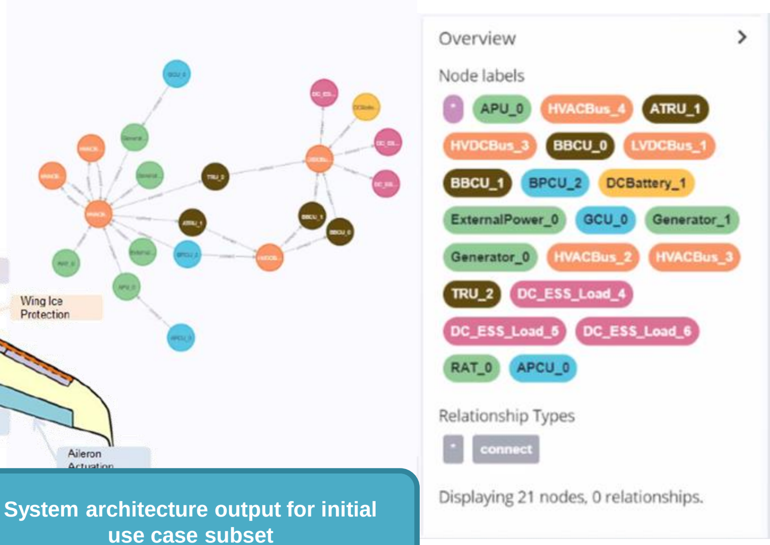


Power system architecture exploration – WP6.1 / 6.2

- **Status**: Model of aircraft electric system, considering increased distribution and load zones
  - Evaluation of in-house tools for system architecture exploration
  - Optimal sizing of candidate system architectures
- **Outlook:** Use-case extension, increased complexity and additional requirements
  - Model extension to consider additional systems and components
  - Extension to full aircraft and evaluation to lower sub-systems
  - Evaluation of flight operating phases and reliability

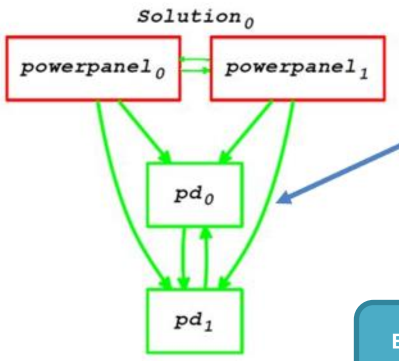


Initial requirements and constraints for design space exploration of wing architectures



System architecture output for initial use case subset

Architecture output example



- Connection paths indicate power flow direction
- Element for engagement with EOFw framework in terms of EWIS interface definitions

- **Variables**
  - *powerpanel$_0$*, *powerpanel$_1$*
  - *pd$_0$*, *pd$_1$*
  - Complete digraph *G*
- **Constraints**
  - ∑ outgoing_arcs(*powerpanel$_0$*) = 3
  - ∑ incoming_arcs(*powerpanel$_0$*) = 1
  - ∑ outgoing_arcs(*powerpanel$_1$*) = 3
  - ∑ incoming _arcs(*powerpanel$_1$*) = 1
  - ∑ incoming _arcs(*pd$_0$*) = 3
  - ∑ incoming _arcs(*pd$_1$*) = 3
  - ∑ arcs(*G*) ≥ 1

Examples of architecture outputs and corresponding constraints

Data Network – T6.3 Architecture and Topology Integration
Objectives and Approach

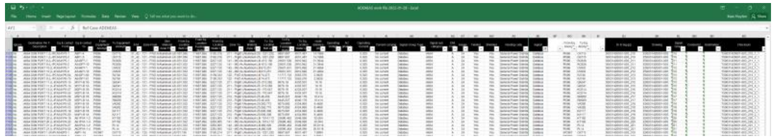
Objective
- Find a way to deal with complexity
- Apply for automated design + optimization

Challenges
- Complexity (high numbers, multi-disciplinary, integration of several architectures)
- Will AI deliver benefit over heuristic approach?

