МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

ФАКУЛЬТЕТАЕРОНАВІГАЦІЇ, 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)

ВИПУСКНИЦІ ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА

ЗА ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ

«ОБСЛУГОВУВАННЯ ПОВІТРЯНОГО РУХУ»

Тема: «Вплив віку на професійну ефективність роботи авіадиспетчера»

Виконала: Ямшанова А. І.

Керівник: Луппо О. Є.

Керівник спеціального розділу

д.т.н. проф. Остроумов Іван Вікторович

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.Yu. Larin

"_____" ___________ 2023

MASTER’S THESIS

ON THE EDUCATIONAL PROFESSIONAL PROGRAM

"AIR TRAFFIC SERVICE"

(EXPLANOTARY NOTE)

Theme: "Examining the Impact of Age on the Job Performance of ATCO"

Performed by: Anna Yamshanova

Supervisor: Luppo O. E.

Special chapter supervisors:

Doctor of Sciences (Engineering), prof. Ostroumov I.V.

Standard inspector: Argunov G. F.

Kyiv 2023

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет Аеронавігації, Електроніки та Телекомунікацій

Кафедра аеронавігаційних систем

Спеціальність: 272 «Авіаційний транспорт»

ОПП: Обслуговування повітряного руху

Затверджую:

Завідувач кафедри АНС

_____________ Ларін В.Ю.

«____»________________

ЗАВДАННЯ

на виконання дипломної роботи

Ямшанової Анни Ігорівни

1. Тема дипломної роботи: «Вплив віку на професійну ефективність роботи авіадиспетчера» затверджена наказом ректора від "22" жовтня 2023 р. № 1443/ст
2. Термін виконання проекту: 23.10.2023 – 31.12.2023
3. Вихідні дані до проекту: EUROCONTROL, ICAO, первинні ресурси
4. Зміст пояснювальної записки: теоретичні відомості щодо впливу віку на професійну ефективність роботи авіадиспетчера, аналіз ймовірності зниження ефективності авіадиспетчера з довгим стажем роботи, аналіз методів щодо покращення ефективності роботи авіадиспетчерів і можливості запобігання негативних наслідків старіння в роботі.
5. Перелік обов'язкового графічного (ілюстративного) матеріалу: 6 таблиць, 30 рисунків.

6. Календарний план-графік

Завдання	Термін виконання	Відмітка про виконання
Підготовка та написання 1 розділу «Вплив віку авіадиспетчера на професійну ефективність роботи»	25.10.2023 -01.11.2023	Виконано
Підготовка та написання 2 розділу «Аналіз ефективності роботи авіадиспетчерів старшого віку»	02.11.2023 -17.11.2023	Виконано
Підготовка та написання 3 розділу «Запобігання зниження ефективності роботи вікових авіадиспетчерів»	18.11.2023 -29.11.2023	Виконано
Підготовка та написання 4 розділу «Спеціальний розділ»	02.11.2023 -10.12.2023	Виконано
Підготовка та написання 5 розділу «Охорона праці та охорона навколишнього середовища»	15.11.2023 -24.11.2023	Виконано
Підготовка доповіді та графічних матеріалів	25.11.2023 -06.12.2023	Виконано
Попередній захист дипломної роботи	13.12.2023	Виконано

7. Консультанти з окремих розділів

Розділ	Консультант (посада, П.І.Б.)	Дата, підпис	
		Завдання видав	Завдання прийняв
Спеціальний розділ	Проф. д.т.н Остроумов І.В.	02.11.2023	02.11.2023

Дата видачі завдання: 23.10.2023

Керівник дипломного проекту: ____________ Луппо Олександр Євгенійович

(підпис керівника) (П.І.Б.)

Завдання прийняла до виконання: __________ Ямшанова Анна Ігорівна

(підпис студента) (П.І.Б.)

NATIONAL AVIATION UNIVERSITY

Faculty of Air Navigation, Electronics and Telecommunications

Air navigation Systems Department

Specialty: 272 «Aviation Transport»

EPP: «Air Traffic Services»

Approved:

Head of the Department

_____________V.Yu.Larin

«____»________________

Graduate Student’s Degree Thesis Assignment

Anna Yamshanova

1. The Master’s degree thesis topic: “Examining the Impact of Age on the Job Performance of Air Traffic Controllers” approved by the Rector’s order of 22.10.2023 № 1443/st.

2. The Master’s degree thesis to be completed between: : 23.10.2023 – 31.12.2023

3. Initial data to the thesis: data of EUROCONTROL, ICAO, primary sources

4. Contents of the explanatory note: theoretical information on the influence of age on the professional efficiency of an ATCO, analysis of the probability of a decrease in the efficiency of an ATCO with a long work experience, analysis of methods to improve the efficiency of ATCO and the possibility of preventing the negative effects of aging in work.

5. The list of mandatory graphic (illustrated) materials: 6 tables, 30 figures.

6. Calendar timetable

Completion stages of Degree Thesis	Stage completion dates	Remarks
Preparation of chapter 1: «Impact of ATCO´s Age on the Job Performance»	25.10.2023 -01.11.2023	Done
Preparation of chapter 2: «Analysis of the Performance of Elderly ATCO»	02.11.2023 -17.11.2023	Done
Preparation of chapter 3: «Preventing a Decline in the Efficiency of Age-related ATCO»	18.11.2023 -29.11.2023	Done
Preparation of chapter 4: «Special Chapter»	02.11.2023 -10.12.2023	Done
Preparation of chapter 5: «Labor precaution and environment safety»	15.11.2023 -24.11.2023	Done
Preparation of report and graphic materials	25.11.2023 -06.12.2023	Done
Preliminary defense of master's thesis	13.12.2023	Done

7. Consultants from separate departments chapters

Chapter	Consultant (position, full name)	Date, signature	
		Task issued	Task accepted
Special chapter	D. Sc., prof. Ivan Ostroumov	02.11.23	02.11.23

Assignment accepted for completion: 23.10.2023

Supervisor: Luppo O. E.

Assignment accepted for completion: Anna Yamshanova

РЕФЕРАТ

Пояснювальна записка до дипломної роботи «Вплив віку на професійну ефективність роботи авіадиспетчера»: 92 сторінки, 30 рисунків, 6 таблиць, 23 використаних джерел.

Об'єкт дослідження – професійна ефективність роботи авіадиспетчера

Предмет дослідження – вплив віку на професійну ефективність роботи авіадиспетчера

Мета роботи – розробка рекомендацій щодо запобігання зниження ефективності роботи авіадиспетчерів старшого віку

Метод дослідження – теоретичні методи, графічне моделювання, аналітичні дослідження

Основна задача написання роботи на тему "Вплив віку на професійну ефективність роботи авіадиспетчера" є дослідження, як вік авіадиспетчера впливає на його професійну продуктивність і результативність. Аналіз впливу віку на професійну ефективність дозволяє нам отримати нові знання про те, які групи авіадиспетчерів можуть потребувати додаткової підтримки, які методи ми можемо використовувати для покращення ефективності роботи авіадиспетчера. А також запобігання зниження ефективності роботи авіадиспетчерів під час старіння.

ВІК, ЕФЕКТИВНІСТЬ РОБОТИ, АВІАДИСПЕТЧЕР, ВПЛИВ, КОГНІТИВНІ ЗДІБНОСТІ, ДОСВІД, ЛЮДСЬКИЙ ФАКТОР, ЕКСПЕРТНІСТЬ, АВТОМАТИЗАЦІЯ, МІЖНАРОДНА ОРГАНІЗАЦІЯ ЦИВІЛЬНОЇ АВІАЦІЇ, ОБСЛУГОВУВАННЯ ПОВІТРЯНОГО РУХУ

ABSTRACT

Explanatory note to the master's thesis, "Examining the Impact of Age on the Job Performance of Air Traffic Controllers": 92 pages, 30 figures, 6 tables, 23 references.

Investigation object – the Job Performance of Air Traffic Controllers

Investigation subject – the Impact of Age on the Job Performance of Air Traffic Controllers

Purpose of the work – development of recommendations to prevent senior air traffic controllers from decreasing their work efficiency

Investigation method – theoretical methods, graphical modeling, analytical research

The main objective of writing a thesis on "The Impact of Age on the Professional Performance of an Air Traffic Controller" is to study how the age of an air traffic controller affects his or her professional performance and effectiveness. Analyzing the impact of age on professional performance allows us to gain new knowledge about which groups of air traffic controllers may need additional support and what methods we can use to improve the performance of air traffic controllers. It also helps to prevent the decline in ATC performance as they age.

AGE, JOB PERFORMANCE, AIR TRAFFIC CONTROLLER, IMPACT, COGNITIVE ABILITIES, EXPERIENCE, HUMAN FACTOR, EXPERTISE, AUTOMATION, ICAO, AIR TRAFFIC SERVICE

PAGE OF REMARKS

CONTENT

LIST OF THE ABBREVIATIONS

AC – Aircraft

ACC – Area Control Centre

AMEs – Advanced Certificate in Aviation Medicine

APP – Approach Control

ATC – Air Traffic Control

ATCC – Air Traffic Control Centre

ATCO – Air Traffic Control Operator

ATM – Air Traffic Management

ATS – Air Traffic Service

CBT – Computer-based Training

EATM – European Air Traffic Management

EUROCONTROL – European Organization for the Safety of the Air Navigation

FIS – Flight Information Service

FAA – Federal Aviation Administration (US)

IATA – International Air Transport Association

ICAO – International Civil Aviation Organization

IT – Information Technology

MUAC – The Maastricht Upper Area Control Centre

OPS – Operations

REP – Report

R/T – Radiotelephony

TWR – Aerodrome Control (Tower)

INTRODUCTION

Relevance of the topic. Aging affects all of us, and nobody can deny that it is important to focus on this topic. According to statistics from recent years, researchers found that life expectancy has increased. As a result, the relative number of elderly people compared to young people is growing. In aviation, this little discussed topic is a very important one. Moreover, because of the increase in air traffic, the topic of aging is becoming more and more important.

It is well known that ATCOs are highly responsible for flight safety and airspace efficiency. Also, their decisions are critical to avoiding accidents and incidents in the airspace.

Age has an impact on the psychophysical state and cognitive abilities of ATCOs. Older air traffic controllers also face difficulties in dealing with the newest technologies. Compared to younger employees, it takes much longer to get used to automation. Adapting to changes in the workplace becomes more difficult over time. These factors can reduce the efficiency of an air traffic controller, which directly affects the level of safety.

Despite the fact that Western culture tends to focus on the negative aspects of aging, in this work I am going to overcome this "anxiety". On the other side of the coin is the accumulation of experience, knowledge and skills. These positive aspects of an air traffic controller's aging allow them to complete most tasks automatically and solve problems according to a known and practiced scenario.

Research on the impact of age will help optimize Air Traffic Control Operator training and retraining throughout their careers, as well as develop programs to support and improve skills for older Air Traffic Control Operators. And with the proper management approach and ergonomics, it is possible to prevent the decrease in the effectiveness of older ATCs.

That is why in this work we have established the following objectives:

1. To investigate how the age of an Air Traffic Control Operator impacts his or her job performance
2. To analyze the performance of Air Traffic Control Operator of the older age group
3. Develop recommendations for preventing a decline in the efficiency of older air traffic controllers Develop recommendations for preventing a decline in the efficiency of older air traffic controllers

CHAPTER 1. IMPACT OF ATCO´s AGE ON THE JOB PERFORMANCE

1.1. Aging

Aging is a complex combination of factors (physiological, social, cultural). It is part of a natural process that begins at birth and continues throughout life. It is also a continuous process of functional change associated with the gain and loss of functionality. An example of this is the human nervous system, which continuously develops throughout life. Each person is born with a certain number of brain cells, and many of these cells die as early as infancy already. At the same time, the network that connects the cells to each other grows dramatically as the child learns more and more skills. At the same time, the network that connects cells to each other grows dramatically as the child learns more and more skills (e.g., walking, speak, etc.). We can differentiate between several concepts of age (see Figure 1.1):

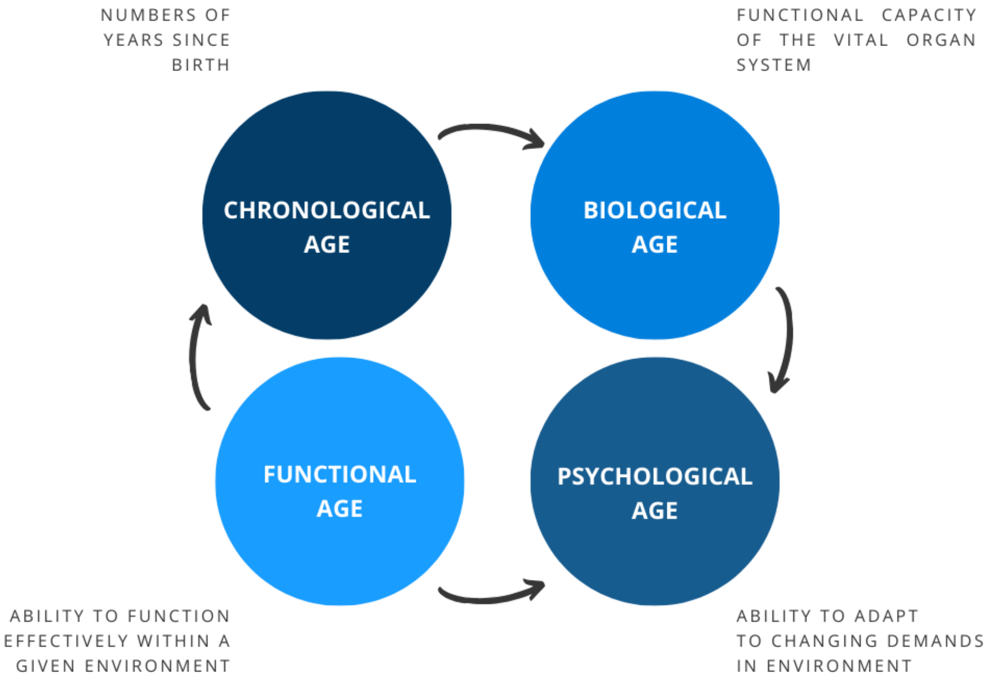

Figure 1.1 – Concepts of age

Firstly, the chronological age (numbers of years that have elapsed since a personís birth) is for most of us identical with the concept of age.

Secondly, the concept of biological age takes the individual functional capacities of the vital organ system as an index for his or her present position with respect to his or her potential life span.

Thirdly, the psychological age of a person is his or her ability to adapt to changing environmental demands as compared to the adaptability of other individuals of identical chronological age. It is the personís adaptive capacity in terms of learning, memory, intelligence, emotional control, motivational strength, coping styles, etc.

Finally, the functional age refers to the ability of an individual to function effectively within a given environment or society.

Many people believe that old age comes at 60 or 65. However, this is more of a convention than a firm conclusion, and there is always a wide variation.

People always disagree on the expressions of aging. In addition, since the focus of my work is on people in the workplace, it considers a broader age range starting at forty. [1]

Aging in the ATM

Why should any of this be a problem for air traffic control? It is becoming increasingly relevant due to increasing air traffic and major changes in technical equipment, procedures, and airspace organization. All of these factors combine to place high demands on air traffic controllers, yet dispatchers over forty years of age may feel a greater impact. Cognitive abilities change with age. Even if skills deteriorate with age, experience gained over the course of a working career will offset these negative effects.

Research in this area has yet to conclude at what point an ATC ceases to be satisfactorily functional. How can we support the elderly air traffic controller - by improving technical systems, adapting training methods.

How can we maintain the required level of professionalism for as long as possible? This section does not aim to answer this question, that would require more in-depth research. I just want to draw attention to the problem of the narrowing down of the freedom of the individual who is doing a job that is becoming more and more complex on a daily basis.

For example, what about the cognitive abilities of an aging person? In the following, I will look at this situation from different angles and analyze which qualities important for effective performance suffer the most as we become older.

Aging and Cognitive Performance

Signal detection can refer to both visual and auditory cues. Most of us are aware of the fact that vision deteriorates with age. In more detail, it is harder to follow moving objects, dark adaptation is less and less good, sensitivity to glare increases, and recovery time from glare exposure increases. Hearing also tends to decline in late adulthood, but hearing difficulties are less common than vision. However, difficulties with hearing are less common than with vision. Nineteen percent of people between the ages of 45-54 experience hearing difficulties. In general, the ability to hear high-frequency sounds degrades and the ability to hear speech declines. The difficulty in understanding speech sounds becomes even greater when the listener is in a noisy environment. Obviously, this problem can lead to severe limitations in auditory communication.

Attention is a global ability required to enable cognitive processing of information. Attention capacity is limited, so information must be prioritized and attention allocated to relevant information based on task goals. This general ability of attention is thought to decline with age. However, as shown in Figure 1.2, we can distinguish between different types of attention: selective attention, divided attention, sustained attention, and automatic versus effortful information processing. Aging affects these types of attention in different ways.

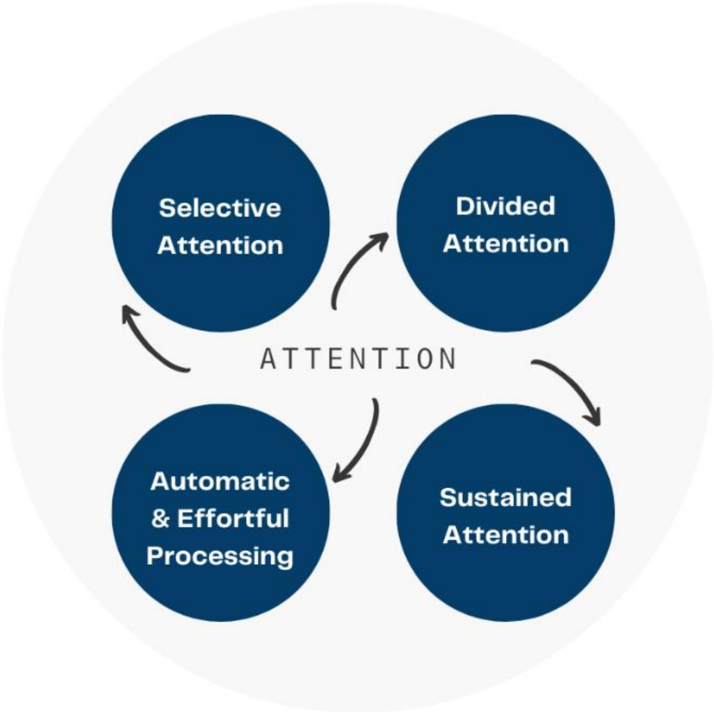

Figure 1.2 – Types of attention

Selective attention: With respect to attention and visual search, older adults have been found to have more difficulty distinguishing between relevant and irrelevant information. This effect is enhanced when the similarity between the target objects (i.e., the relevant piece of information) and the distractor increases as noise appears. In addition, older subjects have reduced perceptual flexibility (they are slower in changing percepts once they are formed) and have difficulty identifying incomplete figures. However, for many other areas of selective attention (i.e., that is, ignoring material irrelevant to our current interests or goals), no scientific evidence of age differences could be obtained.

Divided attention: The scientific debate about divided attention (i.e., the distribution of attention between two or more sources of information) is ongoing and controversial. Typically, divided attention is measured using dual-task tests (performing two different tasks at the same time). Both young and elderly subjects perform decently well under dual-task conditions. However, an age-related decline can be detected when the complexity of the tasks performed increases. It seems that the age differences are due to the overall complexity of the task rather than the need for divided attention itself.

Sustained attention: The effectiveness of sustained attention (i.e., maintaining a certain level of attention over time) was tested by Thackray and Touchstone (1981) in a simulated ATC (radar surveillance) task. The decline in performance depended significantly on age, with the oldest group of subjects showing a decline in performance at the beginning of the session. In a subsequent experiment, it was shown that a five-minute break after every thirty minutes of observation improved the observation performance of the older subjects to the level of the youngest. Similar to this study, Vincenzi, Muldoon & Mouloua (1997) studied the effectiveness of monitoring automation failures in a simulated aviation environment. Subjects monitored system performance during a tracking task and a fuel management task. Older adults performed worse on the monitoring task and showed a decrease in vigilance (indicated by a decrease in the number of detected failures) during the two hours of the experiment.

Automatic versus effortful information processing: As noted above, the human information processing system has only a limited attention span to cope with all incoming information. Two qualitatively different modes of information processing can be distinguished, automatic and effortful. With practice or experience, the need for attention decreases as tasks become automatic, placing fewer demands on information processing. Processing information with effort requires more attention. Overall, experimental studies have found no age differences in performance on tasks requiring automatic information processing.

