МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ АЕРОНАВІГАЦІЇ, ЕЛЕКТРОНІКИ ТА ТЕЛЕКОМУНІКАЦІЙ
КАФЕДРА АЕРОНАВІГАЦІЙНИХ СИСТЕМ

ДОПУСТИТИ ДО ЗАХИСТУ

Завідувач кафедри

д-р техн. наук, проф.

______________В. Ю. Ларін

«____»________2023 р.

ДИПЛОМНА РОБОТА
(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА
ЗА ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ
«ОБСЛУГОВУВАННЯ ПОВІТРЯНОГО РУХУ»

Тема: «Особливості управління повітряним рухом при автоматизованому керуванні повітряним судном »

Виконав:____ Ляшик Р. С.

Керівник:____Богуненко М. М.

Нормоконтролер:_____________________________________ Аргунов Г. Ф.

Київ 2023

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF AIR NAVIGATION, ELECTRONICS AND TELECOMMUNICATIONS
AIR NAVIGATION SYSTEMS DEPARTMENT

PERMISSION FOR DEFENCE
Head of the Department
Doctor of Sciences (Engineering), prof.
_________________V.Y. Larin
"_____" __________ 2023

MASTER'S THESIS
ON THE EDUCATIONAL PROFESSIONAL PROGRAM
"AIR TRAFFIC SERVICE"
(EXPLANOTARY NOTE)

Theme: "Features of air traffic control during automated flight of an aircraft"

Performed by: ____ **Lyashik R. S.**

Supervisor: ____ **Bogunenko M. M.**

Standard inspector: ____________________________________ **Argunov G. F.**

Kyiv 2023

Факультет аеронавігації, електроніки та телекомунікацій

Кафедра аеронавігаційних систем
Навчальний ступінь «Магістр»
Спеціальність 272 «Авіаційний транспорт»
Освітньо-професійна програма «Обслуговування повітряного руху»

ЗАТВЕРДЖУЮ
Завідувач кафедри
д.т.н., професор
____________В. Ларін
« ___ »________2023 р.

ЗАВДАННЯ
на виконання дипломної роботи

_______________Ляшика Ростислава Сергійовича______________
(прізвище, ім'я, по батькові випускника в родовому відмінку)

1. Тема дипломної роботи: **«Особливості управління повітряним рухом при автоматизованому керуванні повітряним судном»** затверджена наказом ректора від "28" серпня 2023 № 1443/ст.2

2. Термін виконання роботи: з 23.10.2023 по 31.12.2023.

3. Вихідні дані до роботи: теоретичні дані керівних документів ICAO, EUROCONTROL та національних документів України у сфері організації повітряного руху, забезпечення та виконання польотів цивільних повітряних суден.

4. Зміст пояснювальної записки: опис та аналіз особливостей по управлінню повітряним рухом при автоматизованому керуванні повітряним судном. Аналіз процедурних методів особливостей по управлінню повітряним рухом при автоматизованому керуванні повітряним судном. Розрахунок ефективності впровадження цих методів в організацію управління повітряним рухом.

5. Перелік обов'язкового графічного (ілюстративного) матеріалу:

6. Календарний план-графік:

№ пор.	Завдання	Термін виконання	Відмітка про виконання
1.	Підготовка та написання 1 розділу «Аналіз дій авіадиспетчера по управлінню повітряним рухом при автоматизованому керуванні повітряним судном »	25.10.2023 – 02.11.2023	Виконано
2.	Підготовка та написання 2 розділу «Методи дослідження процесу прийняття рішення диспетчера по управлінню повітряним рухом при автоматизованому керуванні повітряним судном»	03.11.2023 – 10.11.2023	Виконано
3.	Підготовка та написання 3 розділу «Впровадження методів прийняття рішень авіадиспетчера по управлінню повітряним рухом при автоматизованому керуванні повітряним судном»	11.11.2023 – 23.11.2023	Виконано
4.	Підготовка та написання 4 розділу «Автоматизована обробка великих даних в аеронавігації»	24.11.2023 – 30.11.2023	Виконано
5.	Оформлення та друк пояснювальної записки	01.12.2023 – 03.12.2023	Виконано
6.	Підготовка презентації та доповіді	04.12.2023 – 07.12.2023	Виконано
7.	Попередній захист дипломної роботи	13.12.2023	Виконано

7. Дата видачі завдання: «29» вересня 2023 р.

Керівник дипломної роботи __________________ Богуненко М. М.
(підпис керівника) (П.І.Б.)

Завдання прийняв до виконання ______________ Ляшик Р. С.
(підпис випускника) (П.І.Б.)

РЕФЕРАТ

Пояснювальна записка до дипломної роботи «Особливості управління повітряним рухом при автоматизованому керуванні повітряним судном»: 90 сторінки, 37 малюнків, 1 таблиць, 32 вик джерел

Мета дипломної роботи – визначення оптимальних дій авіадиспетчера по управлінню повітрянним рухом при автоматизованому керуванні повітряним рухом.

Об’єкт дослідження – технологія дій авіадиспетчера по управлінню повітряним рухом рухом при автоматизованому керуванні повітряним судном.

Предмет дослідження - процес організації повітряного руху. Це включає в себе аналіз технічних, технологічних та функціональних аспектів автоматизованих систем, а також вивчення впливу різних факторів на їхню продуктивність та надійність у контексті авіаційних операцій.

Методи дослідження - теоретичні методи, аналітичні розрахунки та комп’ютерне моделювання.

Актуальність - актуальність дослідження полягає в можливості вдосконалити організацію повітряного простору, зробити більш безпечним, ефективним та екологічно стійким за допомогою розробки та оптимізації дій авіадиспетчера.

Результат дипломної роботи рекомендовано використовувати для організації потвітряного руху: Розроблені стратегії дій авіадіспетчера можуть бути використані авіакомпаніями, аеропортами для підвищення ефективності авіаперевезень,а також забезпечення безпеки.

Ключові слова: АВТОМАТИЗОВАНИЙ ПОЛІТ, АВІОНІКА, СИСТЕМА КЕРУВАННЯ ПОЛЬОТОМ, АВТОМАТИЗАЦІЯ НАВІГАЦІЇ, АВТОДРОСЕЛЬ, СИСТЕМА КЕРУВАННЯ ПОЛЬОТОМ (FMS), АВТОПІЛОТ, ПРОЦЕДУРИ ЗВ’ЯЗКУ, РАДІОЛОКАЦІЙНИЙ МОНІТОРИНГ, КООРДИНАЦІЯ ПОЛЬОТУ, ДОЗВОЛИ, КОНФЛІКТИ.

PAGE OF REMARKS

Faculty of Air Navigation, Electronics and Telecommunications
Air Navigation Systems Department
Specialty: 272 “Aviation Transport”
Educational Professional Program: “Air Traffic Service”

APPROVED BY
Head of the Department
_____________ V.Y. Larin
«__»___________________2023

Graduate Student’s Degree Thesis Assignment

_______________Lyashik Rostyslav Sergiyovich______________

1. The work subject: **Features of air traffic control during automated flight of an aircraft** approved by the Rector’s order of № 1443/st 2 from 28.10.2023.
2. The work (Thesis) to be completed between from 23.10.2023 to 31.12.2023.
3. Initial data to the work: theoretical data of ICAO, EUROCONTROL guiding documents and national documents of Ukraine in the field of air traffic management, ensuring and performing flights of civil aircraft.
4. The contents of the explanatory note: description and analysis of air traffic control features in automated flight of an aircraft. Analysis of procedural methods of air traffic control features in automated flight of aircraft. Calculation of the effectiveness of the implementation of these methods in the organisation of air traffic control.
5. The list of mandatory graphic (illustrated) materials

6. Calendar schedule:

№	Completion Stages of Degree Thesis	Stage Completion Dates	Completion Mark
1.	Preparation of Charter 1: “Analysis of air traffic controller's actions for air traffic control during automated flight of an aircraft”	25.10.2023 – 02.11.2023	Completed
2.	Preparation of Chapter 2: “Methods for studying the decision-making process of an air traffic controller during automated flight of an aircraft”	03.11.2023 – 10.11.2023	Completed
3.	Preparation of Chapter 3: “Implementation of air traffic controller's decision-making methods for air traffic control during automated flight of an aircraft”	11.11.2023 – 23.11.2023	Completed
4.	Preparation of Chapter 4: “Automated big data processing in air navigation”	24.11.2023 – 30.11.2023	Completed
5.	Designing and printing of the explanatory note	01.12.2023 – 03.12.2023	Completed
6.	Preparation of report and graphic materials	04.12.2023 – 07.12.2023	Completed
7.	Preliminary presentation of the graduate work	13.12.2023	Completed

7. Assignment accepted for completion: “29” September 2023

Supervisor ________________________ Bogunenko M. M.
(signature) (Full Name)

Assignment Accepted for Completion ___________________ Lyashik R. S.
(signature) (Full Name)

ABSTRACT

Explanatory note to the graduation work: Features of air traffic control during automated flight of an aircraft: 90 pages, 37 figures, 1 table, 32 used sources

The purpose of the research - determination of the optimal actions of the air traffic controller during automated flight of an aircraft.

The object of the research – The technology of the air traffic controller's actions in managing air traffic during automated aircraft control.

The subject of the research - the process of air traffic management. This includes the analysis of technical, technological and functional aspects of automated systems, as well as the study of the impact of various factors on their performance and reliability in the context of aviation operations.

The method of the research - theoretical methods, analytical calculations, mathematical and computer modelling.

Relevance - the relevance of the study lies in the possibility of improving the organisation of airspace, making them safer, more efficient and environmentally sustainable through the development and optimisation of satellite systems.

The results of the thesis are recommended for use in the organisation of downwind traffic: The developed air traffic controller action strategies can be used by airlines

Key words: AUTOMATED FLIGHT, AVIONICS, FLIGHT CONTROL SYSTEM, NAVIGATION AUTOMATION, AUTOTHROTTLE, FLIGHT MANAGEMENT SYSTEM (FMS), AUTOPILOT, COMMUNICATION PROCEDURES, RADAR MONITORING, FLIGHT COORDINATION, PERMISSIONS, CONFLICTS .

LIST OF ABBREVIATIONS

ACFT - Aircraft

AIP – Aeronautical Information Publication

ANS – Air Navigation System

ANSP – Air Navigation Service Provider

AOC – Air Operator Certificate

ATC – Air Traffic Control

ATCO – Air Traffic Control Operator

ATCS – Air Traffic Control System

ATFM – Air Traffic Flow Management

ATM – Air Traffic Management

ATS – Air Traffic Service

CAA – Civil Aviation Authority

CDM – Collaborative Decision-Making

CRM – Crew Resource Management

DSS – Decision Support System

DM – Decision Making

EMS – Environmental Management System

ES – Emergency Situation

EUROCONTROL – European Organization for the Safety of Air Navigation

FIR – Flight Information Region

FIS – Flight Information Service

FAA – Federal Aviation Administration

FE – Flight Emergency

FMS – Flight Management System

GANP – Global Air Navigation Plan

GASeP – Global Aviation Security Plan

IATA – International Air Transport Association

ICAO – International Civil Aviation Organization

ICDMS – Intelligent Collaborative Decision-Making System

IDSS – Intelligent Decision-Making System

IFR – Instrument Flight Rules

HF – Human Factor

KPA – Key Performance Area

SARPs – Standards and Recommended Practices

SESAR – Single European Sky ATM Research

SHEL – Software, Hardware, Environment, Liveware

SMS – Safety Management System

FMS – Flight Management System

TAWS – Terrain Avoidance and Warning System

SOP – Standard Operating Procedure

TCAS – Traffic collision avoidance system

ADS – Automatic Dependent Surveillance

EFIS – Electronic Flight Instrument System

CAT – Clear Air Turbulence

LIST OF DEFINITIONS

Flight Management System (FMS) - is an on-board multi-purpose navigation, performance, and aircraft operations computer designed to provide virtual data and operational harmony between closed and open elements associated with a flight from pre-engine start and take-off, to landing and engine shut-down. **Terrain Avoidance and Warning System (TAWS)** - is a safety net that automatically provides a distinctive warning to pilots when the their aeroplane is, based only on the radio altimeter reading and terrain closure rates derived therefrom, in potentially hazardous proximity to terrain.

Standard Operating Procedure (SOP) - a framework of common procedures set out by an airline which supports pilots in operating a commercial aircraft safely and consistently.

Traffic collision avoidance system (TCAS) - also known as a traffic alert and collision avoidance system, is an aircraft collision avoidance system designed to reduce the incidence of mid-air collision between aircraft.

Automatic Dependent Surveillance (ADS) - a surveillance technique in which aircraft automatically provide, via a data link, data derived from on-board navigation and position-fixing systems, including aircraft identification, four-dimensional position and additional data as appropriate.

Autopilot system - is a device that guides an aircraft without the pilot's direct assistance.

Instrument Landing System (ILS) - is defined as a precision runway approach aid based on two radio beams which together provide pilots with both vertical and horizontal guidance during an approach to land.

Autothrottle - is an electronic or electro-mechanical device that allows a pilot to control the thrust/power setting of an aircraft engine by selecting a specific flight profile, or parameter, rather than controlling fuel flow through manual manipulation of the thrust/power levers.

Electronic Flight Instrument System (EFIS) - a flight deck instrument display system in which the display technology used is electronic rather than electromechanical.

Air traffic management (ATM) - The dynamic, integrated management of air traffic and airspace including air traffic services, airspace management and air traffic flow management — safely, economically and efficiently — through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions.

Air traffic service (ATS) - A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service (area control service, approach control service or aerodrome control service).

Turbulence - caused by the movement of disturbed air relative to the flight path of an aircraft. Its origin can be either thermal or mechanical, occurring within or outside of clouds. Turbulence severity is proportional to the rate of change in airflow speed or direction, with the aircraft's mass influencing the perceived intensity.

Icing - in aviation refer to the formation of ice on an aircraft's surfaces, which can have significant implications for flight safety.

Clear Air Turbulence (CAT) - defined as sudden severe turbulence occurring in cloudless regions that causes violent buffeting of aircraft. This term is commonly applied to higher altitude turbulence associated with wind shear.

INTRODUCTION

Autopilot and automated flight systems stand as indispensable elements in contemporary aviation, playing a crucial role in elevating safety, efficiency, and accuracy across diverse flight phases. Their primary function involves alleviating pilot workload by automating repetitive tasks, allowing pilots to concentrate on higher-level decision-making and comprehensive monitoring. In the cruise phase, autopilot systems can uphold specific heading, altitude, and airspeed, alleviating pilots from continuous manual control and fostering a more relaxed operational environment.

An integral facet of automated flight systems is their advanced navigation capabilities, integrating technologies like GPS and inertial navigation systems. Flight Management Systems (FMS) further bolster navigation by facilitating the planning and execution of optimized routes, taking into account factors such as air traffic, weather conditions, and fuel efficiency. This not only streamlines flight operations but also contributes to overall fuel savings and operational cost-effectiveness.

Autopilot systems excel in enhancing precision and stability, offering meticulous control over the aircraft's pitch, roll, and yaw. This precise control results in a smoother flight experience, augmenting passenger comfort. Moreover, advanced autopilots can execute precise approaches and landings, proving particularly advantageous in challenging weather conditions where precision is paramount.

Automated systems ensure the consistency of flight operations by adhering to Standard Operating Procedures (SOPs). Autopilots strictly follow prescribed climb, cruise, and descent profiles, diminishing the likelihood of human error and enhancing the predictability of flight operations.

Safety during critical flight phases receives a substantial boost from the engagement of autopilots. These systems are frequently employed during takeoff and landing to maintain a stable and predictable flight path. Autoland systems, a subset of automated flight systems, are capable of executing fully automated landings, providing an additional layer of safety, especially in conditions with limited visibility.

Through the integration of Traffic Collision Avoidance Systems (TCAS) and Automatic Dependent Surveillance-Broadcast (ADS-B) technologies, automated flight systems contribute to collision avoidance and traffic management. These systems automatically adjust the aircraft's trajectory to ensure a safe separation from other air traffic, guaranteeing heightened situational awareness.

Fuel efficiency emerges as a notable advantage of autopilots, which optimize the aircraft's performance parameters. This optimization results in fuel savings, reductions in operational costs, and overall enhancements in fleet management. The amalgamation of autopilots with advanced avionics suites, featuring Terrain Awareness and Warning Systems (TAWS) and Enhanced Ground Proximity Warning Systems (EGPWS), further elevates safety and awareness.

As technology progresses, autopilots are evolving to become more adaptive and intelligent, incorporating artificial intelligence and machine learning. These advancements influence the development of automated flight systems, making them more responsive to dynamic flight conditions and enhancing their overall capabilities.

Ultimately, automated flight systems are meticulously designed to handle emergencies and abnormal situations effectively. From engine failures to system malfunctions, these systems can initiate appropriate responses, ensuring the safety and well-being of the aircraft and its occupants.

To achieve the goal of the diploma work, the following tasks must be solved:

1. Analysis of air traffic controller's actions for air traffic control during automated flight of an aircraft.
2. Methods for studying the decision-making process of an air traffic controller during automated flight of an aircraft.
3. Implementation of air traffic controller's decision-making methods for air traffic control during automated flight of an aircraft and modelling of the application of procedural methods.
4. Automated big data processing in air navigation.

1. ANALYSIS OF AIR TRAFFIC CONTROLLER’S ACTIONS FOR AIR TRAFFIC CONTROL DURING AUTOMATED FLIGHT OF AN AIRCRAFT

1.1 Overview of automated flight systems

Automated flight systems are critical in modern aviation because they provide advanced capabilities to improve safety, efficiency, and precision across all flight phases. Pilots use these systems strategically based on aircraft type, operational requirements, and regulatory considerations. Pilots frequently use the autopilot during the cruise phase to maintain a steady and efficient flight profile, allowing them to focus on monitoring systems, communicating with air traffic control (ATC), and managing other aspects of the flight. Automated systems play an important role in navigation and approach, particularly in instrument flight conditions, assisting with precision approaches and ensuring accurate runway alignment. Furthermore, some advanced systems support auto-land capabilities for fully automated landings in low-visibility environments.

By overseeing navigation, altitude control, and fuel efficiency, automated systems play a critical role in optimizing long-haul flights. This not only improves operational efficiency but also reduces the workload on pilots during long flights. The autopilot system, autothrottle system, Flight Management System (FMS), navigation sensors, communication systems, auto-flight envelope protection, and emergency systems are all critical components of automated flight systems. These elements work together to provide a smooth and controlled flight experience. Redundancy and emergency systems ensure the dependability and safety of automated systems, while auto-flight envelope protection keeps the aircraft from exceeding safe operating limits.

Let’s describe each system:

Autopilot system:

An autopilot system is a device that guides an aircraft without the pilot's direct assistance. Early autopilots could only maintain a constant heading and altitude, but modern autopilots can control every aspect of the flight envelope from takeoff to landing. Modern autopilots are typically linked to the flight management system (FMS) and, if equipped, the autothrottle system.

Autopilot software, which is integrated with navigation systems, is capable of controlling the aircraft during all phases of flight. If an autothrottle/autothrust system is installed, the appropriate thrust can be set automatically during takeoff and then adjusted automatically as the aircraft climbs at the appropriate speed for its mass and ambient conditions. The aircraft is then leveled at the desired altitude or flight level, and the power is adjusted to achieve and maintain the programmed speed. Simultaneously, the aircraft follows the flight plan route. If an autothrottle is not installed, the pilot must make all necessary power adjustments for the autopilot mode and phase of flight.