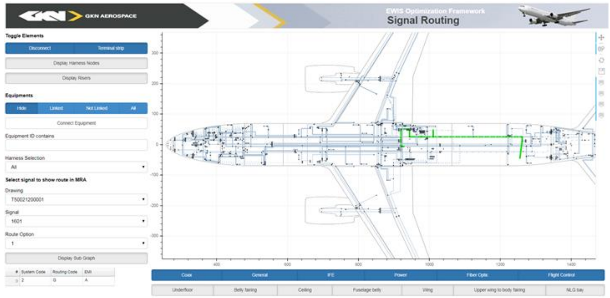
Results
- Reference cases representing aircrafts
  - Different types
  - Input ITU-R inventory (aggregated level)
  - Scaled up and down other aircrafts

#	Flight Phase	Property	Commuter Aircraft	Regional Aircraft	Large Passenger A/C
1	Ground	Net peak rate (kbps)	117584	150509	269389
2		#nodes	1637	2450	4749
3	Take-off	Net peak rate (kbps)	113343	139186	248899
4		#nodes	1583	2135	3479

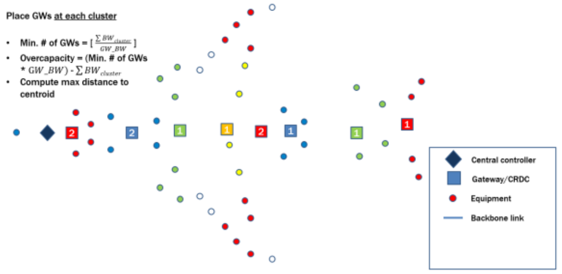
  - Extended with (estimated) data needed for the developments (DAL, data rate, …) based upon detailed design EWIS background
  - Same list as last year, but the list got bigger



- Design automation optimization
  - Weight and costs are optimization space, reliability/safety is not negotiable
  - Extension of EWIS Optimization Framework (EOFw)



  - AI: Automatic gateway positioning
    - Method 1- K-means: Based upon shortest average transfer distance
    - Method 2 – DBSCAN: Based upon node density
    - Method 3 – Agent Based Framework: Autonomous dynamic re-allocating of resources equipped with Machine Learning features
    - Methods currently combined in a workflow

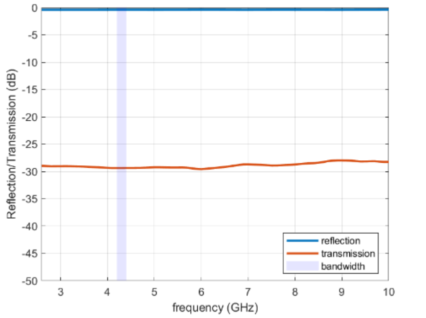


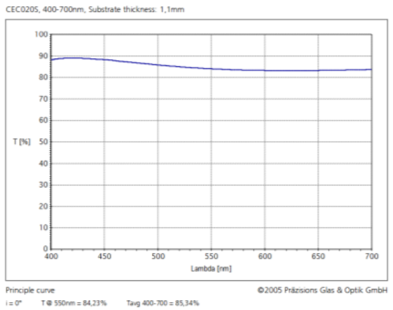
Data Network – T6.3 Architecture and Topology Integration
Objectives and Approach

- Design automation (continued)
  - Inclusion of PLC just started
  - Design strategies for hybrid data network
    - E.g. short distances>data cable; cable supplied power>PLC; wireless power supply>wireless communication; ...
    - Key question to become answered is if AI will deliver benefit over heuristic approach

- Novel Conductor Concepts (NCC)
  - Objective: Reduce weight and raise reliability
  - 5 concepts defined
  - 2 rejected – limited topologies
  - 1 rejected – technical limitation
  - 2 selected
    - Bifilar wiring concept (plc-tec, WP3)
    - Shielding transparencies (passenger windows)

- Shielding windows shields aircraft wireless network form radio altimeter
- SE >20 dB expected
- Existing technology
- Preliminary models defined (NLR), verification test scheduled





ADENEAS

Advanced Data and power Electrical NEtwork Architectures and Systems

Thank you! Questions?

