Introduction to NTNU Clean Aviation

September 27th – NTNU Innovation Hub, Gruva

Jonas Kristiansen Nøland & Camilla Knudsen Tveiten
Objective of this event

- Dessiminate NTNU Clean Aviation’s activities
- Highlight what is going on at NTNU & SINTEF, in the aviation sector, and the broader public
- We want to widen out NTNU’s perspectives on Clean Aviation
Agenda for the day

- Coffee & mingling (08:00–08:20, 09:00–09:20, 10:00–10:20, 11:00–11:20)
- Presentations (08:20–09:00, 09:20–10:00, 10:20–11:00, 11:20–12:00)
- Lunch (12:00–)
Before joining as an associated member:

- **Autumn 2020**: Submitted proposal with Expression of Ideas for Clean Aviation JU.
- **Spring 2021**: SINTEF/NTNU one out of seven short-listed proposals (90 in total).
- **July 30th, 2021**: Call for Expression of Ideas/Potential Members (CEI) signed.
- **October 21th, 2021**: Letter of Intent (LoI) signed.
- **December 7th, 2021**: Letter of Commitment (LoC) signed.
Areas addressed by the 7 short-listed ideas

CEI-2020-61 “WET2030+” (coordinated by MTU Aero Engines AG; Germany; total cost: 160 m€)
- Development of the Water-Enhanced Turbofan (WET) for ultra-efficient SMR aircraft

CEI-2020-25 “HEROPS” (coordinated by MTU Aero Engines AG; Germany; total cost: 242 m€)
- Development of hydrogen fuel-cell based propulsion for regional hybrid electric/full electric aircraft

CEI-2020-53 “TOOP” (coordinated by Airbus; Germany; total cost: 170 m€)
- Development of superconducting and cryogenic powertrain for regional hybrid/full electric aircraft

CEI-2020-52 “HYPE” (coordinated by GE Avio Aero; Italy; total cost: 160 m€)
- Development of hydrogen-combustion turbine for large-scale hydrogen-powered regional aircraft

CEI-2020-42 “HYTALIA” (coordinated by RISE SICOMP; Sweden; total cost: 3.5 m€)
- Development of aircraft ultralight, safe and reliable tanks for liquid hydrogen storage for regional hybrid/full electric aircraft

CEI-2020-32 “Certif2035” (coordinated by Dassault Aviation; France; total cost: 39.4 m€)
- Development and establishment of certification regulations and means of compliance for disruptive technologies

CEI-2020-79 “GREAT” (coordinated by SINTEF AS; Norway; total cost: 25 to 40 m€)
- Development of technologies to increase performance/reliability of electrical components and optimise efficiency of hydrogen-based propulsion system using superconductive power components

90 proposals in total
Camilla delivers a message regarding fast-tracking low-TRL technologies, de-risking currently planned technologies, and the need for academic involvement to ensure the development of next-generation engineers to the TC meeting, representing the Academic Member Forum (AMF).
Facts and figures

- **34** small and medium-sized enterprises
- **120** industry members
- **51** universities
- **33** research centres
- **244** participations in funded projects
- **€654M** EU funding
- **24** countries

Clean Aviation's journey to climate neutrality

Click here
Hybrid Electric propulsion system for regional AiRcrafT

Project description

Setting a course for hybrid electric thermal turboprops in regional aviation

In the next 20 years, regional market growth and a greater demand for lower emissions will push regional aviation towards innovative solutions to decarbonise the sector. The EU-funded HE-ART project will demonstrate the viability of a hybrid electric turboprop within a dedicated integrated “full-scale” ground test demonstrator. By combining an electric drive train with an ultra-efficient thermal turboprop engine and 100% sustainable aviation fuel compatibility, HE-ART will target efficiency improvement and reduction of GHG emissions up to 30%. Moreover, it will integrate new technologies including core thermal engine, electric drive train, electrical distribution, gearbox, propeller, nacelle and heat exchanger. Leading engine, propeller and aircraft manufacturers, research organisations and universities will collaborate to ensure the project’s success.

NTNU budget: €239k

Fields of science

documentation and technology > mechanical engineering > vehicle engineering > aerospace engineering > aircraft
nOVel low-prEssure cRyogenic Liquid hydrogEn storAge For aviation.

