DLR Design Challenge 2024

Dr. Markus Fischer, Chief Aeronautics Officer at the German Aerospace Center (DLR), invites students to delve into the future of regional air traffic. Through their innovative ideas and concepts, students will contribute to making feeder traffic more competitive and environmentally friendly for the future.

The task, set by DLR, is open to students at German universities. Interested students can register for the competition through their university's supervising institutes until March 14, 2024. Each team is limited to a maximum of six students. During the kick-off event on March 26, 2024, all participants will receive this year's task and a detailed explanation of its background. They will then have until July 21, 2024, to develop their concepts and holistic approaches. These proposals will be presented to DLR at a joint closing event, and the most outstanding designs will be honored. Evaluation of the results will be conducted by a jury of technical experts. The top three teams will be invited to present their concepts at the German Aerospace Congress 2024 (DLRK) in Hamburg. Additionally, the winning team will have the opportunity to showcase their results at the Congress of the International Council of the Aeronautical Sciences (ICAS) 2024 in Florence, Italy.

The DLR Design Challenge 2024 is organized around the following challenge:

Development of an environmentally friendly short-haul aircraft to serve regional routes in 2050, analyzing a given regional network of flight routes and selecting a cost-efficient operating concept. Taking innovative technologies into account, the economic efficiency and sustainability of the design will be ensured.

Introduction

Progressive climate change is increasingly determining our daily lives and a transformation of the energy and mobility sector is unavoidable. A holistic view of the process chain is necessary in order to be able to assess the impact of a change in the primary energy source of a means of transport on the environment. Air transport also plays an important role here. Flying in the future should be both environmentally friendly and affordable. To achieve this, new and alternative aircraft concepts with sustainable energy sources are needed. It is important to find out which concepts and technologies are most promising for which purpose.

The freedom to develop new concepts opens up new possibilities for aircraft design. The selection of an aircraft configuration, a suitable propulsion technology, its appropriate integration into the structure and the storage and provision of the energy source are among the greatest and at the same time most exciting challenges of the coming years. Innovations in materials, production methods and aerodynamics will make it possible to increase the efficiency of future aircraft. However, it is not only new technologies but also changing boundary conditions that are influencing the aircraft. Rising energy, labor and material costs as well as the general transformation of society are having an impact on air transport.

Task definition

This is where this year's DLR Design Challenge comes in. By considering the demand on a given network of heavily frequented European regional routes, the aim is to design an aircraft that optimally fulfils the requirements of efficiency and economy. The design space will be opened up so that participants can harmonize the mode of operation, propulsion technology and energy source. They are asked to design an aircraft for market entry in 2050 that fulfils the task set by combining revolutionary technologies with sustainable energy sources and intelligent operating concepts in a way that is both environmentally friendly and economically efficient. The scope is to design a single aircraft.

The aircraft designs are to be optimized based on two key indicators:

- Direct operating costs. The useful life is 20 years.
- Energy consumption / kilometre / passenger carried

It is up to the participants to choose a suitable compromise between these two objectives. To evaluate the concept presented, it should be compared with a suitable reference aircraft chosen by the participants themselves.

Design specifications

It is expected that various propulsion technologies based on sustainable energy sources will be discussed in the conceptual aircraft design. A qualitative comparison is sufficient to justify the choice of propulsion concept. Participants are free to decide in favor of a single or a combination of several energy sources. As the design task focuses on new configurations, concepts based solely on sustainable aviation fuels (SAF) will not be considered. However, the use of SAF is not prohibited in principle.

In order to enable operation with new technologies in 2050 that are not provided for by the current certification regulation (CS-25), the participants can adopt corresponding changes. These changes must be justified and evaluated accordingly.

The aircraft concepts should be capable of handling steep approaches and take-offs with a descent angle of more than 5.5° and a climb angle of 4° in order to meet the growing requirements for noise reduction during take-off and landing. These angle specifications must be adhered to during normal take-off and landing flights (All Engines Operative). In the event of an engine failure, the regular regulations apply.