When the descent begins, the power is adjusted, and the aircraft descends at the appropriate speed and route, leveling as needed in accordance with the flight clearance until the approach begins. If this is a Category III Instrument Landing System (ILS) approach with Autoland, the autopilot directs the aircraft flight path to follow the ILS glide path and localiser, adjusting power to maintain the appropriate speed and initiating the flare as needed to achieve a safe landing without the runway becoming visible until the final stage of the approach. The autopilot on some aircraft can then guide the aircraft so that it maintains the runway center line until it comes to a stop.

The pilot can intervene at any time during the flight by making appropriate inputs to the autopilot or the FMS. In an emergency, the pilot can deactivate the autopilot and take over manual control, typically by pressing a switch conveniently located on the control column (although other methods of deactivating the autopilot are available). Modern aircraft have an additional switch or throttle position that allows the pilot to switch from approach to go-around mode instantly if necessary. If the aircraft lacks an automatic go-around function, the pilot must deactivate the autopilot and fly the missed approach manually.

The safe and efficient operation of automatic systems is dependent on a thorough understanding of the equipment's capabilities and design philosophy. Failure to achieve this level of comprehension has resulted in a number of fatal accidents.

One of the notable features of Boeing autopilot systems is their adaptability and integration with other avionics. Autopilots can work in conjunction with flight management systems (FMS) to follow pre-programmed routes, waypoints, and altitude profiles. This level of automation contributes to more precise and efficient flight operations.

Figure 1.1. Example of autopilot in boeing

Autothrottle / Autothrust

Definition

An automatic throttle, also known as an autothrottle or autothrust (depending on the manufacturer), is an electronic or electro-mechanical device that allows a pilot to control the thrust/power setting of an aircraft engine by selecting a specific flight profile, or parameter, rather than controlling fuel flow through manual manipulation of the thrust/power levers.

Automatic throttles have existed in their most basic form since the late 1940s. The first models were built with the intention of automatically adjusting engine output to maintain a specific aircraft angle of attack. Improvements in design and functionality over time enabled the autothrottle to maintain a preset airspeed, and additional features were eventually added to help prevent airspeed exceedances.

Current cutting-edge A/T systems can be used in all phases of flight, from takeoff to landing, though there are many less capable systems in use that cannot be engaged until the aircraft is airborne or that must be disengaged prior to landing. In general, the autothrottle is controlled strategically via the Flight Management System, either through the input of a Cost Index or through the input of specific IAS/mach values for climb, cruise, and descent, and tactically through manual selections via the Flight Control Unit (FCU) or Mode Control Panel (MCP).

Similarly (and depending on FMS capability), takeoff and approach speed parameters can be manually computed and entered into the FMS by the flight crew, or automatically calculated by the FMS and confirmed by pilot selection. FMS speed parameters and FCU speed selections both result in appropriate Flight Director guidance and autothrottle generated thrust values. The thrust levers may or may not physically move with A/T system changes to engine thrust output, depending on the aircraft manufacturer. The pilot always has the option of disabling the A/T system and controlling the thrust/power via the control levers.

The majority of autothrottle systems are designed to operate in one of two modes: speed mode or thrust mode:

Thrust Mode - Thrust mode is typically used for takeoff, climbing, and descending. For takeoff, the thrust will be set to a fixed value based on rated thrust, derated thrust, or the thrust value associated with an assumed temperature (FLEX) based on pilot selection. It will stay at that setting until the transition to the climb phase occurs. The A/T system will command the engines to maintain the appropriate climb thrust value while in climb, and the aircraft speed will be "on the elevators," that is, the appropriate climb speed will be maintained based on aircraft pitch. For descent, the A/T will reduce thrust to idle, and speed will be determined by the aircraft pitch attitude.

It is worth noting that, for the sake of passenger comfort, many autothrust systems have been refined to not command climb or idle thrust for a minor change in altitude, instead employing an intermediate thrust setting more appropriate to the magnitude of the change.

Speed Mode - In speed mode, the autothrottle adjusts engine thrust to maintain the speed value specified by the FMS or by the pilot via the FCU. Most systems do not allow you to select a speed that is outside of the aircraft's speed envelope.

Liabilities

While an autothrust system can significantly reduce pilot workload in virtually all phases of flight, there are some risks that can result in an undesirable profile or aircraft state, particularly if the A/T system is not used as recommended by the manufacturer or if the pilot's understanding of the autothrust and its integration with other systems and components is incorrect or incomplete. Here are some examples:

Many autothrust systems use Radio Altimeter height information to command idle thrust at the appropriate point during the landing sequence. An incorrect radio altimeter input during another phase of flight could result in an unwelcome, and potentially disastrous, reduction in thrust.

Inadequate understanding and/or incorrect selection of flight director/autopilot modes may result in an autothrust system response that differs from what was expected.

When encountering moderate or greater turbulence, many manufacturers recommend selecting a specific flight director/autopilot mode or disconnecting the autothrust. Failure to comply can result in significant airspeed deviations.

Any of these conditions has the potential to cause an undesirable aircraft state, necessitating immediate pilot intervention to avoid an exceedance or an accident.

A Flight Management System (FMS) is an on-board multi-purpose navigation, performance, and aircraft operations computer that provides virtual data and operational harmony between closed and open elements associated with a flight from pre-engine start and take-off to landing and engine shut-down.

The majority of modern commercial and business aircraft are outfitted with an Electronic Flight Instrument System, which replaces traditional systems and flight deck displays.

An FMS is made up of four major components:

The Flight Management Computer (FMC); the Automatic Flight Control or Automatic Flight Guidance System (AFCS or AFGS); the Aircraft Navigation System;

and an Electronic Flight Instrument System (EFIS) or equivalent electromechanical instrumentation are all part of the flight management system.

The FMC is a computer system that uses a large data base to allow pre-programmed routes to be fed into the system via a data loader. The system is constantly updated with the aircraft's position using available navigation aids. During information update, the most appropriate aids are automatically selected.

Sensor data is received by the AFCS or AFGS from other aircraft systems. AFCS mode selections made by the crew will either automatically move and control the aircraft flight control surfaces or display Flight Director commands for the pilot to follow to achieve the desired status, depending on whether the aircraft is under Autopilot or manual control.

The Navigation System is an integrated package that continuously calculates the aircraft's position. In addition to receivers for ground-based aids, it may include Inertial Reference System (IRS) and Global Positioning System (GPS) (GPS) inputs. The display of these navigational inputs on an EFIS is based on the Attitude and Heading Reference System (AHRS).

The effect of FMS aircraft control is most visible when the aircraft status is displayed on either EFIS or conventional instrumentation.

CNS/ATM stands for Communication, Navigation, and Surveillance.

The manner in which improved capabilities of satellite-based navigation and digital data link communication systems will enable the next generation of ATM systems to combine Automatic Dependent Surveillance (ADS) (ADS) and Controller-to-Pilot Data Link Capability (CPDLC) with traditional ATC functions. CNS/ATM refers to the combination of these enabling CNS technologies and their application to ATM. (EUROCONTROL EATM Terminology Glossary)

History of autopilots

First autopilots

During World War II, autopilot technology became increasingly essential as it allowed pilots to automate certain flight control functions, providing them with much-needed assistance in challenging and dynamic combat situations. The

Honeywell C-1 autopilot control panel would have been a part of various military aircraft, aiding pilots in maintaining control, stability, and accuracy during missions.

Figure 1.2. A World War II-era Honeywell C-1 autopilot control panel

To fly safely in the early days of aviation, aircraft required the constant attention of a pilot. As aircraft range increased, allowing longer flights, the constant attention caused severe fatigue. An autopilot is intended to take over some of the pilot's duties.

Sperry Corporation created the first aircraft autopilot in 1912. A gyroscopic heading indicator and attitude indicator were linked to hydraulically operated elevators and rudder by the autopilot. (Ailerons were not connected because wing dihedral was expected to produce the required roll stability.) It allowed the aircraft to fly straight and level on a compass course without requiring the pilot's attention, reducing the pilot's workload significantly.

Lawrence Sperry, the son of renowned inventor Elmer Sperry, demonstrated it in 1914 at a Paris aviation safety competition. Sperry demonstrated the invention's credibility by flying the plane with his hands away from the controls and visible to onlookers. After the war, Elmer Sperry Jr., the son of Lawrence Sperry, and Capt Shiras worked on the same autopilot, and in 1930, they tested a more compact and reliable autopilot that kept a US Army Air Corps aircraft on a true heading and altitude for three hours.

The Royal Aircraft Establishment in the United Kingdom developed a pilots' assister autopilot in 1930, which used a pneumatically spun gyroscope to move the flight controls.

Autopilot was improved, for example, with improved control algorithms and hydraulic servomechanisms. Adding more instruments, such as radio-navigation aids, enabled night and bad weather flights. In 1947, a US Air Force C-53 flew across the Atlantic entirely under the control of an autopilot, including takeoff and landing. Bill Lear received the Collier Trophy in 1949 for developing his F-5 automatic pilot and automatic approach control system.

The Standard Oil tanker J.A. Moffet was the first ship to use an autopilot in the early 1920s.

The Piasecki HUP-2 Retriever was the first helicopter in production with an autopilot.

The Apollo program's lunar module digital autopilot was an early example of a fully digital autopilot system in spacecraft.

Modern autopilots

The selected flight reference is now the Flight Path Vector (BIRD ON). The BIRD symbol is your flight reference and materializes the aircraft current trajectory. If the FD is ON, the FD Flight Path Director (FPD) is displayed. The selection is now indicated by TRK-FPA legends on the FCU display.

Figure 1.3. A modern flight control unit from an Airbus A340.

Not all passenger planes flying today have an autopilot system. Older and smaller general aviation aircraft, in particular, are still flown by hand, and small airliners with fewer than twenty seats, which are used on short-duration flights with two pilots, may also be without an autopilot. International aviation regulations generally make the installation of autopilots in aircraft with more than twenty seats mandatory.

Autopilots for smaller aircraft have three levels of control. A single-axis autopilot controls an aircraft only in the roll axis; these autopilots are also colloquially known as "wing levellers" due to their single capability.

A two-axis autopilot controls an aircraft in both the pitch and roll axes and may be nothing more than a wing leveller with limited pitch oscillation-correcting capability; or it may receive inputs from on-board radio navigation systems to provide true automatic flight guidance once the aircraft has taken off until shortly before landing; or its capabilities may lie somewhere in between these two extremes. A three-axis autopilot adds yaw control but is not required in many small aircraft.

Modern complex aircraft autopilots are three-axis and divide a flight into taxi, takeoff, climb, cruise (level flight), descent, approach, and landing phases. There are autopilots that can automate all of these flight phases except taxi and takeoff.

An Autoland is an autopilot-controlled approach to landing on a runway and controlling the aircraft on rollout (i.e. keeping it in the center of the runway), where the autopilot uses an Instrument Landing System (ILS) Cat IIIc approach when visibility is zero. These approaches are now available on many major airport runways, particularly at airports prone to adverse weather conditions such as fog. The aircraft can usually stop on their own, but in order to exit the runway and taxi to the gate, the autopilot must be disengaged. An autopilot is frequently used as part of a Flight Management System.

To control the aircraft, modern autopilots use computer software. The software reads the aircraft's current position and then controls the aircraft's flight control system to guide it. In such a system, in addition to traditional flight controls, many autopilots include thrust control capabilities that can control throttles to optimize airspeed.

An inertial guidance system typically reads the autopilot's position and the aircraft's attitude in a modern large aircraft. Errors in inertial guidance systems accumulate over time. They will include error reduction systems such as the carousel system, which rotates once per minute and dissipates errors in different directions, resulting in an overall null effect.

Drift is an error in gyroscopes. This is because physical properties of the system, whether mechanical or laser guided, corrupt positional data. Disagreements between the two are resolved using digital signal processing, specifically a six-dimensional Kalman filter. Roll, pitch, yaw, altitude, latitude, and longitude are the six dimensions most commonly used. Because aircraft may fly routes with a required performance factor, the amount of error or actual performance factor must be monitored in order to fly those routes. The longer the flight, the greater the accumulation of error within the system. To correct the aircraft's position, radio aids such as DME, DME updates, and GPS may be used.

1.2 Influencing Factors on Autopilot System

Aircraft autopilot systems are highly sophisticated and designed to navigate a wide range of scenarios. Their performance during automated flight, however, can be influenced by a variety of factors. Adverse weather conditions, such as severe turbulence or abrupt changes in direction, have the potential to interfere with the autopilot's ability to maintain stable flight. Icing, or the presence of ice on aircraft surfaces, poses a risk because it affects sensors and control surfaces, potentially leading to inaccurate readings.

System failures, including sensor malfunctions such as airspeed indicators or gyroscopes, can cause inaccuracies in data input for the autopilot. Furthermore, errors or bugs in the autopilot software can cause unexpected behavior, jeopardizing the system's overall reliability.

Navigation and communication issues may arise, with GPS signal loss or communication failures affecting the autopilot's navigation precision and ability to receive instructions from air traffic control. Human factors, such as insufficient monitoring or improper pilot intervention, may contribute to autopilot performance issues.

Mechanical failures in aircraft systems such as hydraulics or control surfaces can impede the autopilot's control of the aircraft. The loss of engine power complicates matters even more, affecting the autopilot's ability to maintain both altitude and stability.

Airspace and traffic conditions complicate matters, with conflicting air traffic control instructions or unexpected traffic situations necessitating autopilot adjustments. Regulation and procedure changes, as well as outdated navigation databases, may necessitate autopilot system updates.

The vulnerability of autopilot systems to cybersecurity threats such as hacking or cyber attacks puts functionality and safety at risk. Despite these difficulties, autopilot systems are carefully designed with redundancy and fail-safe features to mitigate potential problems.

The importance of pilots in addressing these issues cannot be overstated. Pilots bring a critical human element to monitoring and responding to complex scenarios during flight, as they are trained to take manual control in the event of autopilot malfunctions or unforeseen circumstances. To ensure safe and efficient flight operations, aviation professionals must stay up to date on the latest developments and guidelines in autopilot systems.

Although aircraft autopilot systems are highly advanced and capable of handling a wide range of situations, a variety of factors can influence their performance during automated flight. Weather conditions are important because severe turbulence can interfere with the autopilot's ability to maintain stability, and ice accumulation on surfaces can disrupt sensors and control systems.

System failures, particularly in sensors such as airspeed indicators or gyroscopes, put autopilot accuracy at risk. Software bugs can cause unexpected behavior, jeopardizing the system's dependability. Issues with navigation and communication, such as GPS signal loss or communication failures with air traffic control, can impair the autopilot's ability to navigate accurately.

Human factors add another layer of complication. Improper pilot intervention, such as overriding the autopilot without complete comprehension, can cause problems.

Furthermore, pilot monitoring is critical; lapses in attention or complacency can lead to delayed responses to potential problems.

Failures in the system, particularly in sensors such as airspeed indicators or gyroscopes, jeopardize autopilot accuracy. Unexpected behavior from software bugs can jeopardize the system's dependability. Navigation and communication issues, such as lost GPS signals or communication breakdowns with air traffic control, can impair the autopilot's ability to navigate accurately.

Human factors complicate matters even more. Improper pilot intervention, such as overriding the autopilot without full comprehension, can lead to issues. In addition, pilot monitoring is critical; lapses in attention or complacency can result in delayed responses to potential problems.

Despite these obstacles, autopilot systems are built with redundancy and fail-safe features to mitigate potential problems. These redundancies ensure that the autopilot can continue to operate safely even in the event of sensor failures or unexpected circumstances. Pilots are extensively trained to handle manual control in the event of an autopilot malfunction or an unexpected situation, emphasizing the importance of human oversight in ensuring flight safety.

Let us go over the most common factors that can have an impact on how well an autopilot system works.

Turbulence and severe turbulence

Description

Turbulence is caused by the movement of disturbed air relative to the flight path of an aircraft. Its origin can be either thermal or mechanical, occurring within or outside of clouds. Turbulence severity is proportional to the rate of change in airflow speed or direction, with the aircraft's mass influencing the perceived intensity.

Strong winds creating significant mechanical turbulence when they pass over irregular terrain or obstacles. Additionally, lower-intensity turbulence near the ground may result from surface heating-induced convection. Convective activity, particularly near thunderstorms or near a Jet Stream with steep temperature gradients, can also contribute to turbulence. Jet Stream Turbulence, like Mountain Wave Turbulence, occurs outside of clouds and manifests as Clear Air Turbulence (CAT).

Following or crossing behind another aircraft may expose an aircraft to Wake Vortex Turbulence, which is characterized by the preceding aircraft's wingtip trailing vortices. Although transient, this turbulence can be localized and severe at times.

Turbulence in the lee of the landscape can be caused by airflow over or around elevated terrain, resulting in violent and potentially uncontrollable effects such as extreme pitch and/or roll, particularly for smaller aircraft.

Wind shear, which is defined as rapid changes in wind velocity within relative air movements, can necessitate significant control inputs to compensate for abrupt deviations from the intended flight path. Such encounters can be especially dangerous at low altitudes, where any loss of control can happen close to the terrain, making recovery difficult. Microbursts, or extreme downdrafts beneath cumulonimbus clouds, are examples of Low-Level Wind Shear conditions.

Turbulent whirls near the size of the aircraft induce chaotic rolls, pitches and yaws.

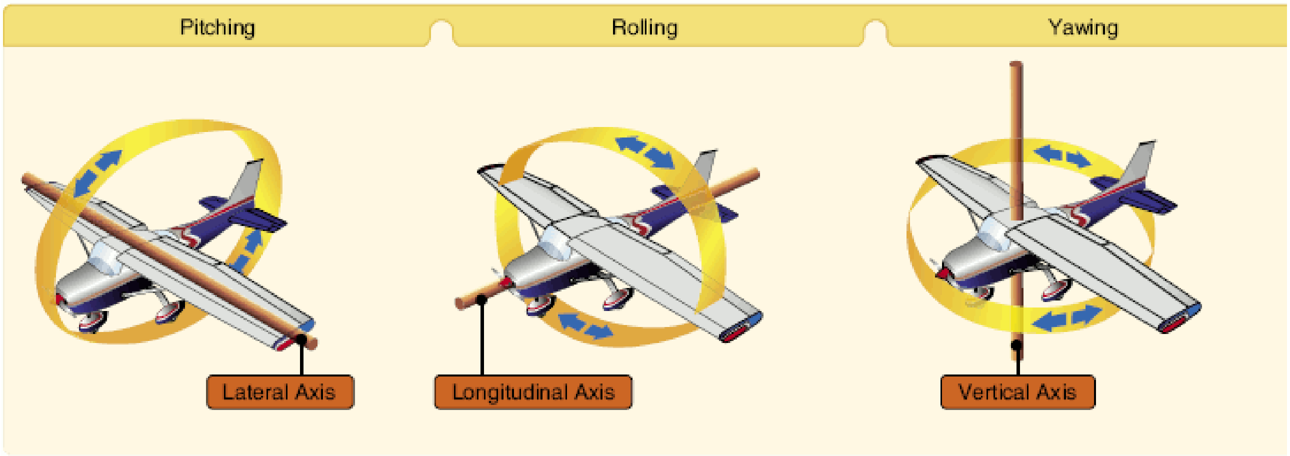


Figure 1.4. Effects on aircraft

Turbulence is commonly classified as light, moderate, severe, or extreme when reported, with the classification determined by the initiating agency and the air's stability.