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006728.

ADENEAS Public Workshop 22 February 2023

WP7: Technology impact Evaluation, Assessment & Optimization

Advanced Data and power Electrical NEtwork Architectures and Systems

Presenter:
Roland Furmanek
Evektor, spol. s r.o.

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WP7 objectives

T7.1: Technology Integration Assessment and Optimization

Testing, optimization and performance evaluation of the solutions as operated stand-alone systems or aggregates (complex interaction with other systems) in relevant environment (demonstrators).

T7.2: Economic Impact and Meeting H2050 Targets

Review economic benefits of the solutions, outline possible challenges with their future commercialization and analyze impact on aircraft systems with respect to H2050 targets.

T7.3: Standardisation and Technology Maturity Assessment

Define and review final TRLs of the ADENEAS technologies. Discuss integration and certification requirements and identify possible tech. challenges that may limit progression to higher TRLs (i.e. maintainability, repairability, etc.)

WP7: General approach

Phase 1 Preparation

- MS17: List of Solutions
- Assessment methodologies

Synergies:
WP 1

Phase 2 Support Test Execution

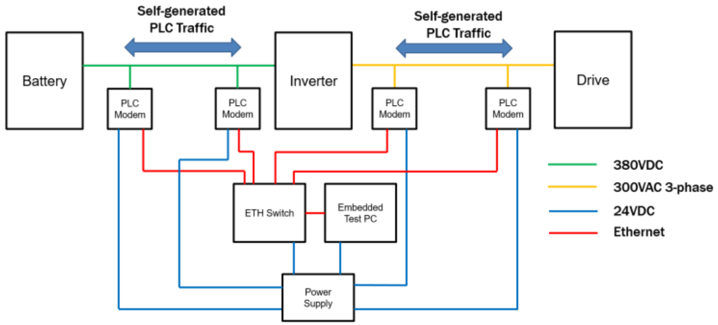
- Demonstrator test specifications
- GBD demonstrator testbeds (MS12, D7.2)
- Optimization / Feedback

Synergies:
WP 2, 3, 4, 5

Phase 3 Evaluation

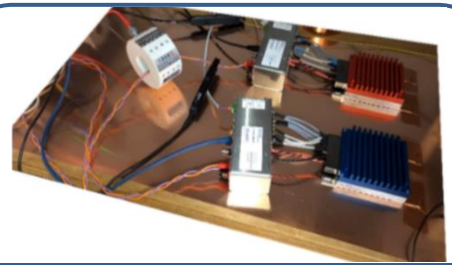
- Tech. Assessment (D7.1)
- Eco. Assessment (D7.3)
- TRL Assessment (D7.4)

Synergies:
WP 1, 2, 3, 4, 5, 6



T7.1: Technology Integration Assessment and Optimization

- Demonstrators (WP 2-6)
  - PLC Electromagnetic Compatibility
  - PLC network configuration tool
  - Two-phase mechanically pumped loop integrated with power module
  - Cooling additives for two-phase cooling
  - Cooling additives for single-phase cooling
  - Cooling plate for two-phase cooling of HVDC converter
  - Cooling plate for liquid and two-phase cooling of EPOS motor
  - Diversity mechanisms to enhance (TSCH) channel access technology
  - Diversity mechanisms – The digital version of the (analog) hardware
  - Shielding Transparencies
- Complex demonstrators (WP 2-7)
  - PLC+NCC (bifilar wiring)
  - PLC+Cabin nano-grid power architecture
  - PLC – Power system control (EPOS flying demonstrator)



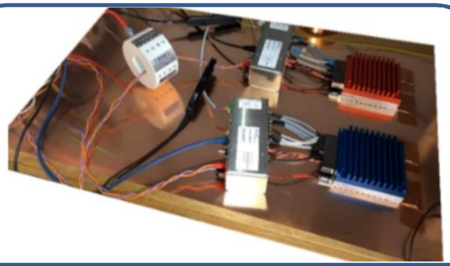
Test Bench Demonstrator (TBD)