These results have important implications for job performance because skilled workers rely heavily on automaticity. However, significant age differences may be found in tasks that require effort, such as the efficient and novel use of control processes, tasks that require selection and coherence of attention, and labor-intensive tasks. Thus, effortful information processing requires attention, whereas automatic processing does not. The former decreases with age, while automatic processing does not.

Memory also deteriorates with age. However, if we approach this question from a scientific point of view, the situation is not so simple:

a) First, humans do not have one continuous and unified memory, they have different kinds of memory with separated and different functions (see also Figure1.4):

1) The first kind is "sensory memory". It stores incoming information in memory for only milliseconds and allows us to first check its relevance and meaningfulness of the incoming information. This process happens completely unconsciously.

2) The information that has passed this first filter and attracted attention goes into the "short-term memory".

3) In this second storehouse, information is stored for a few minutes. Its function is to process information and transfer material that is considered relevant to long-term memory. The process of storing information in long-term memory requires rehearsal. These types of memory are not equally affected by aging.

b) Moreover, in addition to a person's age, there are a number of other factors that have a direct impact on memory performance.

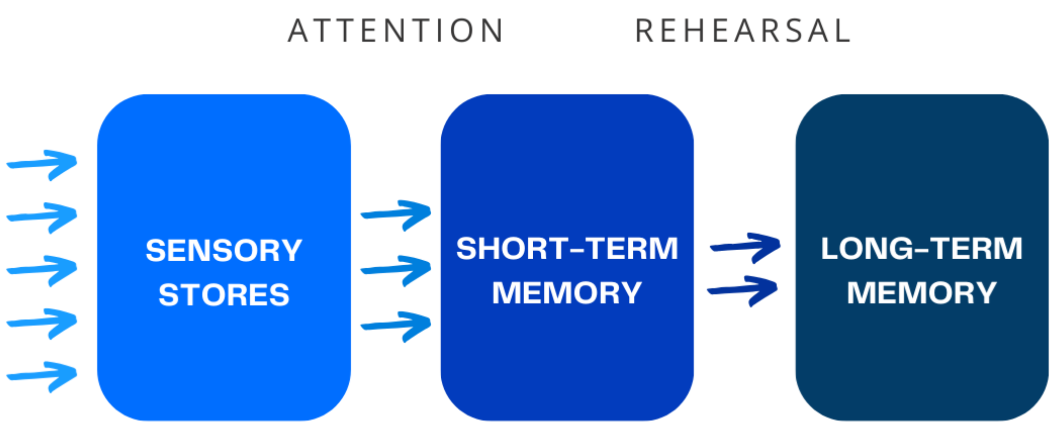

Figure 1.3 – A simplified three-stage model of memory

Sensory reserve is practically independent of age.

The volume of short-term memory is largely independent of age. When tested on the performance of tasks, the volume of short-term memory of fifty-year-old subjects showed the same results as twenty-year-old subjects. Even participants in their sixties and seventies performed almost as well as younger subjects. group. However, this result is only true for healthy older adults who do not suffer from dementia of the Alzheimer's type.

Nevertheless, the dynamics of short-term memory are highly age-dependent, highly age-dependent. Indeed, there is a more dynamic aspect of short-term memory that is responsible for processing information, such as when performing mathematical calculations. This part is called working memory. It selects, coordinates and processes incoming information. With age, working memory deteriorates markedly. Especially significantly reduce the indicators of working memory after sixty years of age. The results of many studies indicate that working memory speed suffers the most.

This decline in speed is noticeable in many working memory tasks. Two well-studied examples are the speed of searching in memory for retrieving information of specific content or processing spatial information, such as turning an upside-down letter.

Decreases are also observed in tasks that place high demands on working memory. This occurs when manipulating and reorganizing material in the mind is required. Another task that requires high working memory resources is allocating attention between retaining individual items and processing incoming material. In general, older adults perform more poorly on tasks the more complex they become and the more they have to process information in parallel (multitasking).

Age differences are more characteristic of long-term memory. However, to what extent the differences are manifested and whether they exist at all depends on a number of factors, including the degree of their manifestation. depends on a number of factors, which will be discussed below. depends on a number of factors, which will be discussed below:

The first factor is the processing strategy used to encode information, i.e., to store it in long-term memory. Three learning strategies can be distinguished: organization, semantic elaboration, and mental imagery (see also Table 1.1.). The use of these strategies rarely occurs spontaneously, but they can be easily taught to subjects. All three strategies have been found to be useful on memorization tasks in all age groups. In some studies, the results have shown that the use of a particular strategy allows older subjects to offset the decline in memorization performance. However, other studies have not produced similar results. This fact points us to the next factor affecting memory performance is the nature of the memory test.

The performance of a memory test also depends on the type of test that is used to measure its effectiveness. There are two ways of testing memory: free recall and recognition. In the free memorization task, subjects are asked to learn the material to be memorized (e.g., a list of animals), and after some time they are asked to reproduce as many animals as possible from this list. In the second condition, recognition, subjects also memorize the same list of animals. However, they are later presented (both with old animals that were on the original list and new animals that were on the list and new animals that were not on the list). The task is to identify which animals are from the original list.

In all age groups, performance in the recognition task is significantly higher. However, in the free memorization task, there is a clear decrease in memory efficiency, i.e. people recall fewer animals from the memorized list. In the recognition task, there are practically no age differences in memorization efficiency.

The third factor that has a significant impact on the effectiveness of memorization is the type of material to be memorized. In many laboratory studies conducted in psychology, especially in the early days of psychology, not very meaningful material has been used to test memory. Many laboratory studies conducted in psychology, especially in the early days of this branch of science, did not use very meaningful material to test memory. At the end of the last century, in his classic memory testing experiments . Ebbinghaus, one of the founders of the discipline, used material that was not very meaningful to the subjects (e.g., meaningless syllables) in memory tests. However, it is known from more recent research that familiarity with the material being memorized is very important for memorization performance. In several studies, familiarity with the material and its relevance to the participants allowed older and even younger adults to outperform them.

Finally, the effectiveness of memorization depends on a number of characteristics of the memorizer: attitudes, interests, state of health, level of intelligence have a great influence. The amount of previously acquired knowledge and skills also matters. Both actual knowledge and skills are well retained in middle age and old age.

Table 1.1 – Summary of learning strategies

Name of Process	Description	Situation
Organisation	The learner actively groups input elements into higher-order units or fragments.	In a long list of words such as laptop, building, metal, child, book, bus, pen, stone, wood, etc., the learner can combine metal, wood, and stone and treat them as one (materials).
Semantic elaboration	The learner associates presented objects with representations in long-term memory that provide access to the meaning of those objects.	To memorize the word laptop, the student can imagine a digital job item, a freelancer working on the beach with a laptop computer
Imagery	The student forms a picture in his or her head, a tape recording in his or her head, or another mental image.	To memorize the word child, the student can remember a picture of a happy family or a Pampers commercial.

Aging and Spatial Thinking

Spatial visualization is of great importance to the ATCO profession. It is known that the processing of spatial information slows down with age. Well-studied examples of spatial reasoning include perspective taking (i.e., the ability to determine the view of a spatial array from a perspective different from the perceived one), mental rotation (i.e., determining the identity of two abstract stimuli viewed from different perspectives), memory for spatial information (e.g., finding a word on a card), and environmental learning (i.e., abstracting and integrating large-scale spatial information, e.g., learning a new route around a city).

On average, older adults can be expected to perform more slowly and less accurately than younger adults on tasks involving perspective taking, mental rotation of objects, spatial memory, or ecological learning. These effects are more pronounced in novel environments and when there are abstract components to the tasks. If the material is concrete rather than abstract and the context is familiar, the age differences diminish or even disappear completely.

Aging and Problem Solving

The process of problem solving can be described as a set of transformations (e.g., mental operations) that allow the solver to reach a goal state from an initial state. Simply put, you encounter a problem and don't immediately understand how to solve it. To solve a problem, you must create an internal representation of the problem. This representation should contain critical aspects of the problem, such as a description of the goal state, the initial state, and possible operations to get from one to the other. Such an internal representation is called a problem space. An analogy for problem solving can be used to make a path through a maze. You have dead ends, detours, obstacles, a return to previous points, and a complete path. The more complex the problem, the more time it will take to find the right path through the maze.

When analyzing the effect of aging on problem solving, it is necessary to distinguish between problem solving in familiar and unfamiliar domains.

Problem solving in unfamiliar domains has been studied mainly using games requiring logical thinking. The main findings of these studies are that older subjects are less efficient at problem solving, although the decline in efficiency usually does not begin until the age of sixty or even seventy. In addition, older adults' performance decreases disproportionately with increasing task difficulty. These results can be explained as follows, referring to the previously described problems of working memory (smaller working memory capacity, lower speed of information processing, etc.).

When solving tasks in familiar domains, the situation is quite different. When elderly subjects are asked to solve a task in their area of expertise - for example, an experienced chess player needs to decide on the next move in the game - there are practically no age-related changes. On the contrary, since increasing age is often accompanied by increasing experience in a particular area, be it a hobby, a pastime, a game.

1.2. Consequences of Shift Work for ATCO's Health and Productivity

The effects of shift work on the health and productivity of ATCOs and other occupations is an issue that has been neglected in scientific research. Of the hundreds of articles from 2017-2021, only a few explicitly mention the impact on health and productivity after years of shift work.

Shift work throughout a working career can be categorized into the following four phases presented in Figure 1.4.

In the adaptation phase during the first five years of shift work, the worker has to adjust to changes in sleeping and eating patterns, social and family life, and stresses at work.

In the subsequent sensitization phase, tolerance to shift work develops, depending on factors such as work career, financial security, satisfaction with shift work and social life.

After about twenty years of shift work, the accumulation of harmful environmental factors and hazardous coping strategies becomes evident. In this accumulation phase, risk factors, sleep quality, and attitudes toward shift work accelerate the biological aging process and strongly affect the health and tolerance of shift work.

Finally, some workers enter the manifestation phase, which is characterized by an increase in the number of disorders and illnesses associated with prolonged shift work. This can occur both before and after retirement.

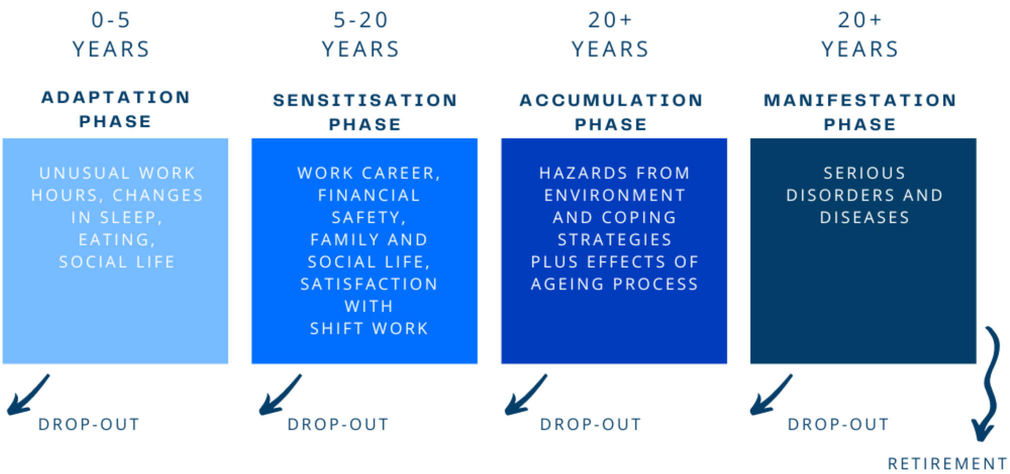

Figure 1.4 – Phases of shift work throughout a working career

Publications devoted to the shift work method emphasize that untypical work schedules take the first place in the list of harmful working conditions. The so-called "shift worker syndrome" can occur at any age. It is characterized by a number of typical health problems. The main symptoms are reduced and altered sleep, digestive disorders, cardiovascular problems, endocrine disorders, mental instability associated with general fatigue.

The same trend as in the case of hard physical labor and time-poor work is also evident in the case of shift work. Older workers take every opportunity to escape from these harsh working conditions. They refuse shift work, especially night shifts, and switch to day work.

If we consider the negative effects of shift work, it appears that they are exacerbated for older workers. The two main groups of complaints are related to sleep disturbances on the one hand and health problems on the other.

There is often a decrease in the duration and quality of sleep. The consequence of sleep disturbance is reduced vigilance during waking periods, including during working hours. Many ATC officers can agree with this conclusion, as most, if not all, are aware of the challenge of maintaining adequate levels of alertness during the early morning hours of night shifts. Studies of ATC incidents and accidents show a significant contribution of fatigue to the occurrence of incidents, although we have no evidence that the night shift per se is more error-prone.

When studying the health of older shift workers, it is important to keep in mind that this is a sample of people already selected by health criteria. Many people who work shift work leave their jobs (e.g., switch to day work or take early retirement) due to declining health. Those who do better with atypical work schedules remain. However, even this relatively healthy group continues to suffer from a cluster of diseases characterized by a general decline in health over many years of shift work. Older shift workers are more likely to report gastrointestinal and skeletal diseases, respiratory infections, appetite disorders and indigestion, as well as an apparently increased risk of coronary heart disease. A very methodologically good study examined shift workers in the newspaper industry. It concluded that there was an increased risk of early mortality among shift workers, possibly related to reduced resistance to high workloads.

In 2018, conducted a series of studies on the effects of shift work on the heart rate, fatigue and sleep of air traffic controllers . The study involved 97 air traffic controllers at an approach control facility. The results showed changes in the circadian rhythm of heart rate in all dispatchers studied, working both day and night shifts. The authors also found a need for longer recovery time for older dispatchers after the night shift. They increased their sleep time after night duty more than their younger counterparts. Unfortunately, even on the basis of such studies, it is not possible to fully assess the impact of shift work on the health of controllers.

1.3. Automation as a Reason for Narrowing the Age Range of ATCO

Modern technology is an integral part of our lives. At work, in our homes, in the public, the support of technological aids can be found everywhere. Modern telecommunication devices, personal computers, automated features in transport systems or in banking are only a few examples. The more sophisticated technology gets, the more functions are available on the devices and the higher their complexity. For younger people this is a natural component of day-to-day life. But how do older people cope with it?

A broader view is taken by research focusing on design for the elderly in more general terms. How should a display look, if somebody with decreased eye sight is supposed to use it with ease? How should the buttons look and feel, if the potential user suffers from decreases in the tactile sense? The specific needs of older people have to be addressed also on a functional level. How many modes can a device have before it gets confusing or over-complicated?

If some of the younger readers of this document felt spontaneously addressed by these questions, even if they are not yet forty, this is not surprising. One of the rules of good design for old age is that it is helpful for all age groups. People of all ages would benefit from it, the older user possibly a bit more than the younger.

Teaching computer skills to older adults is a challenge, because they may be pupils with higher demands than their younger counterparts. Both the content and the way it is delivered need to be adapted to the target group. To adults the content must make sense, they are not willing to learn theoretical materialif they cannot see the practical use of it. Also the didactical style needs to suit adults. They should be treated on an equal level and not like immature children. The pace of learning can be expected to be slower for older adults. They learn best if they can extensively practice the new skill and if they can learn at their own pace without pressure. It also turns out to be of benefit if the teacher is the same age as the trainees.

The use of technology by older people in day-to-day life? This issue is of high public interest, as older individuals may suffer from serious constraints in the participation of public life if they are not able to handle certain machines.

Many human factors issues associated with the introduction of new technology are to be addressed for all age groups, such as trust in automation, skill set changes, new error forms, changes in teamwork, situation awareness and workload. It can be expected that these problems will be even more pronounced for ageing employees.

1.4. Experience and Expertise of Aging ATCO

Performance is largely determined by experience. It is an even better predictor of performance than age. It takes about ten years of intensive study and practice to reach the expert level. In order to master the ATCO profession, a large number of specific facts and procedures must be learned.

A number of differences can be found between experts and beginners in problem solving. Experts are able to catch more configurations of a problem compared to beginners. Due to their extensive knowledge in their field, they store many models of problem situations in their long-term memory. When they have to solve a problem, they identify pieces of information in a given situation and try to relate them to the information in that situation and try to relate them to these stored patterns.

Research has identified six main characteristics of expert knowledge (see Figure 1.5):

- Knowledge structuring: Knowledge elements become well-integrated, experts store coherent pieces of information in memory. This knowledge structure allows them to extract important patterns when solving problems.

- Procedural knowledge: Experts not only have a large knowledge base but also know how to use it, what procedures to apply. This procedural knowledge takes the form of condition-action. Experts know in which situation certain knowledge and skills can be used. [1]

- Skilled memory: Experts use their long-term memory in a way that resembles short-term memory. Therefore, they avoid time-consuming search strategies.

- Automatism: Another benefit of long practice is to perform certain aspects of a task on automaticity. In the section on attention we analyzed how certain aspects of tasks that require attention can be automated over time. Consequently, conscious attention can be directed toward reasoning and decision making.

- Effective problem representation: Experts often spend a great deal of time on the initial analysis of the problem. They carefully assess the nature of the problem and build a mental model of it. This process allows a decision to be made quickly and without unnecessary hesitation.

- Strong self-regulation skills: Experts develop a critical set of self-regulation skills that enable them to take control of their work. They control the problem-solving process by predicting the complexity of the task, allocating time appropriately, noting their mistakes and failures, and checking possible solutions.

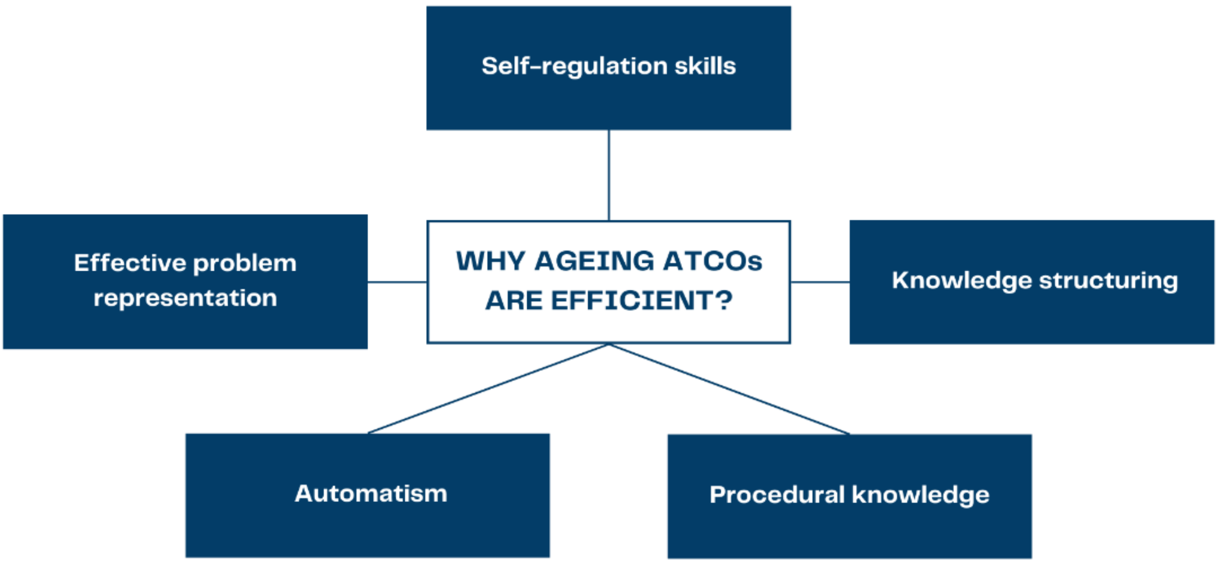

Figure 1.5 – Six main characteristics of expert knowledge

A notable study conducted. in 2016 examined the performance of professional tennis players with varying ages. The researchers found that older tennis players, while potentially experiencing some physical decline in terms of speed and agility, compensated for these age-related changes through their experience, tactical expertise, and mental resilience.

In this study, it was observed that older professional tennis players, were able to compete successfully against younger opponents. They compensated for any loss in physical abilities with a deep understanding of the game, superior strategy, and mental toughness. Their years of experience on the tennis court allowed them to outperform younger, less experienced opponents.

This example illustrates how expertise and experience can compensate for age-related physical changes in a highly competitive field like professional sports.

Conclusion to Chapter 1

Aging is part of a natural process that begins at our birth and continues throughout our lives. It is also a continuous process of functional change, involving the gain and loss of functionality.

In aviation, this little discussed topic is a very important one. With the increase in air traffic, the topic of aging is becoming more and more important. But why? We all know that according to the statistics of the last 10 years, life expectancy has increased and birth rate has decreased, respectively, there are significantly more old people than young. And this figure continues to rise. So that means that the number of older workers is only increasing. How does this threaten aviation? At the moment there are a number of factors that prevent age dispatchers from working effectively: changes in procedures and airspace organization, continuous development of technology and automation. Dispatchers starting at the age of 40 can feel the discomfort of the changes. Moreover, combined with cognitive changes and declining health, aging can have a negative impact on safety.