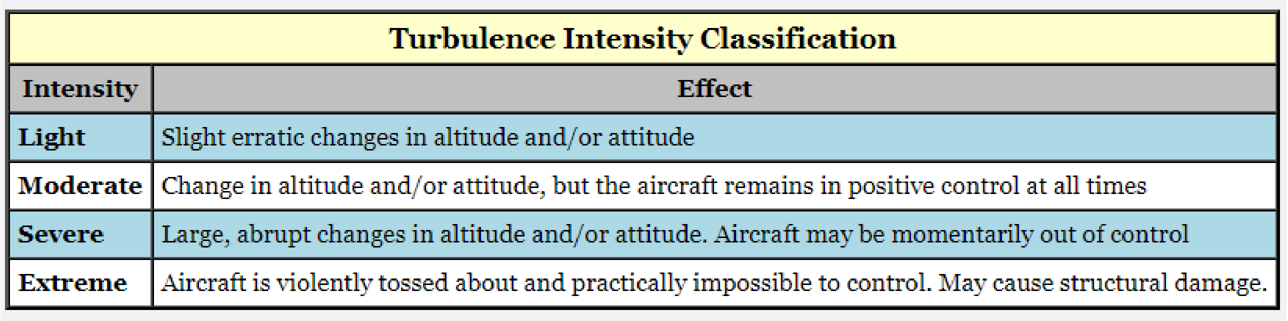
Light turbulence causes brief changes in altitude and/or attitude, as well as mild bumpiness. Passengers may experience a slight strain on their seat belts.

Moderate turbulence is similar to light turbulence but has a higher intensity. While there is no loss of airplane control, passengers will feel a significant strain against their seat belts, and unsecured objects may become dislodged.

Significant and abrupt changes in altitude and/or attitude are caused by severe turbulence, and are frequently accompanied by large variations in indicated airspeed. The plane may lose control for a brief period of time, and passengers will be pushed against their seat belts.

Extreme turbulence causes the airplane to be violently tossed around and uncontrollable, potentially resulting in structural damage.

Chop, a type of turbulence, causes rapid and rhythmic bumpiness.



Turbulence Intensity Classification

Intensity	Effect
Light	Slight erratic changes in altitude and/or attitude
Moderate	Change in altitude and/or attitude, but the aircraft remains in positive control at all times
Severe	Large, abrupt changes in altitude and/or attitude. Aircraft may be momentarily out of control
Extreme	Aircraft is violently tossed about and practically impossible to control. May cause structural damage.

Figure 1.5. Classification of turbulence

Icing

Icing phenomena in aviation refer to the formation of ice on an aircraft's surfaces, which can have significant implications for flight safety. This phenomenon occurs when supercooled water droplets or freezing rain come into contact with the cold surfaces of an aircraft during flight, leading to the freezing of this liquid water. Icing can affect various parts of an aircraft, including the wings, tail, engines, and antennas, and it poses serious challenges to both the aerodynamics and overall performance of the aircraft.

One of the primary areas susceptible to icing is the aircraft's wings. When ice accumulates on the wings, it alters the wing's shape and disrupts the smooth flow of air over its surface. This disrupts the generation of lift, which is crucial for maintaining the aircraft's altitude and stability. Icing on the wings can lead to a reduction in lift, increased drag, and altered stall characteristics, potentially compromising the aircraft's ability to maintain controlled flight.

In addition to affecting lift, icing can have adverse effects on the aircraft's control surfaces, such as ailerons and elevators. Ice accumulation on these surfaces can impede their movement, leading to reduced controllability and responsiveness. Pilots may experience difficulties in maneuvering the aircraft, especially during critical phases of flight such as takeoff and landing.

Engine components are also vulnerable to icing. Ice accumulation on the engine inlets can disrupt the airflow, potentially causing engine performance degradation or flameouts. In severe cases, ice accretion on engine components can lead to engine damage or failure. To mitigate these risks, modern aircraft are equipped with anti-icing and de-icing systems, such as heated engine inlets and anti-icing fluids, which help prevent or remove ice from critical areas.

Icing is categorized into different types based on the conditions under which it forms. Structural icing occurs when ice accumulates on exposed surfaces, while induction icing affects engine components. Frost and rime ice are two common forms of ice that can form in various atmospheric conditions. Understanding these distinctions is crucial for pilots and aviation authorities to develop effective strategies for preventing and managing icing encounters.

Given the complexities and potential hazards associated with icing, pilots receive extensive training on recognizing and responding to icing conditions. Aircraft are also equipped with advanced weather radar and de-icing systems to enhance safety during flights in conditions conducive to icing. Strict adherence to pre-flight weather briefings and continuous monitoring of in-flight weather conditions are essential elements of aviation practices aimed at minimizing the risks posed by icing phenomena.

Categories of icing: Icing in aviation is often categorized based on the thickness of the ice accretion, and these categories are crucial for understanding the potential impact on aircraft performance and safety. The classifications help pilots and aviation professionals assess the severity of icing conditions and implement appropriate preventive measures.

The first category is known as "Trace Icing." In this stage, the ice accretion is minimal, with a thickness typically less than 1 millimeter. Despite its thin nature, trace icing can still pose a threat, particularly on critical surfaces like wings and control surfaces. Pilots need to be vigilant and consider anti-icing or de-icing measures to prevent further ice buildup.

The next category is "Light Icing," where the ice thickness ranges from 1 to 5 millimeters. Although still relatively thin, light icing can begin to affect the aircraft's aerodynamics. It may lead to changes in lift and drag, prompting pilots to take precautionary actions such as activating anti-icing systems to prevent further ice accumulation.

"Moderate Icing" is the third category, characterized by ice thickness ranging from 5 to 15 millimeters. At this stage, the ice accumulation becomes more significant, impacting the aircraft's performance noticeably. The increased weight and altered aerodynamics can compromise lift and control, necessitating more assertive anti-icing or de-icing measures.

The fourth category, "Severe Icing," involves ice thickness exceeding 15 millimeters. Severe icing poses a substantial risk to flight safety, as the significant ice accumulation can lead to a dramatic reduction in lift, increased drag, and impaired control surfaces. Pilots encountering severe icing conditions must take immediate corrective actions, including the activation of anti-icing systems or seeking an altitude change to escape the adverse weather.

Beyond these categories, icing severity is also influenced by the type of ice formed, such as clear ice or rime ice, each with its distinct characteristics and implications for flight safety. Pilots are trained to recognize these conditions, and modern aircraft are equipped with advanced anti-icing and de-icing systems to address and mitigate the effects of ice accretion.

Understanding the categories of icing is vital for pilots to make informed decisions during flight, especially in regions where supercooled liquid droplets are present. It allows for the implementation of appropriate procedures and helps ensure the safety of the aircraft and its occupants when operating in icing conditions.

How icing phenomena can influence in autopilot system:

Icing phenomena can have a significant impact on an aircraft's autopilot system, posing challenges to the system's performance and overall flight stability. The alteration of aerodynamic surfaces caused by ice accumulation is one of the primary concerns. Ice on the aircraft's control surfaces, such as ailerons, elevators, and rudders, can disrupt intended movements and jeopardize the autopilot's ability to maintain precise control. Ice-induced changes in aerodynamic properties can cause unexpected deviations from the programmed flight path, affecting the autopilot's response to commands and reducing its effectiveness in maintaining stable flight.

Icing can harm sensors and probes that provide critical information about airspeed, altitude, and angle of attack in the context of the autopilot's reliance on air data. Ice accumulation, for example, on pitot tubes can result in incorrect airspeed readings, potentially causing the autopilot to make incorrect adjustments. Because the autopilot system relies on accurate and timely air data, distorted sensor inputs may cause unintended control inputs and jeopardize the aircraft's stability.

Icing can also have an effect on engine performance, reducing power output and thrust. If ice forms on engine components, the autopilot system, which relies on the engines to maintain speed and altitude, may have difficulty managing power settings accurately. This can cause deviations from the intended flight path, necessitating autopilot disengagement or manual intervention by the flight crew to regain control.

Modern aircraft autopilot systems are outfitted with sophisticated sensors and algorithms designed to detect and mitigate the effects of icing. Anti-icing and de-icing systems are used to protect critical surfaces and sensors from ice accumulation. Furthermore, advanced algorithms in autopilot systems can adapt to changes in aerodynamic conditions caused by icing, providing more reliable and stable control during adverse weather conditions.

Pilots, too, play an important role in controlling the effects of icing on the autopilot system. They are trained to recognize the signs of icing conditions and in the procedures for engaging or disengaging the autopilot depending on the circumstances. Effective communication between the autopilot system and the flight crew is critical for ensuring a coordinated response to the icing challenges, contributing to the overall safety and reliability of automated flight systems in icy conditions.

1.3 Accidents and Incidents

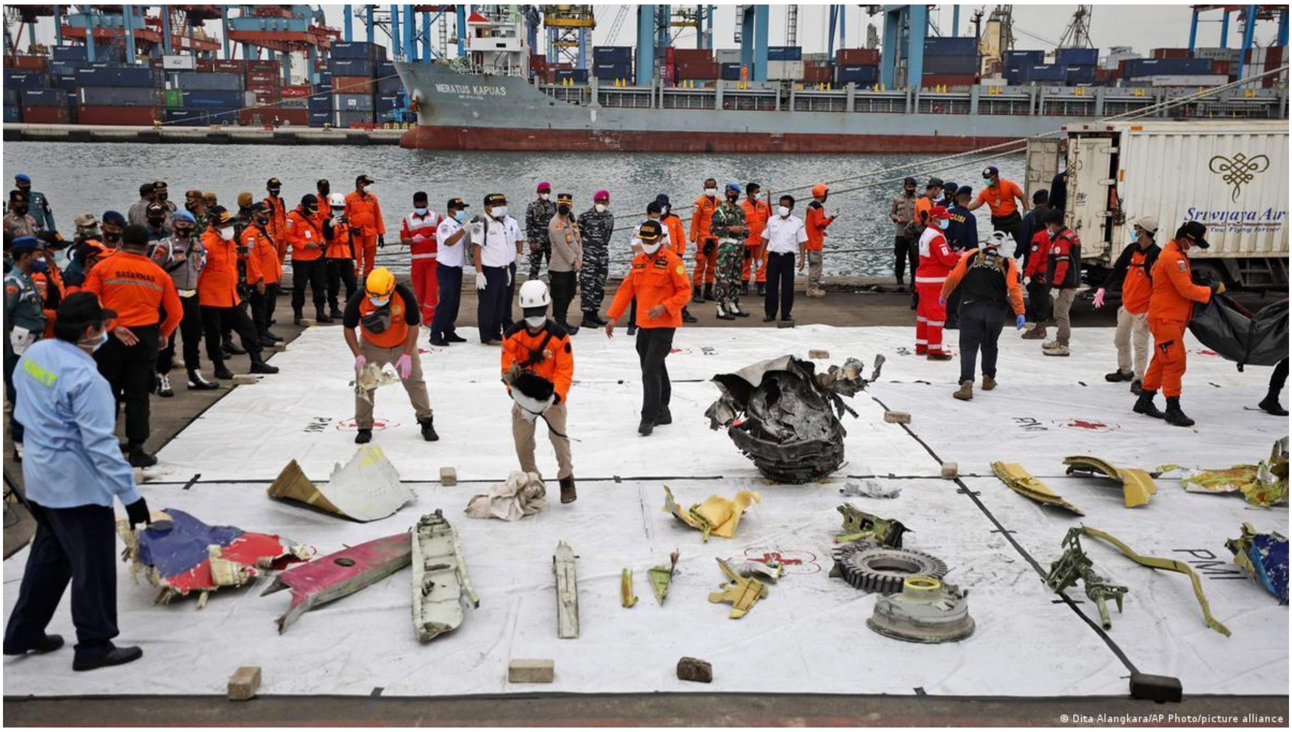
The following events involved airworthiness issues associated with the autoflight system:

B735, near Madrid Barajas, Spain, 2019.

On April 5, 2019, a Boeing 737-500 crew declared an emergency shortly after departing Madrid Barajas after experiencing difficulties maintaining normal lateral, vertical, or airspeed control of their aircraft in IMC. The flight successfully landed at a nearby military airbase after two failed ILS approaches in unexceptional weather conditions. The investigation discovered that a malfunction discovered prior to departure that likely prevented use of the Captain's autopilot was not documented until after the flight, but it was unable to find a technical explanation for the inability to control the aircraft manually given that dispatch without either autopilot working is permitted.

2021, B735, en route, north northwest of Jakarta, Indonesia

On 9 January 2021, less than five minutes after departing Jakarta in daylight, a Boeing 737-500 began to descend at an increasing rate, from which no recovery occurred, and was destroyed by sea surface impact, killing all 62 occupants. The investigation concluded that the departure from controlled flight was unintentional and the result of the pilots' inattention to their primary flight instruments when, during a turn with the autopilot engaged, an autothrottle malfunction caused apparently unrecognized thrust asymmetry, resulting in wing drop and loss of control.



© Dita Alangkara/AP Photo/picture alliance

Figure 1.6 Debris of Boeing 737-500 Jakarta, Indonesia

RJ1H, Zurich, Switzerland, 2011.

On July 20, 2011, the flight crew of a Swiss European Avro RJ-100 on a positioning flight from Nuremburg to Zurich overreacted to an unexpected 'bank angle' alert in IMC. Following a near-loss of control, a PAN was eventually declared. A belated application of the QRH checklist applicable to the failure symptoms experienced resolved the situation. The subsequent investigation blamed the incident on an inappropriate crew response to a single IRU failure and poor manual flying skill while the situation was resolved.

Munich, flight A319 2017 Germany

On July 3, 2017, an Airbus A319 sustained significant landing gear damage during the First Officer's manual landing in Munich, resulting in a vertical acceleration that exceeded the threshold for a mandatory airworthiness inspection. Damage to the nose and one of the main landing gear legs was discovered during the inspection, and all three were replaced before the aircraft was released to the public. The investigation was unable to explain why neither pilot detected the incorrect pitch attitude and excessive rate of descent in time to take corrective action, and it was determined that the reversion to manual flight during the intermediate approach was caused by a technical malfunction.

E190 en route in southwest Vermont, USA, in 2016.

An Embraer ERJ 190 experienced a major electrical system failure shortly after reaching its cruise altitude of FL 360 on May 25, 2016. ATC was notified of the problems, and a descent was made to allow the APU to start. This action restored the majority of the lost systems, and the crew chose to complete their planned 400nm flight despite not declaring an emergency. The investigation determined that liquid contamination of an underfloor avionics bay caused the electrical failure, which also resulted in fire and smoke without crew awareness because the smoke detection and air recirculation systems were turned off.

B743, near Tehran Mehrabad Iran, 2015

On October 15, 2015, a Boeing 747-300 experienced significant engine vibration almost immediately after takeoff from Tehran Mehrabad. After continuing the climb out without reducing the affected engine thrust, an uncontained failure occurred 3 minutes later. The ejected debris caused the No. 4 engine to fail almost simultaneously, as well as multiple hydraulic systems and all of the fuel in one wing tank. The vibration was attributed to the Operator's continued use of the engine without relevant Airworthiness Directive action, and the subsequent failure to continued operation of the engine after its onset, according to the investigation.

Manoeuvring UAV north of Reims, France, 2006.

Control of a 50 kg, 3.8 metre wingspan UAV was lost during a flight test in a Temporary Segregated Area in northern Belgium on February 29, 2016. The UAV then rose to 4,000 feet and flew south-southwest across Belgium and into northern France, where it crashed after the engine failed. The investigation discovered that control communications had been disrupted due to an incorrectly manufactured co-axial cable assembly and an unidentified autopilot software design flaw. This then rendered the default recovery process inoperable. There was a loss of prescribed traffic separation.

B735, near Perm Russian Federation, 2008.

On September 13, 2008, at night and in good visual conditions*, an Aeroflot-Nord Boeing 737-500 executed an unstabilised approach to Runway 21 at Bolshoye Savino Airport (Perm), resulting in loss of control and terrain impact.

A306, near Nagoya, Japan, 1994

The crew of an Airbus A300-600 lost control of their aircraft on final approach to Nagoya on April 26, 1994, and the plane crashed within the airport's perimeter. The investigation discovered that an inadvertent mode selection error had caused control issues, which were ultimately caused by both pilots' apparent lack of understanding of the full nature of the interaction between the systems controlling thrust and pitch on the aircraft type, which was not typical of most other contemporary types. It was also determined that the Captain's delay in taking command from the First Officer aggravated the situation.

2005, A319 south of London, UK

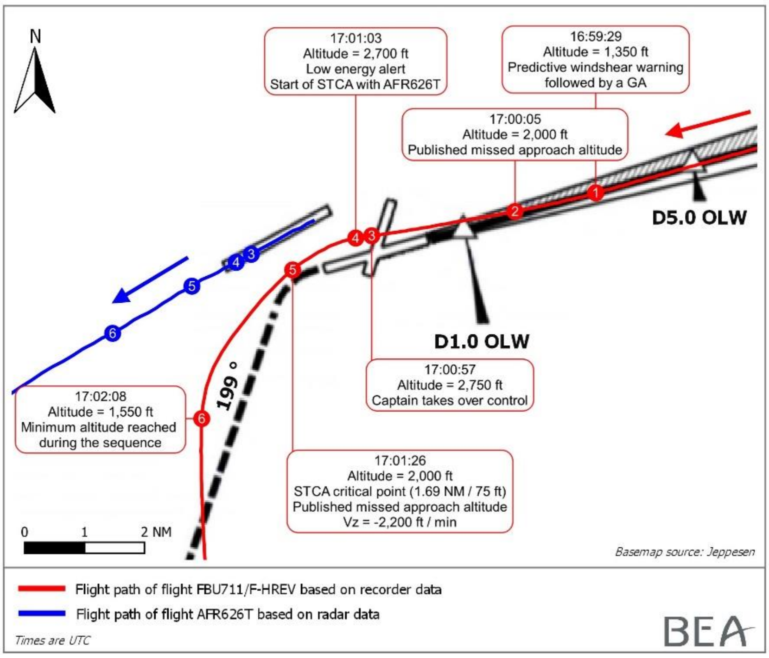
On October 22, 2005, a British Airways Airbus A319 in VMC climbing en route to destination over south east England experienced a major but temporary electrical failure. The majority of services were quickly restored, and the flight resumed. However, during the subsequent investigation, which lasted over two years, a number of significant flaws in the design of the A320 series electrical system and the manufacturer-recommended responses to failures in it were discovered, and Airbus developed solutions to the majority of them.

A320, near Muscat Oman, 2019

On January 28, 2019, an Airbus A320 became unstabilized below 1000 feet after continuing an ILS approach at Muscat with insufficient thrust resulted in increasing pitch, which eventually triggered an automatic thrust intervention, allowing a normal landing to be completed. The investigation discovered that the Captain had temporarily taken control from the First Officer due to failure to follow radar vectors to the ILS, and then handed control back to the First Officer, who was unaware that the autothrust had been disconnected. The context for this was identified as a widespread failure to adhere to multiple operational procedures and engage in meaningful CRM.

A359, near Paris Orly Airport, France, 2020

On February 4, 2020, an Airbus A350-900 initiated a go around from its destination approach at 1,400 feet aal in response to a predictive windshear alert that was unsupported by the prevailing environmental conditions, but the First Officer mishandled it, and the stop altitude was first exceeded, then flown through again in a descent before control was finally regained four minutes later. During this time, there was a collision with another aircraft. The investigation determined that the underlying cause of the upset was the First Officer's lack of awareness of the autopilot status, which was followed by a significant delay before the Captain took control.


17:01:03
Altitude = 2,700 ft
Low energy alert
Start of STCA with AFR626T

16:59:29
Altitude = 1,350 ft
Predictive windshear warning
followed by a GA

17:00:05
Altitude = 2,000 ft
Published missed approach altitude

17:00:57
Altitude = 2,750 ft
Captain takes over control

17:02:08
Altitude = 1,550 ft
Minimum altitude reached
during the sequence

17:01:26
Altitude = 2,000 ft
STCA critical point (1.69 NM / 75 ft)
Published missed approach altitude
Vz = -2,200 ft / min

Basemap source: Jeppesen

Times are UTC

Figure 1.7 Example of the ground track of the aircraft and that of the conflicting traffic

B738, nearby Bristol, United Kingdom, 2019.