Project description

Better hydrogen storage can make air travel greener

The future of green, more sustainable flying will depend on hydrogen-powered aviation. At the moment, this technology is limited by the hydrogen storage aboard aircraft, whose energy-to-mass ratio is too low to be practical. The EU-funded OVERLEAF project will solve this by employing a design that utilises innovative materials to develop an innovative liquid hydrogen storage tank. This tank will seamlessly integrate with an aircraft’s fuselage and structure, while simultaneously achieving a gravimetric index of approximately 50% for 500 kilograms of hydrogen. This high energy-to-mass ratio will make the transition to hydrogen-powered flight viable for the first time and help achieve the European Green Deal by lowering the environmental burden of air travel.

NTNU budget: €603k

Project Information

OVERLEAF
Grant agreement ID: 101056818

DOI
10.3030/101056818

Start date
1 May 2022

End date
30 April 2025

Funded under
Climate, Energy and Mobility

Total cost
€ 5 951 731,25

EU contribution
€ 5 951 728,00

Coordinated by
ACITURRI ENGINEERING SL
Spain

Fields of science

engineering and technology > mechanical engineering > vehicle engineering > aerospace engineering > aircraft
engineering and technology > environmental engineering > energy and fuels
social sciences > economics and business > economics > sustainable economy
HydrogEn Lightweight & Innovative tank for zerO-emissions aircraft

Objective

To enable a technologically and economically feasible H2-powered aviation, new integral LH2 tank solutions are required that could serve as part of the airframe main structure and capable of withstanding its respective loads. The H2ELIOS project will develop an innovative and effective lightweight LH2 storage system for aircraft. It will be implemented as demonstrators in two fuselage-like cylinder section with approximately 1.9 m of external diameter and approximately 2.3 m of external length. These demonstrators would be duly supported by component and subsystem ground tests at appropriate scale at project completion (TRL 5 at storage level). The aim is that the concept is ready to be embedded and integrated in a specified aircraft architecture for flight demonstration in later stages.

H2ELIOS will provide a feasible and novel low-pressure double-layer composite tank-based system, enabling the tank shape to be either conformal or non-conformal to the profile of the aircraft. Its general effectiveness will be assessed in terms of high G1 performance and easiness of integration within the aircraft structure. This concept will be supported by latest evolutions of innovative methods and technologies in terms of multidisciplinary design development, manufacturing processes and means of compliance and shall be demonstrated in operational conditions: first on ground up to TRL5 and then in flight by the end of Clean Aviation Phase 2 clearing a TRL6 maturation gate. Finally, delivery to the market is expected in the 2030-2035 period. In this way this project shall contribute to accomplish the objectives of the European Green Deal regarding decarbonization of the aviation industry.

The activities of H2ELIOS will be supported by explicit agreed support of EASA and an External Advisory Board comprising commercial aircraft OEMs, H2 management and cryogenics experts, MRO services, airlines, aircraft system integrators, materials developers and suppliers and airports operation.

NTNU budget: €964k
Gemini Centre Green Aviation, 40 k€, 2022 - 2025: "Create a hub for national collaboration on R&D towards zero-emission aviation and accelerate international collaboration with other research institutes, universities, and industrial partners", NTNU & SINTEF.
The goal of Clean Aviation is net zero climate emissions for all flights by 2050. Electric propulsion is the preferred sustainable solution. We are conducting research on different solutions depending on the flight segment considered.

- Electric motors powered by batteries is a solution for commuter aircraft over shorter distances. It is very well suited for Norway, as we have one of the largest short haul networks in Europe.
- Hydrogen is even lighter than today’s aviation fuels, even without CO2 emissions. Through fuel cells, the chemical energy of the hydrogen may be converted into electricity, with clean water as the only byproduct. As a result, other influential climate gases, such as water vapor and NOx, are removed. Batteries tend to be too heavy for regional- and medium-haul flight segments.

Our interdisciplinary research initiative at NTNU aims to develop scalable zero-emission technology for the future. The development will accelerate through demonstrators of integrated solutions with the aim of increased sustainability, electrification, digitalization, and safety. We closely collaborate with the European partners in our journey toward future aviation, aiming to reduce emissions in aviation beyond “Highpath 2050”, i.e., CO2 by 75%, NOx by 90%, noise pollution by 60%.