It is well known that the work of an air traffic controller requires quick reaction, visual and hearing acuity. But shift work and high stress levels become the main reasons for premature deterioration of health.

At first sight, the situation is not comforting at all, but let's look at it from a different angle. If we ask an older worker to solve a problem in his or her professional field, we are unlikely to be able to identify age-related deterioration. For example, an experienced dentist has honed his skills over the years and has automatized all possible procedures; during surgery, he makes decisions without thinking.

Not everyone thinks about it, but the aging process is generally accompanied by the accumulation of experience. Components such as concentration, much of long-term memory, and even some aspects of attention do not change with age. Moreover, accuracy, judgment, skill, experience, and a sense of responsibility tend only to increase. It can be declared without doubt that the experience of age dispatches antithetical to the negative effects of age.

Intelligence is a single entity, which in turn is divided into two broad basic components: fluid and crystalline intelligence.

- Crystallized intelligence includes all the skills and knowledge-related aspects of intelligence needed to solve well-known and familiar problems. It contains factual knowledge about the world and specific areas of knowledge, as well as procedural knowledge concerning strategies for mastering an aspect of life. This aspect can also be called pragmatic intelligence.

- Fluid intelligence describes the basic processes underlying information processing and problem solving. It is required to solve new and unfamiliar problems. It can also be referred to as mechanical intelligence.

Aging affects these two components of intelligence in different ways. In short, we retain wisdom and lose intelligence.

The results of the experiments cited in this section cannot completely disprove the fact that age prevents an air traffic controller from working as effectively as his younger counterpart. The onset of decline in mental function may vary from age forty to age seventy. But all studies lead us to the conclusion that mental performance is not only affected by chronological age. Mental performance at a certain age is highly dependent on a person's personal history, it is determined by the set of specific circumstances and experiences encountered throughout life. Aspects such as education level, professional skills, lifestyle, health, genetics, and life situation have a much greater influence.

CHAPTER 2. ANALYSIS OF THE PERFORMANCE OF ELDERLY ATCO

2.1. Investigation of the Probability of Loss of Proficiency With Age

It has been said earlier about the significant impact of age on many mental functions: signal perception, attention, memory, spatial reasoning, and problem solving. Quite a bleak picture of aging, isn't it? Accordingly, one would expect equally disappointing prospects in the sphere of professional activity.

However, the situation in the professional sphere is much more complex and ambiguous than in the pure world of scientific laboratories. While we have scientific evidence of a decline in many basic mental processes, we do not always find the same decline in performance.

A general assessment of job performance is almost impossible. Naturally, any classification of job performance depends on the type of profession in question. The measures we use to evaluate performance also have a significant impact on the outcome. The two main measures are production reports and peer or supervisor evaluations.

Nevertheless, there are some general trends in the relationship between age and job performance and job outcomes. As shown in Figure 2.1, it can be broken down into components, some of which will decrease with age, while others will increase or remain the same.

Decreases are observed for a number of functional abilities such as muscular strength, mobility, vision and hearing, flexibility, information processing speed, reaction time, and working memory.

Increases are observed for a number of abilities such as skill, accuracy, experience, judgment, reliability, and sense of responsibility. In addition, older workers have better knowledge of internal aspects of company operations and production procedures.

Some components of performance did not change at all, such as concentration, some aspects of attention, and most long-term memory.

COMPONENTS TO DECREASE WITH AGE:	COMPONENTS TO REMAIN THE SAME:	COMPONENTS TO INCREASE WITH AGE:
MUSCULAR STRENGTH	CONCENTRATION	PROFICIENCY
MOVABILITY	ATTENTION	EXACTNESS
VISION AND HEARING	LONG-TERM MEMORY	EXPERIENCE
FLEXIBILITY		FACULTY OF JUDGEMENT
SPEED OF INFO PROCESSING		RELIABILITY
SPEED OF REACTIONS		SENSE OF RESPONSIBILITY
WORKING MEMORY		KNOWLEDGE OF COMPANY AND PROCEDURES

Figure 2.1 – Components of job performance and how they change over the course of a professional career

The age structures of occupations are interesting characteristics in this context. It can be hypothesized that a selection process takes place over the years of occupational activity. Those who feel suited for a particular position or who are considered suitable for a particular position have a better chance of remaining in that position. Thus, the age structure of occupations may to some extent be determined by the demands of tasks and the strain these tasks place on older workers.

Two pronounced trends can be observed in a wide range of professions:

- First, older workers tend to move away from physically demanding labor. This tendency to move to lighter work is particularly pronounced among unskilled and semi-skilled workers from the age of forty.
- The second tendency is to leave jobs that take up a lot of the aging worker's time. The pace of work seems to be a major factor in choosing a particular job and even more important than physical activity. Older workers are rarely found in

jobs with time pressure caused either by external factors (e.g., working on an assembly line) or time pressure caused by piece-rate pay.

There are two approaches used in performance appraisal: production records and performance ratings. Production accounts are mainly used for production workers in industry and for sales personnel or clerical work, while performance ratings are applicable to all types of work, they not only rely on the physical product as the outcome of work, but also take into account a wide range of work behavior.

In most studies using production records as a measure of labor productivity, for skilled and semi-skilled workers we find an inverted U-shaped relationship between age and labor productivity. Productivity increases in the early years of work, peaks in the late thirties and early forties, and shows a slight decline. Thereafter, a slight decline is observed (see also Figure 2.2).

However, some studies have found no decline in productivity; often workers in their fifties and sixties perform as well or even better than younger colleagues. Studies of clerical workers and salespeople have found similar levels of productivity among older and younger employees. A broad study by the U.S. Department of Labor found no age differences among office workers. The positive relationship between age and job performance found in many studies may be seen as a result of older workers having more years of experience. They seem to be helped by the experience they gain over the years. Experience appears to be a stronger predictor of job performance than age.

Performance ratings are an easily applicable measure. However, they carry the risk of biased results due to negative stereotypes about older workers. Stereotypes about older workers are common among middle and upper management. In middle and upper management, common stereotypes about older workers emphasize their lower learning ability, lower potential for development, resistance to change, and lower productivity. In addition, younger colleagues and peer colleagues tend to perceive their older colleagues in this negative way. Despite the possible formation of negative stereotypes, many studies have found no difference in performance evaluations between younger and older employees. [2]

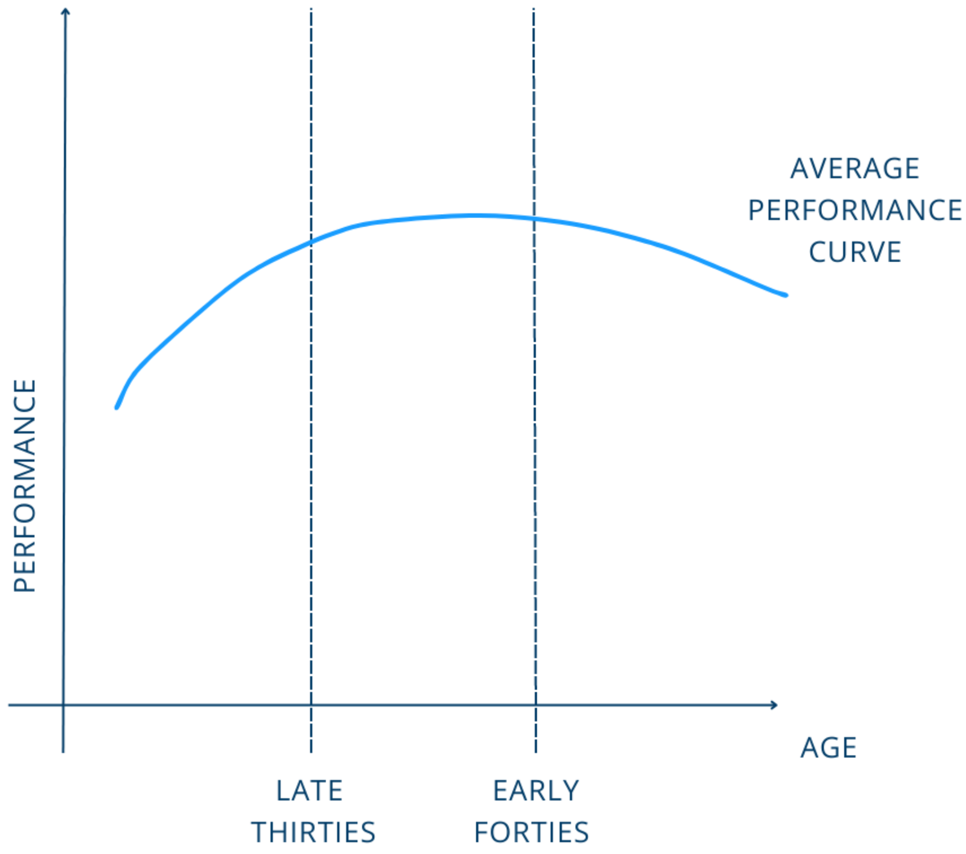

Figure 2.2 – Hypothetical performance curve for various jobs

Why don't we detect a decrease in performance, even though mental processes are based on such a decrease? One possible explanation is related to the nature of psychological testing. In laboratory experiments, subjects are required to maximize their efficiency when performing a single, often complex task under conditions of time deficit. This is not the case in work behavior. Performance at maximum level is usually required for only a short period of time. Moreover, success in most jobs is additionally dependent on motivational factors, interpersonal behavior, and the effectiveness of the overall work strategy. With increasing experience, a person can develop particularly effective strategies.

Work capacity can be broken down into components, some of which decrease with age, some of which increase, and some of which remain unchanged. The age structure of occupations shows that older workers tend to leave jobs that involve high physical workload and high time stress. Performance measures are productivity level and performance rating. Labor productivity shows an inverted U-shaped relationship with age for skilled and semi-skilled workers. Productivity peaks mainly between the ages of thirty and forty. There is no clear decline in productivity in sales and office work. Productivity estimates often suffer from bias due to negative stereotypes about older workers. Nevertheless, many of them do not conclude that productivity declines with age.

2.2. Identifying the causes of age effects on ATCO's cognitive skills

This subsection summarizes the assessment of cognitive skills. These are divided into three areas: cognitive skills that are likely to decline with age, cognitive skills that are likely to improve with experience, and cognitive skills that are likely to remain unchanged and therefore neutral in terms of aging and experience. Figure 2.3 below provides an overview of all skills and their categorisation.

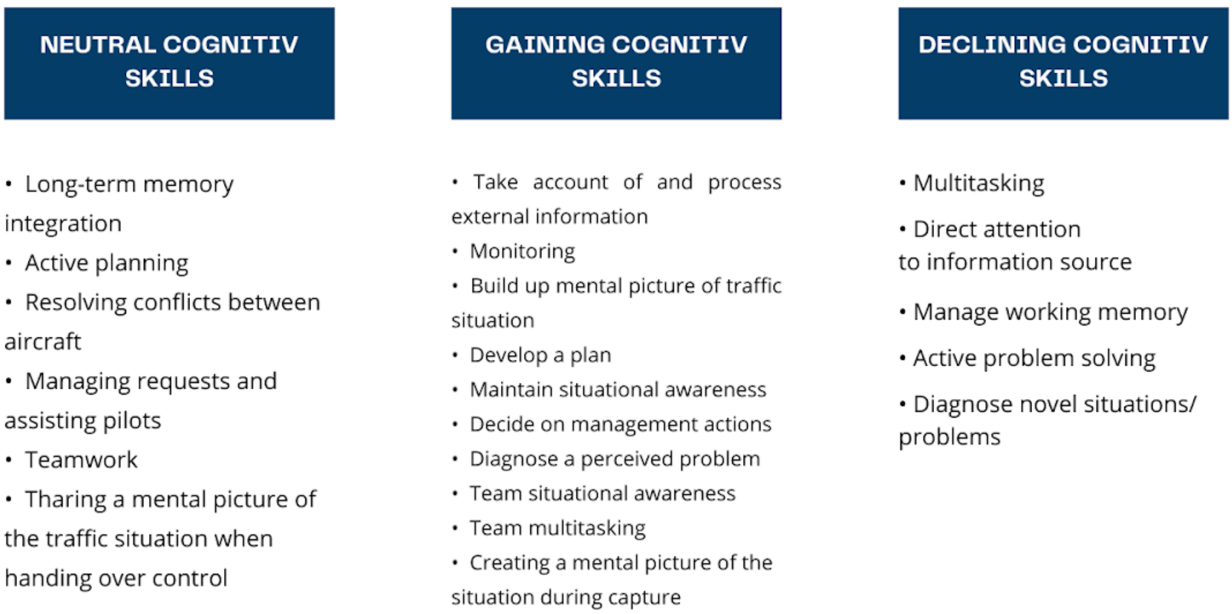

Figure 2.3 – Neutral, gaining and declining cognitive skills with regard to age and experience

Cognitive skills that are likely to decline (see also Figure 2.4):

- multitasking
- directing attention to the source of information
- working memory management
- active problem solving
- diagnosing new situations/problems

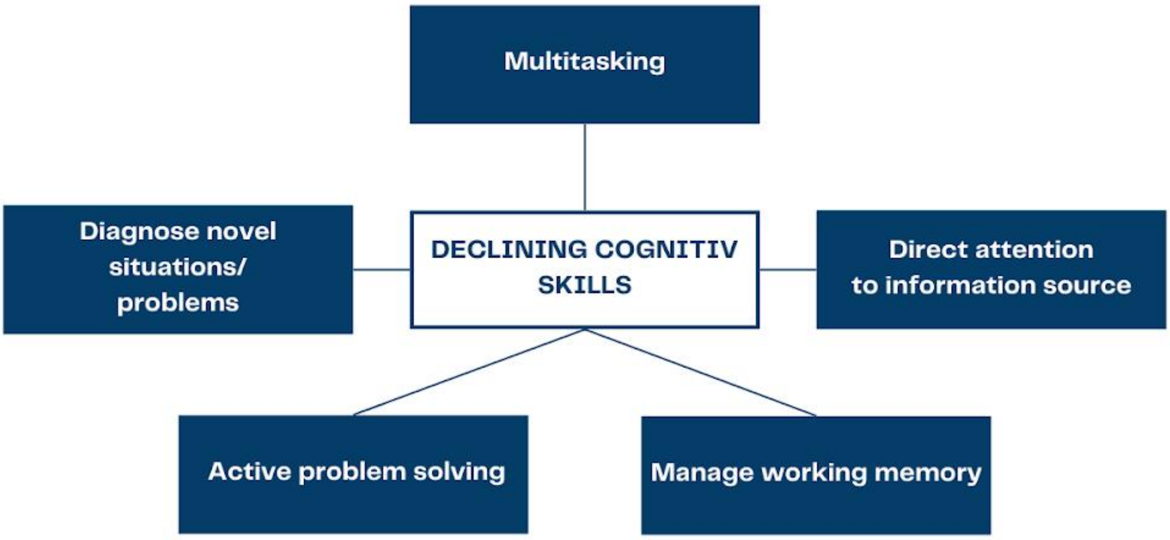

Figure 2.4 – Cognitive skills declining with increased age

Cognitive skills that can improve (see also Figure 2.5):

- Taking note of and processing external information
- monitoring
- creating a mental picture of a traffic situation
- developing a plan
- maintain situational awareness
- decide on management actions
- diagnose a perceived problem
- team situational awareness
- team multitasking
- creating a mental picture of the situation during capture

Cognitive skills remain neutral:

- Long-term memory integration

- active planning
- resolving conflicts between aircraft
- managing requests and assisting pilots
- teamwork
- sharing a mental picture of the traffic situation when handing over control [3]

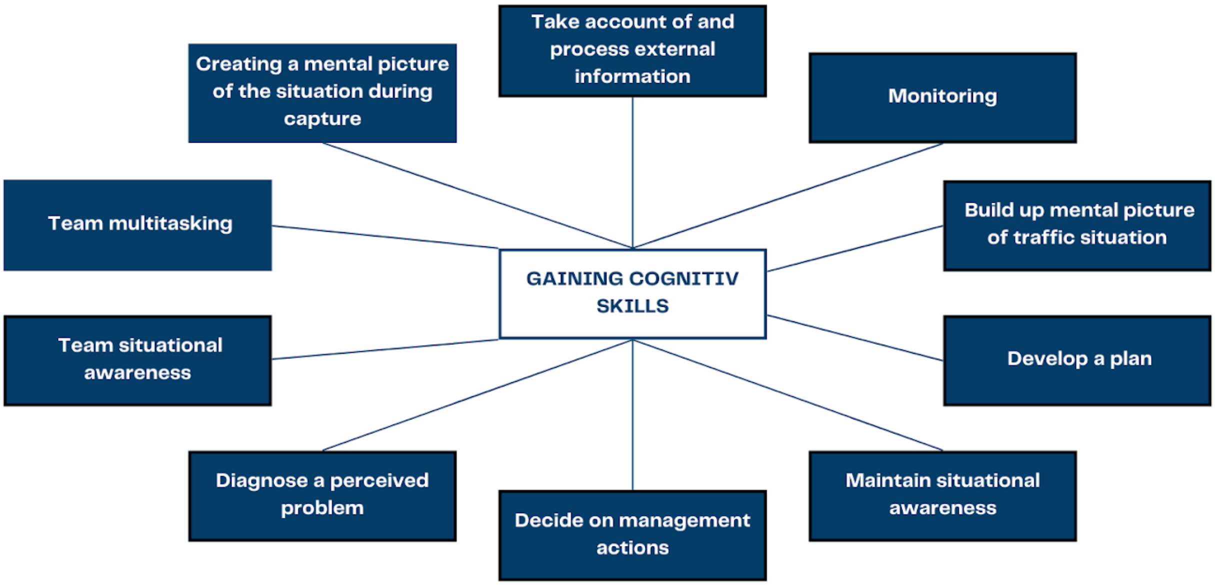

Figure 2.5 – Cognitive skills gaining with increased age

Neutral skills are not considered as key elements of aging. Only those cognitive skills that will be positively or negatively affected by age and experience are considered as key elements of aging.

2.3. Exploring Performance Decline in ATCOs: Investigating Professional Stress Across Age Groups

The main objective of this unit was to find out the "extent" of occupational stress among air traffic controllers of different age groups and to assess its negative impact on health and efficiency of air traffic controllers' work.

Medical statistics were considered as the evidence base. We examined two sets of data: (a) the incidence rates of specific disorders among air traffic controllers compared to other occupational groups and (b) disability retirement data.

The disorders considered were coronary heart disease, coronary thrombosis, hypertension, and peptic ulcer disease, which at the time were "considered to be more or less stress-related." Numerous studies have reported that the incidence of these diseases among air traffic controllers between the ages of 35 and 39 is 1.5 to 4 times higher than among civilian pilots.

The comparisons made cannot be statistically reliable because they did not use the same medical diagnostic criteria and examination methods for the groups compared. Nevertheless, the higher morbidity rates compared to groups subjected to similar annual examinations are "consistent with the expected results if one assumes a high degree of occupational stress among air traffic controllers." In other words, if two assumptions are accepted - (1) the air traffic controller profession is stressful and (2) diseases such as coronary heart disease, coronary thrombosis, hypertension and peptic ulcer disease are "caused" by stress, then the finding of a higher incidence of "stress-related" diseases in air traffic controllers is evidence that the profession is highly stressful.

The Air Traffic Controller Career, Review of Medical Information Regarding Occupational Stress Among Eurocontrol Air Traffic Controllers study also examined medical retirements from 2017-2019. On the one hand, air traffic controllers accounted for 45% of the labor force in those three years and 45% of all medical retirements. In other words, the disability retirement rate among air traffic controllers was proportional to their representation in the workforce.

On the other hand, dispatchers accounted for 67% of all disability retirements among workers under age 45. In other words, the rate of disability retirements among younger dispatchers was disproportionately high. [3]

The higher incidence of "stress" disorders among dispatchers, as well as the disproportionately high rate of disability retirements among younger employees, suggests that "there is a significant degree of stress associated with dispatchers' jobs."

In addition, a study was conducted on stress indices among dispatchers at a terminal in Düsseldorf, Germany. This study was conducted in the summer of 2017 and included 11 ATCOs. A number of physiological and biochemical indices were measured, including epinephrine, norepinephrine, and 17-hydroxycorticosteroid, a metabolite of cortisol. The relative magnitude of the changes in body functions was compared. Based on this comparison and the physician's report, the researchers concluded that the findings "strongly suggest a strong biochemical response of air traffic controllers.... to conditions that were perceived by their bodies as acute stress."