Ground Based Demonstrator (GBD)

Flying Demonstrator (FD)

T7.1: Technology Integration Assessment and Optimization

- PLC integrated with Novel Conductor Concept (bifilar wiring)
  - PLC performance on the bifilar wiring architecture
  - Test goal
    - Establish network performance, latency, and message loss
- PLC integrated with Cabin Nano-Grid power architecture
  - Test variants
    - High-voltage (540VDC)
    - Low-voltage (28VDC)
  - Test goal
    - Define integration potential and performance impact on integrated solutions

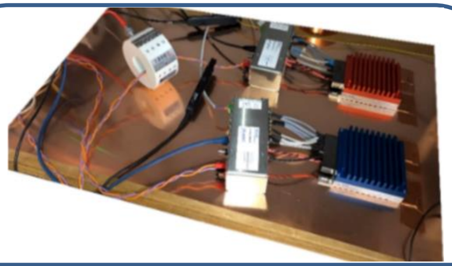


Test Bench Demonstrator (TBD)

Ground Based Demonstrator (GBD)

Flying Demonstrator (FD)

- EPOS + PLC/ complex demonstrator
  - Test variants:
    - In-Flight
      - 380 VDC: self-generated comm. traffic
      - 300 VAC 3-phase: self-generated comm. traffic
    - On-ground
      - 380 VDC: self-generated comm. traffic + BMS-INV CAN traffic
      - 300 VAC 3-phase: self-generated comm. Traffic
  - Test goal
    - Test functionality and performance of the PLC solution in relevant environment



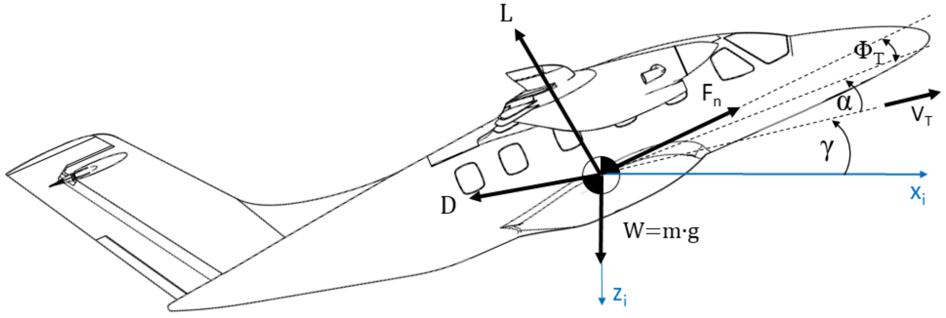
Test Bench Demonstrator (TBD)

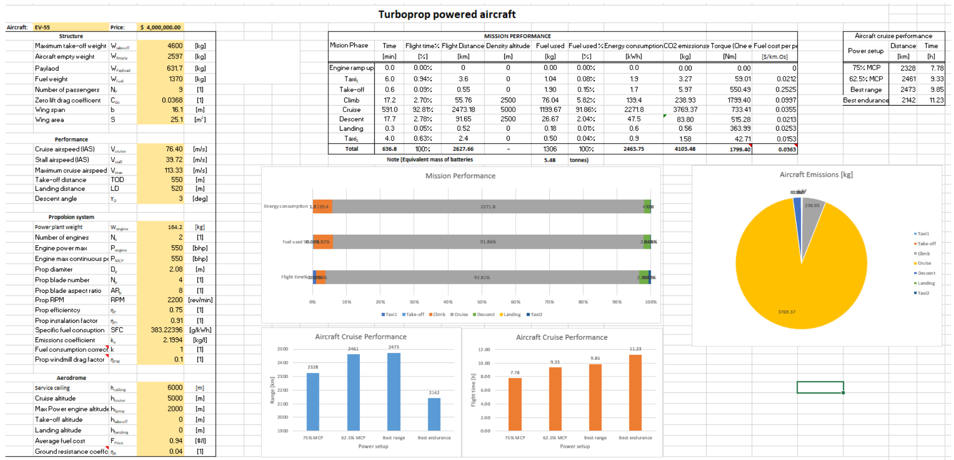
Ground Based Demonstrator (GBD)