Specific requirements apply to the aircraft and the following assumptions must be made:

Table 1: Design specifications

Maximum runway length	<1510 m
Sink angle below 1000 m	>5,5°
Ascending angle below 1000 m	≥4,0°
Average passenger weight (incl. luggage)	95 kg
Entry-Into-Service	2050
Diversion Range	250 km

All passengers are transported in a single-class configuration.

Assumptions for energy sources

The assumptions for various available energy sources are shown in Table *2* listed. These assumptions are projections for the year 2050 and are based on the results of the DLR EXACT project. For simplicity, it is assumed that these prices are constant at all airports in the network and that each energy source is available in sufficient quantities at each airport. All prices are given in $ /kWh.$_{2019}$

Table 2: Forecasted prices of various energy sources in 2050

Energy source	**Price**	**Lower calorific value**
SAF (E-Fuels)	0.104 $ /kWh$_{2019}$	43.2171 MJ/kg
Hydrogen	0.097 $ /kWh$_{2019}$	119.96 MJ/kg
Electrical energy	0.038 $ /kWh$_{2019}$	-

Direct operating costs

In order to ensure the comparability of the various designs, the Thorbeck methodology[1] must be used to calculate the direct operating costs (DOC). This method is based on data from aircraft with conventional propulsion architectures and the costs are scaled approximately linearly with the operating empty mass (OEM). For alternative energy sources such as batteries or hydrogen, however, the additional masses must be considered in a differentiated manner. Hoelzen et al. propose[2] modifications for this method, which will also be applied here. The modification for hydrogen-powered aircraft can be taken from the publication. When choosing electric or hybrid drive architectures, it is up to the participants to adapt the method accordingly. For this purpose, formula A11 of the paper should be generalized as follows for any propulsion architecture:

$$RC = RC_{kerosene} + \sum_{i} E_i \cdot k_i$$

The factor k represents the cost of energy storage. E_i is the amount of energy that can be carried in this energy storage system. For hydrogen, these values can be taken from the specified source; for batteries, a value of $\$200_{2019}$ /kWh can be assumed.

Network specifications

The network of regional routes comprises 15 European regional airports, mainly centralized on Hamburg. The corresponding connections are shown in IATA coding in Table *3* and are to be regarded as direct connections. However, Trondheim, Marseille, Sarajevo and Bari are exceptions. On these routes, a stopover at the specified airports is possible, but not mandatory. Only the airports specified for these routes may be considered for stopovers. A possible stopover must be considered when calculating the operating costs. A graphical representation of the network is Illustration 1 in the appendix. The participants are given a forecast weekly passenger demand, which must be covered by the aircraft and a corresponding operating concept. The specified total distance between the airports is to be regarded as the great circle distance.
The following assumptions must be considered when analyzing the network and developing a suitable operating concept:

- The demand is given per direction, but applies to both directions. Airport A to airport B 120 PAX/week therefore means A to B 120 PAX **and** B to A 120 PAX.
- All routes (A to B) should be carried out at least twice a week in each direction in order to achieve a high level of connectivity in the network.
- Only an integer number of flights per week should be considered (empty seats, if applicable; costs are allocated to passengers, not seats).
- Demand is to be regarded as constant (irrespective of transport supply).

[1] TU Berlin - Simplified DOC model, J. Thorbeck (remarks by D. Scholz)

[2] Hoelzen et al (2022): Hydrogen-powered aviation and its reliance on green hydrogen infrastructure - Review and research gaps. In: International Journal of Hydrogen Energy

- All passengers must be carried. Not transporting individual passengers or not flying some routes in order to achieve better efficiency is not permitted. The given passenger demand is already the result of further planning steps (ticket prices, flight scheduling, competition, etc.).
- It is not necessary to work out a precise flight plan. A weekly review is not required.
- All passengers accept the flight offer (regardless of the timing of the flight, etc.).
- In Hamburg, a maximum of 276 airport slots per week are available for this network. At least 142 of these are to be utilized. One slot is required per take-off and landing. This restricts the maximum number of available flight movements.