In 2019, German students undergoing Ausbildung at Deutsche Flugsicherung conducted a research project entitled "How much stress do you experience in the workplace?". The article was published in the student magazine in May 2019. As a result, we can see the statistics. The data may not be reliable because the study did not take into account the individual characteristics of air traffic controllers. In addition, the study involved air traffic controllers from different cities with different airfield congestion. [4] The results of the research are shown in Figure 2.6:

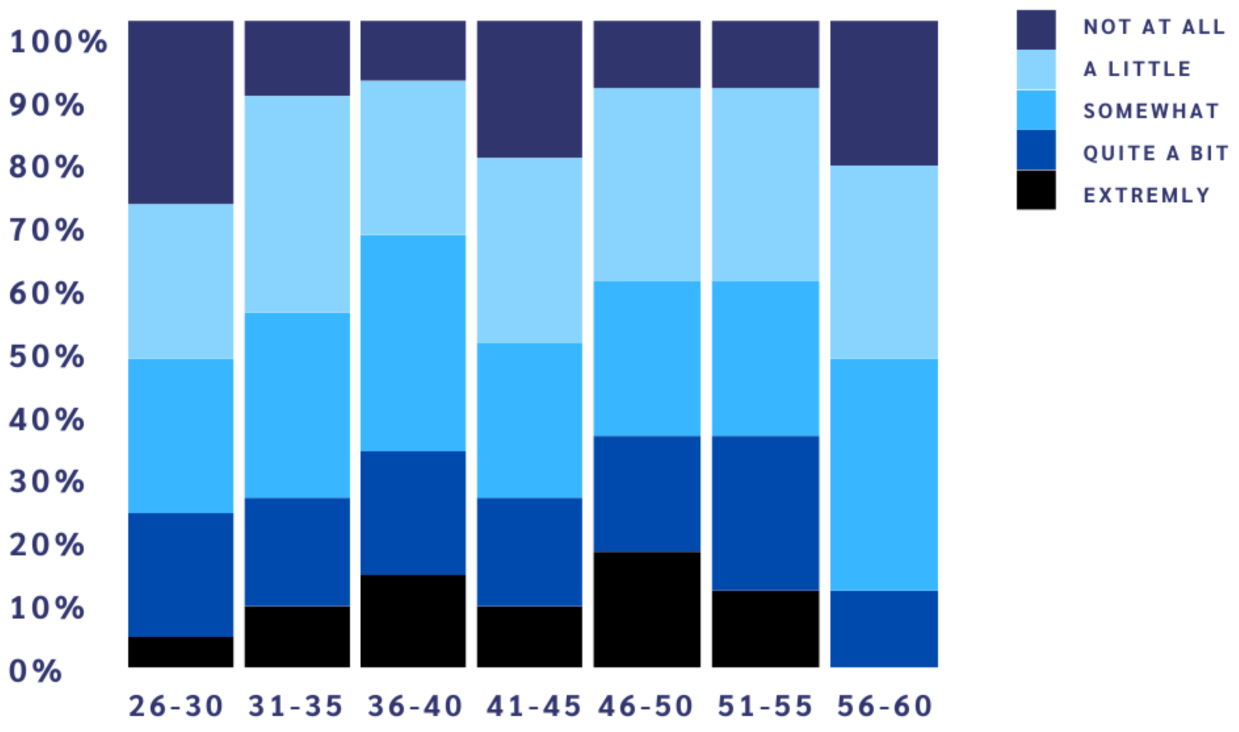

Figure 2.6 – Responses of FSS controllers by age group to 2019 survey question "How much stress do you experience in the workplace?"

Medical reasons for definitive unfitness of ATCO's at EUROCONTROL

We prepared a chart (Figure 2.7) that shows the percentage age of ATCs who were written off for health reasons from 2013 to 2020.

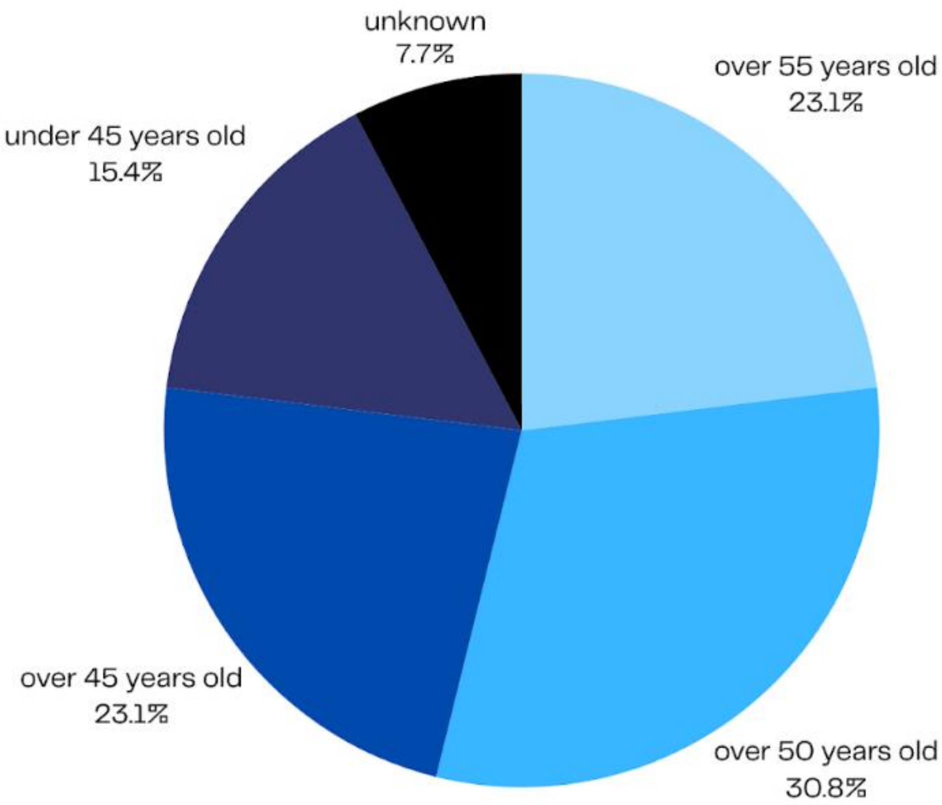

Figure 2.7 – INVALIDs for air traffic control functions 2013 to 2020

The data was provided by The Maastricht Upper Area Control Centre (MUAC) The area controlled by EUROCONTROL MUAC

- Delta-Coastal sectors : part of the North sea, The Netherlands, Northern Germany
- Brussels sectors : Belgium, Luxemburg, part of Northern France until Nancy
- Hannover sectors : Mid – /Western Germany
- Above 24.500 feet, (7.5 km)
- Approximately 1.5 million controlled flights per year, 5000/day

In the Table 2.1. you can see how many air traffic controllers have been written off for health reasons in the time period from 2013 to 2020. The table also shows the age and length of service of air traffic controllers. It can be seen that almost all air traffic controllers have already reached the age of 40. The work experience of these air traffic controllers is more than 20 years. We have noticed that the most popular diagnoses among age-matched air traffic controllers are psychiatry, orthopedics and cardiology. [6]

Table 2.1 – ATCO written off for health reasons from 2013 to 2020

YEAR	PERSONEL INFO	DIAGNOSIS
2013	Age: 48 Years of service : 16	**multifactorial** • endocrino: non insulin-dependent diabetes • psychiatric: aggressive/manic psychosis alcohol abuse
	Age: 56 Years of service : 26	**psychological** vital depression + intolerance to shifts + alcohol abuse
	Age: 50 Years of service : 20	**orthopedic** back problems + sleep problems + shiftwork intolerance
	Age: 49 Years of service : 20	**orthopedic** + sleep problems
2014	Age: 52 Years of service : 23	cardio + **psychological** angina pectoris + cardiac rhythm disorder + post traumatic depression / burnout
2015	Age: 43 Years of service : 5	**ophthalmology** metamorphopsia + in 1 eye atrophic scars on macula from laser therapy + chorioretinitis serosa
	Age: 57 Years of service : 25	**multifactorial** • pulmo: asthma, allergy • endocrinol: diabetes II non insulin-dependent, obesity - Urogenital : kidney stones • cardiac: arrhythmia (ventr + supraventr), ES • psychological : burn out, stress intolerance, palpitations, depressive reactions

2016	Age : unknown Years of service : 20	**post-accidental** **orthopedic** (back)
	Age: 53 Years of service : 28	**multifactorial** • ENT : hearing loss • psychological: recurrent depressions
2017	Age: 33 Years of service : 7	**immunological** « multiple sensitivity syndrome » intolerance to quasi all food – vitamin depletion
	Age: 49 Years of service : 23	**cardiac** coronaropathy + hypertension
	Age: 55 Years of service : 25	**psychological** • burnout: depression + surmenage • compulsory personality
2018-2019	Age: 52 Years of service : 11	**alcoholism**

Conclusion Chapter 2

In conclusion, the analysis of the performance of elderly Air Traffic Controllers (ATCOs) reveals a nuanced relationship between age and job proficiency. While certain cognitive abilities may decline with age, other crucial aspects such as skill, accuracy, experience, judgment, reliability, and a sense of responsibility tend to improve or remain stable. The age structures of occupations suggest a potential self-selection process, where individuals well-suited for their positions are more likely to stay, influencing the age distribution within professions.

Performance appraisal methodologies, such as production records and performance ratings, contribute to the understanding of age-related trends.

Moving forward, the exploration of performance decline in ATCOs delves into occupational stress across different age groups. Medical data, including incidence rates of stress-related disorders and disability retirements, provides evidence of the demanding nature of the profession. Despite statistical challenges in comparisons, higher morbidity rates among air traffic controllers, particularly in their mid-thirties to late forties, hint at the potential toll of occupational stress on health.

In essence, this chapter paints a comprehensive picture of the multifaceted relationship between age, performance, and occupational stress among ATCOs. While age may bring about changes in certain cognitive functions, the accrued benefits of experience and other competencies contribute to a nuanced understanding of professional proficiency. The identification of stress-related challenges emphasizes the need for ongoing efforts to mitigate occupational stress and ensure the long-term well-being and effectiveness of air traffic controllers in the dynamic field of aviation.

CHAPTER 3. PREVENTING A DECLINE IN THE EFFICIENCY OF AGE-RELATED ATC

3.1. Fourth level of acting to prevent a Decline in the Efficiency of Age-related ATCO

A systems approach is the most effective way to solve a problem. Therefore, in this work, we engage different methods of influencing the performance of aging air traffic controllers into a system. There are four possible levels of action: society, management, work process and individual (see Figures 3.1 – 3.2). Obviously, these four levels are not equally easy to influence. We have developed general recommendations that could have a positive impact on the performance of aging air traffic controllers.

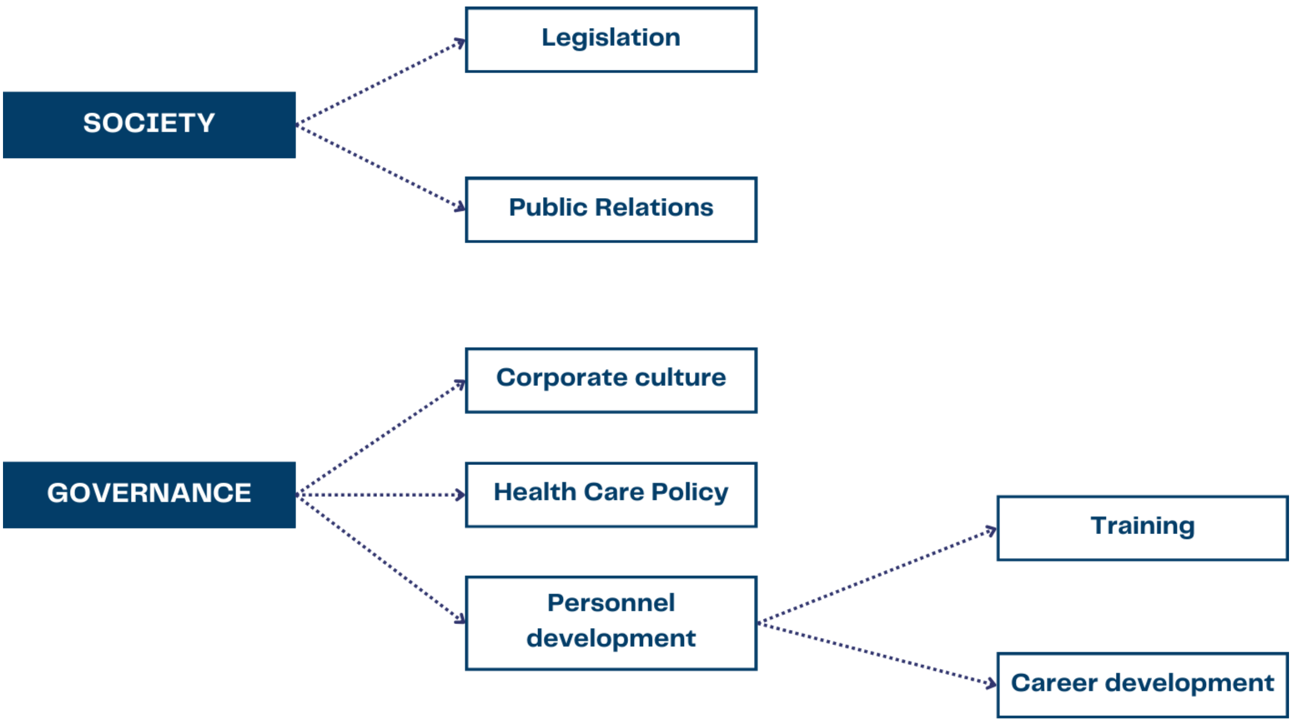

Figure 3.1 – The first and the second possible levels of action

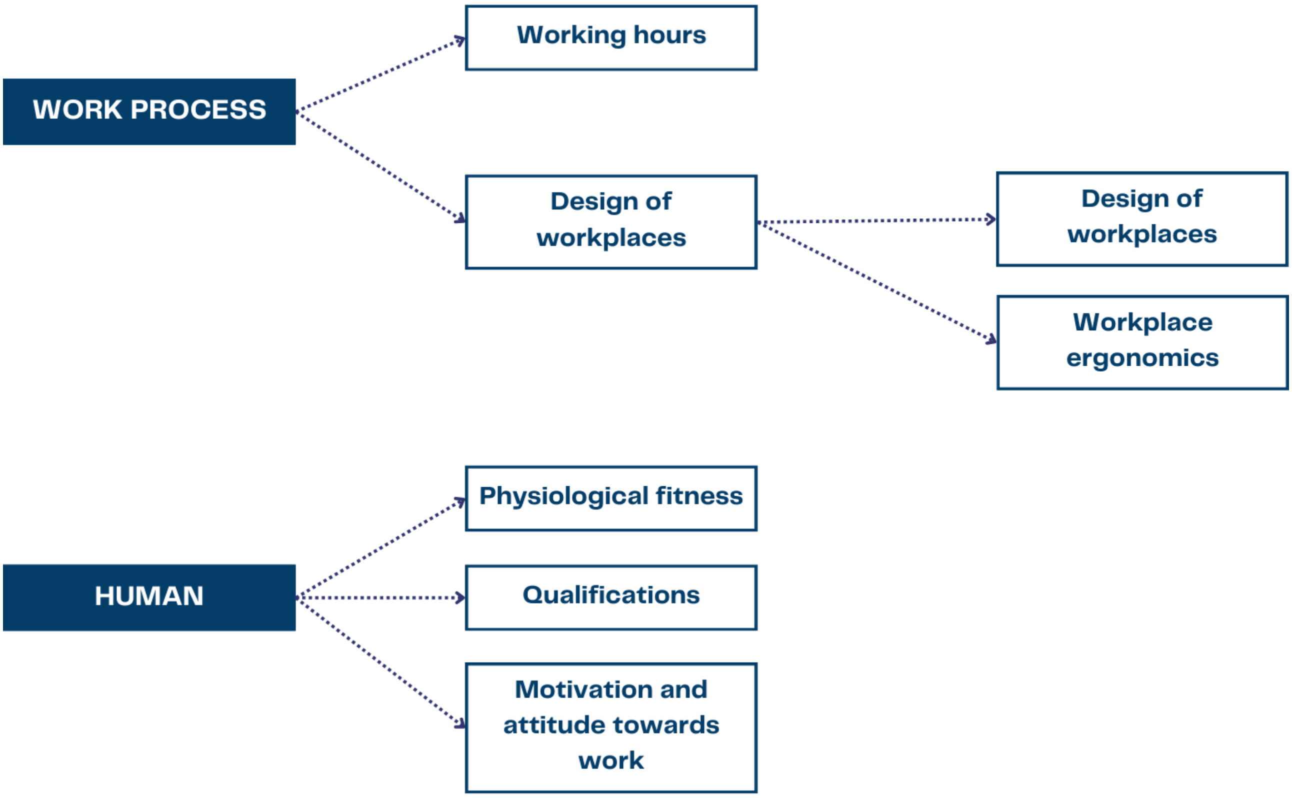

Figure 3.2 – The third and the fourth possible levels of action

Society

The highest level of impact that can be addressed is society with its means of influencing a particular situation or problem. The most important means available to society to address a problem is legislation. In the context of aging in place at ATM, a number of legislative steps are possible.

Legislation. First, adjusting the retirement age is a strong tool to address the issue of aging and work. This paper does not recommend setting a specific retirement age. This would require not only more research, but mainly a broad public debate and a consensus decision by all stakeholders that takes into account all social and financial implications of such a decision.

Secondly, legislation already sets minimum standards in terms of working hours, breaks, workplace design, etc. However, these standards should be carefully reviewed and, if necessary, adjusted to take into account the needs of older workers.

Public Relations. The importance of public relations to the topic of aging cannot be underestimated. As pension systems in many countries come under increasing pressure and unemployment rates are high, older employees are seen as a labor pool that needs to be adjusted to real needs. When unemployment is too high, older workers are pushed out of the labor market and into early retirement, and when pension systems are strained to the breaking point, people are forced to extend their working lives. What both approaches have in common is that they fail to respect people's dignity and ignore both the opportunities and needs of older workers. There needs to be public recognition of the value of older workers, which benefits both companies and society. A realistic appraisal of this value can contribute to a more relaxed discussion about how best to utilize the potential inherent in older employees.

A first step in the right direction has been taken with the establishment of several national research programs on ageing workers, all of which are supported by the European Union (e.g. the FinnAge program in Finland or the National Program on Ageing Workforce in Sweden).

Governance

There are many aspects that can be touched upon here. Management is responsible for everything - at least in the eyes of many employees. This report highlights three elements that are considered particularly interesting from an ageing perspective.

Corporate culture. Corporate culture can play a crucial role in how aging is viewed in a company. Managers who recognize the value of the wealth of experience gained by older employees will be able to make optimal use of this resource. The individual benefit of experience is also a great benefit to the company in many areas. Managers who can express their appreciation for older colleagues will also motivate this group of people to deal with the challenges of their age. It is necessary to discuss this issue in an unbiased manner. Treating it as a taboo will only make life more difficult for everyone. Only a realistic view of the effects of aging and the benefits of experience will allow for optimal utilization of human resources, assigning the most appropriate position according to personal capabilities. Related to this theme is the safety culture of the service provider. ATCOs should not be superheroes; they need appropriate professional skills and a sense of responsibility, as well as an awareness of their personal boundaries. Abandoning those boundaries can have serious safety implications. This is why an open approach to aging is so important and should be supported by management, e.g., through internal publications, workgroups, etc.

The main challenge for management is to prevent the belief that declining performance leads to unfavorable consequences for air traffic controllers. Aging air traffic controllers are still experienced employees who have a lot to offer their company. Management is responsible for finding the best solutions for both the controller and the company.

Health Care Policy. There is a widespread prejudice that age is accompanied by declining health. However, this is not necessarily the case. Physical fitness and health depend largely on ourselves. This applies to diet, exercise, sleep and rest patterns, stress management, and utilizing health screenings. While it is the responsibility of individuals to take care of their health, managers should do everything they can to encourage their employees to live a healthy lifestyle. This starts with offering healthy food in the cafeteria, providing sports facilities in the unit, and organizing regular health screenings. Noise-proof and well-equipped rooms are also essential for those recovering from or preparing for night shifts. It is also highly recommended to organize training courses on stress management. Working groups composed of management and operational staff exclusively dedicated to health issues in the unit can be very useful. Such groups could monitor the health status of staff and suggest measures to improve it.

Personnel development. *Training*. Training is an important area to address the declining performance of age-related air traffic controllers. Different types of training can help balance the decline in cognitive skills and enhance the benefits of experience.

First, regular and frequent refresher training can help avoid "rusting" of skills. In quite a few cases, aging deterioration is probably due to lack of practice. Especially training that includes traffic scenarios with unexpected events can help older dispatchers deal with unexpected situations in their daily work.