Contacts
- Ole Morten Miltgård, Vice-Chair Sustainability and Innovation, Professor
- Jonas Kristiansen Neland, Coordinator, Associate Professor
- Camilla Knudsen Tveiten, Administrator

Publications
- C. M. Martlyn, J. K. Neland & R. Nilsson (2022), "Fuel Use of Liquid

Projects
- Gemini Centre Green Aviation, 40+k, 2022 – 2025: "Create a hub for national collaboration on R&D towards zero-emission aviation and accelerate international collaboration with other research institutes, universities, and industrial partners, NTNU, SINTEF"

Ongoing researcher projects
- Cryo-Electric Aviation, 2022-2023, 1 PhD student (1), 1 Industrial PhD student
- Electric Aviation, 2021-2024, 1 PhD student

Researchers
- Andreas Eckterweg
  Composite structures
- Marja Egesfargas
  H2 materials
- Svenkar Grammelott
  Sustainable Carbon Co-polymer
- Androa Graber
  H2 Combustion

BMS Haugen
Lightweight design
Paradislev Kobs
Hydrogen combustion materials
Robert Nilson
Permanent magnet machines
Jonas Kristiansen Neland
Electromagnetic, energy conversion
Pål Kure Olsen
S iron formations
Nicolai Pahrmaker
H2 fuel and safety
William Thonstad
Invert ice acceptance

Gemini Centre Green Aviation, 40+ k, 2022 - 2025: "Create a hub for national collaboration on R&D towards zero-emission aviation and accelerate international colaberation with other research institutes, universities, and industrial partners, NTNU, SINTEF"
Zero emission

STATUS QUO

Shut down aviation

A

2028

B

2035

C

Clean Aviation

NTNU
Leadership in education

Basic research for next-generation disruptive technologies

Complete demonstrators from source to propulsion

Public perception and societal acceptance

Socio-economic drivers & techno-economic benefits

Strategic measures NTNU (ambition)
Cryo-Electric Aviation Lab @ NTNU
Potential and Limitations of Battery-Powered All-Electric Regional Flights—A Norwegian Case Study

Abstract—The purpose of this study is to assess the viability of electric aircraft for short-haul regional flights in Norway. The study evaluates the technical feasibility, operational aspects, and economic viability of all-electric aircraft for regional flight operations. The analysis includes a comparison of all-electric and conventional aircraft in terms of performance, operational efficiency, and economic benefits.

Feasibility of Battery-Powered All-Electric Propulsion Systems for All-Electric Short-Haul Commuter Aircraft

Markus Aase Anker, Christian Barfus, Member IEEE, and Jesper Kristianen Nylinder, Senior Member IEEE

Abstract—Battery-electric aircraft are expected to play a significant role in the future of regional air transport. This paper investigates the feasibility of using all-electric propulsion systems for short-haul commuter aircraft. The study presents a comprehensive analysis of the technical, economic, and environmental implications of all-electric flight operations. The results highlight key design considerations and the potential benefits of electric propulsion in the aviation sector.

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Index Terms—Battery-electric aircraft, electric propulsion, mission profile modeling, regional flights, air transport, all-electric, battery performance, system integration, fuel efficiency.
Case 1: Tecnam P-Volt
9-seater
222 km/h
4.1 ton

Case 2: Heart Aerospace ES-19
19-seater
330 km/h
8.6 ton

Route 1: Kirkenes–Vadsø
38 km

Route 2: Bodo–Leknes
102 km

Route 3: Bodo–Stokmarknes
149 km

Route 4: Tromsø–Hammerfest
211 km
An abstract of the article: "Design of a Power-Dense Aviation Motor with a Low-Loss Superconducting Slotted Armature"

Abstract—This paper describes the design and analysis of a 2.5-kW, 3-phase superconducting motor designed for aviation applications. The motor, operating at 4.2 K, contains a superconducting core and windings, with the superconducting properties used to achieve low losses and high power density. The motor is designed to be compact, lightweight, and suitable for use in various aviation applications, such as hybrid-electric aircraft and electric propulsion systems for small aircraft. The design includes a novel slotted armature, which significantly reduces the eddy current losses in the armature, leading to improved efficiency and power density. The motor is designed to operate at 4.2 K, which allows the use of superconducting magnets and windings, resulting in very low eddy current losses. The paper presents the design details, including the superconducting material selection, coil design, and armature configuration, along with experimental results demonstrating the motor's performance.