Table 3: Route network including passenger demand and great circle distance

				Distance in km			
Start	**Stop (optional)**	**Goal**	**Demand (PAX / week)**	**Total (direct)**	**Start - Stop**	**Stop - Goal**	**Total (incl. stop)**
GOT	-	VBY	751	361	-	-	-
HAM	-	RTM	228	419	-	-	-
HAM	-	ANR	177	464	-	-	-
HAM	-	GOT	1044	471	-	-	-
HAM	-	PRG	821	490	-	-	-
HAM	-	LUX	356	517	-	-	-
HAM	-	MUC	1263	601	-	-	-
HAM	-	SVG	498	643	-	-	-
HAM	-	BGO	559	795	-	-	-
GOT	-	UME	634	808	-	-	-
HAM	-	EDI	897	894	-	-	-
HAM	TRF	TRD	547	1095	478	619	1097
HAM	FDH	MRS	588	1188	578	665	1243
HAM	SZG	SJJ	534	1250	605	683	1288
BRI	SZG	HAM	431	1480	799	683	1482

Technical report, presentation and video

Technical report

The report is limited to 25 pages and should include a discussion of the derived design requirements. This includes all derived requirements for subsystems. A thorough literature search should be carried out. Dimensions, masses and key performance parameters of the aircraft should be presented. All tools and methods used to design and analyze the concept should be briefly described. This includes tool validation and verification of results using plausibility checks, handbook methods, historical data or other appropriate means. A systematic approach should be taken to substantiate the final concept as reasonable. The following data should be provided as a minimum:

- Three-sided view of the designed aircraft including dimensions.
- List of key technologies and reasons why they will be available for the EIS. (TRL estimation)
- Table summarizing the fulfilment of the design specifications

- Tables showing the weight composition of the concept, including weight of the structure (wings, fuselage, empennage, etc.), weight of the propulsion system, payload, energy storage, etc. The table should include empty weight, MZFW (empty weight + payload) and MTOW.
- Tables and/or figures containing the most important mission parameters of the concepts. These include climb and descent rates, cruising speed and altitude, aerodynamic and propulsion characteristics (e.g. glide ratio, energy consumption), energy consumption of the mission segments and the total energy consumption of the design missions.
- Payload/range diagram
- Tables and/or illustrations showing the aerodynamic properties of the concept. This includes an L/D- C_L trade and a breakdown of the total drag into the individual components.
- Explanation and graphical representation of a load and structure concept
- List of energy requirements and energy supply.
- Estimation of the costs of operating the design on the specified network.

Structure of the technical report

- Introductory material: The introductory material is required, but does not fall under the 25-page limit.
    - o Title page: Name of the project, name of the sponsoring organization or institution, name of the supervisor, head of the student team, date of submission;
    - o Abstract (1 page, written in German and English);
    - o List of members of the student team and number of semesters (Bachelor's or Master's degree programme);
    - o Letter from the supervisor confirming that the student has completed the thesis independently;
    - o Table of contents and nomenclature
- Main body: The main body (maximum 25 pages) must include the following:
    - o Introduction and brief overview of the underlying literature;
    - o Illustration of the developed aircraft design;
    - o Detailed specification of the aeroplane, based on the requirements set out in the "Terms of Reference" and "Technical Report" sections. The required tables and figures must be included.
    - o Conclusion and recommendations for further investigations;

Please note: Appendices are not assessed. Make sure that all essential information is included in the main body of your paper.

- Supplementary material: Supplementary material is required, but does not fall under the 25-page limit.
    - o Bibliography
- Optional additional material: This section does not fall under the 25-page limit:
    - o Picture of the submitting student group and/or pictures of the participants.

- List of students' postal addresses.

Lecture

The results must be presented at the final event of the challenge. The presentation of each team should not be longer than 20 minutes. The language of the slides and the presentation is English. Details of the presentation and the event will be communicated after the submission of the report. The slides used must be submitted to DLR no later than two days before the final event.

Video

In addition, the teams must create a pitch video in English lasting a maximum of 3 minutes. The content of the video can be freely customized by the participants. The video may only be created by team members. The required file format is .mp4 (video codec H.264). The resolution should be at least 1080p (**video format 16:9**). The video must be submitted to DLR with the slides no later than two days before the final event.

Evaluation of the concepts

The submitted reports are assessed by an independent jury on the basis of various criteria, which are derived from the "Technical report" section and the optimization objectives. In general, the form of the technical report and the use of specialized literature are included in the evaluation. The feasibility and innovation of the concept are also assessed. This includes that the use and availability of new technologies is assessed and well justified.

