

R&D for Safety and Human Performance



Royal NLR - Netherlands Aerospace Centre

AEROSPACE OPERATIONS SAFETY AND HUMAN PERFORMANCE

The Royal Netherlands Aerospace Centre (NLR) is an ambitious organisation that focuses on innovation in the aerospace industry. We assist aviation companies, air traffic control, airports, regulatory bodies and governmental authorities by translating trends and developments into solutions. Our cutting-edge research and unique facilities ensure that NLR stays abreast of new developments and innovations in an ever-changing industry.

This booklet gives an overview of our expertise in the fields of safety and human performance, plus some of the projects that we have been working on in recent years in operational safety, organisational performance, human-machine interaction and human performance. Discover more about our research, facilities and services.

Henk van Dijk Vice President Aerospace Operations Division In the operational safety field, NLR carries out research and gives advice on the safety of changes in the industry and the introduction of new concepts, operations and technology. Performing risk analyses gives customers an understanding of the risks and potential hazards that are identified. We are also involved in aeronautical studies (analysing safety at airports) and collision avoidance studies (analysing the division of the available airspace, e.g. with the increasing use of drones). Finally, NLR is involved in new certification methodologies in operations and organisations to enhance the safety of aviation in the future.

Operational safety

- Flight Data Monitoring
- Aeronautical study
- Collision risk modelling
- Safety assessments (e.g. operations, new technologies)
- Certification support

Research organisations: NLR, DLR, ONERA, CIRA, RTHA, Schiphol, AIA, ANA, Airbus Operations, Pipistrel, DeepBlue, Ferronats, JAA, FMI, OULU, ENSOSP, SOMNI, AEGEAN, Airbus Protect, EASA, FHNW Programme: Horizon Europe Duration: 2023 - 2025

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ALBATROS

Advanced systems and solutions for better practices against hazards in the aviation system

Since air travel is one of the most progressive branches of the transportation sector it is under pressure to be more environmentally efficient. ALBATROS is a wide scale initiative of major European aviation stakeholder groups to demonstrate how the technical and operational R&D achievements of the past years can transform the current fuel intensive aviation to an environment-friendly industry sector. Within the project, NLR focusses on new hazards in aviation and the impact of climate change on airports in Europe.

THE CHALLENGE

The goals of the work packages are:

- to assess the risk related to new hazards in aviation and of new aircraft entrants through a combination of modelling, expert judgment, and safety data analyses.
- to identify the potential impact of climate change on flight safety and flight operations at the airports.

WHAT WE ARE DOING

A new risk assessment method is developed with a scenariobased approach to determine the risk related to new hazards. Furthermore, a methodology and analysis of safety data for the identified scenarios is developed.

As for climate change, a risk profile per location and airport type is developed and the impact of climate change is assessed for airports in Europe.



This is done using a risk matrix showing each possible combination of probability of occurrence of a climatological change of a meteorological variable.

THE SOLUTION

Based on the proposed scenarios of new hazards, support to the process of safety assessment is given for identification and management of hazards posed by new systems/configurations or by new aircraft entrants e.g., specific analyses such as FMECA and FTA complementing the approach and contributing to the directed safety studies. The climate change effects and the forecasted changes are identified, using the latest available climate forecasts for Europe. Future changes in aircraft, ATC and airport operations are by identifying new concepts. An considered assessment with experts is done, where all hazards are identified and applied to generic airports and their locations. Finally, the risk levels are determined and mitigating measures are taken.

Integral Safety Analysis

The Dutch government has stated that an Integral Safety Analysis needs to be performed when new decisions about noise pollution lead to significant changes in air traffic. These decisions can have a significant impact on the development of air traffic at Amsterdam Airport Schiphol. The potential consequences of the decisions are therefore analysed.

THE CHALLENGE

The goal of the research project is to carry out an independent analysis of how new noise pollution measures affect overall and other relevant policy parameters, such as external safety, noise and emissions near Amsterdam Airport Schiphol and to address where safety might be compromised.