Flying Demonstrator (FD)

T7.2: Economic Impact and Meeting H2050 Targets

- Main goals:
  - Put ADENEAS outcomes into context of FP2050 goals (*ACARE/SRIA: „FlightPath 2050“*)
- FlightPath 2050 goals:
  - 75% reduction in CO2 emissions (PAX/km)
  - 90% reduction in NOx emissions (PAX/km)
- Emissions reduction via targeted weight reduction
  - Innovative EWIS systems
    - 10%/15% reduction of EWIS power/signal cables
    - 40% reduction of the cabin and power distribution network equipment
  - 2-phase MPL with nano-fluid additives
    - 30% weight reduction
  - PLC (PLUS) systems implementation
    - 36% reduction in the number of wired links/connectors (TAUPE)
  - EXAMPLE
    - Expected Total weight savings > 450 kg for medium and large aircraft (Airbus A220)





T7.2: Economic Impact and Meeting H2050 Targets

- Flight Performance Calculator
  - Calculate emission reduction and weight saving
- Input data
  - Structural data
  - Wing Span, Weight…
  - Operational performance
  - Take-off distance, Stall Speed…
  - Propulsion System
  - Engine Power, Prop RPM…
  - Airfield
  - Runway type, Fuel Price…
- Applied Methodologies
  - Semi-empirical methods
  - Based on classical aerodynamic approach
- Considered Scenarios
  - Flight profile
    - Taxi, Take-off, Climb, Cruise, Descent, and Landing, Take-off
  - Aircraft type
    - CS23A (EPOS, Cesna 172,…)
    - CS23B (EV-55, Pilatus PC-24,…)
    - CS25 (A320, Fokker 70 or 100,…)
- Output
  - Energy required, flight profile, CO_2 emissions

T7.2: Economic Impact and Meeting H2050 Targets

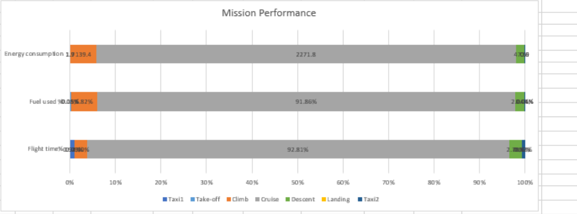
- Flight Performance Calculator
  - Additional data
    - Time to climb
    - Characteristic Assessment
    - Fuel/energy cost pre person
    - Cruise and Endurance performance at multiple power settings