The results are included in the evaluation as follows:

- Written report 70 %
- Presentation 20 %
- Video 10 %

In the written report, the focus is on the aircraft concept presented. Care must be taken to ensure that the technical report contains the minimum data required in the relevant chapter. The specific assessment criteria for the assignment and their weighting are as follows:

- Aircraft design 60 %
- Optimization targets 30 %
- Form of the report 10 %

Further information

Within the scope of this DLR Design Challenge, DLR does not provide any technical supervision of the work that goes beyond the questions within the scope of the Q&A rules.

Conditions of participation

All participants must be enrolled at a German university, university of applied sciences or university of applied sciences. Registration for participation in the competition and for the kick-off event takes place via the supervising chair. In the case of inter-chair teams, registration is made by the chair of the team spokesperson. The application and documents must also be submitted via the supervising chair. Participants must agree that all submitted documents, illustrations and diagrams may be used for publication on the DLR website or for other types of public relations work, stating the author's name. This consent must be received by DLR before the kick-off event.

Dates

08.02.2024 **Announcement** of the DLR Design Challenge

14.03.2024 **Application for participation** by e-mail to DLR at DesignChallenge@dlr.de via the university supervisor

26.03.2024 **Kick-off event** for potentially interested professors and all participating teams

- Place: Braunschweig
- Costs: Travel costs (2nd class train journey, overnight stay the evening before) will be covered by DLR for all participating teams and the supervising university employee. A maximum reimbursement amount per team applies.

17.04.2024 **Q&A session**, virtual

21.07.2024 **Electronic submission** of the technical report by e-mail to DLR at DesignChallenge@dlr.de by 23:59

08.08.2024 **Final event** at DLR for all participating teams and the supervising professors to present the work and announce the winner or winning team

- Location: Hamburg-Finkenwerder (ZAL)
- Costs: Travel costs (2nd class train journey, overnight stay the evening before) will be covered by DLR for all participating teams and the supervising university employee. A maximum reimbursement amount per team applies.

09.-13.09.2024 **Presentation of** the winning team at the **34th Congress of the International Council of the Aeronautical Sciences (ICAS)**

- Location: Florence, Italy
- Costs: (economy flight, meals, accommodation) will be covered by DLR for the winning team. There is a maximum reimbursement amount for the team.

30.09.-02.10.2024 **Presentation** of award-winning work at the **German Aerospace Congress 2024 (DLRK 2024)**

- Place: Hamburg
- Costs: Travel costs (2nd class rail travel, conference fees) will be covered by DLR for the award-winning teams and the supervising university employee. A maximum reimbursement amount per team applies.

Submission guidelines

The following applies as a condition of participation and format requirement for all submitted work: contributions must be submitted in English. There are no restrictions on the part of the participants regarding the use, reproduction and publication of the content by DLR.

All entries must be received by 21/07/2024 at 23:59; entries received after this time will not be considered. Please do not wait until the last minute to check the file size and reduce the resolution of any integrated graphics, tables or images. All documents must be in **English. Save** the **file as .pdf**; other file formats will not be accepted.

Entries must be submitted electronically by e-mail to the following address:

- **E-mail address**: DesignChallenge@dlr.de
- **Subject**: DLR Design Challenge 2024 [team name]

All contributions must have the attachments to the email listed below. If your email server has an email size limit, the various attachments can be distributed across several emails. These emails should all be sent on the same day. Alternatively, it is preferable to submit the files via GigaMove at https://gigamove.rwth-aachen.de as a link in the email for large attachments.

1. A **digital document** that includes the following in one (!) file: Introduction, title page, main body, references, graphics, figures, scanned letter from the faculty, supplementary material, etc. The letter from the faculty must certify that the student's contribution has been reviewed and approved by a member of the faculty's academic staff and that the submission to the DLR Design Challenge is endorsed. Please also note the following:
   - Compress the file size of graphics and images in your work so that the file remains under **80 MB.**
   - Follow the instructions in point 5 for naming files.