WHAT WE ARE DOING

In the 2024 Integral Safety Analysis, an analysis is made of whether measures aiming at limiting noise pollution have a detrimental effect on the overall safety of Amsterdam Airport Schiphol (both flight safety and external safety). NLR determines which ICAO accident categories are relevant and how the new measures affect the fatality risk. Furthermore, the impact on third party risk with respect to the accident probability, accident location and accident consequence is investigated.

THE SOLUTION

NLR will analyse how the ICAO accident categories are affected by new policies and how autonomous safety improvement influences safety at the airport. The research will result in an advisory report indicating how new policies affect safety at Amsterdam Airport Schiphol.

Project partners: Royal NLR Client; Dutch Ministry of Infrastructure and Water Management Year: 2024



Client: ATNS Zuid Afrika (Air Traffic Navigation Services) **Duration** : 2005 - 2024

Reduced Vertical Separation Minima in the African–Indian Ocean region

Since 2005, NLR has been involved in implementing Reduced Vertical Separation Minima (RVSM) in the African – Indian Ocean region (AFI region). RVSM allows the vertical separation between aircraft to be reduced from 2000ft to 1000ft between FL290 and FL410, allowing a more efficient division of the airspace. NLR is evaluating the vertical risk as a consequence of the introduction of RVSM annually to allow for safe implementation.

THE CHALLENGE

The AFI RVSM Safety Policy lists two specific safety objectives for collision risk assessment, namely an assessment of the technical vertical risk against a Target Level of Safety (TLS) of 2.5 x 10⁹ fatal accidents per flight-hour, and an assessment of the total vertical risk against a TLS of 5.0 x 10⁹ fatal accidents per flight-hour.

The annual analysis considers the pertinent preimplementation collision risk assessments based on the best possible data and information available prior to the actual implementation

WHAT WE ARE DOING

NLR has a long track record in this research area and has developed software tools for carrying out the analysis efficiently. The results of the annual assessments are being used by the regional monitoring agency to report the current state of affairs to the AFI states and to highlight the areas for improvement.

THE SOLUTION

NLR performs the annual assessment of the technical vertical risk and the total vertical risk against the TLSs. The assessment is based on the ICAO collision risk models. Based on operational data provided by the AFI States, the various parameters in the collision risk models are estimated and whether the TLSs have been met is evaluated.

Airport safety studies

A major area of expertise within the AOSH department is performing safety studies for airports. When there are changes in operations at an airport, a safety case is performed to analyse the impact of the new operation on safety at the airport and the associated risks are analysed.

THE CHALLENGE

The goal is to keep the operation of the airport safe. This can only be achieved by assessment of operational and infrastructural changes, data analysis for pro-active safety, assuring compliance with regulations and by installing a healthy safety management system. NLR supports all these areas.

WHAT WE DID/WHAT WE ARE DOING

Examples of safety cases by NLR:

 Research into the possibility of adjusting the airspace structure so that the probability of Traffic Alert and Collision Avoidance System (TCAS) Resolution Advisories (RA) between Visual Flight Rules traffic (VFR) under the

THE SOLUTION

In depth knowledge of airport related regulations, safety and risk management, safety data analysis and operational procedures enable a helicopter view of all the factors that build a safe airport operation. Terminal Manoeuvering Area (TMA) and Instrument Flight Rules traffic (IFR) in the TMA is minimised.

- Considering the ATC-related safety risks of using runway 18L in low visibility at Schiphol Airport.
- Analysis of the risk of runway crossings by aircraft, tow and vehicles at those locations during periods that the runway can be used for take-off or landing at Schiphol Airport.
- Workshops with airport, ground handlers, operators and ATC, to arrive at a shared understanding of the major risks of a change.
- ICAO Annex 14 compliance: transverse slope nonconformity and mitigating measures.
- Research into the braking performance of aircraft on contaminated runways.
- Determination of safety hotspots based on the analysis of a year of ground radar data.
- Cost benefit analysis: determination of the effectiveness of Runway Status Lights to reduce the risk of runway incursions.