Secondly, the needs of middle-aged and older dispatchers should be carefully considered when preparing for the introduction of new equipment. A key requirement is that each dispatcher receive the necessary training time. to feel comfortable with the new system. To support such individualized training, computer-based training tools can be used to allow everyone to devote as much time as necessary to a particular issue. In addition, theoretical knowledge regarding the new system should be as practical and applicable as possible. If possible, a link should be created between the theory and the ultimate application of this knowledge in the new system. For example, underutilized components of the system can be studied by creating exercises to recover the system in case of failure.

A fairly new idea for ATCO training would be to address aging directly in the training course. Aging continues to be a sensitive topic. Developing the self-awareness necessary to recognize and acknowledge the deterioration that occurs with age requires a significant level of maturity. Since this self-awareness of one's own boundaries is critical to safe work behaviors, lectures on the negative and positive processes of aging can be arranged to help break taboos and encourage the courage to face the facts.

Career development. Currently, virtually no European national ATCO provider has a systematic approach to ATCO career development. Given the results of this survey, a more organized approach to this issue would be highly desirable. Dispatchers need clear and achievable alternatives to operational work in case they are unable to cope with demand for whatever reason.

The data confirms that there is already a high level of flexibility in task organization. This allows older dispatchers to find a position that matches their expertise. This flexibility applies not only to transitions between multiple ATC services, but also to less drastic changes. It can be useful to be able to move from an operational position, such as executive dispatcher, to another operational position, such as coordinating dispatcher, or from less responsible sectors/positions to more responsible ones. Participation in non-operational tasks is another way to minimize the workload of the operations department. This should include all types of training, supervisory, managerial or administrative tasks, as well as performance evaluation, personnel selection, incident investigation and technology systems development. [7]

You might argue that since these capabilities are available now, no additional action needs to be taken to improve the situation. However, increasing security regarding possible career paths could help to address aging issues more openly and find solutions that are agreed upon by all stakeholders. This, in turn, would contribute to improving the overall safety of the ATC system.

Work Process

Working hours. Working the night shift can exacerbate age-related changes. Shift work is a very sensitive issue in terms of aging. In a profession like air traffic controller, night shifts are inevitable. However, the accumulated risks for older employees should not be ignored. Starting at a certain age, which is yet to be determined by medical experts, the number of night shifts should be reduced to an achievable minimum.

Some researchers are in favor of changing the break regimen for older employees. It has been found that older coworkers have longer breaks.

A fairly simple and effective way to combat aging in the back office is to schedule shifts. Most managers consider the age of their coworkers when assigning them to jobs, although age is certainly not the only criterion. Moreover, replacing night shifts with younger colleagues is very useful and has become a common practice.

Very useful and has become a common practice. Another useful practice is the careful formation of work teams: very often a senior supervisor is assigned to the position of scheduler and a younger colleague to the position of supervisor. it turns out to be a good combination.

Design of workplaces. *Design of new technological systems*. Well-developed technological equipment is one of the most powerful ways to combat the negative effects of aging. The scope of this study does not allow for recommendations on the design of individual types of equipment. Nevertheless, some suggestions to keep in mind when designing systems are possible. possible. possible. As a general rule, new technological tools should provide support for working memory, as this is a very vulnerable area. The five declining cognitive skills are closely related to working memory, that is, they require large working memory resources. Simple little aids such as audio or visual reminders will help meet this need as much as the more sophisticated features of new systems, such as automating complex refined mental processes.

In addition, it is desirable that the equipment supports the planning process and limits the number of unexpected events. Since such events are inevitable in air traffic control, it would be useful to develop supporting tools for active problem solving and situation diagnosis. Another way to support an aging controller is to design the hardware to help compensate for slowdowns. In particular, all input functions should be as simple and time-saving as possible (e.g., on-screen drop-down menus should be intelligent and simple). In terms of input media, the use of the mouse should be challenged. Older controllers find it more difficult to achieve speed and accuracy of input when they have to be done with a mouse.

In general, it would be useful to involve a representative sample of older controllers during the design phase of new equipment. This should be done not only to interest this group in the final product, but mainly to improve it. The input of experienced controllers can be very valuable. It can also help to reflect the positive aspects of aging, i.e. the benefits of experience. A sensible approach to system design can allow this experience to be built into the new system.

Workplace ergonomics. The working environment in the unit should be as conducive to the controller's work as possible. All rules concerning the proper design of the workplace are particularly important for older controllers. Many aspects can be summarized under the heading "ergonomics". This section highlights just a few aspects that are particularly important for older people.

Lighting is an important factor. Since vision often deteriorates with age, elderly dispatchers need adequate lighting. Facilities with daylight should be preferred. At night or in centers where daylight is not available, it is desirable to have an adjustable light source at each workstation.

The location of the sources should be such that they can be easily reached without twisting or stretching the body. For the same reason, chairs and consoles should be individually adaptable.

Hearing sometimes deteriorates with age. Background noise should therefore be minimized, e.g. with noise-absorbing floor coverings. In addition, all sources of auditory information should be volume controlled.

Human

With respect to the person, four attributes are important for aging:

Mental state. Much has already been said in this paper about the cognitive aspects of aging. We will not repeat ourselves here. Cognitive activities are the most important part of a dispatcher's job. It is basically mental work that ATCs have to do every day. Some of these cognitive skills decline with age, others improve with experience. One thing that is absolutely supported by research is that there is a big difference between people in terms of aging. This is why individual patterns of decline and improvement in cognitive skills can also differ.

Aging is an elemental process. Little is yet known about how cognitive aging can be effectively influenced. Regular mental exercise appears to be important to avoid or minimize skill loss and performance decline. However, a realistic view of one's own skills is equally important. A decline in skills in one area is accompanied by gains in other areas. A sign of maturity and responsibility is the ability to recognize one's limitations and act accordingly.

Physiological fitness. The importance of physical fitness has already been described. Management can only encourage healthy behavior. However, it is up to each individual to take advantage of opportunities such as healthy meals in the canteen or sports facilities. It is the responsibility of every employee to do something for their own well-being. A healthy lifestyle will not stop aging, but it can help mitigate its effects or delay the onset of aging ailments. [7]

Qualifications. Air traffic controllers are well-trained individuals. In addition to training, they must meet other requirements to stay current. First of all, they must keep up with the advancement of technology. Sooner or later computer technology will come to the operations room. In most departments, this process has already occurred, and some senior colleagues are faced with brand new technology. New computer technology challenges supervisors of all ages who are not "computer literate." The best way to prepare for this step is to familiarize yourself with computers outside of work hours, in your own time, such as by buying and using a PC at home.

Second, because not only the technological aspects of ATCO work are changing, but also work in general, air traffic controllers - like everyone else today - need to learn to adapt to new work situations. Lifelong learning is not just a slogan, it is a basic requirement of our modern society. An air traffic controller who manages to stay current with his job is able to adapt to change much more easily.

Motivation and attitude towards work. When interviewed, most ATCO employees indicate that they are highly intrinsically motivated to work. Doing work as such gives them pleasure and motivates them. This motivation is accompanied by high job satisfaction. The ability to maintain this motivation even after years of doing the same job will enhance overall job performance. Successful older dispatchers are very often highly motivated supervisors.

3.2. Aging, shift work and stress. An integrated approach.

The analysis conducted in this work showed that age has a negative impact on the cognitive abilities of an air traffic controller. Constant stress in the workplace and long shift work has a negative impact on health, which in turn leads to loss of efficiency and premature retirement. We believe that an employee's health is directly related to their job performance. (see also Figure 3.3)

Figure 3.3 – Overlapping negative factors that affect productivity

After about twenty years of shift work, sleep quality and attitudes towards shift work accelerate the biological aging process and strongly affect the health and tolerance of shift work. Subsequently, a number of health conditions arise that lead to premature retirement.

We distinguished 3 phases during the career of an air traffic controller. In fact, there are 4 of them, but in this work, 3 phases are more important for us: synthesizing, accumulation and manefestation phases (see Figure 3.4). The synthesizing phase lasts from 5 to 20 years of shift work, when the air traffic controller is already used to his schedule and is satisfied with it. After 20 years of work experience, fatigue accumulates, various diseases start to develop, shift worker syndrome, etc. The air traffic controller probably ceases to be tolerant to shift work. Manephistasis phase can occur differently for everyone, but also after 20 years of shift work, it can lead to retirement or occur even after retirement.

However, evidence also supports that experience and expertise can delay the decline in performance and help the aging air traffic controller to successfully manage his or her job responsibilities. Moreover, older colleagues help the younger ones to get acclimated to the workplace faster, pass on their experience and support less experienced colleagues. This proves the importance of aging air traffic controllers, so our task is to help them stay healthy and fit for effective work for as long as possible.

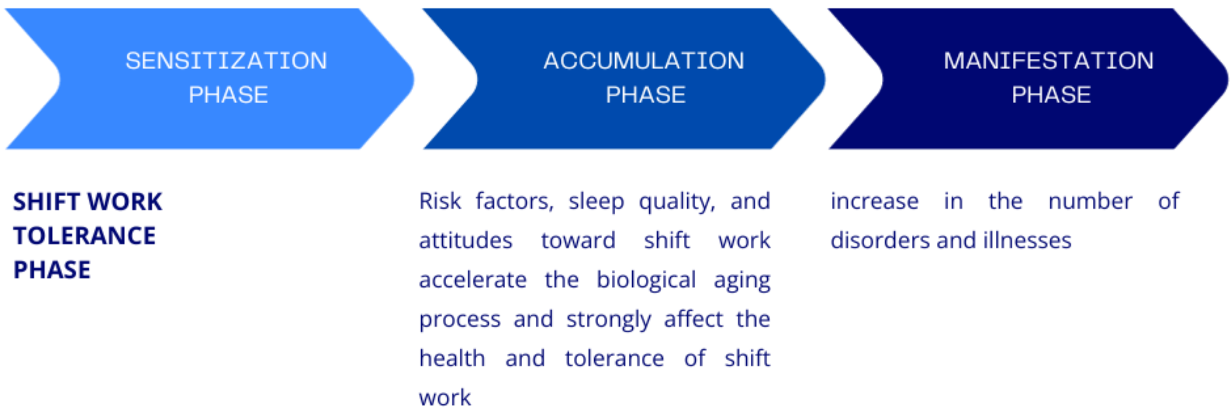

Figure 3.4 – Phases during the career of an air traffic controller

It is important to remain in a shift work tolerant phase for as long as possible. Therefore, we have developed special recommendations that will help minimize the negative effects of shift work and long periods of stress.

We considered a system that consists of 3 elements: Aging, shift work, and stress. Combined, these factors rapidly bring an air traffic controller closer to the end of his or her ability to work. The air traffic controller may experience Fatigue, which already negatively impacts his or her effectiveness. Aging air traffic controllers need to be given the opportunity to rest more. If this problem is not given proper attention, health problems on the background of fatigue may begin. Moreover, coupled with stress, shift work and age can lead to a write-off. The battery phase is unfortunately inevitable, after 20 years of service, night shifts are no longer tolerable for an air traffic controller. The main challenge remains to avoid manifestation (see Figure 3.5):

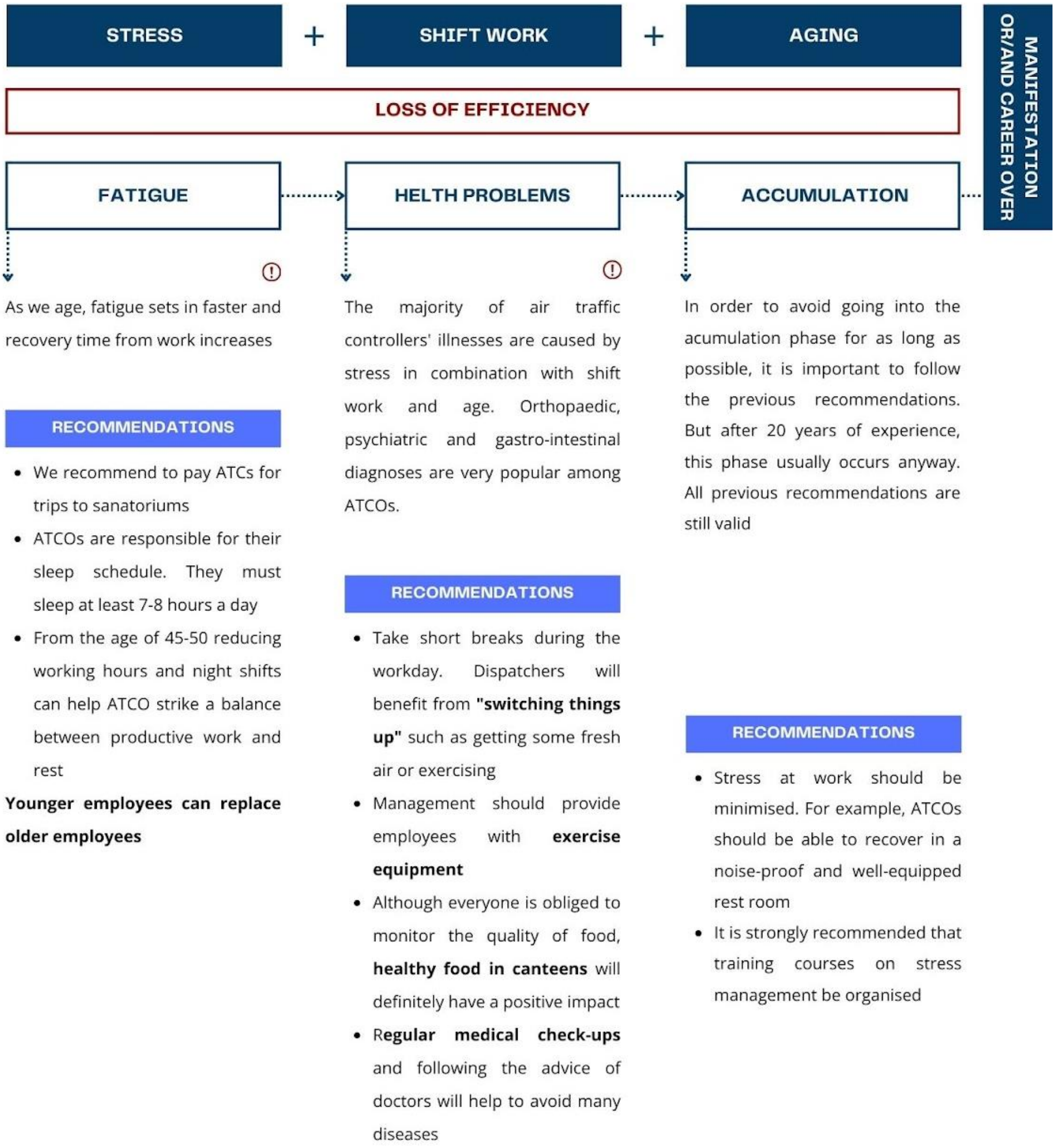

Figure 3.5 – Scheme, what aging, shift work and stress leads to, how to avoid the consequences

3.3. A systematic approach to dealing with the challenges posed by the continuous evolution of technology

Technology is constantly evolving and, when used correctly, can greatly simplify work, especially for aging employees. At the same time, if an air traffic controller doesn't understand their value or doesn't know how to use them, it can make things worse.

The analysis in this paper revealed the difficulties of aging air traffic controllers in dealing with any changes in the workplace, including the introduction of new equipment to the workplace. Automation can cause rejection and difficulties for air traffic controllers starting from the age of 40.

That is why we have developed recommendations for smooth transition of aging air traffic controllers to the new system. With the right systematic approach, aging air traffic controllers will easily accept any changes without losing efficiency.

Our systematic approach is that we combine 4 important factors that influence success when innovating an age-based air traffic controller. Figure 3.6:

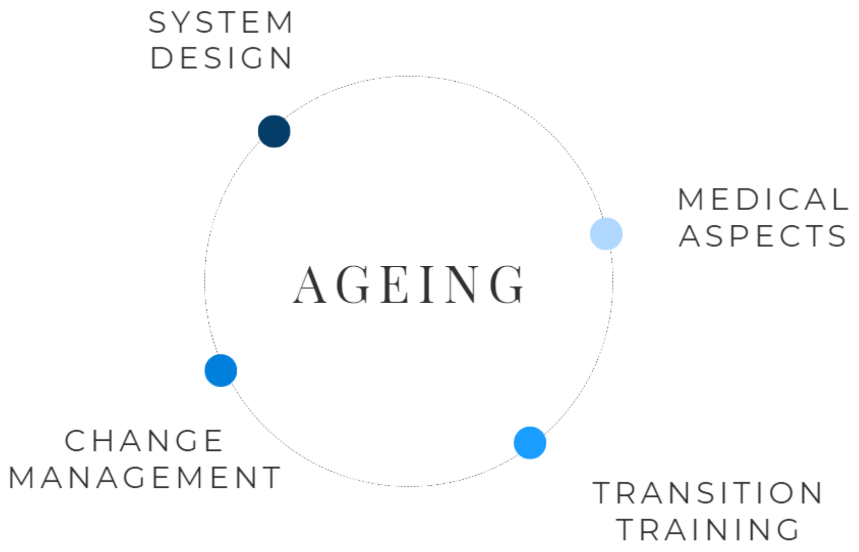

Figure 3.6 – Areas to focus on to avoid the effects of aging

To prevent productivity loss we have developed a system, all elements are interconnected. Figure 3.7:

	WHY DO WE NEED IT?	POTENTIAL PROBLEMS	RECOMMENDATIONS
SYSTEM DESIGN AND AUTOMATION	Ideally, Automation becomes a great assistant to the ageing air traffic controller: • reduces cognitive and physical strain on the worker • mitigates the impact of age on performance For example, the user-friendly intuitive interface and audible alerts help to complete actions faster	• Rejection of age-related ATCO changes • Fear of change • Inefficiency of the new system	• In co-operation with operations staff and system developers, improve the design of systems and tools • Engage operational and human factors experts • Develop automated tools only on the basis of reliable experimental data
CHANGE MANAGEMENT	Implementing a new system always involves a change management process, whether that process is actively managed or just a "see what happens next" approach. Management plays a key role here. **Good communication ensures that employees are ready for change**	The bigger the step and the more aspects of the work to be changed, the more important it is to manage the transition effectively	• It should be clearly explained why the change is necessary, what impact it will have on the individual and how significant the efforts of the staff can be. In this way minimise resistance from air traffic controllers to the new system. • A change management working group that includes operational staff can also be a way to ensure a smooth transition • Involve ATCOs of all age groups in the development and design of the system
TRANSITION TRAINING	During the introduction phase of a new system, transition training can contribute greatly to the success of the new system. Actually setting up the system can ease the transition for older ATCOs		• flexible training time • providing sufficient possibilities for practical training • providing additional computer courses if necessary • a systematic approach to improve transition training
MEDICAL ASPECTS	The accumulated health effects of shift work are a serious problem and need to be addressed. Regular health checks and examinations can identify potential problems at an early stage, allowing timely action to be taken	Ageing air traffic controllers, fearing being written off for health reasons, may hide their diagnoses and deceive management. This can lead to sudden death in the workplace	• Collaborate with medical professionals to develop individualised wellness programmes tailored to the specific needs of ATCO's ageing workforce • Regular health trainings for staff, with recommendations on nutrition, exercise, hygiene, and sleep

Figure 3.7 – Areas to focus on to avoid the effects of aging and reccomendations

The essence of the developed system: Automation and adaptive system design can certainly help the aging air traffic controller maintain efficiency. Despite the potential success of the new system, there may be resistance from employees. To prevent this from happening, we suggest ensuring a smooth and comfortable transition. At this stage, management plays a key role and needs to clearly explain why this innovation is necessary and how it can help the workplace. Direct training and transition exercises are an integral part of this. There is a medical aspect to any systems approach, especially when it comes to the elderly. While automation can help an air traffic controller work faster, keeping fit and monitoring health is an integral part of the job. Each component of the system contains appropriate recommendations and cautions. While our recommendations are intended for older air traffic controllers, they will be useful for all ages.

Conclusion to Chapter 3

The section begins by describing four levels of action recognized as useful in addressing aging: society, governance, workflow and the individual. At each level, useful solutions are proposed. These scenarios can be seen as initial recommendations.

A three element system was then considered: stress, shift work and age. Combined, these aspects rapidly lead the air traffic controller to lose efficiency and also carry health risks. The combination of these interacting elements was organized to achieve a goal: preventing aging air traffic controllers from losing effectiveness.

The next step in achieving the goal was to focus on automation. Based on the analysis, we identified problems and developed appropriate recommendations.

Most of the recommendations in this paper will benefit all ATCO employees, regardless of their age. However, older employees will benefit the most. We believe that older employees are the company's most valuable resource.