2. A **digital document** that includes the following in one (!) file: Introduction, title page, main body, references, graphics, illustrations, additional material, etc. This document is identical in content to the document in point 1, but must **not** allow **any conclusions to be drawn about the name of the university or the participants.** Care must be taken to remove logos, university names, etc. from the pictures of the aircraft. This document ensures an unbiased assessment of the design.

   All other boundary conditions are identical to point 1.

3. A **digital document** that describes the design with the most important properties on **one page.** Please also note the following: The file must contain the following elements:
   - a **three-sided view** of the aircraft.
   - A table with the following data:
     - Geometric dimensions (wingspan, wing area, etc.)
     - Operating costs/pax/kilometer
     - Energy requirement/pax/kilometer
     - Surface load
     - Shear load
     - L/D
     - C_L in cruising flight
     - MTOM, OEM
     - Maximum range
     - Maximum payload
     - Cruising speed (in km/h and Ma)
     - Cruising altitude
   - Explanatory text on the aircraft concept and its special features. The operating concept and propulsion technology should also be explained.
   - A freely selectable illustration that justifies the choice of concept.

4. A high-resolution **digital photo of yourself at the university** or, if it is a team, a digital photo of the entire team at the university. Name the photo files with your surname or that of the team leader and submit them as **.png files.** Send us a caption in the body of the email with the name of the student in the photo from left to right. Images will not be judged; they will only be used to announce winners and other public recognition. For use in print media, images should be saved in the highest possible resolution, preferably at least **300 ppi** (image format: 4:3). Obtain the consent of the persons depicted for the publication of the images by DLR to announce the winners or for its other public relations purposes in advance. Please keep the declarations of consent and be able to produce them on request; please submit an electronic copy of the **declarations of consent** with your entry; all participating teams will receive a sample of such a declaration of consent by e-mail.

5. A high-resolution **digital image of the aircraft configuration**. The image should contain an appropriate caption stating the name of the student or team leader, the name of the university and, if applicable, the name of the aircraft. File format should also be **.png**. For use in print media, images should be saved in the highest possible resolution, preferably with at least **300 ppi** (image format 4:3). If you have built a model, please also send a photo of the model with the design team. Please keep the consent forms and be able to produce them on request; please submit an electronic copy of the **consent forms** with your entry; all participating teams will receive a sample consent form by e-mail.

6. Student release forms for small teams for each team member and for larger teams a release form with a signature page for all team members. Save everything in a **.pdf** file and send it by e-mail like the files mentioned above.

7. Please follow the instructions below when naming and saving your files:
   - Article: university_name_draft_name_report.pdf
   - Neutral contribution: Hochschulname_Entwurfname_Bericht_anonym.pdf
   - Photo: university_name_design_name_team_photo.jpg
   - Aircraft image: Hochschulname_Entwurfname_Luftfahrzeug.png
   - Student release forms: Hochschulname_Entwurfname_Freiga-ben.pdf
   - Declaration of consent: Hochschulname_Nachname_Einverstaendnis.pdf

   The terms DLR and competition should **NOT** be used in file names. Abbreviations of university names are acceptable. Example: Ludwig-Maximilians-Universität to LMU.

Formal requirements
Under no circumstances may formulations or ideas from other authors be used without correct acknowledgement of the source. If you use the statements or ideas, they must be clearly labelled as quotations and the source must be named in the footnotes. Submitted work that contains plagiarism will be **disqualified**. The paper, presentation and video must be prepared independently and **exclusively by team members.**

The structure of the technical report is already explained in the section "Structure of the technical report". As a reminder: the entire report (excluding the title page, foreword, abstract and directories) **must** not exceed **25 single-sided pages.** Furthermore, the **minimum font size is 10 points** and the **minimum line spacing is 1.0.** The page number is in the bottom right-hand corner. All tables, photos and illustrations must be signed. Sources must be cited in a citation format commonly used in scientific publications.

The paper should follow the standards of a technical report and should be well organized using headings and subheadings, with a clear transition from one section to another. The text should be clear and concise. The addition of appendices to the technical report is **prohibited**; ensure that all relevant information is included in the paper itself.