Project partners: Royal NLR Clients: Amsterdam Airport Schiphol, Dutch Air Traffic Control (LVNL) Period: 2023 -2026

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The main driver of successful human-machine interaction is how the interaction between the operator and technology is shaped. To that end, NLR conducts research into automation within the aviation industry, for example with remote towers and single-pilot operations. Key areas of research are the impact of advanced automation on HMI design, effective task division between automation and operator, and adaptive automation.

Human-Machine interaction

- Development of effective HMIs
- Introduction of AI based decision support systems
- Human automation teaming





eMCO-SiPO Extended minimum crew operations – single-pilot operations

Ongoing developments in technology, automation and autonomous unmanned aircraft pave the way towards operating Commercial Air Transport (CAT) with reduced flight crews in large aeroplanes. Hence there is an interest to explore the options. Research is conducted into whether extended Minimum-Crew Operations (eMCO) and Single-Pilot Operations (SiPO) affect safety as compared to Multi-Crew Operations.

THE CHALLENGE

The two main objectives of this research project are to assess the feasibility and relevant issues of:

- the implementation of eMCO in the EU regulatory framework by developing a reference risk-assessment framework and investigating a series of key safety hazards and mitigations
- the implementation of SiPO in the EU regulatory framework through a preliminary analysis of the related main safety hazards

WHAT WE DID/WHAT WE ARE DOING

The feasibility of eMCO–SiPO is considered from the perspectives of both safety and efficiency. Within this scope, NLR focuses on the roles played by fatigue, sleep inertia, boredom and physiological needs for nominal and non-nominal flights and how these affect safety when going from Multi-Crew to eMCO or SiPO.



THE SOLUTION

A safety risk assessment covers the analysis of potential failure cases and the characterisation of their potential impact on flight operations, while evaluating the main mitigations at the level of flight crew working methods, operational procedures, and training. Furthermore, the relevant quantitative and qualitative input for the future impact assessment exercises launched for the development of eMCOs initially and later SiPOs rulemaking actions are provided. This includes an estimation of the operational benefits and cost elements associated with the introduction of eMCO and SiPO considering different types of aircraft operators and air operations.

JARVIS Just A Rather Very Intelligent System

Digitalisation presents possible solutions to the challenges that arise due to the ever-increasing complexity in the aviation ecosystem while simultaneously raising challenges that need to be addressed. For example, with increased air traffic due to autonomous and human operated aircraft, what will help to make safe and efficient Air Traffic Management possible within this new ecosystem? Applying the digitalisation trend means that new solutions to these kinds of problems can arise in the form of digital support.

THE CHALLENGE

The three key challenges addressed in JARVIS are:

- Data availability addresses how to manage the distributed data within the environment.
- Digital assistance addresses how to design digital agents that assist humans in comfortable, transparent, and simplified ways.
- Digital multi-agent system addresses how to assure safety and performance in AI-based decision making.

THE SOLUTION

JARVIS will design and validate three Al-based ATM solutions to support pilots, ATC operators and airport operators in non-safety and safety critical operations:

- An airborne digital assistant to support pilots.
- An ATC digital assistant to support ATC operators in different tasks.
- An airport digital assistant to support airport operators in several operative, safety tasks.

WHAT WE DID

Within the JARVIS project, NLR focusses on two main tasks:

- Creating a safety framework for the development of a digital assistance in the cockpit, in order to support the digital assistant designers in creating a safe cockpit tool.
- Develop guidelines for the design of human-Al teaming. These guidelines will among others be used for human-Al interfaces in the cockpit, at ATC and at airports.