CHAPTER 4. AUTOMATED BIG DATA PROCESSING IN AIR NAVIGATION

Automated data processing is a typical task, which is solved by modern air navigation systems. Processing of air navigation data is provided both on board airplanes in particular avionics units and in ground data processing equipment. Navigation parameters in modern systems are measured using a significant number of different sensors, which ensure creation of a data archive, the processing of which requires the use of specialized statistical data processing algorithms. Each sensor performs measurements with a certain amount of error, the effect of which cannot be excluded, but it can be reduced to an acceptable level. Therefore, the combined processing of data in the aeronautical system is performed by taking into account each sensor error. In this case, confidence bands are used, which guarantee getting a particular frame in the interval with a certain probability [10]. The most commonly used confidence band is the double root mean square deviation, which provides 95% localization of the measured values, based on the assumption of a normal distribution of errors.

The structure of each unit of avionics is more similar to the architecture of a personal computer with the corresponding elements: processor, memory, and analog-to-digital / digital-to-analog converters, which allows processing of measured data at the software level [11]. The sensor’s data is converted to digital form by sampling analog values. Results of different value measurements are stored in appropriate registers, variables, matrices, or data archives.

Detection of an airplane's exact location is one of the most important tasks in civil aviation [12-14]. Continuously growing volumes of air transportation require a constant review of separation minimums to meet needs of modern air transport. Separation minimums between airplanes set up maximum permissible limits of airplane separation in space on vertical plane, lateral and longitudinal sides. One of the possible ways to solve the issue of airspace congestion is to increase the bandwidth of a particular part of the airspace by reducing the safe distances between airplanes. In practice, this is implemented by introducing more precise requirements for determining the location of airplanes in the air space. The introduction of more precise requirements for airplane positioning is possible only if there are appropriate systems capable of satisfying them. Operation of on-board positioning sensors of a civil airplane is provided by the field of aeronautical signals created in space by various systems.

As an example of big-data processing, we will use the trajectory of particular aircraft and perform its calculation using MATLAB software.

4.1. Input data

The safety of air transportation mostly depends on the accuracy of preplanned trajectory maintained by each airspace user. Flight technique and performance of on-board positioning sensor specify the level of airplane deviation from cleared trajectory. The receiver of Global Navigation Satellite System (GNSS) is the main positioning sensor on board a modern airplane of civil aviation. Performance of on-board positioning system specifies an area of airplane location with a certain level of probability. Airplane operation within a particular airspace volume is regulated by navigation specification which specifies requirements for the performance of on-board positioning system. To guarantee a safe flight through a particular airspace volume each user should perform navigation with the required levels of performance.

Measured position of an airplane is classified as critical data due to its role in the safety of the whole air transport system. According to Automatic Dependent Surveillance-Broadcast (ADS-B), the position is shared with other airspace users to guarantee surveillance and improve the safety of aviation. Today the majority of airplanes are equipped with transponders of mode 1090 ES (extended squitter). The airplane transponder transmits periodically digital message which includes a position report [15, 16]. This data can be easily received and used on-board of other airplanes for improving situation awareness or can be received by ground receivers. An air navigation service provider uses a national network of ground ADS-B receivers to support surveillance and airspace user identification [17, 18]. Also, there are multiple commercial networks of ADS-B receivers, that process and collect all data transmitted via the 1090 MHz channel.

In particular, computation clusters of Flightradar24 and FlightAware companies provide simultaneous processing of data from more than 30,000 software-defined radios of ADS-B signals located all over the globe (Fig. 4.1).

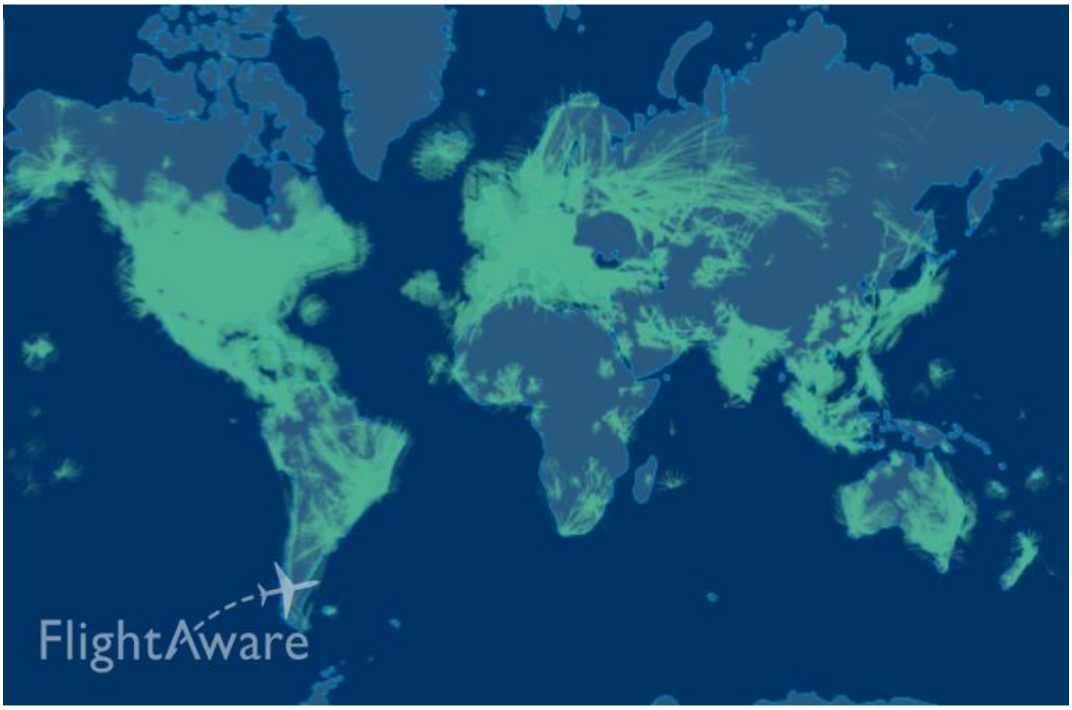

Figure 4.1 – Maps of global traffic [10]

Access to global databases of trajectory data is open and provided on a commercial basis. The *application programming interface* allows us to easily get any segment of trajectory data for analysis. As input, I use flight path data of WZZ2394 (Wizz Air 2394) operated by Wizz Air for connection between Lisbon, Portugal (LIS) and Budapest, Hungary (BUD). Departure date is December 6, 2023 at 03:23PM (EST). Landing date is December 6 at 6:32 PM (EST). The flight ended 9 minutes earlier than the scheduled landing time. This flight was performed by Airbus A321-neo (A21N). Input data obtained from the archive at https://flightaware.com/live/flight/WZZ2394/history/20231206/2020Z/LPPT/LHBP. Table 4.1 shows the first and final 15 rows of flight raw data.

Table 4.1. Trajectory data of WZZ2394 (6 December 2023)

Time (EEST)	**Latitude**	**Longitude**	**Heading angle**	**Ground speed (kts)**	**Ground speed (mph)**	**Barometric altitude (feet)**
Wed 03:23:06 PM	38.7953	-9.1281	↗ 23°	172	198	750
Wed 03:23:23 PM	38.8085	-9.1211	↗ 23°	177	204	1,425
Wed 03:23:39 PM	38.8211	-9.1142	↗ 23°	197	227	1,775
Wed 03:23:55 PM	38.8349	-9.1056	↗ 33°	218	251	2,1
Wed 03:24:25 PM	38.8546	-9.0725	↗ 58°	254	292	2,85
Wed 03:24:48 PM	38.8687	-9.0425	↗ 59°	272	313	3,725
Wed 03:25:18 PM	38.8868	-8.9980	↗ 65°	279	321	5,175
Wed 03:25:48 PM	38.9039	-8.9513	↗ 65°	285	328	6,7
Wed 03:26:18 PM	38.9209	-8.9069	↗ 63°	300	345	7,8
Wed 03:26:48 PM	38.9404	-8.8568	↗ 63°	309	356	9,1
Wed 03:27:33 PM	38.9690	-8.7837	↗ 63°	333	383	10,5
Wed 03:28:04 PM	38.9918	-8.7253	↗ 64°	363	418	11,1
Wed 03:28:34 PM	39.0154	-8.6642	↗ 64°	372	428	12,275
Wed 03:29:04 PM	39.0381	-8.6053	↗ 64°	377	434	13,375
Wed 03:29:34 PM	39.0607	-8.5465	↗ 64°	387	445	14,375
Wed 06:26:41 PM	47.2872	19.4718	↑ 342°	170	196	3,8
Wed 06:27:07 PM	47.3032	19.4541	↖ 317°	169	194	3,675
Wed 06:27:33 PM	47.3178	19.4320	← 313°	172	198	3,525
Wed 06:28:02 PM	47.3332	19.4071	← 312°	168	193	3,375
Wed 06:28:32 PM	47.3484	19.3828	← 313°	164	189	2,925
Wed 06:29:02 PM	47.3633	19.3587	← 313°	163	188	2,5
Wed 06:29:32 PM	47.3784	19.3344	← 312°	159	183	2,075
Wed 06:29:42 PM	47.3832	19.3266	← 312°	153	176	1,9
Wed 06:29:48 PM	47.3858	19.3224	← 313°	147	169	1,825
Wed 06:30:04 PM	47.3929	19.3110	← 312°	137	158	1,6
Wed 06:30:20 PM	47.3996	19.3001	← 312°	132	152	1,4
Wed 06:30:37 PM	47.4065	19.2890	← 313°	133	153	1,2
Wed 06:30:53 PM	47.4132	19.2783	← 313°	132	152	1
Wed 06:31:09 PM	47.4196	19.2679	← 313°	130	150	800
Wed 06:31:25 PM	47.4263	19.2571	← 313°	127	146	600

4.2. Visualization of trajectory data at specific software

Let`s import trajectory data of WZZ2394 (6 December 2023) into specialized software of MATLAB [19]. Results of trajectory data visualization for flight is represented in fig. 5.2. and vertical profile of flight is in fig.5.3.

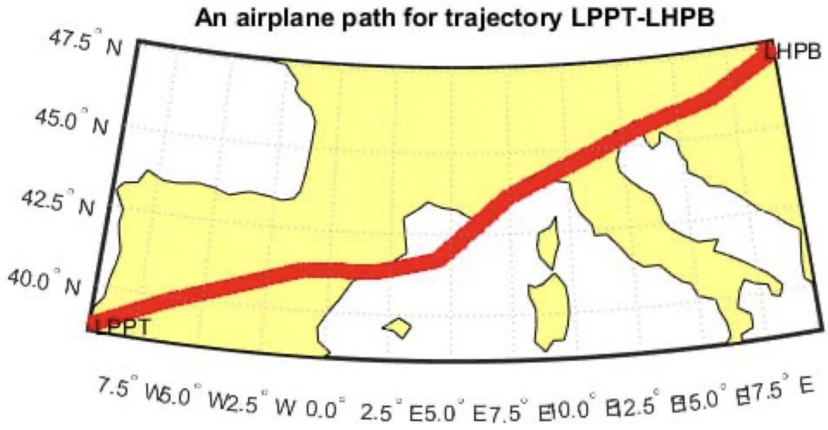

Figure 4.2 – Flight path of WZZ2394 (6 December 2023)

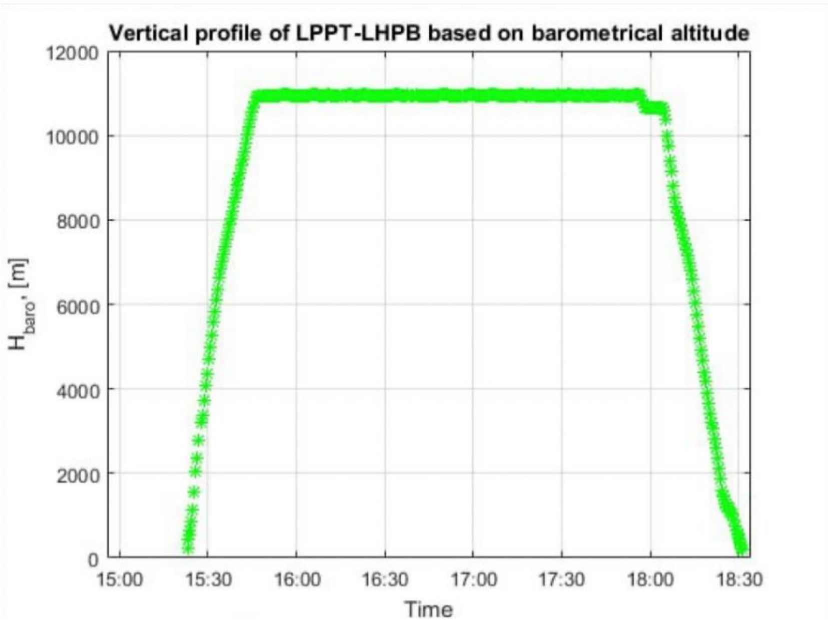

Figure 4.3 – Vertical profile WZZ2394 (6 December 2023)

4.3. Trajectory data interpolation

The digital messages transmitted within ADS-B are not synchronized in time. A transmitter of each airspace user can be set to its frequency of digital message generation. In addition, it should be noted that the frequency of 1090 MHz is quite busy, since secondary radars, airborne collision and avoidance systems, and ADS-B use it. This leads to the fact that many digital messages may interfere with each other that destroy data transmitted inside of these messages. Therefore ADS-B trajectory data includes many gaps in the sequence and broken messages. At the stage of data processing usually, methods of data interpolation are used to solve this problem. The interpolating function can be polynomials or spline functions. The results of interpolation of input data at a frequency of 1 Hz are shown in Fig. 4.4 - 4.6. All subsequent calculations will be performed with interpolated data. Let's display the data in the local NEU system. As the center of the system, we will use the coordinates of the first point of the trajectory. The results of visualization of the trajectory in the local system are shown in fig. 4.7 and fig. 4.8.

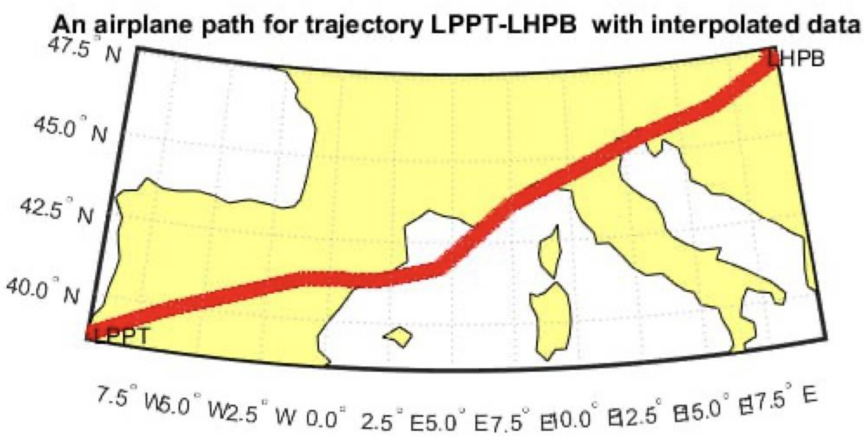

Figure 4.4 – Interpolated airplane trajectory of WZZ2394 (6 December 2023)

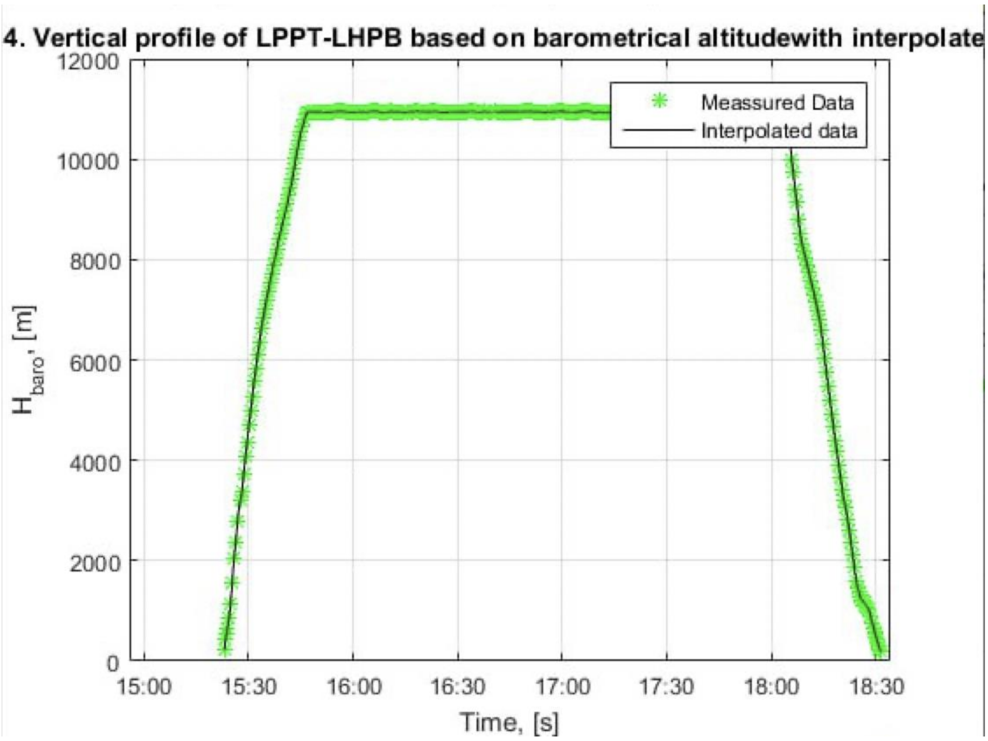

Figure 4.5 – Interpolated vertical profile of WZZ2394 (6 December 2023)

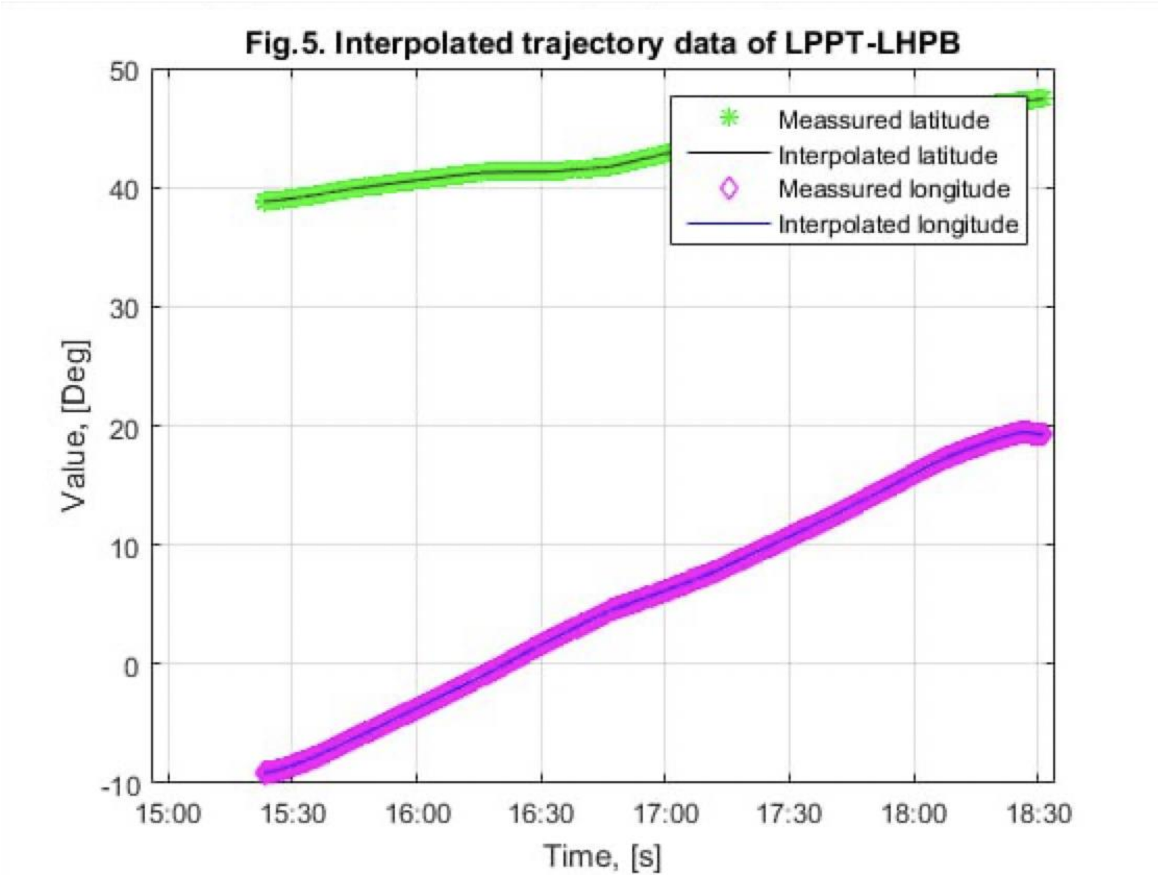

Figure 4.6 – Interpolated data for 1 Hz of WZZ2394 (6 December 2023)