Recognitions

- Interested supervisors and the associated teams who have expressed an interest will be invited to the kick-off event in Braunschweig by DLR Executive Board Member for Aeronautics Dr Markus Fischer.
- Participating teams that have submitted work will receive feedback from the jury and will be invited to DLR by DLR Executive Board Member for Aeronautics Dr Markus Fischer for a presentation of their work and the announcement of the winning team (travel costs will be reimbursed, there is a maximum cost per team).
- All participants will receive a "DLR Design Challenge 2024" certificate and a high-quality photo print of their designed aircraft.
- The best three teams will be invited to present their designs at the German Aerospace Congress 2024 in Hamburg (travel costs will be reimbursed, a maximum cost per team applies).
- The winning team will be invited to a presentation of the design at ICAS 2024 in Florence (travel costs will be reimbursed, a maximum cost per team applies). Supervisors of the winning team are welcome to participate (self-financed).

Background information

DLR Design Challenge:	https://www.dlr.de/de/karriere-und-nachwuchs/angebote-fuer-studierende/dlr-design-challenge
Other:	https://www.dlr.de/de/forschung-und-transfer/luftfahrt/leitkonzepte

Jury

The jury selects the winners based on independent expert opinions.

- Jury chair: Dr Markus Fischer
- Jury members: Institute directors from the DLR Aeronautics research field

Contact us

Lucas Kugler, Simon Müller and Claudio Niro, e-mail: DesignChallenge@dlr.de

All information is subject to change. The Federal Travel Expenses Act applies. Legal recourse is excluded

Release notes

Version	date	Notes
1.0	26.03.2024	Publication of the document
1.1	17.04.2024	Q&A added. Questions also added to the respective chapter.

Questions and answers

Q: How should the distinction be made in the naming between anonymized and regular reports?

A: When submitting the reports, the addition "_anonymous" must be placed after the anonymized version. The full name is therefore "Hochschulname_Entwurfname_Bericht_anonym.pdf". After reviewing all reports, we will change the file names in a neutral way (Team A/B/C, etc.) and pass them on to the jury.

Q: Can you define the term "diversion range" precisely?

A: In the reserve mission, the *diversion range is* the distance to the alternate airport.

Q: What must be taken into account when calculating the reserve fuel? (e.g. additional fuel for 30mins + 5% allowance for temperature fluctuations)

A: The reserve mission consists of the following sub-phases: Go-Around, Flight to alternate airport (250km), Holding (typically for 30 minutes), Approach & Landing, 5% Contingency.

Q: Are there also slot restrictions for connections that do not depart from/to Hamburg?

A: No, these connections do not count towards the Hamburg slot limit.

Q: When calculating the operating costs, can/should the data given in the source (e.g. salaries for staff) be used, or should own data for the year 2050 be assumed?

A: The data available in the specified source should be adopted.

Q: What stage of development of the technology can be assumed for the year 2050? Does a previous design and test period have to be taken into account?

A: For technologies that are not yet certified, a technology assessment must be carried out. This can be done with the help of a standard TRL roadmap (Technology Readiness Level). It must be argued why the desired technology will be ready for use (tested and certified) in 2050.

Q: Can fuel types other than those specified in the task be considered? (e.g. methane)

A: Yes, fuel types other than those specified in the task can also be considered. However, care must be taken to make reasonable and realistic assumptions for fuel prices and technologies (propulsion, storage, distribution, etc.) and to be able to justify these. The infrastructure on the ground must also be considered. The goal of a climate-neutral aircraft must not be neglected.

Q: Can SAF be used as the only energy source in a hybrid-electric architecture (SAF gas turbine)? If not, is SAF hybrid-electric with a battery for intermediate storage allowed?

A: The first concept mentioned here is based on SAF as the only energy source. Therefore, this combination of an SAF gas turbine and electric drives is not authorized. However, the inclusion of a battery (e.g. in certain flight phases) for storing electrical energy makes the concept hybrid-electric and is therefore permitted.

Q: How is SAF defined? Are biofuels and e-fuels included?

A: The SAF prices shown are for e-fuels.

Q: For which configuration is the rate of climb meant?

A: The rate of climb requirement is for a normal, all engines operative (AEO), take-off. In case of an engine failure (OEI), it is sufficient for the aircraft to meet the regular certification requirements.