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Project partners: Royal NLR, Collins, Deep Blue, NAIS, CIRA INDRA, Enaire, AIA Airbus, DLR, ENAV, Leonardo, Boeing, ENAC, Eurocontrol, Swedavia **Period:** 2023 - 2026

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In the field of human performance, NLR carries out research into the aspects of human performance that have the highest impact on safety and explores the potential of new sensors and algorithms to objectively measure aspects of human performance. The main drivers in this research are fatigue, workload and situational awareness. Research is conducted by doing experiments, e.g. by measuring brain activity or pupil size to give an indication of the workload. This is how NLR research helps enhance the working conditions of among others Air Traffic Controllers.

ROYAL NLR | SAFETY

Human performance

- Situational Awareness
- Fatigue / Vigilance
- Workload / Stress
- Resilience
- Teamwork



Project partners: Royal NLR, Welbees, Ecorys, MovingDot, CAAi, Ries Simons Consulting Client: EASA Period: 2022 - 2024

ATCO Fatigue

Air Traffic Controllers (ATCOs) face numerous fatigue-related challenges due to irregular working hours and demanding workloads. In response to the European regulations aimed at preventing ATCO fatigue and stress, a scientific evaluation funded by the European Union Aviation Safety Agency (EASA) was undertaken by a consortium of NLR and Welbees.

THE CHALLENGE

The three objectives of the research:

- 1. To assess the implementation of EU regulations on ATCO fatigue by Air Traffic Service Providers (ATSPs) in the EU.
- 2. To conduct research into the prevalence, causes and effects of ATCO fatigue to provide guidance and assess the need for possible further development of the related EU rules and practices.
- 3. To assess the potential impact of future technologies on the ATCO workload and fatigue.

THE SOLUTION

Data collection on a representative sample of 216 volunteer ATCOs at six ATSPs showed that 5.6% of duties were associated with a critical level of fatigue. The factors contributing most to these critical fatigue levels are night shifts, challenging weather conditions, monotonous traffic situations and extended working hours without breaks. To decrease the critical fatigue level further, improvements to the rostering process, enhanced fatigue data collection/monitoring mechanisms and practical operational measures for preventing ATCO fatigue should be considered.

WHAT WE DID

Research was conducted into the prevalence, causes and effects of ATCO fatigue in actual operations. This research included analysing exposure to fatigue in a sample of actual rosters from a representative sample of 16 Air Traffic Service Providers (ATSPs) in the EU. Both subjective and objective data on ATCOs' fatigue, sleep and workload was collected from ATCOs of six ATSPs. The aim was to validate the subjective fatigue ratings used in the subjective data collection campaign, to analyse the effects of fatigue on ATCO performance and to determine the feasibility for ATSPs of using objective measurement techniques to measure fatigue in real time during ATC operations.

CODA COntroller adaptive Digital Assistant

The Digital European Sky vision anticipates a complex future ATM environment with new airspace vehicles flying at varying speeds and altitudes, increasing the need to reduce ATM infrastructure costs while simultaneously enhancing performance. All is expected to provide the capacity to address challenges caused by increased air traffic complexity. However, the expanding use of Al in ATM poses a risk of inadequate man-machine integration, potentially leading to efficiency loss or accidents.

THE CHALLENGE

The major objective of the CODA project is to increase the efficiency, capacity, and safety of ATM, by optimising human–AI teaming. To this end, the aim is to demonstrate the possibility of developing a system in which tasks are performed collaboratively by hybrid human-machine teams and dynamically allocated through adaptive automation principles.

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WHAT WE ARE DOING

Prior to development of the AI application itself, it is important to establish the level of automation that is applicable nowadays in ATC, to describe how automation is applied in the operation (i.e. in a number of use cases) and to offer a perspective on the future role of the ATCO, and in particular how this role may be influenced by higher levels of adaptive AI. Within CODA, NLR is therefore focusing on conducting research into the definition of the ATCO future role.