On June 1, 2019, a Boeing 737-800 was told to circle after it was discovered to be significantly below the vertical profile for its RNAV approach as it approached the procedure minimum descent altitude. After climbing less than 300 feet, the aircraft began to descend, reaching 457 feet above ground before resuming its ascent. The investigation determined that the terrain proximity on approach was caused by a failure to terminate a comprehensively unstable approach, and the terrain proximity episode during the go around was caused by the Flight Director's continued following, which was providing guidance based on incorrect mode selections.

B763, east southeast of Houston, TX, USA, 2019.

On February 23, 2019, a Boeing 767-300 abruptly transitioned from a normal descent towards Houston into a steep dive, resulting in a high-speed terrain impact. After neither pilot noticed the First Officer's inadvertent selection of go around mode during automated flight, the First Officer quickly responded with an increasingly severe manual pitch-down, possibly influenced by a somatogravic illusion. He was discovered to have a history of short-term air carrier employments that ended due to failure to complete training, to have deliberately and repeatedly attempted to conceal this history, and to lack sufficient aptitude and competency.

Conclusion to chapter 1

In summary, autopilot and automated flight systems have become integral to modern aviation, significantly enhancing the safety, efficiency, and dependability of air travel. These systems empower pilots, streamline operations, and provide a level of precision that elevates the overall quality of flight operations.

Autopilot systems in aircraft serve a crucial role in enhancing flight safety, efficiency, and precision. The primary purpose of autopilot is to assist pilots in managing the aircraft's trajectory, maintaining stable flight, and alleviating their workload during routine operations. Autopilot systems are designed to follow pre-programmed routes, execute specific maneuvers, and ensure consistent performance, allowing pilots to focus on higher-level tasks such as navigation, communication, and systems monitoring. Moreover, autopilot plays a vital role in mitigating pilot fatigue during long flights, contributing to overall aviation safety.

Furthermore, as evidenced by examples of incidents and accidents, if pilots/air traffic controllers are not vigilant to this system, serious consequences will result.

Chapter 2 METHODS FOR STUDYING THE DECISION-MAKING PROCESS OF AN AIR TRAFFIC CONTROLLER DURING AUTOMATED FLIGHT OF AN AIRCRAFT

2.1 Pilot decision-making system

Pilot decision-making is a complex and essential process in ensuring aviation safety, requiring pilots to engage in cognitive evaluations and make choices throughout a flight. This dynamic function involves synthesizing information from various sources to evaluate the current state of the aircraft, the environment, and potential risks. The effectiveness of this process is not solely dependent on technical skills but is also heavily influenced by a pilot's situational awareness, experience, and ability to navigate uncertainties.

At the core of effective decision-making for pilots lies situational awareness, which entails the continuous acquisition and processing of information from instruments, communications, and external observations. The pilot's capacity to accurately perceive and comprehend this information contributes to a comprehensive understanding of the flight environment, forming the basis for evaluating potential risks and making well-informed decisions.

A critical element of pilot decision-making is risk assessment, wherein pilots must consistently evaluate the level of risk associated with factors such as weather conditions, aircraft performance, air traffic, and their own physical and mental state. This involves estimating the probability and severity of potential hazards, enabling pilots to systematically prioritize and address safety concerns.

Decision-making models, such as DECIDE (Detect, Estimate, Choose, Identify, Do, and Evaluate), offer pilots structured approaches to navigate the complexities of the aviation environment. These models guide pilots through step-by-step processes, fostering systematic decision-making, particularly in high-stakes or time-sensitive situations.

Undoubtedly, the significance of training and experience in pilot decision-making cannot be overstated. Training programs equip pilots with essential skills and knowledge, while experience enhances their ability to anticipate and manage diverse situations. Adherence to aviation regulations and standard operating procedures provides a standardized framework for decision-making, ensuring consistency and safety industry-wide.

In the context of multi-crew aircraft, Crew Resource Management (CRM) emerges as a vital aspect of effective decision-making. CRM underscores the importance of open communication, collaboration, and shared decision-making within the cockpit, emphasizing a coordinated team approach to address challenges and mitigate risks.

Despite rigorous training and structured approaches, errors in decision-making can occur. Pilots must remain vigilant against cognitive biases such as confirmation bias or overconfidence that may impact their judgments. Continuous monitoring of the evolving situation and the ability to adapt decisions as circumstances change are imperative for maintaining safety and successfully navigating the inherent challenges of aviation.

In conclusion, pilot decision-making is an intricate and ongoing process that involves the integration of information, risk assessment, and choices within the dynamic aviation environment. This skill is honed through training, experience, and a steadfast commitment to safety, ensuring the successful and secure execution of flights.

Decision-making models are instrumental in helping pilots navigate the complex challenges of aviation, and one widely utilized framework is the DECIDE model - an acronym that delineates a systematic, step-by-step approach to decision-making during flight operations.

The initial stage in the DECIDE model is "Detect." Pilots are trained to discern and recognize potential issues or alterations in the flight environment. This entails a continual monitoring of instruments, communications, and external factors to identify any deviations from the anticipated or usual conditions. Early detection is imperative for proactive decision-making.

Subsequent to detection comes the "Estimate" phase. Once a potential issue is identified, pilots must gauge its significance and potential consequences. This involves evaluating the severity and urgency of the situation based on available information.

Precise estimation is crucial for prioritizing and addressing issues in a manner that ensures safety.

The third step is "Choose." Pilots, having detected and estimated the situation, are then tasked with selecting a course of action. This involves assessing available options and choosing the most suitable response based on evaluated risks, adherence to regulations, and operational considerations. The decision-making process at this stage is influenced by the pilot's training, experience, and the specific circumstances of the flight

Following the selection of a course of action, the pilot proceeds to "Identify." This step encompasses recognizing the actions necessary to implement the chosen decision. It includes identifying the required adjustments to the aircraft's configuration, navigation, or communication systems. Clearly identifying these specific steps ensures a precise and effective execution of the chosen course of action.

The subsequent phase is "Do." Here, pilots execute the identified actions to address the situation. This step demands effective coordination and execution of the selected decision. Pilots may need to liaise with air traffic control, alter the aircraft's altitude or heading, or undertake other actions as deemed necessary.

The final step is "Evaluate." Following the implementation of the decision and the execution of necessary actions, pilots assess the outcome. This involves evaluating whether the chosen course of action effectively addressed the issue and determining if further adjustments or corrections are required. Evaluation is an ongoing process that informs subsequent decision-making and contributes to the pilot's continual learning and improvement.

2.2 Example of minimizing the risk of accidents or incidents

Minimizing the risk of accidents or incidents during automated flight, particularly when the pilot uses the autopilot system, involves a combination of proactive measures, training, and continuous vigilance. Learning from incidents and accidents that were attributed to problems or failures of the autopilot system provides valuable insights for improving air traffic controller (ATC) actions and protocols. Here are detailed recommendations:

1. Comprehensive Training:

Air traffic controllers should receive comprehensive training on the functionalities, limitations, and potential failure modes of autopilot systems. Understanding the intricacies of automated flight assists controllers in making informed decisions and providing appropriate instructions to pilots.

2. Regular Proficiency Checks:

Regular proficiency checks for air traffic controllers can help maintain and enhance their skills in managing automated flights. These checks should include scenarios simulating autopilot malfunctions or unexpected events, allowing controllers to practice effective responses.

3. Effective Communication:

Clear and concise communication between air traffic controllers and pilots is paramount. Controllers should confirm with pilots the status of the autopilot system, especially during critical phases of flight. In the event of an autopilot malfunction or disengagement, controllers should promptly communicate and coordinate with the pilot to ensure a safe resolution.

4. Continuous Monitoring:

Air traffic controllers should continuously monitor automated flights, paying attention to the aircraft's trajectory, altitude, and speed. Regular checks on the status of the autopilot system, as reported by the pilot, help controllers identify anomalies or discrepancies and take corrective actions.

5. Prompt Recognition of Anomalies:

Rapid recognition of anomalies in the aircraft's behavior is crucial. Air traffic controllers should be trained to identify unusual flight parameters, deviations from the intended route, or abrupt changes in altitude that may indicate autopilot-related issues.

6. Coordination with Maintenance:

Establishing effective coordination between air traffic controllers and aircraft maintenance teams is essential. Controllers should promptly relay information about any reported autopilot issues to maintenance personnel, facilitating timely inspections and necessary repairs.

7. Emergency Procedures:

Air traffic controllers should be well-versed in emergency procedures related to autopilot malfunctions. This includes having predefined protocols for managing flights experiencing autopilot failures and coordinating with pilots to ensure a safe handover of control if necessary.

8. Data Analysis and Reporting:

Regular analysis of data from incidents and accidents related to autopilot failures can provide valuable insights. Air traffic management organizations should use this information to update procedures, enhance training programs, and implement corrective measures to minimize the risk of recurrence.

9. Human-Machine Interface Awareness:

Controllers should be aware of the human-machine interface aspects of autopilot systems. Understanding how pilots interact with and receive information from the autopilot system enables controllers to anticipate potential challenges and offer timely assistance.

10. Collaborative Decision Making:

Promoting collaborative decision-making between air traffic controllers and pilots fosters a shared understanding of the situation. Controllers should encourage pilots to communicate openly about any autopilot-related concerns or uncertainties, creating a collaborative environment for addressing issues.

By incorporating these recommendations into training programs, standard operating procedures, and collaborative efforts between air traffic controllers, pilots, and maintenance teams, the aviation industry can work towards minimizing the risks associated with autopilot-related incidents and accidents. Continuous learning, effective communication, and a proactive safety culture contribute to the overall enhancement of automated flight safety.

In the realm of air traffic control, a critical aspect of ensuring flight safety during automated flight involves the establishment of well-defined emergency procedures specifically tailored to address autopilot malfunctions. Air traffic controllers play a pivotal role in this process and must be thoroughly versed in these emergency protocols. The procedures encompass a comprehensive set of predefined steps and actions aimed at effectively managing flights experiencing autopilot failures. This includes precise instructions on communication protocols, real-time monitoring techniques, and coordination strategies with the affected aircraft's pilot.

2.3 Emergency procedures

In the event of an autopilot malfunction, controllers need to act swiftly and decisively. The emergency procedures should delineate clear guidelines for controllers to follow, ensuring a systematic response to the situation. This involves the prompt identification of the issue, verification of the pilot's awareness and understanding of the problem, and initiation of necessary corrective measures. If circumstances necessitate a handover of control from the autopilot to manual piloting, controllers should be prepared to facilitate this transition seamlessly.

Coordination with the pilot is a critical element of emergency procedures. Controllers should establish effective communication channels to relay crucial information regarding the autopilot malfunction, providing real-time updates and guidance to the pilot. The protocols should also incorporate measures for confirming the pilot's acknowledgment of the situation and their ability to assume manual control, if required.

Furthermore, the emergency procedures must account for varying degrees of autopilot failures. Whether it's a partial loss of functionality or a complete system breakdown, controllers need to be equipped with the knowledge and tools to assess the severity of the situation accurately. This assessment influences the decision-making process and dictates the appropriate course of action, ranging from providing guidance to the pilot for autopilot system reactivation to overseeing a safe transition to manual control.

The effectiveness of these emergency procedures hinges on regular training and simulations. Controllers should engage in scenario-based training exercises that replicate autopilot malfunctions, allowing them to practice the prescribed protocols in a controlled environment. Simulations help enhance the controllers' ability to make quick, informed decisions and foster a proactive mindset when faced with unexpected challenges.

While specific incidents may vary, examples of precise instructions and support from air traffic controllers to pilots during autopilot malfunctions or emergencies can be outlined based on general principles and common best practices. It's important to note that the following examples are illustrative, and real-world situations may involve unique circumstances.

Clear Communication on Autopilot Status:

In the event of an autopilot malfunction, air traffic controllers should provide clear and concise information to the pilot regarding the status of the autopilot system. This includes detailing any observed anomalies, potential reasons for the malfunction, and available options for corrective actions. For instance, if the autopilot disengages unexpectedly, controllers might instruct the pilot to confirm the status of the autopilot mode and take manual control if necessary.

Guidance for Autopilot Re-engagement:

If the autopilot failure is partial or reversible, controllers can offer guidance on reactivating the autopilot system. This may involve step-by-step instructions for the pilot to troubleshoot and attempt to re-engage specific autopilot modes. Clear and precise instructions enhance the pilot's understanding and enable them to take corrective actions efficiently.

Assistance in Aircraft Navigation:

In situations where autopilot malfunctions affect the aircraft's navigation, controllers can provide immediate assistance by suggesting alternative routes, altitude adjustments, or heading changes. For example, if a lateral mode malfunction occurs, controllers might instruct the pilot to follow specific headings or waypoints to ensure the aircraft stays on a safe and predefined path.

Real-time Monitoring and Updates:

Controllers should continuously monitor the aircraft's progress and provide real-time updates to the pilot. This includes conveying critical information about the aircraft's altitude, speed, and heading. In cases where the aircraft deviates from its assigned course due to autopilot malfunctions, controllers can offer timely corrections and adjustments to maintain safe separation from other air traffic.

Preparation for Manual Control:

If circumstances necessitate a transition from autopilot to manual control, controllers should prepare the pilot for this shift. This involves clear communication on the procedures for disengaging the autopilot, adjusting control inputs, and maintaining stable flight. Controllers might advise the pilot to expect changes in aircraft behavior and provide guidance on managing the transition smoothly.

Acknowledgment of Pilot Actions:

Controllers should acknowledge the pilot's actions promptly and provide feedback on the effectiveness of implemented measures. For example, if the pilot successfully re-engages the autopilot or mitigates the effects of a malfunction, controllers can confirm the resolution and offer additional guidance if needed.

Conclusion to chapter 2

In essence, the emergency procedures related to autopilot malfunctions for air traffic controllers are a meticulously crafted set of guidelines that prioritize swift response, effective communication, and collaboration with pilots. By adhering to these protocols and engaging in continuous training, air traffic controllers contribute significantly to the overall safety and resilience of automated flight operations.

While the examples provided are general in nature, the effectiveness of instructions and support from air traffic controllers depends on the specific circumstances of each incident. By incorporating these principles into their emergency procedures, controllers can contribute to a safer and more coordinated response to autopilot malfunctions, mitigating potential risks and ensuring the well-being of both the aircraft and its occupants.

Chapter 3 IMPLEMENTATION OF AIR TRAFFIC CONTROLLER'S DECISION-MAKING METHODS FOR AIR TRAFFIC CONTROL DURING AUTOMATED FLIGHT OF AN AIRCRAFT

3.1 Modelling real situations:

For the practical part I used Microsoft Flight Simulator and below I will describe why I choose this simulator:

Microsoft Flight Simulator offers a range of immersive features that contribute to its exceptional gaming experience.

The game excels in creating a Realistic World by harnessing satellite imagery and Bing Maps data, allowing players to explore a meticulously recreated Earth. The integration of Azure AI ensures a lifelike 3D environment, featuring accurate topography, terrain, buildings, and vegetation.

The extensive Aircraft Fleet encompasses a diverse selection, from small propeller planes to large commercial jets and historically significant aircraft. Each plane is intricately modeled, capturing detailed interiors and exteriors, including cockpit instruments.

Live Weather and Time of Day add a dynamic element to the gaming experience. The incorporation of real-time weather data introduces dynamic and realistic conditions such as clouds, rain, snow, and storms. The time of day changes dynamically, providing a visually stunning and diverse flying experience.

The game boasts Flight Dynamics that deliver a highly realistic and authentic flying experience. Players can tailor their experience with various difficulty settings, accommodating everyone from beginners with simplified controls to seasoned pilots seeking a more complex challenge.

Live Traffic integrates real-time air traffic data, allowing players to encounter real-world aircraft in the skies and at airports. Attention to detail extends to faithfully recreating airports, capturing realistic layouts and intricate details.

The Multiplayer feature enables players to connect with friends or others globally, fostering cooperative and competitive experiences. Whether engaging in shared exploration or organized events, multiplayer options enhance the overall sense of community.

In the realm of Training and Tutorials, the game provides a comprehensive range of instructional content. From basic takeoff and landing procedures to advanced topics like navigation and instrument usage, players have access to guides that cater to various skill levels.

The Marketplace and Modding aspects further enrich the gaming landscape. The Marketplace allows players to purchase and download additional content, including aircraft, scenery, and more from third-party developers. The game supports a vibrant modding community, where users can contribute their modifications to enhance and expand the overall gaming experience.

In summary, Microsoft Flight Simulator stands out for its realistic world, diverse aircraft fleet, dynamic weather and time features, authentic flight dynamics, live traffic, multiplayer options, training resources, and a marketplace with modding support, collectively providing a captivating and comprehensive flight simulation experience.

In the simulator I picked, I've chosen two planes. They will deal with specific weather situations I talked about in Chapter 1. These weather conditions might affect how the autopilot works on the chosen planes, making the simulation more complex and challenging.