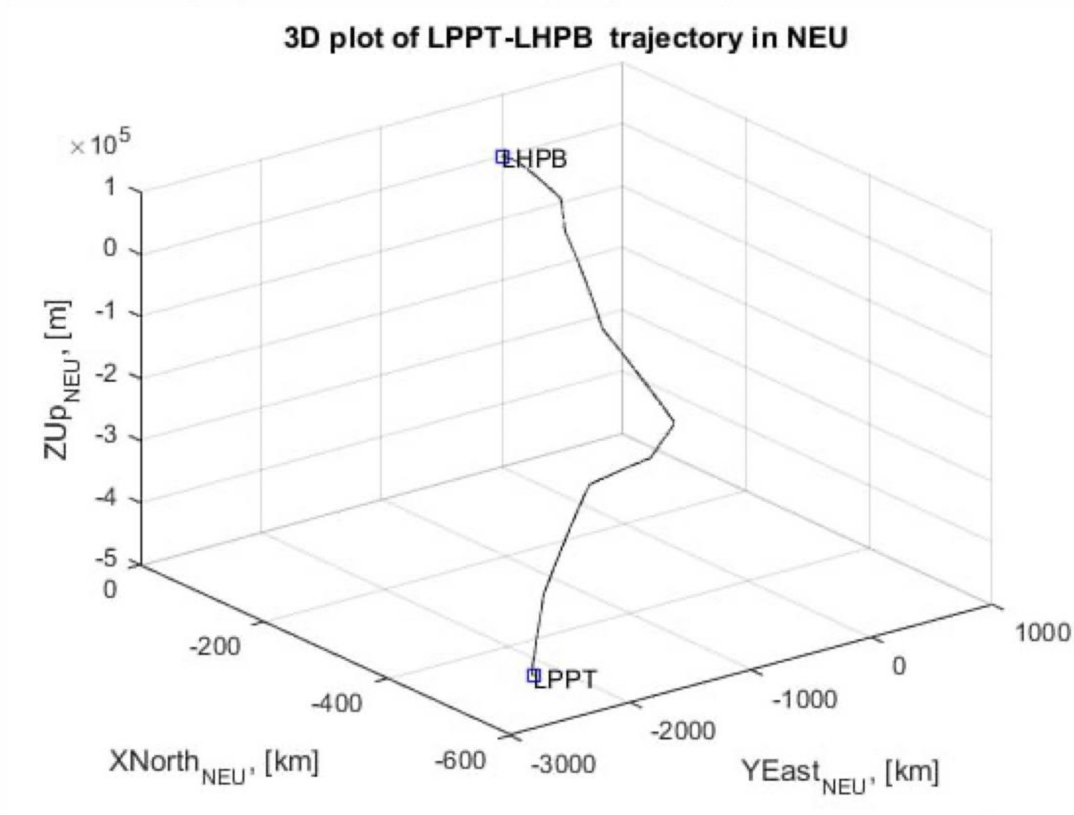

Figure 4.7 – 3D trajectory of WZZ2394 (6 December 2023) in NEU reference frame

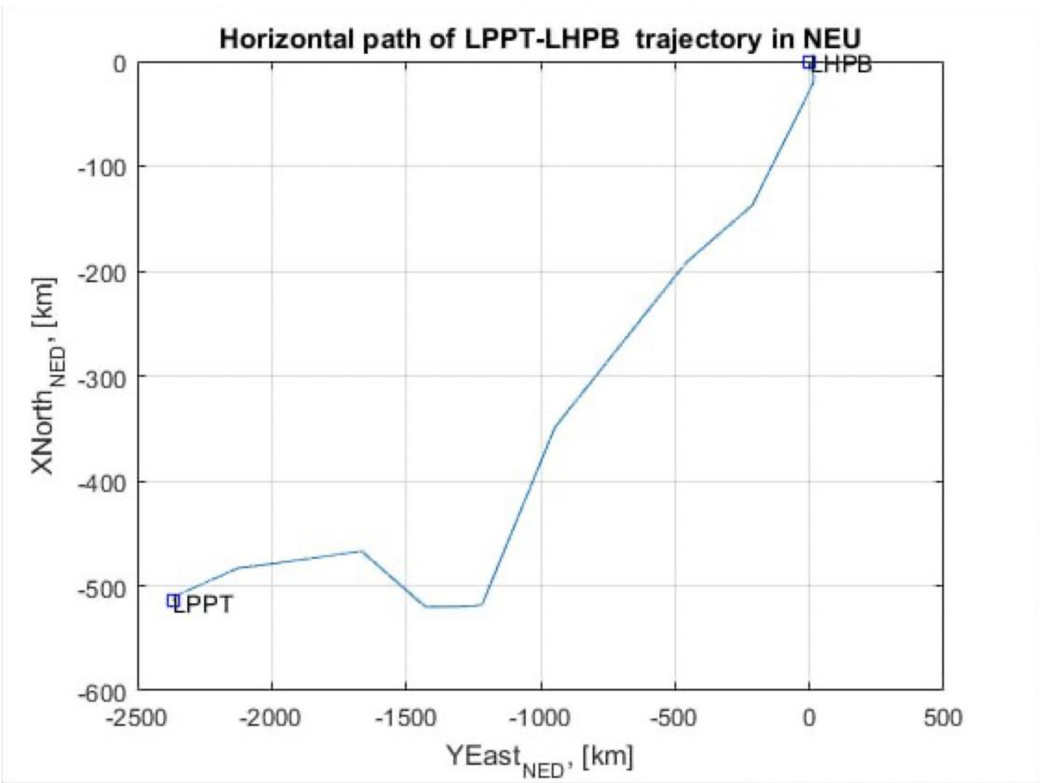

Figure 4.8 – Flight path of WZZ2394 (6 December 2023) in local NEU

4.4. Trajectory data calculation

Based on the data set of the three-dimensional movement trajectory, we will calculate the speed components. In particular, I calculate the full speed of an airplane, vertical, and horizontal components. The results of the speed calculation are shown in fig. 4.9., and the estimated course of the plane in fig. 4.10. Also, I calculate the total flight time and the length of the route and trajectory.

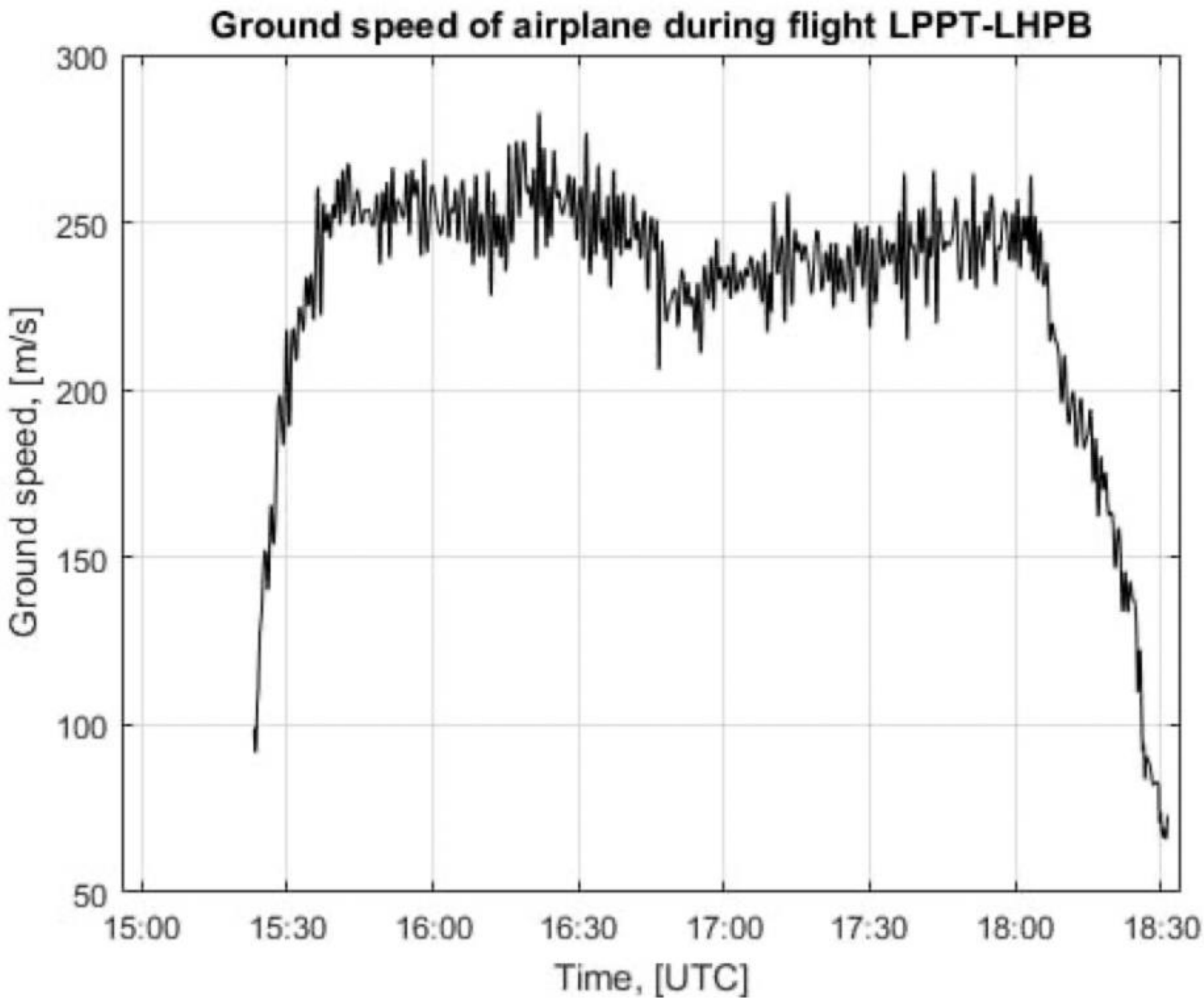

Figure 4.9 – Results of velocity estimation of WZZ2394 (6 December 2023)

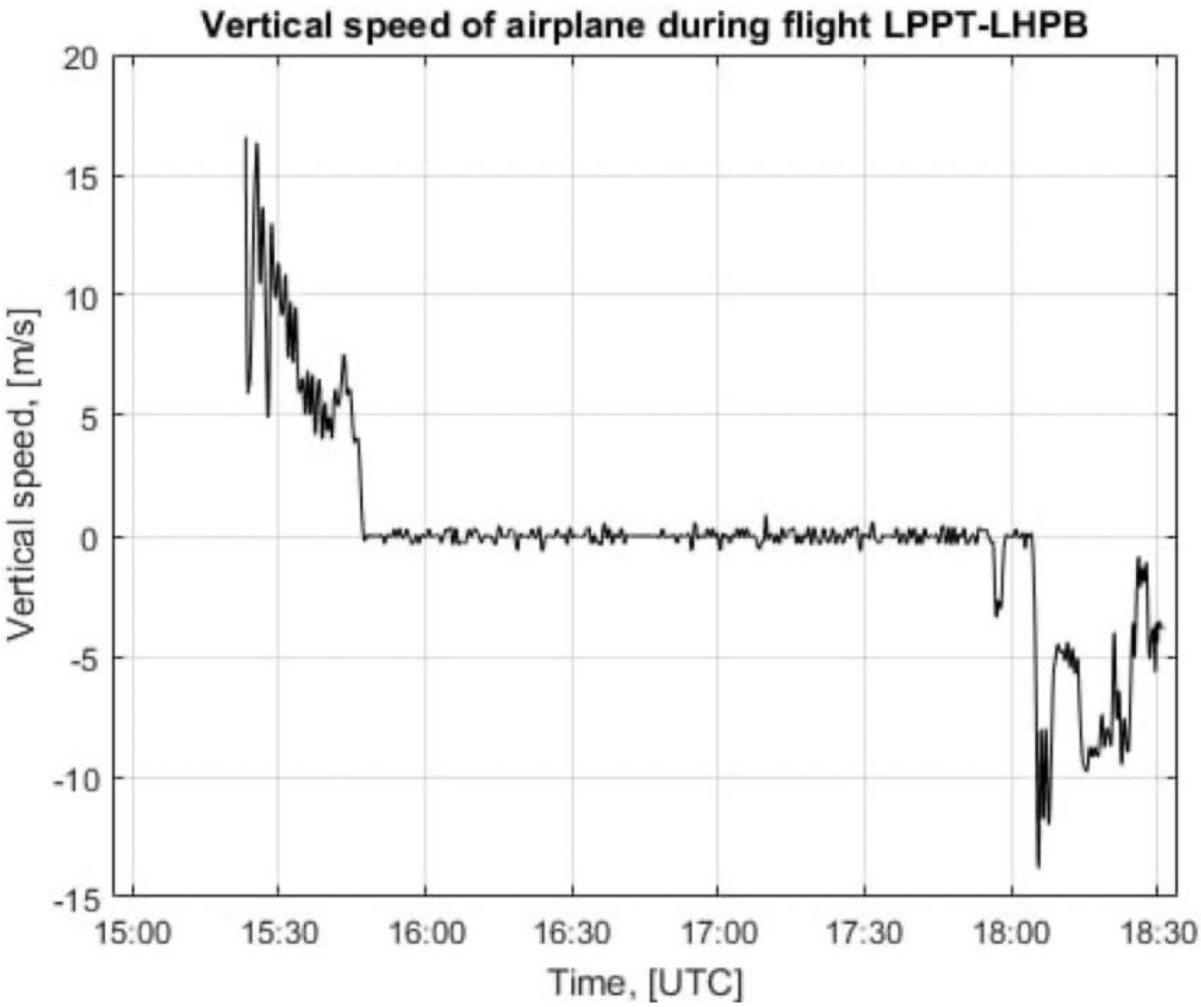

Figure 4.10 – Results of heading angle calculation of WZZ2394 (6 December 2023)

Conclusion to Chapter 4

The total flight time of WZZ2394 on December 6, 2023, was 3 hours 8 minutes 19 s. The length of the trajectory is 2589.5 km, and the length of the flight path (horizontal component) is 2589 km.

In this course work named as Parameters of airplane trajectory estimation, based on a particular task we have studied polynomial and spline interpolation. As input I have used flight path data of flight WZZ2394 on December 6, 2023, from website https:// flightaware.com.

All skills and knowledge acquired during this course work performance will be useful for us, as future students and Air Traffic Control Operators.

CHAPTER 5. LABOR PRECAUTION AND ENVIRONMENT SAFETY

5.1. Occupational health and safety of air traffic controllers

For the efficient and well-coordinated operation of the entire aviation transportation system, all its elements must function properly. One of the links in this system is the air traffic controller.

His or her responsibilities include management and control of a certain area of airspace with aircraft operating in it. Each air traffic controller's workplace must be specially equipped and furnished for comfortable work.

In this section, we will consider the requirements for the equipment of the air traffic controller's workplace and the premises in which it is located.

Requirements for air traffic control rooms

The spatial planning and design of industrial and sanitary buildings at checkpoints must comply with sanitary and hygiene regulations.

Control room buildings intended for ATC dispatchers should have natural and artificial lighting that meets the hygienic requirements of the workplace.

The absence of natural light in the control room building is allowed if it is related to production needs and is provided for in the design documentation approved in accordance with the established procedure.

The control room buildings shall be equipped with heating, ventilation and exhaust systems or air conditioning systems that provide favorable working conditions.

The sound insulation of the control room building must meet hygienic requirements and ensure the standard sound parameters at the ATC dispatcher's workplace.

Interior decoration of control point buildings is carried out using diffusely reflective materials with a reflection coefficient: for ceilings - 0.7 - 0.8; walls - 0.5 - 0.6; floor - 0.3 - 0.5.

The color scheme of the building is carried out in accordance with the requirements for interior design of residential, medical and industrial buildings and the design of buildings and ancillary buildings and industrial buildings.

Floor coverings in checkpoint buildings should be constructed of materials that have antistatic properties, provide a smooth surface, and are clean and moisture-free [20].

Requirements for the workplace of an ATC controller

The workplace of an air traffic controller should be designed in accordance with the hygienic requirements for workplaces equipped with video display terminals (VDTs).

Hygienic requirements for workplaces of air traffic controllers equipped with VDTs:

- the area for one workplace with a VDT should be at least 6 m2 and a volume of at least 20.0 m3;
- workstations of ATC dispatchers working with VDT should be located relative to the light openings in such a way that natural light falls from the side, mainly from the left;
- when arranging the workstations of the ATC dispatcher with VDT, the distance between the work desks of employees with video monitors (in the direction behind one and the screen of other video monitors) should be at least 2 m, the distance between the sides of the video monitors should be at least 1.2 m;
- window openings in buildings where CRTs are used should be equipped with adjustable devices, such as curtains, blinds, external windows, which allow normal operation of CRTs and provide protection against flame and additional sound protection;

- workplaces with HPWT should be separated from each other by a partition of 1.5 - 2.0 m height made of frosted glass;

- cabinets for storing working documents and materials should be located in utility rooms. In the absence of utility rooms, it is allowed to place them in the offices of the ATC dispatchers, provided that the requirements for the area and size of the above-mentioned rooms are met;

- when creating a workplace of an ATC dispatcher equipped with a VDT, it is necessary to ensure the compatibility of the designs of all elements of the workplace and their relative location, taking into account the nature of the activity, technical complexity, forms of labor organization and the main task of the dispatcher;

- a workstation with a display should allow the ATC dispatcher to work comfortably in a sitting position and not create an overload system.

Hygiene requirements for the desktop (remote control):

- The design of the desktop (console) should be based on the nature of the work, taking into account the number and design functions (size of the VDT, communication equipment, telephone, etc.) and files to ensure the best placement of the necessary equipment. Use workbenches of various designs that meet the requirements of modern ergonomics and are approved in accordance with the established procedure;

- the height of the workbench's working surface (remote control) should be adjustable within 680-800 mm. If this is not possible, the height of the workbench work surface shall be 725 mm. The height adjuster on the work surface of the table should be easily accessible while sitting, providing free control and firm fixation;

- the modular size of the working surface of the workbench for calculating the size of the workbench should be: width - not less than 1200 (1600) mm, depth - not less than 800 (1000) mm;

- the desktop should have a sliding surface separated from the main working surface to accommodate the display keyboard;

- the best distance between the video monitor screen and the eyes of the ATC dispatcher should be 600-700 mm, but not less than 500 mm;

- the location of the input and output devices should provide the best visibility of the screen;

- The workbench legroom should be at least 600 mm high, at least 500 mm wide, at least 450 mm deep at the knees and at least 650 mm high from the feet.

Requirements for a work chair:

- Ergonomic requirements should be taken into account when selecting a chair type that is ergonomically appropriate, suitable for the environment and allows for free movement;

- the design and finishing materials of the seat of the ATC controller's chair must be durable, fire-resistant and non-toxic. Seat covers, backrests, armrests and headrests must be made of shock-absorbing, moisture-proof, non-charged hermetic materials;

- the work chair must support the physiological and reasonable working posture of the ATC dispatcher during the work process, as well as create conditions for changing the posture to reduce the static tension of the muscles of the neck, shoulders and back, as well as to exclude the blood circulation of the lower extremities to prevent the development of fatigue;

- the work chair should be rotatable and adjustable, and the height, seat and backrest angle and distance between the backrest and the front edge of the seat should be adjustable.

- the adjustment of each parameter of the seat position shall be independent, simple and feasible, and fixed and reliable;

- the seat surface shall have a width and depth of at least 400 mm. It shall be possible to change the angle of inclination of the seat surface from 15o forward to 15o backward, the height of the seat surface shall be adjustable from 400 to 550 mm. The seat surface shall have a rounded front edge;

- the support surface of the backrest shall have a height of 300 ± 20 mm, a width of at least 380 mm, a radius of curvature of the horizontal plane - 400 mm; the angle of inclination of the backrest in the vertical plane shall be adjustable within 0 ± 30°. The distance of the backrest from the front edge of the seat shall be adjustable within the range of 260 to 400 mm;

- the armrests shall be at least 250 mm long, 50 to 70 mm wide, adjustable in height above the seat within 230 ± 30 mm and adjustable in internal distance between the armrests within 350 to 500 mm.

Display requirements:

- the display at the workplace of the ATC dispatcher must be located so that the image in any part of it is visible without the need to change the position of the head (raise or lower the head);

- the angle of observation of the screen by the dispatcher relative to the horizontal line of sight should not exceed 30°;

- the design of the display must provide the possibility of frontal observation of the screen by rotating the body in the horizontal plane around the vertical axis within ± 30° with fixation in a given position.