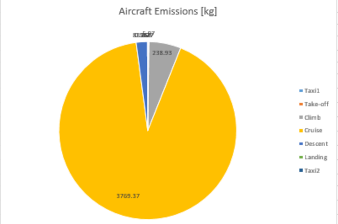
Turboprop powered aircraft

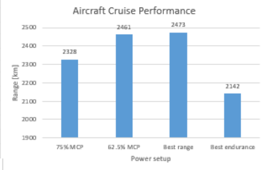
Aircraft:	EV-55	Price:	$ 4,000,000.00	
Structure				
	Maximum take-off weight	$W_{take-off}$	4600	[kg]
	Aircraft empty weight	W_{Empty}	2597	[kg]
	Paylaod	$W_{Payload}$	631.7	[kg]
	Fuel weight	W_{Fuel}	1370	[kg]
	Number of passengers	N_P	9	[1]
	Zero lift drag coefficent	C_{Do}	0.0368	[1]
	Wing span	b	16.1	[m]
	Wing area	S	25.1	[m^2]
Performance				
	Cruise airspeed (IAS)	V_{cruise}	76.40	[m/s]
	Stall airspeed (IAS)	V_{stall}	39.72	[m/s]
	Maximum cruise airspeed	V_{max}	113.33	[m/s]
	Take-off distance	TOD	550	[m]
	Landing distance	LD	520	[m]
	Descent angle	γ_D	3	[deg]
Propolsion system				
	Power plant weight	W_{engine}	164.2	[kg]
	Number of engines	N_e	2	[1]
	Engine power max	P_{engine}	550	[bhp]
	Engine max continuous pc	P_{MCP}	550	[bhp]
	Prop diamiter	D_p	2.08	[m]
	Prop blade number	N_p	4	[1]
	Prop blade aspect ratio	AR_p	8	[1]
	Prop RPM	RPM	2200	[rev/min]
	Prop efficientcy	η_P	0.75	[1]
	Prop instalation factor	η_{PI}	0.91	[1]
	Specific fuel consuption	SFC	383.22396	[g/kWh]
	Emissions coefficient	k_e	2.1994	[kg/l]
	Fuel consumption correct	k	1	[1]
	Prop windmill drag factor	η_{PW}	0.1	[1]
Aerodrome				
	Service ceiling	$h_{ceiling}$	6000	[m]
	Cruise altitude	h_{cruise}	5000	[m]
	Max Power engine altitude	h_{Tprop}	2000	[m]
	Take-off altitude	$h_{take-off}$	0	[m]
	Landing altitude	$h_{landing}$	0	[m]
	Average fuel cost	F_{Price}	0.94	[$/l]

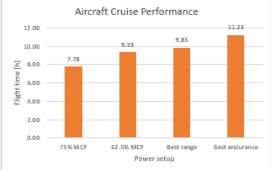
MISSION PERFORMANCE										
Mision Phase	Time	Flight time%	Flight Distance	Density altitude	Fuel used	Fuel used %	Energy consumption	CO2 emissionss	Torque (One e	Fuel cost per pe
	[min]	[%]	[km]	[m]	[kg]	[%]	[kWh]	[kg]	[Nm]	[$/km.Os]
Engine ramp up	0.0	0.00%	0	0	0.00	0.00%	0.0	0.00	0.00	0
$Taxi_1$	6.0	0.94%	3.6	0	1.04	0.08%	1.9	3.27	59.01	0.0212
Take-off	0.6	0.09%	0.55	0	1.90	0.15%	1.7	5.97	550.49	0.2525
Climb	17.2	2.70%	55.76	2500	76.04	5.82%	139.4	238.93	1799.40	0.0997
Cruise	591.0	92.81%	2473.18	5000	1199.67	91.86%	2271.8	3769.37	733.41	0.0355
Descent	17.7	2.78%	91.65	2500	26.67	2.04%	47.5	83.80	515.28	0.0213
Landing	0.3	0.05%	0.52	0	0.18	0.01%	0.6	0.56	363.99	0.0253
$Taxi_2$	4.0	0.63%	2.4	0	0.50	0.04%	0.9	1.58	42.71	0.0153
Total	**636.8**	100%	**2627.66**	-	1306	100%	**2463.75**	**4103.48**	**1799.40**	**0.0363**
Note (Equivalent mass of batteries					5.48	tonnes)				

Aircraft cruise performance		
Power setup	Distance [km]	Time [h]
75% MCP	2328	7.78
62.5% MCP	2461	9.33
Best range	2473	9.85
Best endurance	2142	11.23