Also I have picked 2 different aircrafts by their size, usage and other specifics

Below I will describe how will each of the aircraft and autopilot system behave:

First aircraft will be the TBM 930

Aircraft details:

- Year Started: 2016
- Year Ended: In Production
- Pilots Required: 1

CABIN:

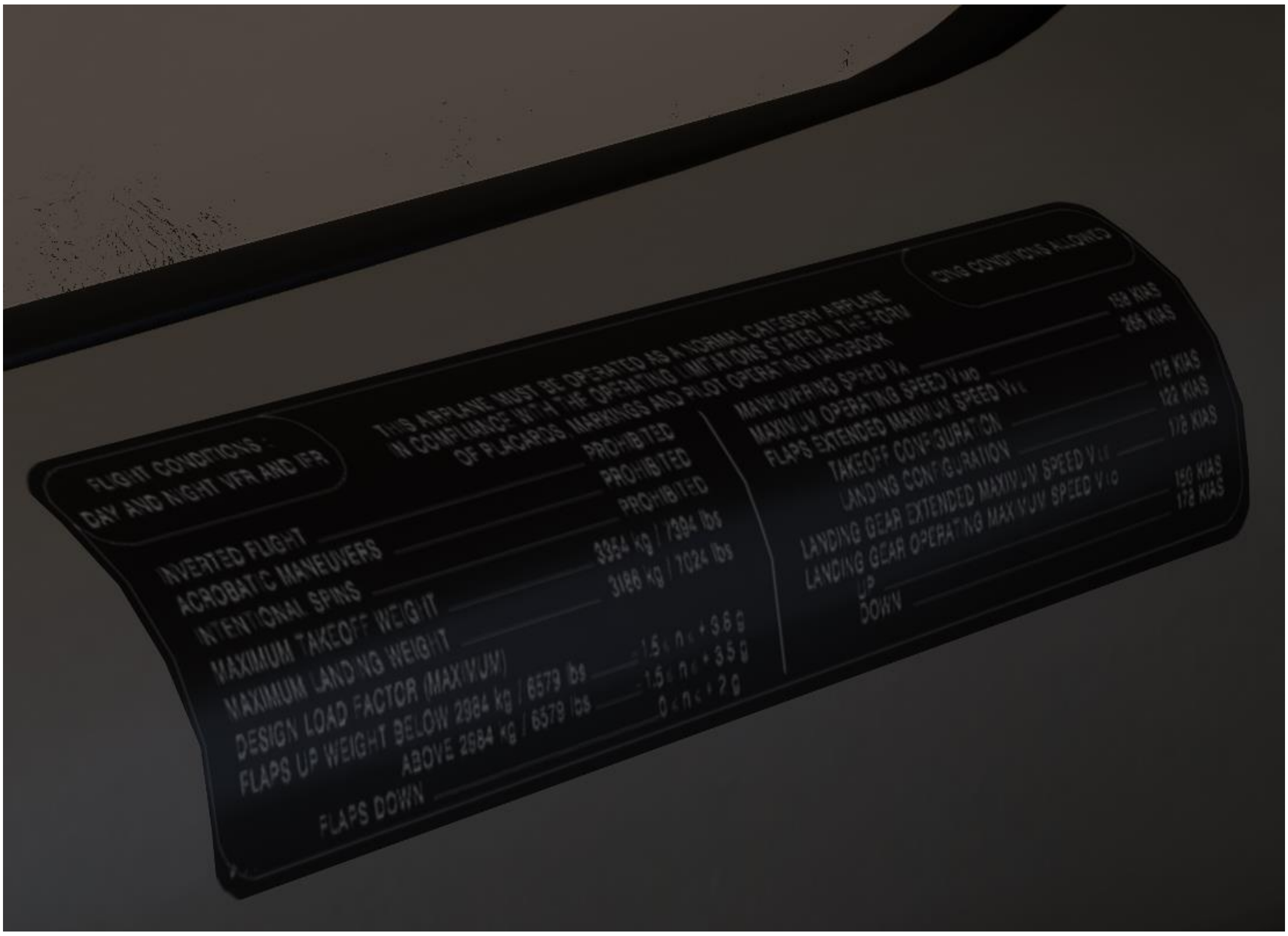
- Passengers (Typical): 5
- Cabin Volume: 143 cu ft

- Cabin Height: 4 ft
- Cabin Width: 4 ft
- Cabin Length: 10 ft

PERFORMANCE:

- Range: 989 nm
- Maximum Cruise Speed: 324 ktas
- Maximum Takeoff Weight: 7,394 lb
- Payload with Maximum Fuel: 645 lb
- Maximum Altitude: 31,000 ft
- Balanced Field Length: 2,823 ft

Also some more characteristics which we can see inside of cockpit



FLIGHT CONDITIONS :
DAY AND NIGHT VFR AND IFR

THIS AIRPLANE MUST BE OPERATED AS A NORMAL CATEGORY AIRPLANE
IN COMPLIANCE WITH THE OPERATING LIMITATIONS STATED IN THE FORM
OF PLACARDS, MARKINGS AND PILOT OPERATING HANDBOOK

ICING CONDITIONS ALLOWED

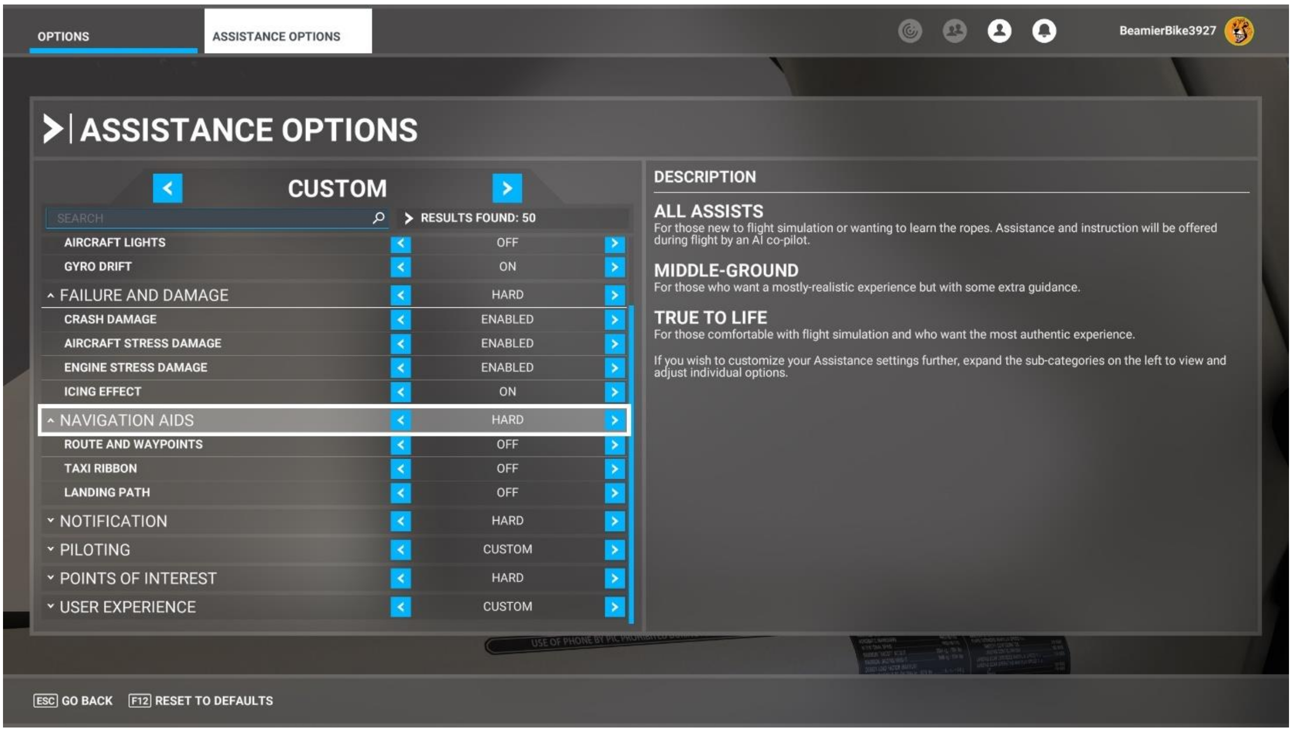
INVERTED FLIGHT —— PROHIBITED
ACROBATIC MANEUVERS —— PROHIBITED
INTENTIONAL SPINS —— PROHIBITED
MAXIMUM TAKEOFF WEIGHT —— 3354 kg / 7394 lbs
MAXIMUM LANDING WEIGHT —— 3186 kg / 7024 lbs
DESIGN LOAD FACTOR (MAXIMUM)
FLAPS UP WEIGHT BELOW 2984 kg / 6579 lbs —— $-1.5 \leq n \leq +3.6$ g
ABOVE 2984 kg / 6579 lbs —— $-1.5 \leq n \leq +3.5$ g
FLAPS DOWN —— $0 \leq n \leq +2$ g

MANEUVERING SPEED V_A —— 158 KIAS
MAXIMUM OPERATING SPEED V_{MO} —— 265 KIAS
FLAPS EXTENDED MAXIMUM SPEED V_{FE}
TAKEOFF CONFIGURATION —— 178 KIAS
LANDING CONFIGURATION —— 122 KIAS
LANDING GEAR EXTENDED MAXIMUM SPEED V_{LE} —— 178 KIAS
LANDING GEAR OPERATING MAXIMUM SPEED V_{LO}
UP —— 150 KIAS
DOWN —— 178 KIAS

Figure 3.1. Aircraft details

Figure 3.2. TBM 930 in Microsoft flight simulator

For this aircraft I wanted to see and test how will icing phenomena will influence at working of an autopilot system, so for that I turned on the icing effect which we can see below at screenshot



ASSISTANCE OPTIONS

CUSTOM

RESULTS FOUND: 50

AIRCRAFT LIGHTS	OFF
GYRO DRIFT	ON
FAILURE AND DAMAGE	HARD
CRASH DAMAGE	ENABLED
AIRCRAFT STRESS DAMAGE	ENABLED
ENGINE STRESS DAMAGE	ENABLED
ICING EFFECT	ON
NAVIGATION AIDS	HARD
ROUTE AND WAYPOINTS	OFF
TAXI RIBBON	OFF
LANDING PATH	OFF
NOTIFICATION	HARD
PILOTING	CUSTOM
POINTS OF INTEREST	HARD
USER EXPERIENCE	CUSTOM

DESCRIPTION

ALL ASSISTS
For those new to flight simulation or wanting to learn the ropes. Assistance and instruction will be offered during flight by an AI co-pilot.

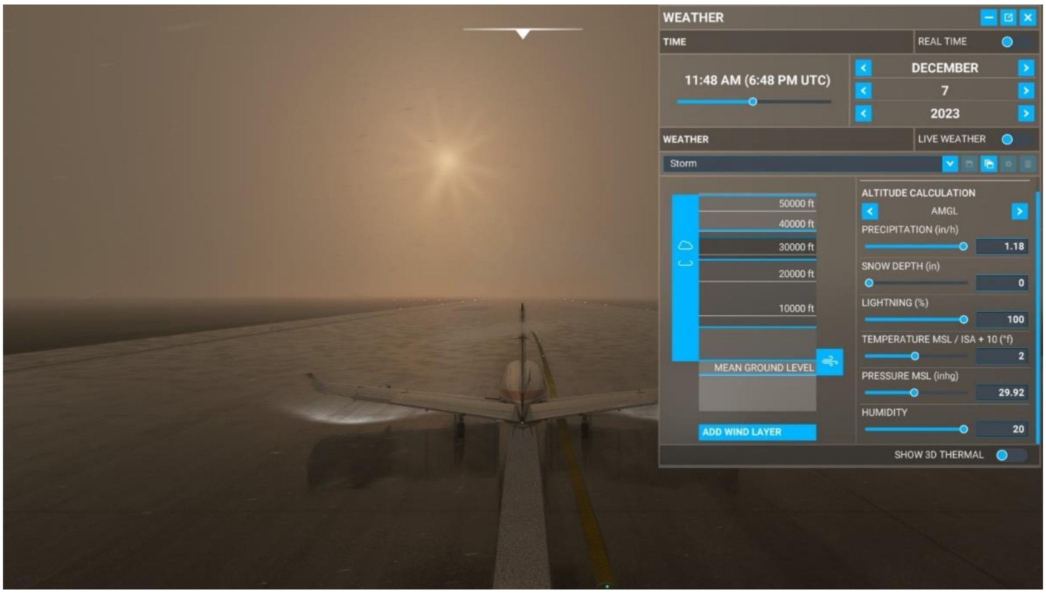
MIDDLE-GROUND
For those who want a mostly-realistic experience but with some extra guidance.

TRUE TO LIFE
For those comfortable with flight simulation and who want the most authentic experience.

If you wish to customize your Assistance settings further, expand the sub-categories on the left to view and adjust individual options.

Figure 3.3. Navigation options in Microsoft flight simulator

After I set all parameters for the weather which we can see below, I was ready for take off from Calgary International Airport (Canada)

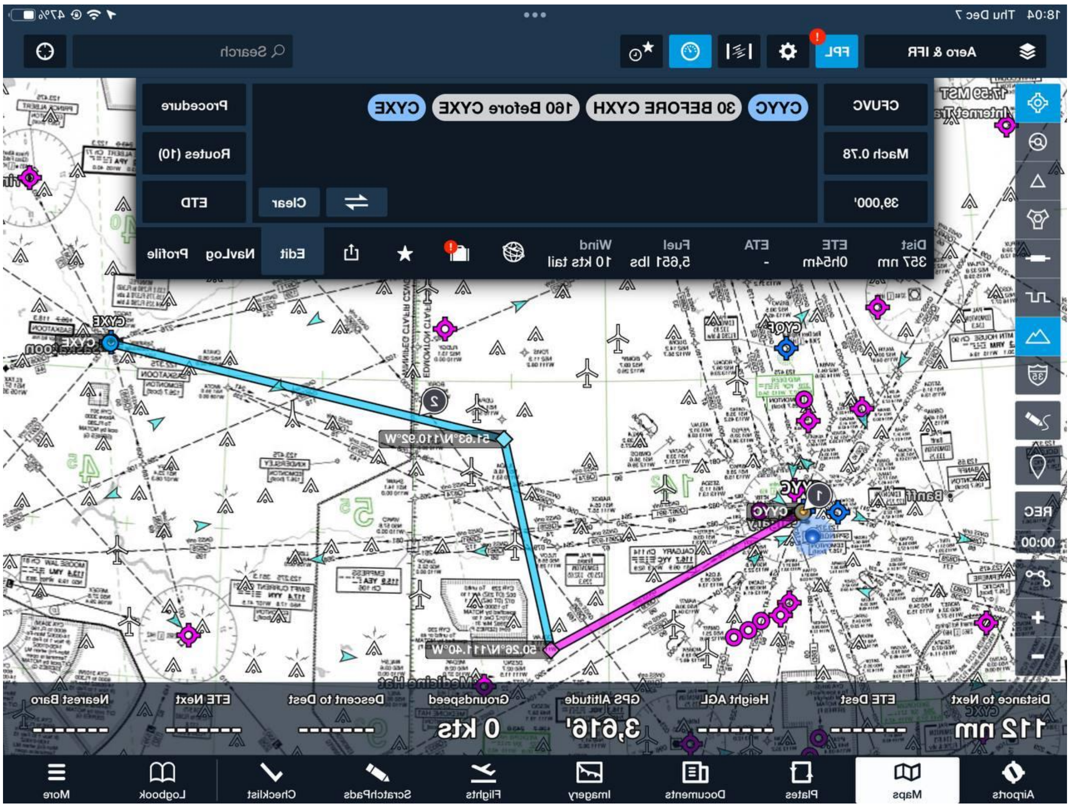


11:48 AM (6:48 PM UTC)
DECEMBER
7
2023
Storm
ALTITUDE CALCULATION: AMGL
PRECIPITATION (in/h): 1.18
SNOW DEPTH (in): 0
LIGHTNING (%): 100
TEMPERATURE MSL / ISA + 10 (°f): 2
PRESSURE MSL (inhg): 29.92
HUMIDITY: 20

Picture 3.4. Weather options in Microsoft flight simulator

For this flight I have chosen IFR flight and flight plan:

CYYC DCT CYXH, 30 NM FROM CYXH, INTERCEPT CYYC DCT CYXE



CFUVC
Mach 0.78
36,000'
CYYC 30 BEFORE CYXH 160 Before CYXE CYXE
Dist 357 nm
ETE 0h54m
ATA -
Fuel 5,661 lbs
Wind 10 kts tail
51.63°N/110.92°W
50.28°N/111.40°W
Distance to Next 112 nm
ETE Dest --------
Height AGL --------
GPS Altitude 3,616'
Groundspeed 0 kts
Descent to Dest --------
ETE Next --------
Nearest Baro --------

Figure 3.5. Flight plan for TBM 930

After takeoff, I activated the autopilot and set the altitude to 5000 feet and the speed to 185 knots. All deicing systems were turned off to see how icing affected the aircraft, particularly the autopilot.

Figure 3.6. De ice system in TBM 930

Also I have tested different stages of icing, so we can see at practical in which stages of icing autopilot will work not properly

1st stage of flight we can see small frostbite of the cockpit and a minor one on the fuselage this appeared after 15 minutes of flight

Figure 3.7. Look inside from the cockpit of TBM 930

During 1st stage of flight all systems and autopilot were working properly and nothing went wrong

After 2nd stage of flight I tried to increase the ice cut for that I were flying inside of the clouds with the maximum of humidity

Figure 3.8. Weather radar in TBM 930

And after few minutes we can see the impact of it at aircraft

Figure 3.9. Look from outside of TBM 930

Because of big icing at aircraft autopilot could work properly, first of all pitot system was frozen and aircraft couldn’t get true data of airspeed. Because of that autopilot was unable to maintain the previously set speed.

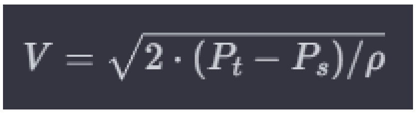
Figure 3.10. Picture of cockpit of TBM 930

A Pitot tube is a device used in fluid dynamics to measure the velocity of a fluid, often employed in aerodynamics and fluid mechanics for determining the airspeed of aircraft or the flow of liquids in various applications. Named after Henri Pitot, the French engineer who invented it in the early 18th century, the Pitot tube operates on the principle of Bernoulli's equation, which relates fluid velocity to pressure.

The main component of a Pitot tube is a slender, hollow tube open at one end and pointed into the fluid flow. This open end, known as the Pitot or impact port, faces directly into the oncoming fluid, capturing its dynamic pressure. Dynamic pressure is the force exerted by a fluid due to its motion, and in the case of the Pitot tube, it represents the kinetic energy of the fluid.

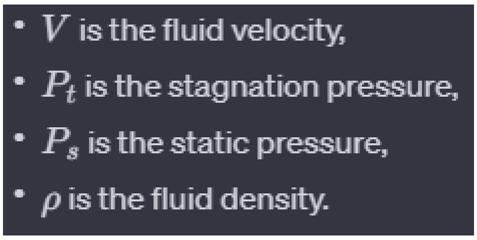
As the fluid enters the Pitot tube, it is decelerated and brought to rest at the stagnation point inside the tube. At this point, the fluid pressure is at its maximum, and this pressure is known as the stagnation pressure. The difference between the stagnation pressure and the static pressure of the fluid (measured outside the tube, perpendicular to the flow) is used to calculate the fluid velocity through Bernoulli's equation.

The basic formula derived from Bernoulli's equation for the Pitot tube is:



$$V = \sqrt{2 \cdot (P_t - P_s)/\rho}$$

Where:



- V is the fluid velocity,
- P_t is the stagnation pressure,
- P_s is the static pressure,
- ρ is the fluid density.

Pitot tubes are commonly used in aviation to determine airspeed. The Pitot tube is mounted on the aircraft with its open end facing into the airstream. The dynamic pressure measured by the Pitot tube provides an accurate indication of the aircraft's airspeed. Additionally, Pitot tubes are employed in various industrial applications for measuring fluid flow in pipes and conduits, providing a versatile and reliable method for velocity measurement in fluid systems.

But it wasn't the last thing that resulted in lost control of aircraft, so when air traffic controller gave the instruction to climb to 13000 ft.

I have chosen to climb by using FLC mode at autopilot and also to turn to 030 degrees

Figure 3.11. Picture of FLC mode at monitor

Flight Level Change (FLC) is a mode within an aircraft's autopilot system designed to facilitate control over the aircraft's vertical speed while maintaining a specific flight level or altitude. The operation of FLC involves several key steps.

Firstly, the pilot initiates the process by selecting a desired altitude or flight level using either the autopilot controls or the Flight Management System (FMS). This sets the target altitude for the aircraft.

Upon setting the target altitude, the pilot engages the Flight Level Change (FLC) mode. Activation of this mode typically occurs through the autopilot panel or the aircraft's avionics system, signaling the system to take control of the vertical aspects of flight.

An integral feature of FLC mode is automatic speed control. The autopilot adjusts the aircraft's pitch to ensure it maintains the selected flight level while concurrently automatically adjusting the airspeed to a predetermined value. This predetermined speed is generally reflective of the aircraft's velocity at the moment FLC mode was engaged.

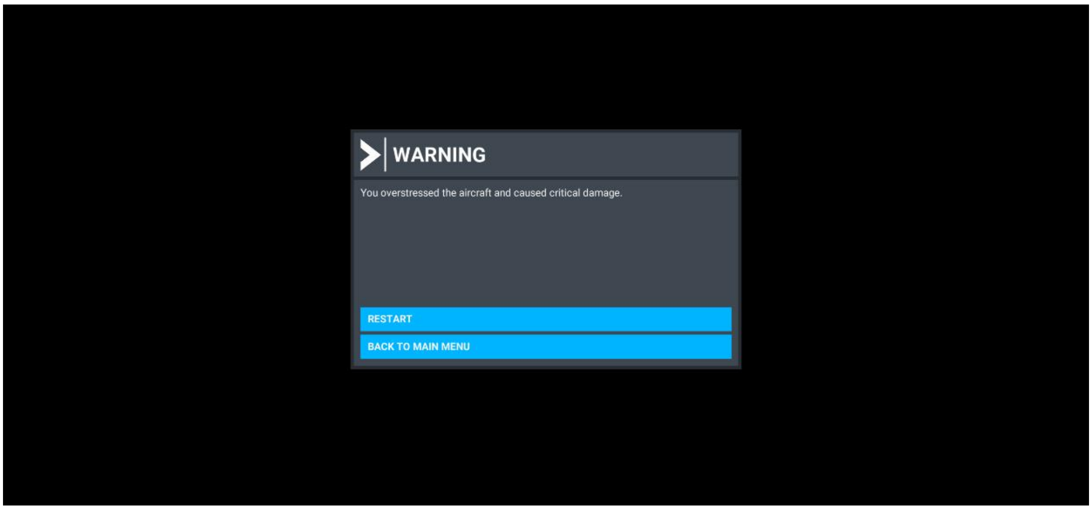
Thrust management is another crucial aspect of FLC mode. The autopilot takes charge of managing the thrust or engine power to achieve and sustain the selected airspeed. Should the aircraft deviate from the chosen airspeed, the autopilot responds by making appropriate adjustments to both pitch and thrust.