Devices, equipment, computers and others installed at the workplaces of ATC dispatchers must have sanitary and epidemiological conclusions on compliance with sanitary rules and regulations [21].

Workplace lighting

Natural lighting of administrative buildings for ATC dispatchers should be provided by transparent openings, and the natural light coefficient (NLC) should be at least 1.2% in areas with persistent snow and less than 1.5% in the rest of the territory. Artificial lighting of control rooms should be provided by the same or a combined lighting system.

The brightness of the level of the ATC dispatcher's desk (console) in the area where working documents are placed should be 300 - 500 lux, the video monitor screen (radar indicator) - 200 lux; keyboard - 400 suites; over the main passages - 100 lux. It is allowed to install local lamps to illuminate documents.

Local lighting devices used to illuminate documents should not create a bright surface level and increase the brightness of the screen by more than 300 lux.

Local lighting devices must have an opaque reflector with a protective angle of at least 40°.

The value of the illumination coefficient generated by incandescent lamps should not exceed 5%.

Control over the level of illumination is carried out in accordance with the instructions for assessing the brightness of workplaces [21].

Requirements for the microclimate and air of the working area

In the industrial premises of control centers, at the workplaces of ATC dispatchers, in accordance with the hygienic requirements for the microclimate of industrial premises, the optimal values of microclimate indicators should be ensured: air temperature 21 - 25°C, relative humidity 40 - 60%, air velocity - no more than 0.1 m/s, surface temperature 20 - 26°C.

Air temperature variations in height and horizontal, as well as changes in air temperature during a shift, while ensuring optimal microclimate values at workplaces should not exceed 2°C and should not exceed the normative values for air temperature. The content of positive and negative air ions in the air of the working area of the ATC dispatchers should comply with the sanitary standards of permissible levels of air ionization in industrial and public buildings (Table 5.1).

The content of harmful substances in the air of the working area of the ATC dispatchers must meet the requirements of hygienic standards.

Table 5.1 - Normative values of air ionization in industrial premises

Level	Number of ions in 1 cm3 air		Polarity indicator
	n	n^-	$\Pi = [(n^+)-(n^-)]:[(n^+) + (n^-)]$
optimal	1500 - 3000	3000 - 5000	от 0,05 до 0
allowable	400 - 50000	600 - 50000	от -0,20 до +0,05

Note: P - polarity index is determined by the ratio of the difference in the number of ions of positive (n +) and negative (n-) polarity to their sum. P may vary from + 1 to - 1, with equal number of positive and negative ions P = 0.

Noise, vibration, infrasound

Sound levels at the workplaces of ATC dispatchers shall not exceed 50 dBA in accordance with the requirements of sanitary standards for permissible noise levels at workplaces (sanitary noise standards at workplaces are established taking into account the degree of intensity and severity of the work activity performed. For ATC dispatchers, whose work is assessed as "strenuous labor of the 2nd degree" and "light or medium physical activity" in terms of intensity, the maximum permissible noise level at the workplace should not exceed 50 dBA).

The infrasound levels at the workplaces of ATC dispatchers must meet the requirements of the sanitary standards for infrasound at workplaces (Table 5.2).

Table 5.2 - Maximum permissible levels of infrasound at the workplaces of ATC dispatchers

Levels Sound pressure, dB, in Octave bands with mean geometric frequencies, Hz				Total level sound pressure, dB Lin
2	4	8	16	95
95	90	85	80	

In accordance with the requirements of sanitary standards, vibration levels at the workplaces of ATC dispatchers should not exceed the standard corrected frequency and equivalent corrected values - 83 dB for vibration acceleration and 75 dB for vibration velocity [22].

Requirements for the organization of work and rest regimes

ATC dispatchers work according to a shift schedule that ensures the continuity of the production process and days off.

For employees who directly control air traffic and have a valid air traffic controller certificate, a short working week is set at 36 hours and they are entitled to additional vacation.

To ensure the optimal performance and efficiency of ATC controllers, it is necessary to establish regulated breaks in the work shift, which are included in the working time. The time, duration, and frequency of regulated breaks in the work shift should be set depending on the actual conditions of the production load and the duration of the work shift.

Dispatchers who directly control air traffic at a control panel equipped with a video display terminal are allowed a regulated break of at least 20 minutes after 2 hours of continuous work and with air traffic intensity exceeding the permissible 10 additional minutes of break after each working hour.

When working in the night shift, ATC controllers should be given an hour of rest with the right to sleep in a specially equipped room, usually after 4 hours of work.

Recreation centers for ATC dispatchers must meet hygienic requirements, including in terms of microclimate and sound. Window openings should be equipped with sound-absorbing devices and double curtains.

To relieve nervous and emotional stress, the negative effects of hypodynamia and hypokinesia, and visual analyzer fatigue, it is advisable to perform a special set of exercises during adjusted breaks.

It is possible to reduce the negative impact of monotony in the process of changing the forms of activity of the ATC dispatcher.

To prevent stress in ATC dispatchers, it is recommended to carry out psychophysiological unloading at the end of the shift in a specially equipped room. The design of the psychological assistance room is carried out in accordance with the recommendations for preventing fatigue of physical and mental workers.

The duration of daily rest between shifts should be at least double the duration of the working day (shift).

5.2. Environmental protection from the impact of air transport

Compared to other modes of transportation, aviation is a specific pollutant with a fairly wide range of environmental impacts. The negative impact of air transport on the environment is both global and local in nature.

The global impact is the formation of the greenhouse effect and the destruction of the ozone layer.

Ground-based sources of pollution are conditionally divided into those located inside the airport and those located outside it. The latter include, first and foremost, heat and power plants that run on various types of local fuel, so the nature of pollution is determined by the types of fuel, methods of combustion, and emission disposal routes.

Intra-port sources of environmental pollution include

- ventilation systems used in certain aircraft maintenance areas;
- aviation fuel supply enterprises;
- special vehicles.

If necessary, when the air removed from workplaces contains large amounts of harmful substances, it is cleaned in dust and gas cleaning facilities before being released into the atmosphere.

The air from production facilities and certain airport facilities is released into the atmosphere as follows:

- Vapors of oil products, solvents, paints and varnishes, alkalis, acids;
- aerosols of aqueous solutions of caustic, carbon dioxide and phosphoric acid sodium, sulfur dioxide, nitrogen oxides, carbon monoxide, and dust.

The amount of hazardous substances released into the air from the production facilities of an airport or aircraft repair plant through ventilation systems may exceed the maximum permissible values, which cause the maximum permissible concentrations of these hazardous substances to be exceeded. This most often occurs when ventilation shafts are located in groups, when the effect of summation of harmful emissions occurs, and even new harmful substances of greater toxicity are formed [22]

Impact of air sources of aviation transport on the environment

Aircraft pollute the atmosphere by emitting harmful substances with exhaust gases from aircraft engines.

Aircraft move from one airport to another during a flight, causing pollution in the atmosphere on a global scale, i.e. significant pollution occurs both in airport areas and on flight routes. Moreover, while on flight routes (at an altitude of 8-12 km) the danger from this pollution is insignificant (aircraft flying at high altitudes and at high speeds causes the dispersion of combustion products in the upper atmosphere and over large areas, which reduces the level of their impact on living organisms), in the airport area such pollution cannot be neglected.

Gases are emitted into the atmosphere by engine nozzles and exhaust pipes. This process is called aircraft engine emissions. Gases generated by aircraft engines account for 87% of all civil aviation emissions, including emissions from special vehicles and stationary sources.

The most unfavorable operating modes are low speeds and engine idling, when pollutants are emitted into the atmosphere in quantities that significantly exceed emissions during load conditions [24].

In order to create a unified approach to the regulation of pollutant emissions, ICAO introduced the concept of a standard takeoff and landing cycle, which includes all aircraft operations from the moment the engines start until the aircraft reaches an altitude of 1000 m, as well as from the moment the aircraft approaches the landing from an altitude of 1000 m until the engine stops after the aircraft lands. The ICAO takeoff and landing cycle parameters are shown in Table 5.3

Table 5.3 - Average characteristics of the takeoff and landing cycle of civil aircraft

Mode number	Move robot mode	Relative thrust $\bar{R}$	Mode duration, t, хв
1	Idle gas (useless stroke) during taxiing before take-off	0,07	15
2	Take-off mode	1	0,7
3	Climb mode 1000 m	0,85	2,2
4	Approach mode	0,3	4
5	Idle gas (useless stroke) during taxiing after landing	0,07	7

Emissions of harmful substances during the operation of an aviation fuel supply facility

The main function of aviation fuel supply enterprises is to ensure timely refueling of aircraft by storing the required fuel reserve, preparing for dispensing and refueling into the aircraft.

Today, 75% of oil product losses in the tank farms of these companies are due to evaporation losses, which leads not only to a deterioration in product quality but also to significant environmental pollution.

In terms of environmental safety, the largest mass of air pollution is generated by the process of fuel storage. This is due to the physical and chemical properties of fuels, their storage conditions, and the design and operation of process equipment.
The main factor in fuel evaporation is the high pressure of saturated oil vapors and, as a result, the increasing transition of volatile fractions to the gas phase. Evaporation increases when the surface temperature of oil products increases or the pressure in the gas space of tanks decreases.

During the storage of petroleum products in tanks, fuel losses usually occur as a result of the following processes: small tank "breaths", large tank "breaths", reverse tank "breaths", ventilation of the gas space of the tank tanks, etc. Percentage shares in total losses caused by these processes are shown in Figure 5.1.

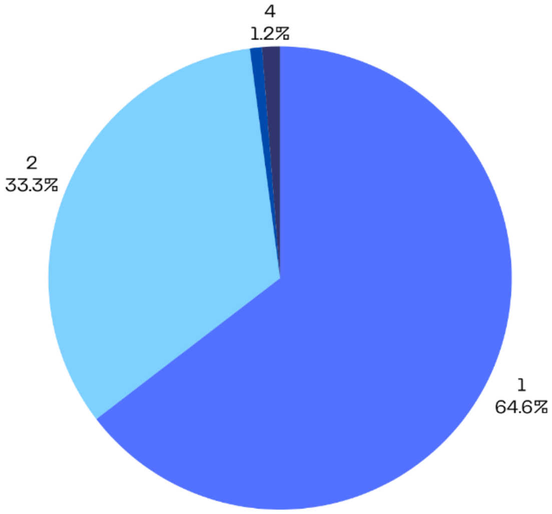

Figure 5.1 - Structure of natural losses of oil products:

1 - due to ventilation of the gas space of the tank (62%); 2 - due to large "breathing" of the tank (32%); 3 - due to small "breathing" of the tank (8%); 4 - due to reverse "exhalation" of the tank (0.8%); 5 - other types of losses (1.2%).

Losses from small "breaths" occur as a result of cyclic fluctuations in temperature and partial pressure in the gas space of the tank caused by the daily effect of solar radiation and atmospheric conditions on the walls and roof of the tanks. The duration of one cycle is usually equal to a day.

Losses from large "breaths" depend mainly on the volume and temperature of the fuel pumped into the tank, as well as the concentration of oil product vapors in the vapor-air mixture, their density and pressure.

Losses from ventilation of the gas space are losses resulting from improper installation of breathing valves and insufficient tightness of the tank roof. The value of such losses can sometimes exceed the losses from small and large "breaths". Ventilation losses are considered to be the result of wind blowing out oil product vapors through leaky tank roofs, as well as the result of a gas siphon in the space above the fuel.

There is also the concept of reverse exhalation losses. Its essence lies in the fact that after partial or complete emptying of the tank, the gas space remains unsaturated with oil vapors. During the fixed storage of the remaining oil product, the gas space is saturated due to the evaporation of the residue. This process is accompanied by an increase in the partial pressure of vapors in the gas space and an increase in the overall pressure. When the total pressure reaches a level equal to the design pressure, the breathing valve is activated, and a certain volume of the gas-air mixture is released into the atmosphere, i.e., a reverse "exhalation" [23].

5.3. Ways to reduce environmental hazards from oil vapor emissions

Losses of aviation fuels due to evaporation are the most significant in the tanker fleet of fuel supply companies. The main ways to reduce them are:

- Reducing the volume of gas space in tanks through the use of timely pumping of fuels from other tanks during the coldest time of day (morning);
- use of double-walled and double-bottomed tanks (glass-in-glass type);
- capture and regeneration of petroleum product vapors coming out of the tank by creating gas-comparison systems, absorption-adsorption and ejection units;
- taking organizational measures to systematically inspect and maintain the technical condition of tanks and their breathing equipment;
- reflective painting of the tank farm.

In order to reduce emissions of oil vapors into the environment, it is expedient and economically justified to install reflector disks under the mounting nozzle of the tank's breathing valve. The principle of their operation is to change the direction of the air jet entering the tank from vertical to horizontal. In this case, the gas-air layers located near the fuel surface, which are heavily saturated with oil vapor, will be practically unaffected by convective flows.

Another effective way to preserve volatile oil products is to store them in buried and underground tanks. This method of storage is characterized by relative stability of temperature conditions. When stored in buried tanks, losses from small "breaths" are almost completely excluded, because they are covered with soil and are not exposed to solar radiation, so there are almost no daily changes in the temperature of the gas space.

Operational measures include:

- timely maintenance of equipment and facilities, testing of tanks for leaks and strength
- performing flaw detection and inspection of fuel storage tanks to identify possible structural defects;
- sealing and strengthening the inner bottom of the tank with a layer of special coating based on epoxy compositions.

Organizational measures include:

- organization of continuous concrete bunding of the fuel storage area;
- organization of scheduled maintenance of process equipment;
- timely briefing and advanced training of technical personnel [23].

Conclusion to Chapter 5

This chapter describes the requirements for an air traffic controller. The conditions created should ensure comfortable work. Based on the literature on the subject, the optimal dimensions of the table and chair, the working level, as well as the choice of system and the calculation of the optimal brightness of the production room, as well as the calculation of noise at the workplace. We also investigated the negative environmental impact of oil product vapors and methods of their prevention.

GENERAL CONCLUSIONS

Today, the topic of aging is not a very popular one among studies. Nevertheless, no one would deny that it is a quite natural and unavoidable process. It is well known that air traffic controllers are highly responsible for flight safety and airspace efficiency. Moreover, their decisions are crucial in preventing airspace accidents and incidents.

The topic of aging is becoming more relevant due to the increase in air traffic. Therefore, it is very important for an air traffic controller to be as efficient as possible.

The objectives of this paper were:

1. To study how the age of an ATC officer affects the efficiency of the ATC officer
2. To analyze the effectiveness of the ATC of the older age group
3. To develop recommendations to prevent senior air traffic controllers from reducing their performance efficiency

In the first section, we examined the effect of age on the cognitive abilities of an air traffic controller. It was examined how aging affects spatial reasoning and problem solving ability. It was found that shift work has a very negative effect on the mental and physical health of air traffic controller. And automation can cause the aging air traffic controller to reject it and lead to a decrease in his or her efficiency.

The results of the data evaluation clearly confirm that aging is a problem that needs to be addressed. Few people know that increasing age is accompanied by both negative and positive consequences. It turns out that an air traffic controller's expertise and experience often have a key role in performance. Aged air traffic controllers transfer their knowledge to less young colleagues, which maintains a balance of experience and new creative perspectives.

A number of cognitive abilities have been identified that only improve with age. Interestingly, due to experience, the age-matched air traffic controller quickly solves problems, makes good decisions, and acts according to a long-established script.

The chapter on preventing age-related decline in air traffic controller performance describes the following four levels of action recognized as useful in addressing aging: society, management, workflow, and the individual. At each level, useful solutions are proposed.

A three element system was then studied: stress, shift work, and age. Together, these aspects rapidly lead to a decline in air traffic controller performance and also carry health risks. The combination of these interacting elements was organized to achieve a goal: preventing aging air traffic controllers from declining performance.

The next step in achieving the goal was automation. Based on our analysis, we identified potential problems and developed recommendations.

Most of the tips in this work will be useful to everyone, regardless of their age. However, older air traffic controllers will benefit the most. As we have said many times, older employees are a company's most valuable resource. To displace them would be extremely short-sighted. The challenge is to help aging air traffic controllers stay healthy and productive for as long as possible.

Aging cannot be ignored. Today's young air traffic controllers will be tomorrow's seniors. They will face the same challenges of aging. Taking action and optimizing the situation of older air traffic controllers now is the best investment in the future.

REFERENCES

1. Age, Experience and Automation in European Air Traffic Control. EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION
2. Comparing Methods to Evaluate Cognitive Deficits https://www.icao.int/safety/aviation-medicine/Documents/Potocko ICAO AsMA 2019 Public.pptx
3. Medicine Washington. Review of the Scientific Basis for the Mandatory Separation of an Air Traffic Control Specialist at Age 56
4. MUAC Student Magazine May 2020
5. MUAC Student Magazine February 2023
6. Articles about frequent medical diagnoses of air traffic controllers. 2020. Dr. Roland Vermeiren https://esam-academy.aero/
7. https://www.eurocontrol.int/articles/age-related
8. The Manual on HP for Regulators (Doc 10151)
9. Manual for the Oversight of Fatigue Management Approaches (Doc 9966) 2020
10. Ostroumov I.V., Kuzmenko N.S. Outliers detection in Unmanned Aerial System data. 2021 11th International Conference on Advanced Computer Information Technologies (ACIT). 2021. P. 591-594.
11. Kharchenko V.P., Ostroumov I.V. Avionics. Kyiv, 2013. 281p. ISBN: 978-966-598-573-0 (in Ukrainian language).
12. Ostroumov I.V., Kuzmenko N.S. Performance Modeling of Aircraft Positioning System. Conference on Integrated Computer Technologies in Mechanical Engineering–Synergetic Engineering – ICTM 2021. ICTM 2021. Lecture Notes in Networks and Systems. 2022. № 367. P. 297-310 DOI: 10.1007/978-3-030-94259-5_26.
13. Ostroumov I.V., Marais K., Kuzmenko N.S. Aircraft positioning using multiple distance measurements and spline prediction. Aviation. 2022. № 26(1). P. 1-10 DOI: 10.3846/aviation.2022.16589.
14. Ostroumov I.V., Kharchenko V.P., Kuzmenko N.S. An airspace analysis according to area navigation requirements. Aviation. 2019. № 23(2). P. 36-42 DOI: 10.3846/aviation.2019.10302 .

15. Ostroumov I.V., Kuzmenko N.S. Statistical Analysis and Flight Route Extraction from Automatic Dependent Surveillance-Broadcast Data. 2022 Integrated Communications Navigation and Surveillance Conference (ICNS). 2022. P. 1-9. DOI: 10.1109/ICNS54818.2022.9771515.
16. Ostroumov I.V., Ivashchuk O. Risk of mid-air collision estimation using minimum spanning tree of air traffic graph. Paper presented at the CEUR Workshop Proceedings of the 2st International Workshop on Computational & Information Technologies for Risk-Informed Systems CITRisk-2021. 2022. № 3101. P. 322-334.
17. Ostroumov I.V., Kuzmenko N.S. A Probability Estimation of Aircraft Departures and Arrivals Delays. Gervasi O. et al. (eds) Computational Science and Its Applications – ICCSA 2021. ICCSA 2021. Lecture Notes in Computer Science. 2021. № 12950. P. 363-377 DOI: 10.1007/978-3-030-86960-1_26.
18. Ostroumov I.V., Kuzmenko N.S. Incident detection systems, airplanes. In Vickerman, Roger. International Encyclopedia of Transportation. vol. 2. 4569 p. UK: Elsevier Ltd., 2021. 351-357p. DOI: 10.1016/B978-0-08-102671-7.10150-2. ISBN: 9780081026717.
19. Software for Air Navigation analysis. Visualization of airplane trajectory based on ADS-B data messages. [Electronic source]. URL :https://www.ostroumov.sciary.com/codes_airplane-trajectory-visualization
20. СП 2.5.1.1107-02. Гігєнічні вимоги до умов організації праці диспетчерів УПР цивільної авіації. [Електронний ресурс] – ВР. Режим доступу: \www/ URL: https://dnaop.com/html/57430/doc-%D0%A1%D0%9F_2.5.1.1107-02 – доступ 01.12.2023.
21. Закон України про охорону праці. [Електронний ресурс] Режим доступу: \www/ URL: https://zakon.rada.gov.ua/laws/show/2694-12#Text – доступ 01.12.2023.
22. Буріченко Л.А., Гулевець В.Д. Охорона праці в авіації. К.: НАУ, 2003. 448 с.
23. Ісаєнко В.М., Бойченко С.В., Бабікова К.О., Вовк О.О. Захист навколишнього середовища в авіатранспортних процесах: підручник. Київ: НАУ, 2020. 320 с.