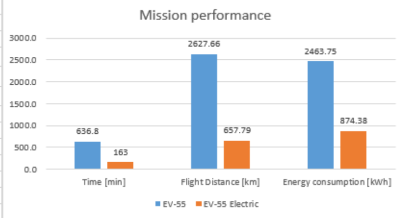


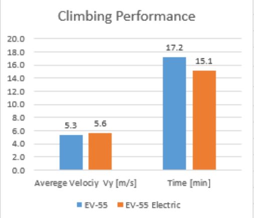


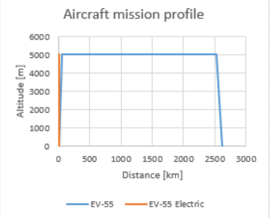
Mission Phase	EV-55 Time [min]	EV-55 Flight time [%]	EV-55 Flight Distance [km]	EV-55 Energy consumption [kWh]	EV-55 Electric Time [min]	EV-55 Electric Flight time [%]	EV-55 Electric Flight Distance [km]	EV-55 Electric Energy consumption [kWh]
Engine ramp up	0.0	0.00%	0.0	0.00	0	0.00%	0	0.00
$Taxi_1$	6.0	0.94%	3.6	1.86	6	3.67%	3.6	1.86
Take-off	0.6	0.09%	0.6	1.69	1	0.34%	0.6	2.80
Climb	17.2	2.70%	55.8	139.38	15	9.27%	44.7	116.43
Cruise	591.0	92.81%	2473.2	2271.80	120	73.25%	510.5	713.45
Descent	17.7	2.78%	91.6	47.50	18	10.81%	95.5	38.28
Landing	0.3	0.05%	0.5	0.64	0	0.21%	0.5	0.32
$Taxi_2$	4.0	0.63%	2.4	0.90	4	2.45%	2.4	1.24
Total	**636.8**	100%	**2627.66**	**2463.75**	**163**	100%	**657.79**	**874.38**

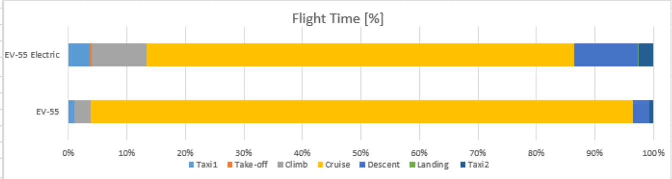
Climbing performance	EV-55	EV-55 Electric
Altitude	5000	5000
Averege Velociy Vy [	5.3	5.6
Time [min]	17.2	15.1

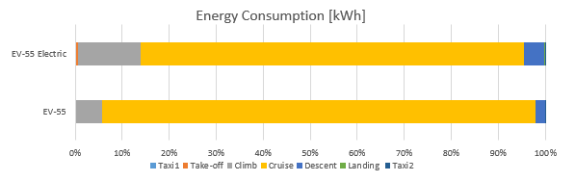
Evaluation parameter	EV-55	EV-55 Electric	Notes
Weight v power	1	1.00	Ability to accelerate, manoeuver, climb
Span loading	1	1.00	Efficiency of aircraft (increased range and endurance)
Speed v power and wing area	1	1.00	Indicator of aerodynamic and propulsice efficiency
Everling number E	1	1.00	Efficiency indicator (aerodynamic and propulsive)
disposable load v gross weigh	1	1.00	Structural weight performance
Disposable v empty weight	1	1.00	Structural integrity indicator (If too big --> structure might be ina
Fild performance	1	1.00	Airport performance indicator
weight v field length	1	1.00	High lift devices effectiveness
Top speed v stall speed	1	1.00	High speed performance indicator
Range per dollar price	1	0.25	Price indicator
Range flying efficiency	1	1.00	Range efficiency indicator
Range per pound gross weight	1	0.25	Structural efficiency indicator
Service ceiling	1	1.00	Aircraft complexity indicator
Occupants per dollar	1	1.00	Airliner performance indicator
Powerplant effectiveness p_η	1	1.00	Power plant effectiveness; where $C_{Lmax}=W_{take\ off}/(1/2*S*1.225*V_{S0}^2)$
Pazmany 'efficiency' factor η_x	1	1.00	Alternative indicator of aerodynamic and propulsive efficiency
Transport Efficiency	1	1.00	Transport efficiency
Total	17	15.50	