FLC mode is versatile and applicable to both climb and descent scenarios. When climbing, the autopilot adjusts pitch and thrust to ascend at the predetermined speed to reach the selected altitude. Similarly, during descent, the autopilot employs similar adjustments to achieve the chosen descent rate while maintaining the specified airspeed.

For added flexibility, pilots retain the ability to manually override FLC mode by adjusting pitch or thrust as needed. This capability allows pilots to respond effectively to changing conditions or comply with instructions from air traffic control (ATC).

As a result the aircraft stall due to low speed and crashed

Figure 3.12. Aircraft stall



WARNING

You overstressed the aircraft and caused critical damage.

Figure 3.13. Aircraft crashed

The second aircraft I have chosen airbus A320 neo

Airbus A320 neo

Fan diameter:PW1100G: 81 in (206 cm), LEAP-1A: 78 in (198 cm)

Seat width Economy at 6 abreast: 18 in (46 cm), 3.7 m (12 ft 2 in) cabin width, Business at 4 abreast

Speed Cruise: Mach 0.78 (450 kn; 833 km/h), Max.: Mach 0.82 (473 kn; 876 km/h)

Engines: (×2) CFM International LEAP-1A or Pratt & Whitney PW1100G

ICAO Type:A20N

1-class maximum:195

2-class seats:165

Max. Thrust:120.6 kN (27,120 lbf)

Max. takeoff weight:79 t (174,200 lb)

Operating empty:44.3 t (97,700 lb)

Minimum Weight:40.3–40.6 t (89,000–90,000 lb)

Ceiling:39,100–39,800 ft (11,900–12,100 m)

Length:37.57 m (123 ft 3 in)

Cargo capacity:37 m3 (1,300 cu ft)

Wingspan:35.80 m (117 ft 5 in)

Fuel capacity:29,659 L (7,835 US gal)

Max. payload:20 t (44,100 lb)

Height:11.76 m (38 ft 7 in)

Typical range:6,500 km (3,500 nmi; 4,000 mi)

Cockpit crew:2 pilots

Takeoff:1,951 m (6,400 ft)

Below I have attached the screenshot how it looks like in the simulator

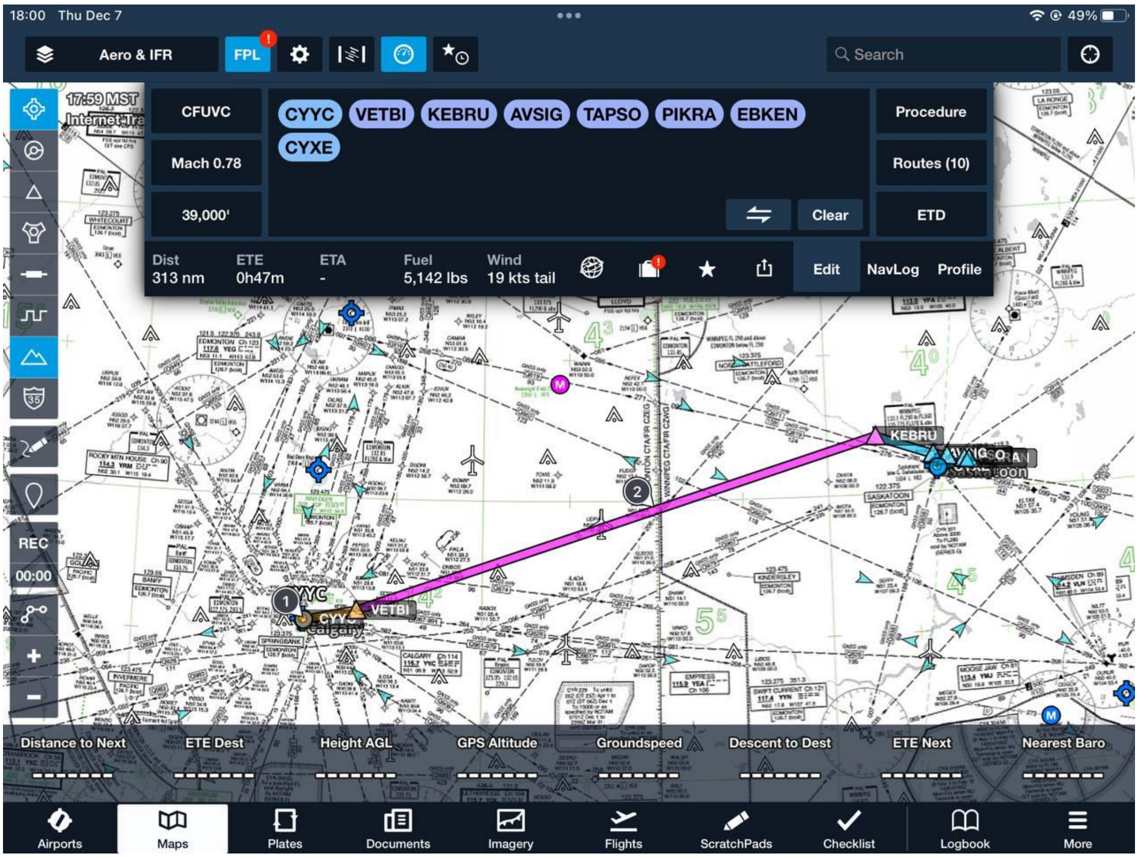
Figure 3.14. Airbus A320 neo in Microsoft flight simulator

For this aircraft I wanted to see and test how will turbulence phenomena will influence at working of an autopilot system, so for that I turned on the turbulence effect.

After I set all parameters for the weather which we can see below, I was ready for take off from Calgary International Airport (Canada)

For this flight I have chosen IFR flight and flight plan:

CYYC - VETBI - KEBRU - AVSIG - TAPSO - PIKRA - EBKEN -CYXE



CFUVC

Mach 0.78

39,000'

CYYC VETBI KEBRU AVSIG TAPSO PIKRA EBKEN CYXE

Dist 313 nm

ETE 0h47m

ETA -

Fuel 5,142 lbs

Wind 19 kts tail

Figure 3.15. Flight plan for airbus A320 neo

For testing autopilot at airbus A320 neo I was using FMS

Figure 3.16. FMS at airbus A320 neo

After setting flight plan at FMS I was ready for take off

```
          FROM CYYC17L
FROM       UTC    SPD/ALT
CYYC17L    1802   ---/ ---
                        2
D0         1804   ---/4010A
                        7
D1         1806   ---/5250
                       30
VETBI      1815   ---/10850
                      265
KEBRU      1846   ---/17300A
DEST       UTC    DIST EFOB
CYXE       0216   330  ----
```

Figure 3.17. Filled flight plan in FMS

Figure 3.18. Example of autopilot in airbus A320 neo

After setting of all initial data I was ready for taking off. Taking off was smooth and nothing unusual were happened.

As I flight was going initially I climbed to 5000 ft and then 11000 ft

Figure 3.19. Look from inside of cockpit airbus A320 neo

After that air traffic controller gave the instruction to climb to 38000 ft and in that segment there was severe turbulence and because of that aircraft autopilot couldn’t maintain the course which I set at autopilot

Figure 3.20. Direction of aircraft at monitor

At the screenshot above we can see that aircraft position and direction differs from the route of the flight plan. Even though the autopilot was trying to keep the initial course because of the severe turbulence it was impossible.

Also, with the A320, I attempted to test in practice how the autopilot will react if the air traffic controller makes a vectoring to avoid an obstacle/dangerous weather conditions, and what the autopilot will do if the aircraft deviates from the original course?

Will it try to go back to the course which were set previously or will it recalculate the course and continue to fly in recalculated course

Also, with the A320, I attempted to test in practice how the autopilot will react if the air traffic controller makes a vectoring to avoid a dangerous weather conditions, and what the autopilot will do if the aircraft deviates from the original course.

So in Microsoft flight simulator were two scenarios:

1. If the aircraft's course deflection is less than 10 degrees, the aircraft's autopilot will attempt to return to the original course.
2. If the aircraft off course by more than 10 degrees, the aircraft's autopilot will not to return to the original course.

3.2 Examples of what an air traffic controller should not do in an emergency situation:

In the realm of air traffic control, understanding how to navigate emergency situations involving autopilot or autopilot system failures is paramount. Reflecting on historical incidents provides valuable insights into the actions controllers should avoid to ensure the highest levels of safety.

One critical aspect is the potential for a delayed response from air traffic controllers when an aircraft experiences an autopilot failure and declares an emergency. Such delays can significantly increase the pilot's workload, compromise situational awareness, and elevate risks, especially during critical phases of flight. Thus, it is imperative for controllers to promptly acknowledge emergency declarations and initiate necessary procedures without hesitation.

Another scenario worth considering involves inadequate traffic separation. When an aircraft encounters autopilot issues and requests deviation from its route for troubleshooting, the controller's failure to provide sufficient traffic separation may lead to near-miss incidents. This situation heightens the risk of mid-air collisions or loss of separation between aircraft, underscoring the importance of controllers prioritizing safe separation, particularly when deviations are requested due to emergencies.

Coordination between different sectors or facilities is a key factor in managing emergencies effectively. In instances where an aircraft experiencing autopilot failure requests a change in altitude or route, a failure to coordinate with adjacent sectors or facilities can result in confusion or conflicting instructions. This lack of coordination increases the risk of airspace incursions and conflicts with other traffic, emphasizing the need for controllers to communicate effectively with neighboring entities for seamless emergency handling.

Communication breakdowns between controllers and pilots during autopilot malfunctions pose significant risks. When an aircraft reports autopilot malfunctions and receives minimal communication or support from the controller, the potential consequences include an increased pilot workload, misinterpretation of instructions, and decreased situational awareness. In such cases, open and clear communication is crucial, and controllers should provide timely information and support to pilots experiencing emergencies.

Lastly, overloading pilots with instructions during an emergency, particularly in the case of autopilot failures, can have severe repercussions. If an aircraft declares an emergency due to autopilot failure, and the controller issues a rapid succession of complex instructions without allowing the pilot sufficient time to manage the situation, the outcome may include an increased pilot workload, potential errors, and compromised safety. Therefore, controllers should prioritize delivering clear and concise instructions, taking into consideration the pilot's workload during emergency situations.

3.3 Recommendation and instructions:

Because of human factors or other influences, air traffic controllers' actions or instructions may differ for each situation, but in most cases, they provide effective support. Not only should pilots be aware of how to avoid dangerous and adverse events, but air traffic controllers should also assist in any way they can, such as initial communication:

Pilot: "Mayday, mayday, mayday. [ATC Facility], this is [Aircraft Call Sign] declaring an emergency. Autopilot is inoperative due to icing, and the pitot system is compromised. Requesting immediate assistance and vectors for an approach."

ATC: "[Aircraft Call Sign], this is [ATC Facility]. Roger mayday. Understand autopilot inoperative due to icing, pitot system compromised. State your intentions."

Pilot: "[ATC Facility], [Aircraft Call Sign]. Intentions are to continue the flight under manual control. Request vectors for an instrument approach and priority handling. Advising fuel status is sufficient for the diversion if needed."

ATC: "[Aircraft Call Sign], roger. Understand you intend to continue manually. Expect vectors for the [Approach Procedure] and advise fuel status. You are cleared to divert to [Alternate Airport] if needed. Traffic in your vicinity is [provide traffic information]."

Pilot: "[ATC Facility], [Aircraft Call Sign]. Copy vectors for [Approach Procedure], will advise fuel status. Thank you. Requesting priority handling."

ATC: "[Aircraft Call Sign], roger. Priority handling granted. Continue on present heading. Traffic information is [additional traffic information]. Report fuel status and any further assistance required."

Pilot: "[ATC Facility], [Aircraft Call Sign]. Continuing on present heading. Will report fuel status and require further assistance if needed. Thank you."

Also, it is critical for air traffic controllers to maintain precise monitoring and provide real-time data to pilots. Air traffic controllers should establish priority communication for the aircraft that has declared an emergency and contact other sectors and aircrafts.

It is designed to use the entire airspace and assist pilots.

Conclusion to chapter 3:

While we acknowledge that it's impossible to create perfect algorithms for addressing every conceivable failure in aviation, our paramount goal is to ensure the maximum safety for aircraft and their occupants. In emergency situations, the collaboration between air traffic control (ATC) and pilots becomes pivotal. ATC plays a crucial role in facilitating clear communication, providing timely assistance, and coordinating with relevant parties to support the pilot in managing the emergency.

To enhance safety, ATC procedures should emphasize:

Prompt Response: Ensuring a prompt and professional response to pilot declarations of emergencies, maydays, or pan-pan calls.

Clear Communication: Facilitating clear and concise communication between ATC and pilots, focusing on obtaining essential information and conveying instructions effectively.

Prioritization: Prioritizing emergency traffic over routine operations to expedite clearances and assistance.

Assistance and Coordination: Offering proactive assistance, providing traffic advisories, and coordinating with other sectors or facilities when needed.

Flexibility: Recognizing the dynamic nature of emergencies and being flexible in adapting procedures to address the specific needs of the situation.

Documentation: Thoroughly documenting incidents, including communications and actions taken, for post-event analysis and continuous improvement.

Training and Familiarity: Ensuring that ATC personnel are adequately trained and familiar with procedures for handling various emergency scenarios.

In summary, while perfection may be unattainable in the face of unforeseen failures, a commitment to continuous improvement, robust communication protocols, and collaborative efforts between ATC and pilots significantly contribute to the overarching goal of ensuring the highest possible level of safety in aviation.

Chapter 4. AUTOMATED BIG DATA PROCESSING IN AIR NAVIGATION

Modern air navigation systems routinely address the task of automated data processing. This involves the processing of air navigation data both on board airplanes, particularly within avionics units, and on the ground through dedicated data processing equipment. Navigation parameters in contemporary systems are measured using an array of diverse sensors, contributing to the creation of a data archive. The processing of this archive necessitates the application of specialized statistical data processing algorithms. Although each sensor introduces a certain margin of error in measurements, the impact of these errors, while unavoidable, can be mitigated to an acceptable level. Consequently, the integrated processing of data in aeronautical systems takes into consideration the error associated with each sensor. Confidence bands, ensuring a specific range within an interval with a certain probability, are employed in this context. The double root mean square deviation is a widely used confidence band, providing 95% localization of measured values based on the assumption of a normal distribution of errors.

The architecture of each avionics unit closely resembles that of a personal computer, featuring essential elements such as a processor, memory, and analog-to-digital/digital-to-analog converters. This configuration enables the processing of measured data at the software level. Sensor data is converted to digital form through the sampling of analog values, and the results of various measurements are stored in appropriate registers, variables, matrices, or data archives.

Detecting the exact location of an airplane stands out as one of the pivotal tasks in civil aviation. The continual growth in air transportation volumes necessitates a regular reassessment of separation minimums to align with the demands of modern air transport. Separation minimums, governing the maximum permissible limits of airplane separation in spatial terms—on the vertical plane, lateral dimensions, and longitudinal sides—are subject to constant review. Addressing airspace congestion involves enhancing the bandwidth of specific airspace segments by reducing safe distances between airplanes. This is practically executed through the imposition of more precise requirements for determining airplane locations in airspace. The implementation of more stringent requirements for airplane positioning relies on the availability of systems capable of meeting these standards. The operation of on-board positioning sensors in civil airplanes is facilitated by aeronautical signals created in space by various systems.

As an illustrative example of big-data processing, the trajectory of a specific aircraft will be considered. The calculation of this trajectory will be carried out using MATLAB software.

4.1 Input data

The safety of air transportation predominantly relies on the precision of the preplanned trajectories adhered to by each user of airspace. The flight technique and performance of on-board positioning sensors dictate the extent of an airplane's deviation from its cleared trajectory. In modern civil aviation aircraft, the primary positioning sensor is the receiver of the Global Navigation Satellite System (GNSS). The performance of the on-board positioning system defines the area within which the airplane is located with a specified level of probability. The operation of an airplane within a designated airspace volume is governed by navigation specifications that outline the requirements for on-board positioning system performance. To ensure a safe flight through a specific airspace volume, each user must navigate with the prescribed levels of performance.