THE SOLUTION

During the project, the following outcomes will be generated:

- an ATCO future tasks prediction model
- an ATCO future mental conditions prediction model
- a current ATCO mental state monitoring tool
- a human-AI teaming quality/level assessment tool
- an adaptive automation strategy
- a prototype of the CODA system capable of simulating specific scenarios in real time

Project partners: Deep Blue, ENAC, Brainsigns, CRIDA, UPM, Eurocontrol, IFATCA,UGR **Period:** 2023 - 2026

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Departures

Project partners: DLR, Stockholm University, Finish Institute of Occupational Health (FIOH), Jeppesen Client : EASA Period: 2021 - 2025

FTL 2.0 Flight Time Limitations Effectiveness study

To maintain safety during flight operations, flight time limitation requirements have been set to prevent crew fatigue. The research study FTL2.0 aims to perform a review of the effectiveness of the provisions concerning flight and duty time limitations and rest requirements contained in Annexes II and III of Commission.

THE CHALLENGE

The research includes an assessment of the impact on aircrew alertness of the following aircrew duty periods:

- Duties of more than 13 hours at the most favourable time of the day.
- Duties of more than 11 hours for crew members in an unknown state of acclimatisation .
- Duties including a high level of sectors (more than 6).
- On-call duties such as standby or reserve followed by flight duties, with a specific focus on 'other than airport standby'.

The research also comprises an assessment of the impact on aircrew alertness of controlled rest, including an analysis of the conditions and circumstances under which aircrew members take controlled rest.

WHAT WE ARE DOING

First, a literature review, online survey and selection of the airlines is done. Then fatigue-related data is collected from the representative sample of airlines; that data is cleaned, processed and analysed. Next, the end reports are written and (if needed) based on the results, these reports will include recommendations for EASA about altering current FTL regulations. Both the results and recommendations will be shared with the EU stakeholders (unions, NAAs, airlines etc.).

THE SOLUTION

The main task of the review is to collect objective and subjective fatigue-related data during the shifts of flight crews from a representative sample of at least 8 European airlines. This data collection campaign is supplemented by a literature review to determine the state of the art, as well as an online survey on standby and controlled rest, where more than 4500 responses of crew members have been gathered. An effective safety management system needs a healthy safety culture. Therefore NLR conducts research into organisational cultures and how changes in the organisation affect that culture. NLR also assists with the development and documentation of procedures and helps authorities with ways to increase the efficiency of oversight. A major topic in organisational cultures is the Safety Management System (SMS), which is a mandatory tool for organisations that allows them to manage safety in a structured way. Safety performance monitoring, risk management and change management are the main elements of the SMS. NLR assists in safety analyses domestically and in operational processes to enhance the organisational performance of companies in the aviation industry.

Organisational performance

- Performance monitoring
- Safety culture scan
- Change management
- Safety management systems (SMS/SSP)
- Risk based oversight
- Operational processes



Civil Aviation Authority Singaporesafety culture

The Singapore Aviation Safety Culture Framework was developed in early 2023, providing a safety culture framework specifically adapted for the Singapore aviation sector. This provides the sector with a shared basis for communication and improvement of the safety culture. The framework is consistent with ICAO publications on safety culture and contains both existing and new insights into safety culture.

THE CHALLENGE

What is innovative about the Singapore Aviation Safety Culture Framework is that it contains four sociocultural factors that indicate which sociocultural factors in Singapore need to be taken into account so that actions to improve the safety culture will be most effective.

WHAT WE DID

The following four milestones were developed during the project:

- Developing a Singapore Aviation Safety Culture Framework
- Developing and conducting a Safety Culture Survey
- Organising focus group meetings with leading organisations in the Singapore aviation sector
- Developing and publishing a Safety Culture Handbook

THE SOLUTION

The Singapore Aviation Safety Culture Framework was used as the basis for the Singapore Aviation Safety Culture Survey, which was sent to all 400+ organisations in the Singapore aviation sector. The target group includes inter alia airlines, air navigation service providers, ground handling services, maintenance organisations, aviation training organisations and CAAS Safety Regulation Officers. The results of this survey were presented at the Singapore Aviation Forum.