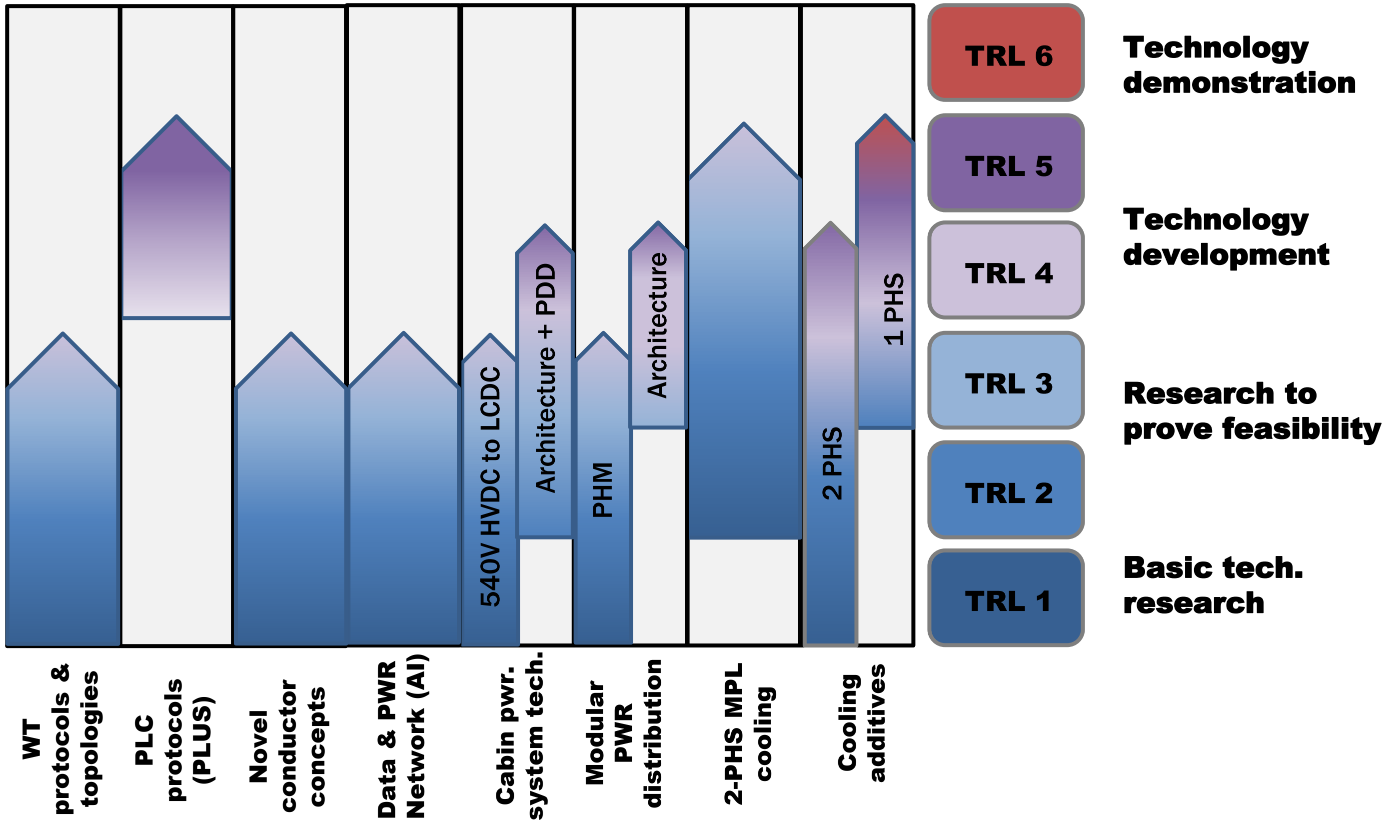






WP7.4 Main achievements and technical highlights

- Standardisation and Technology Maturity Assessment
  - Tailored TRL levels solutions for
    - Electrical Hardware
    - Thermal Hardware
    - Network Hardware
    - Protocols and Software
  - The adequate TRL levels are derived for specific solutions from
    - H2020
    - EASA
    - NASA



Advanced Data and power Electrical NEtwork Architectures and Systems

Thank you! Questions?

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006728.

Advanced Data and power Electrical NEtwork Architectures and Systems

Start date: 01/02/2021 - End date: 31/01/2024
Total EC funding: 4,018,012.75 EUR

Beneficiaries:

ADENEAS Project Coordinator
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