The measured position of an airplane holds a critical status as it plays a pivotal role in the safety of the entire air transport system. According to Automatic Dependent Surveillance-Broadcast (ADS-B), the airplane's position is shared with other airspace users to ensure surveillance and enhance aviation safety. Presently, the majority of airplanes are equipped with transponders of mode 1090 ES (extended squitter). These airplane transponders periodically transmit digital messages, including a position report. This data can be easily received and utilized on-board other airplanes to enhance situational awareness or received by ground receivers. Air navigation service providers leverage a national network of ground ADS-B receivers for surveillance and airspace user identification. Additionally, multiple commercial networks of ADS-B receivers process and collect all data transmitted via the 1090 MHz channel. Notably, computation clusters operated by companies like Flightradar24 and FlightAware engage in simultaneous processing of data from over 30,000 software-defined radios capturing ADS-B signals worldwide. (Picture 4.1)

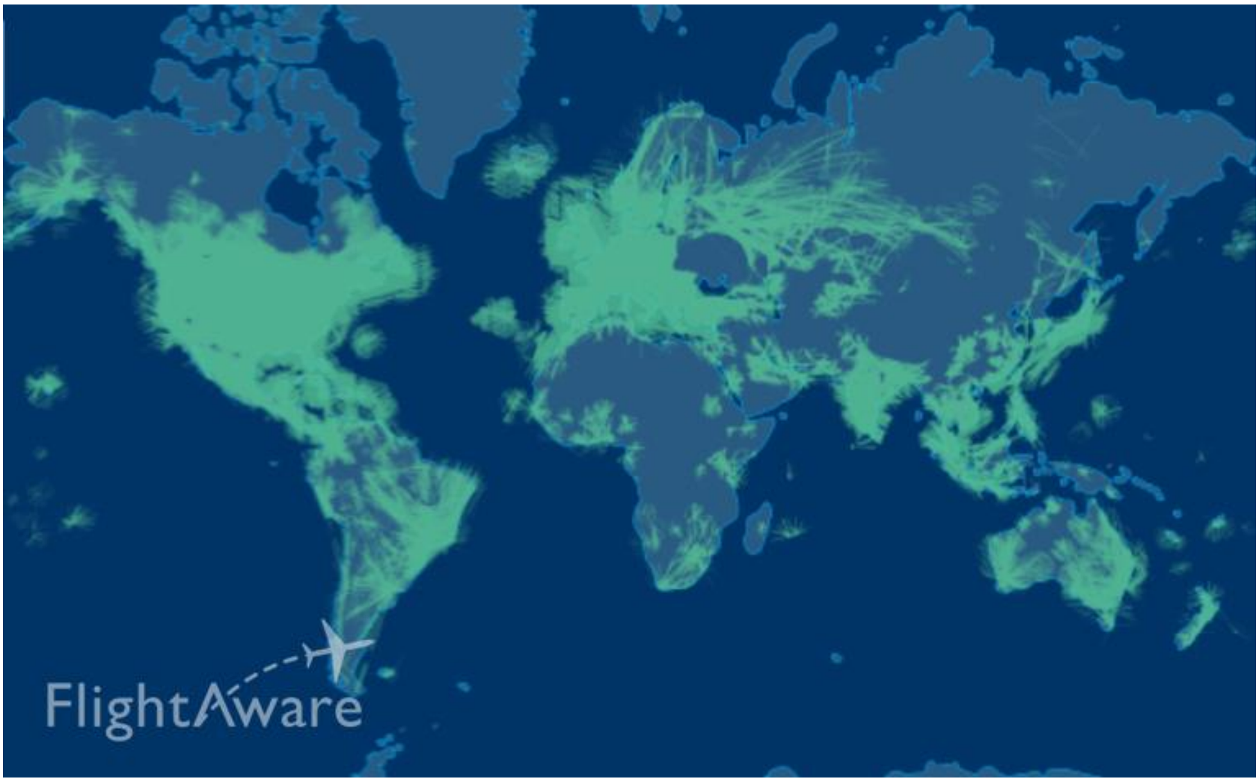


Figure 4.1. Maps of global traffic [10]

Time (EEST)	**Latitude**	**Longitude**	**Heading angle**	**Ground speed (kts)**	**Ground speed (mph)**	**Barometric altitude (feet)**
Wed 11:33:58 AM	41.3113	28.7604	↗ 27°	160	184	1,750
Wed 11:34:07 AM	41.3172	28.7659	↗ 36°	165	190	1,950
Wed 11:34:32 AM	41.3331	28.7839	↗ 41°	193	222	2,325
Wed 11:34:54 AM	41.3517	28.8019	↗ 33°	237	273	2,750
Wed 11:35:10 AM	41.3665	28.8138	↗ 30°	249	287	3,325
Wed 11:35:30 AM	41.3891	28.8254	↑ 8°	254	292	4,325
Wed 11:35:47 AM	41.4092	28.8237	↑ 354°	273	314	4,900
Wed 11:36:17 AM	41.4479	28.8178	↑ 354°	279	321	6,475
Wed 11:36:47 AM	41.4890	28.8125	↑ 355°	289	333	7,975
Wed 11:37:06 AM	41.5136	28.8072	↑ 344°	291	335	8,900
Wed 11:37:24 AM	41.5333	28.7920	↖ 318°	298	343	9,575
Wed 11:38:02 AM	41.5628	28.7309	← 302°	304	350	11,400
Wed 11:38:34 AM	41.5862	28.6792	← 300°	303	349	13,050
Wed 11:39:04 AM	41.6065	28.6317	← 299°	304	350	14,450
Wed 11:39:34 AM	41.6274	28.5819	← 299°	311	358	15,650
…						
Wed 02:24:02 PM	52.5563	4.8370	← 274°	190	219	3,700
Wed 02:24:21 PM	52.5571	4.8131	← 270°	181	208	3,550

Wed 02:24:38 PM	52.5515	4.7910	↙228°	182	209	3,325
Wed 02:25:06 PM	52.5312	4.7677	↙ 213°	191	220	3,050
Wed 02:25:36 PM	52.5094	4.7442	↙ 213°	187	215	2,750
Wed 02:25:54 PM	52.4957	4.7310	↙ 203°	179	206	2,550
Wed 02:26:13 PM	52.4821	4.7244	↓ 192°	172	198	2,325
Wed 02:26:39 PM	52.4613	4.7211	↓ 184°	169	194	1,925
Wed 02:27:09 PM	52.4385	4.7189	↓ 183°	152	175	1,450
Wed 02:27:39 PM	52.4185	4.7171	↓ 183°	143	165	1,050
Wed 02:28:09 PM	52.3987	4.7153	↓ 183°	143	165	650
Wed 02:28:25 PM	52.3878	4.7142	↓ 183°	141	162	425
Wed 02:28:41 PM	52.3780	4.7134	↓ 183°	139	160	225
Wed 02:28:49 PM	52.3729	4.7130	↓ 183°	138	159	125
Wed 02:28:57 PM	52.3678	4.7124	↓ 183°	138	159	50

4.2 Visualization of trajectory data at specific software

Let`s import trajectory data of THY1955 from 6 December 2023 into specialized software of MATLAB [10]. Results of trajectory data visualization for flight is represented in fig. 4.2. and vertical profile of flight is in fig.4.3.

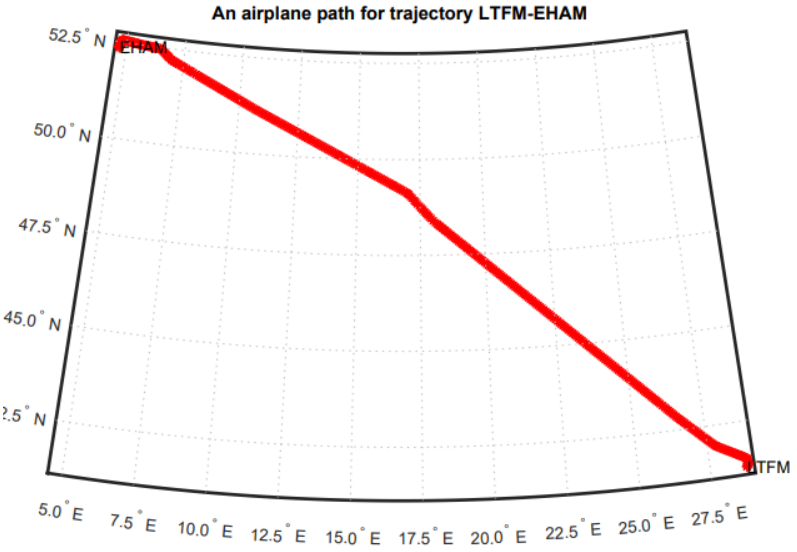


Figure 4.2. Flight path of THY1955 (6 December 2023)

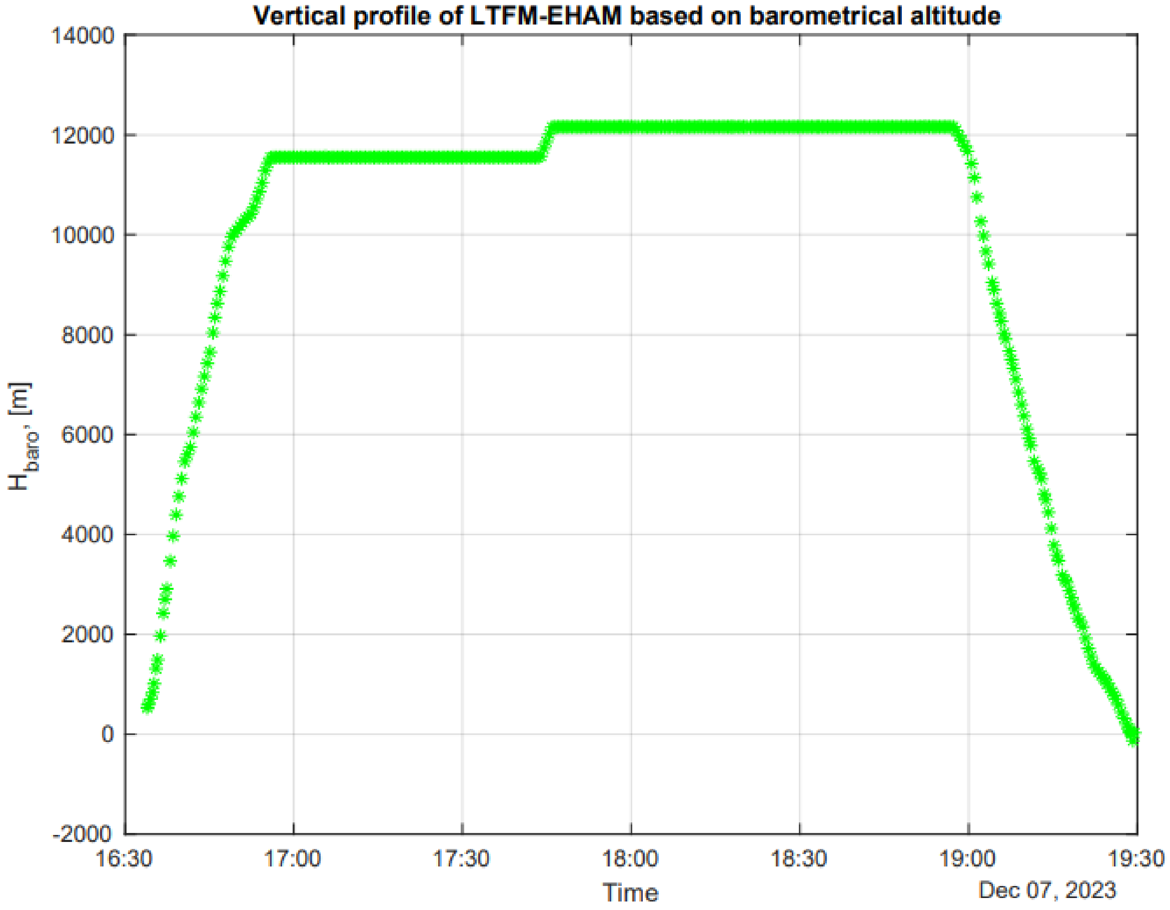


Figure 4.3. Vertical profile THY1955 (6 December 2023)

4.3. Trajectory data interpolation

The digital messages transmitted through ADS-B lack synchronization in time. Each airspace user's transmitter can be configured to its unique frequency for generating digital messages. Additionally, it's important to acknowledge that the frequency of 1090 MHz is frequently utilized, shared by secondary radars, airborne collision and avoidance systems, and ADS-B. This congestion results in potential interference among numerous digital messages, leading to the degradation of data transmitted within these messages. Consequently, ADS-B trajectory data often exhibits gaps in the sequence and fragmented messages. To address this issue during data processing, interpolation methods are typically employed. Interpolation functions, such as polynomials or spline functions, are utilized to fill in missing data points. The outcomes of interpolating input data at a frequency of 1 Hz are depicted in Figures 4.4 to 4.6. All subsequent calculations will be based on the interpolated data. For visualization purposes, the data will be represented in the local NEU system, using the coordinates of the initial trajectory point as the center. The visual representation of the trajectory in the local system is illustrated in Figures 4.7 and 4.8.

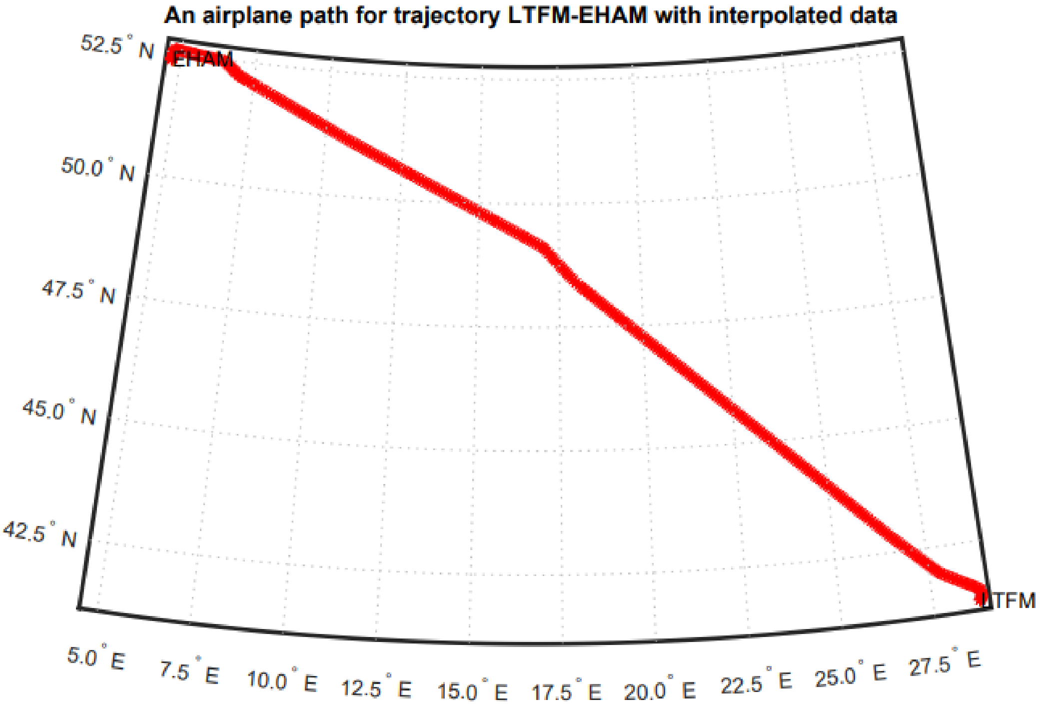


Figure 4.4. Interpolated airplane trajectory of THY1955 (6 December 2023)

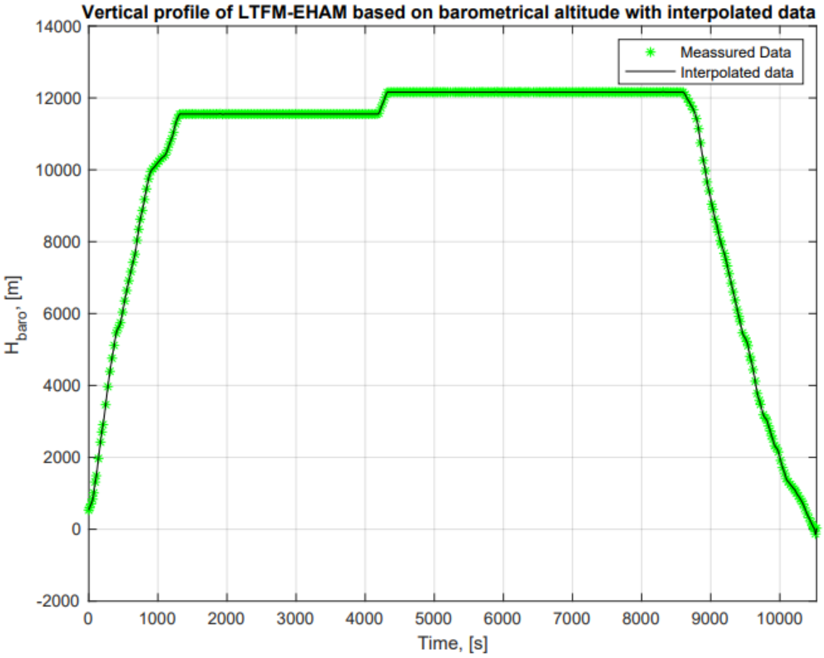


Figure 4.5. Interpolated vertical profile of THY1955 (6 December 2023)

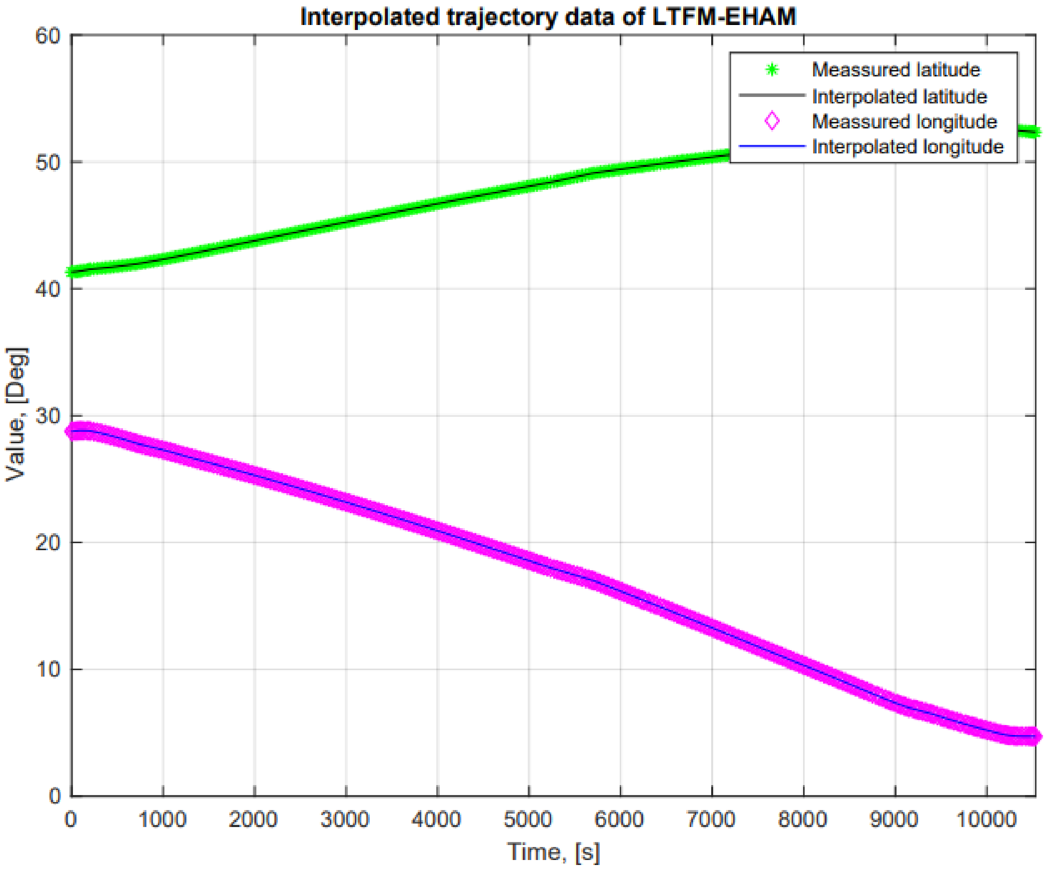


Figure 4.6. Interpolated data for 1 Hz of THY1955 (6 December 2023)