Focus group meetings and interviews were then organised with the leading organisations in the Singapore aviation sector. A total of 17 focus group meetings were conducted with the goal of obtaining information from management and operational personnel in the Singapore aviation sector that would help CAAS strengthen the trust between management and operational staff and foster a positive safety culture amongst all aviation workers.



Project partners: Royal NLR Client: Civil Aviation Authority Singapore (CAAS) Period: 2020 - 2024



SINGAPORE AVIATION SAFETY CULTURE FRAMEWORK





Deep Blue, ENAV, Indra, LFV, Nats, Pansa, UPM, LIU **Period:** 2023 - 2026

IFAV3 Increased Flexibility of ATCO Validations 3

In current operations, airspace is organised in sectors and an ATCO is responsible for handling the traffic within an allocated sector. These sectors have their own specificities in terms of shape, available routes, traffic patterns, and entry and exit procedures to surrounding sectors. ATCOs are trained to work in one specific sector. Increasing the number of sectors an ATCO is endorsed to work for, increases flexibility, cost efficiency of ATC and ATCO productivity. This will hold for Remote Tower Centres (RTCs), operating multiple airports with a flexible controller deployment, as well.

THE CHALLENGE

The major aim of IFAV3 is to simplify the process of acquiring and maintaining ratings for air traffic controllers to allow more flexible deployment of controllers within the control sectors of an Air Traffic Services Unit (ATSU). Furthermore, it will be investigated if the developed IFAV methods and ideas can be applied for a Remote Tower Centre (RTC).

WHAT WE ARE DOING

Within IFAV3, NLR investigates how training for the Area Control Centre (ACC) and RTC can be standardised, so that an ATCO can work in multiple sectors and towers, while maintaining the current level of safety. The successful and promising flexible endorsement strategies will be developed to TRL6 complete maturity and validated accordingly

THE SOLUTION

Building further on the FALCO project, IFAV3 will deliver detailed ready-to-use procedures about operations, training, rating maintenance and deployment. ATCO endorsement strategies will be further investigated and detailed to supplement all remaining aspects needed to reach a TRL 6 complete maturity. Furthermore, the knowhow about flexible ATCO endorsements from SESAR2020 will be transferred to RTCs.

About NLR

Royal Netherlands Aerospace Centre

NLR is a leading international research centre for aerospace. Its mission is to make air transport safer, more efficient, more effective and more sustainable. Bolstered by its multidisciplinary expertise and unrivalled research facilities, NLR provides innovative and comprehensive solutions to the complex challenges of the aerospace sector.

NLR's activities span the full spectrum of Research, Development, Testing & Evaluation (RDT & E). Given NLR's specialist knowledge and state-of-the-art facilities, companies turn to NLR for validation, verification, qualification, simulation and evaluation. They also turn to NLR because of its deep engagement with the challenges facing our clients. In this way, NLR bridges the gap between research and practical applications, while working for both government and industry at home and abroad.

Royal NLR stands for practical and innovative solutions, technical expertise and a long-term design vision, regarding their fixed wing aircraft, helicopter, drones and space exploration projects. This allows NLR's cutting-edge technology to find its way also into successful aerospace programmes of OEMs like Airbus, Boeing and Embraer.

NLR in brief



NLR AEROSPACE OPERATIONS SAFETY AND HUMAN PERFORMANCE:

NLR supports innovation in safety and human performance to ensure effective, efficient and safe operations. Royal NLR is ready to assist in :

- Airport safety studies
- Safety management studies
- Safety case and Risk assessments
- Human factors evaluation and measurements

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