Additionally, it is prescribed that the increased climb and sink angles are only valid below an altitude of 1000 m. Above this altitude, normal trajectories can be assumed.

Appendix

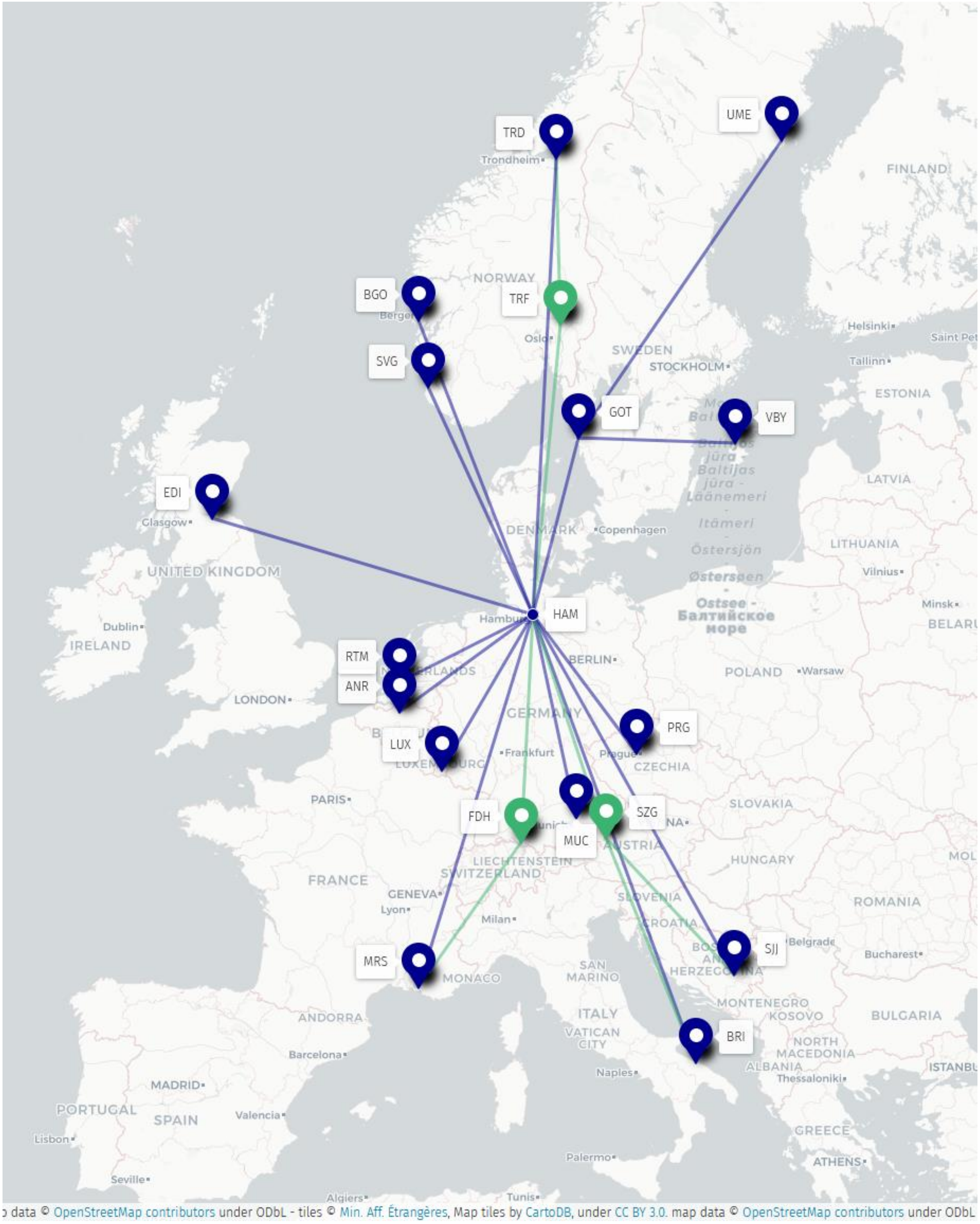

Illustration 1Regional route network with main airports (blue) and possible stopovers (green) (Source: OpenStreetMap)