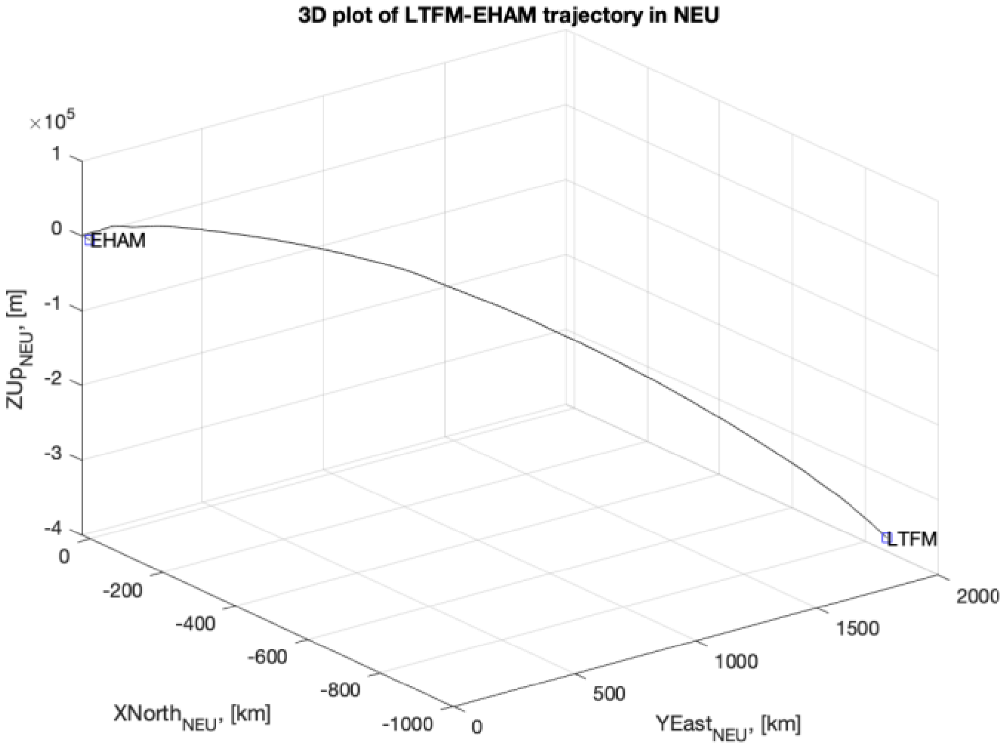


Figure 4.7. 3D trajectory of THY1955 in NED reference frame

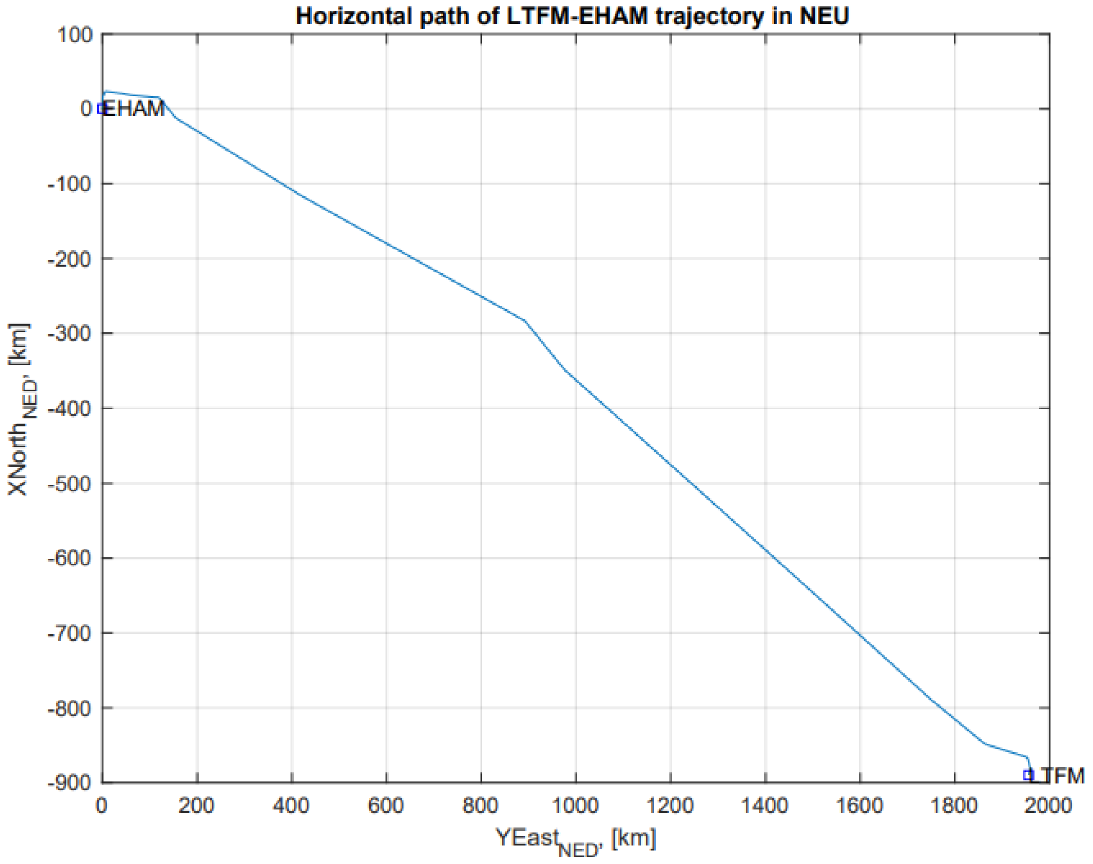


Figure 5.8. Flight path of THY1955 in local NED

4.4 Trajectory data calculation

Utilizing the dataset of the three-dimensional movement trajectory, we are engaged in the computation of the aircraft's speed components. Specifically, we are determining the overall speed of the airplane, along with its vertical and horizontal components. The outcomes of these speed calculations are visually presented in Figure 4.9, showcasing the results, and the inferred course of the aircraft is depicted in Figure 4.10. Additionally, I am conducting computations to ascertain the total flight duration and the extent of the route and trajectory.

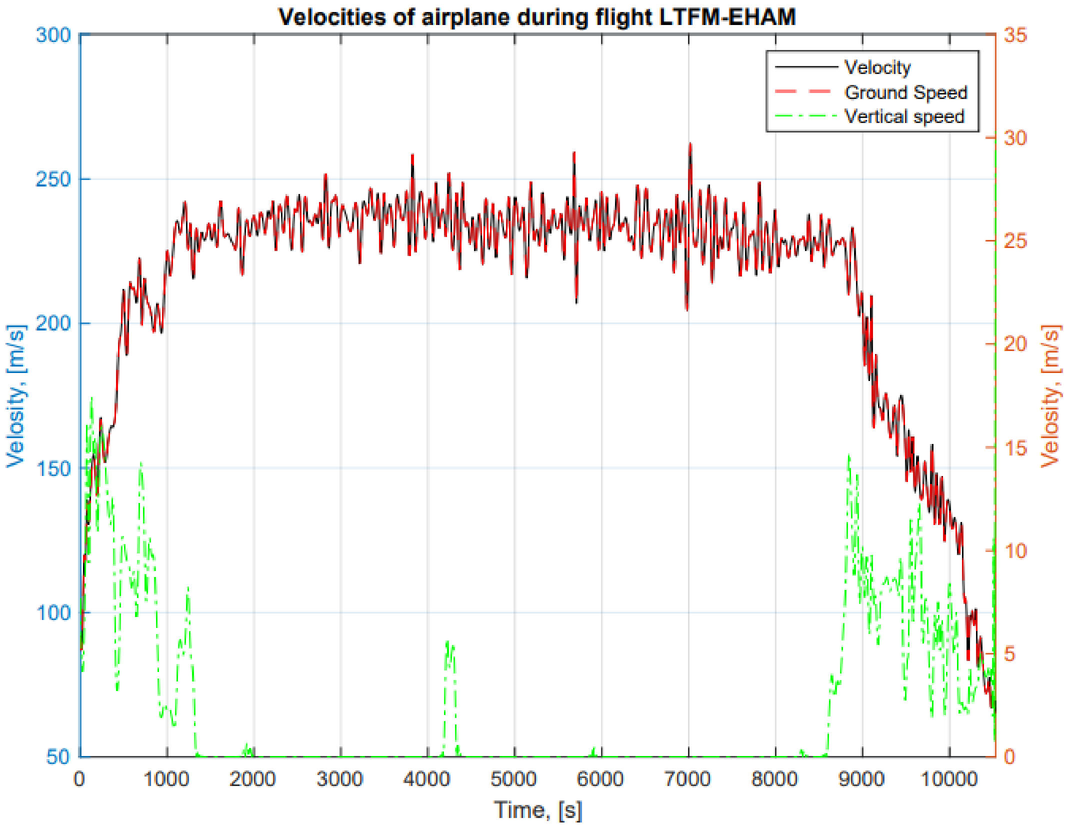


Figure 4.9. Results of velocity estimation of THY1955 (6 December 2023)

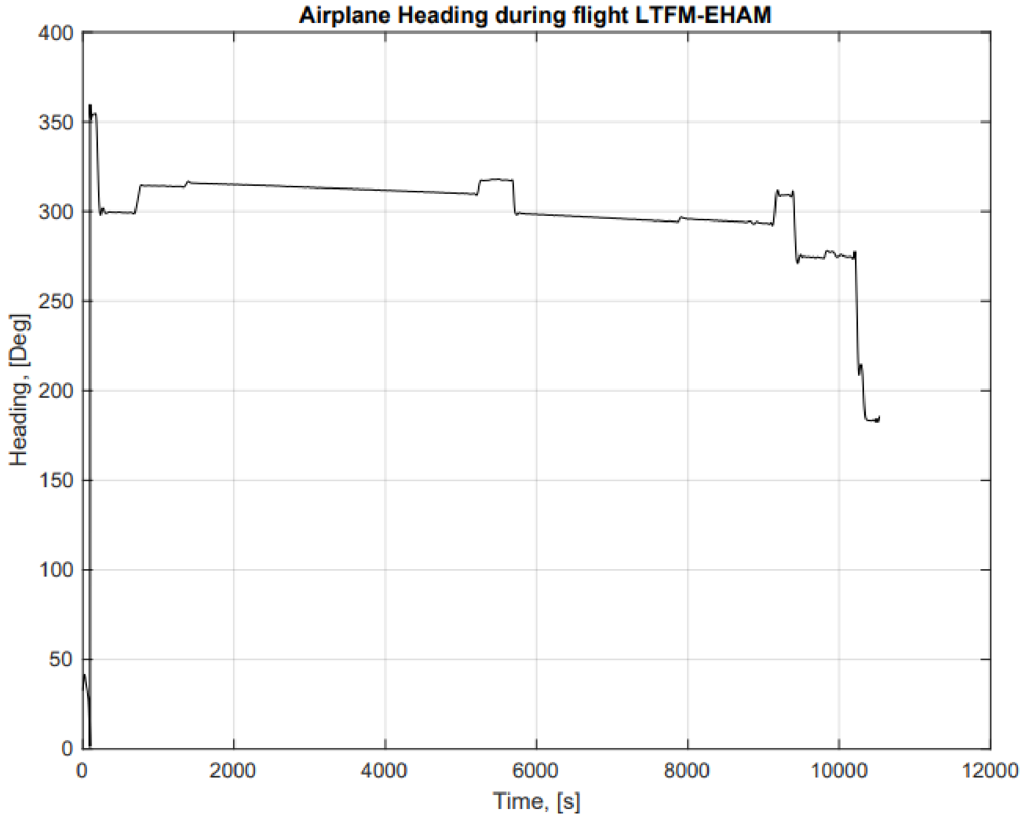


Figure 4.10. Results of heading angle calculation of THY1955 (6 December 2023)

The total flight time of THY1955 on December 6, 2023, was 2 hours 55 minutes. The length of the trajectory is 2261 km.

Conclusion to chapter 4:

Automated big data processing in air navigation not only enhances the precision and reliability of navigation systems but also plays a pivotal role in ensuring the seamless coordination between airborne and ground-based components. As technological advancements continue to evolve, the continued refinement of processing algorithms and systematic analysis will be paramount in meeting the ever-growing demands of the aviation industry, ultimately contributing to safer and more efficient air travel.

CHAPTER 5. LABOR AND ENVIRONMENTAL PROTECTION

5.1 Labor protection

The aviation industry is a shining example of progress, connecting the world and facilitating global mobility. Air traffic controllers orchestrate the movement of aircraft with precision and expertise at the heart of this intricate web of flights. The importance of protecting these controllers' safety and reducing the environmental impact of aviation operations cannot be overstated. As we delve deeper into the complexities of air traffic control, it becomes clear that a dual commitment to labor and environmental protection is not only a moral imperative, but also a strategic necessity for the aviation sector's long-term evolution.

Here are some examples of labor and environmental protection measures that apply to air traffic controllers:

Labor Security:

Programs for Fatigue Management:

Air traffic controllers frequently work in high-stress, irregular-hour environments. By implementing rest periods and scheduling practices that prioritize controller well-being, fatigue management programs help monitor and mitigate fatigue-related risks.

Professional Development and Training:

Air traffic controllers are kept up to date on the latest technologies and procedures thanks to ongoing training and professional development opportunities. This contributes to controllers maintaining a high level of competence and job satisfaction.

Support for Mental Health:

Air traffic control can be a mentally taxing job. Aviation organizations are increasingly recognizing the value of mental health support programs, such as counseling services and stress management initiatives.

Measures to Improve Workplace Safety:

Implementing safety measures within control towers and radar facilities is critical for protecting air traffic controllers' health and safety. This includes ergonomic considerations, proper lighting, and workplace injury prevention measures.

Labour Standards:

Ensuring fair and equitable labor practices, such as reasonable working hours, overtime compensation, and adherence to international labor standards, contributes to air traffic controllers' overall job satisfaction and well-being.

Environmental Defence:

Routing and Procedures for Saving Fuel:

Air traffic controllers help optimize flight routes and procedures in order to reduce fuel consumption and emissions. Efficient routing reduces the environmental impact of flights and helps to achieve sustainability goals.

Collaboration on Noise Reduction:

Noise abatement procedures are implemented in collaboration with pilots and airport authorities by controllers. This entails optimizing departure and arrival routes to reduce noise impact on neighboring communities.

Continuous Descent Approaches Implementation:

Encourage continuous descent approaches during aircraft landings to save fuel and reduce noise levels. The role of air traffic controllers in coordinating these approaches for arriving flights is critical.

Electric Aircraft Integration:

Air traffic controllers will be involved in facilitating the integration of these more environmentally friendly aircraft into airspace and airport operations as electric and hybrid-electric aircraft technologies advance.

Adoption of Green Technologies:

To reduce their overall environmental footprint, air traffic management facilities can implement sustainable technologies such as energy-efficient lighting, renewable energy sources, and eco-friendly building designs.

Let’s describe more useful in my opinion example of labor protection ergonomic considerations:

Adjustable Workstations: Provide control tower and radar facility operators with adjustable workstations that allow them to customize the height and position of monitors, keyboards, and other equipment to reduce strain and fatigue.

Ergonomic Seating: Use ergonomic chairs that provide proper lumbar support and encourage good posture. Chairs should be adjustable to accommodate different body types and preferences.

Anti-Fatigue Mats: Install anti-fatigue mats in areas where controllers stand for extended periods. These mats can reduce pressure on the feet and legs, minimizing the risk of musculoskeletal issues.

Proper Lighting:

Natural Light: Design control towers and radar facilities with windows to maximize natural light exposure. Natural light has been shown to improve mood, alertness, and overall well-being.

Adjustable Lighting Systems: Install adjustable lighting systems to control the brightness and color temperature of artificial light. This allows controllers to adapt the lighting conditions to the specific needs of their tasks and time of day.

Glare Reduction: Implement measures to reduce glare on computer screens and radar displays, such as anti-glare filters and proper placement of lighting fixtures.

Workplace Injury Prevention:

Training Programs: Provide comprehensive training programs on ergonomic practices, proper lifting techniques, and injury prevention. Ensure that controllers are aware of the potential risks associated with their tasks and understand how to mitigate them.

Regular Breaks: Encourage and enforce regular breaks to prevent prolonged periods of sitting or standing. Breaks allow controllers to stretch, move around, and reduce the risk of repetitive strain injuries.

Safety Equipment: Ensure the availability and proper use of safety equipment, such as anti-static mats, to prevent electrical shocks, and wrist supports to minimize the risk of repetitive stress injuries.

Noise Reduction Measures: Implement noise reduction measures, such as soundproofing and noise-canceling headphones, to protect controllers from the negative effects of prolonged exposure to high noise levels.

Environmental Controls:

Temperature Regulation: Maintain a comfortable temperature within control towers and radar facilities to prevent discomfort and minimize the risk of heat or cold-related stress.

Air Quality: Implement measures to ensure good indoor air quality, including proper ventilation and air filtration systems. Poor air quality can contribute to health issues and decreased cognitive performance.

Emergency Preparedness:

Emergency Equipment: Ensure the availability and accessibility of emergency equipment, including first aid kits and fire extinguishers.

Continuous Improvement:

Feedback Mechanisms: Establish channels for controllers to provide feedback on workplace safety concerns. Regularly review and address feedback to make ongoing improvements.

Risk Assessments: Conduct regular risk assessments to identify potential hazards and implement measures to mitigate or eliminate them.

Collaboration with Health Professionals: Work with occupational health professionals to assess the workplace and provide recommendations for improvements.

5.2. Environmental Protection

Aircraft noise is a significant concern for communities living near airports, as it can negatively impact residents' quality of life. To address this issue, manufacturers and airlines have been actively engaged in developing quieter aircraft engines and implementing operational procedures aimed at minimizing noise pollution in and around airports.

One key approach to reducing aircraft noise is through advancements in engine technology. Manufacturers invest in research and development to design and produce quieter engines that meet or exceed stringent noise regulations. These advancements often involve improvements in fan and exhaust nozzle designs, as well as the incorporation of sound-absorbing materials. The goal is to strike a balance between maintaining the necessary thrust for flight and minimizing the noise generated during takeoff, landing, and taxiing.

Operational procedures also play a crucial role in noise reduction efforts. Airlines work closely with air traffic control to optimize flight paths and minimize unnecessary low-altitude flying over populated areas. Additionally, modern navigation technologies and procedures allow for steeper approach angles during landings, which can reduce the duration of time an aircraft spends at lower altitudes, thereby mitigating noise impact on the ground.

Moreover, many airports have implemented strict noise abatement procedures, including designated flight paths and runway usage policies that prioritize routes over less densely populated areas. These measures aim to distribute the noise footprint more evenly and away from residential neighborhoods, minimizing the impact on local communities.

To further address the issue, aviation authorities and regulatory bodies set noise standards that aircraft must adhere to. Compliance with these standards is mandatory for aircraft certification, encouraging manufacturers to invest in noise reduction technologies. Governments may also provide incentives for airlines to retire older, noisier aircraft and replace them with newer, quieter models.

Conclusion to chapter 5:

These examples demonstrate the aviation industry's dual commitment to protecting air traffic controllers' well-being while also contributing to environmental sustainability. The incorporation of advanced technologies, as well as ongoing collaboration among stakeholders, are critical components of achieving these objectives.

By implementing these measures, air traffic control facilities can create a safer and healthier work environment for controllers, ultimately contributing to enhanced job satisfaction, productivity, and overall safety in air traffic management. Also the aviation industry recognizes the importance of mitigating the impact of aircraft noise on local communities. A combination of technological innovation, operational adjustments, regulatory measures, and collaborative efforts between manufacturers, airlines, and regulatory bodies is essential to achieving meaningful noise reduction and creating more sustainable and harmonious relationships between airports and the communities they serve.

Conclusion:

During the process of writing the diploma I studied pilot’s and air traffic controller’s interactions during automated flight and its failure and also consequences of it.

In overall conclusion, the paramount goal of aviation safety, particularly in emergency situations, revolves around the collaboration between air traffic control (ATC) and pilots. Acknowledging the impossibility of creating perfect algorithms for every conceivable failure, the emphasis is on ensuring the maximum safety for aircraft and occupants.

The collaborative efforts between ATC and pilots are critical during emergencies. ATC's role encompasses facilitating clear communication, providing timely assistance, and coordinating with relevant parties to support pilots in managing emergencies. Key safety-enhancing procedures for ATC include ensuring a prompt and professional response, fostering clear communication, prioritizing emergency traffic, offering proactive assistance, being flexible in adapting procedures, and thorough documentation for post-event analysis.

The commitment to continuous improvement, robust communication protocols, and collaborative efforts significantly contributes to the overarching goal of achieving the highest possible level of safety in aviation. While perfection may be elusive in the face of unforeseen failures, adherence to meticulously crafted guidelines and ongoing training ensures that air traffic controllers are well-equipped to handle various emergency scenarios, ultimately contributing to the safety and resilience of automated flight operations.

In essence, the effectiveness of ATC instructions and support during emergencies, such as autopilot malfunctions, depends on the specific circumstances of each incident. By incorporating principles that prioritize swift response, effective communication, and collaboration with pilots, controllers play a crucial role in mitigating potential risks and ensuring the well-being of both the aircraft and its occupants. This collaborative and proactive approach underscores the aviation industry's commitment to continuous improvement and unwavering dedication to safety.

I think that my recommendations and actions that air traffic controller should do and should not do will help in future to avoid the emergency situations or better judgement if these situations will happen. So because of it I think that I achieved to provide better understanding and better acting in unfavourable situations

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