

Air Traffic Control Operations: Communication Errors and Resolution

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AIR TRAFFIC CONTROL OPERATIONS: COMMUNICATION ERRORS AND RESOLUTION

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Summary

Following research will present insight about air traffic control conflicts analyzing current communication between pilots and ATC operators to detect causes of wrong operability and system misuse.

It is pretended to identify conflicting variables in order to minimize errors during air traffic control operations. After identifying the source of error it is developed and presented a solution to reduce detected air traffic conflicts called ATCF.

The solution is used to solve verbal communication issues and transmission errors during air traffic control. It uses a non verbal code to transmit instruction for ATC operations. It also introduces concepts such as automation, clustering and pattern technique to pilots and cockpit system.

The result is a compressed, universal and logical communication code based on quick understanding, low cognition and ease operation ability. The objective is to reach transmission, translation and problem-solving performance during air traffic control operations. It is also pretended to increase pilots awareness, conscious and attention levels during flight which have been proved to be biased and disorderly.

Abstract

Following research pretends to study air traffic control operations between pilots and controllers to identify problems and present a solution. The objective is to reduce air traffic incidents and minimize economical and environmental damages caused by those problems.

With increased traffic verbal communication code used by ATC to monitor flight have revealed to be inefficient and biased. Data is congested and need to become more compact for faster transmission and safer monitoring.

Pilots are mostly overloaded which lead to misunderstanding, distraction through fatigue and mistakes operating air craft during conflict situations. Monitoring should become more autonomous and ease pilots operation ability in order to reach performance.

As a response to those components and according to current projects and researches it was developed a new non verbal communication code to reduce bias, distortions and complexity. The result is a compact message easy to be transmitted and understood. Communications were simplified and should happen only through pilot and system without interference of controllers.

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Glossary

ATC	Air Traffic Control
ATM	Air Traffic Management
LSTMs	Long Short- Term Memories
ATCS	Air Traffic Control Systems
MFFT	Matching Familiar Figures Test
SMS	Safety Management System
ICAO	International Civil Aviation Organisation
HMI	Human Machine Interaction
HCI	Human Centered Interaction
GDENet	Graph Differential Equations Network
STAMP	System-Theoretic Accident Model and Process
DEB	Disturbance Effect Barrier
EM	Emergency Management
RDSS	Recommendation and Decision Support System
CI	Critical Infrastructure
ATCF	Air Traffic Control Framework
MMT	Man-Machine-Teaming
CSE	Cognitive System Engineering
MNL	Mental Number Line
SAA	Space-Arithmetic-Association
RSVP	Rapid Serial Visual Presentation
LPDC	Low-Parity-Density-Check-Codes
VMD	Variation Modal Decomposition
WPD	Wavelet Packet Decomposition
AI	Artificial Intelligence
ML	Machine Learning

VR	Virtual Reality
AR	Artificial Reality
RL	Reinforcement Learning
DL	Deep Learning
GPS	Global Positioning System
GCAS	Automatic Ground Collision Avoidance System
CAD	Computer Aided Detection
UAV	Unmanned Aerial Vehicle
IP	Internet Protocol
CPDLC	Controller Pilot Data Link Communication
CNS	Communication, Navigation and Surveillance
VHF	Very High Frequency
ATCo	Air Traffic Controller
ASRU	Automatic Speech Recognition and Understanding
ASR	Automatic Speech Recognition
SE	Standard Error
FPM	Flight Path Management
IS	Information System
MACS	Multi Aircraft Control System
AOP	Autonomous Operations Planner
PDF	Portable Document Format

1.Introduction

With following research, we pretend to define human perception against air traffic management and control systems. Human error is one of the main causes of aviation failure. Mainly those errors happen due to system overload and excessive mental load from pilots and air traffic controllers.

By defining the source of error, we will be able to design personalized control and management features as well as create suited content adapted to specific traffic control needs. This may reduce the probability of sharing misinformation, information overload and failure handling conflict maneuver and risk detection.

According to previous research, audition is one of the main sources of information transmission during conflict and risk management. Analyzing existing traffic reports, testing's, trainings and flight simulations is crucial to identify gabs and create solutions to optimize communication and information transmission among ATC (Air Traffic Control) and pilots.

To define the cause that led to perception error from pilots when dealing with ATC we analyzed flight simulations, system optimizations and models designed to improve conflict resolution. Understanding “How does pilot risk perception fail?” and “What caused ATC failure?” was the focus of the search.

The objective is to create new features for traffic control systems that enables better risk detection, sharing and resolution to minimize aviation accidents and/or abolish them.

1.1. Context/Framing/Motivation

This dissertation inserts in the Industrial Setting field, more specifically the aviation and air traffic control. As it is in its general electronically equipped, airplane can play a complex role in the implementation and monitoring of digital communication solutions for different stages of flight, traffic control or even airport management like road supervision.

Knowing the needs of air traffic personnel is important for further content creating. They can be images, graphs, audio files, text, visual effects, etc. It prevents the use of excessive communication means, misinformation and wrong information application during critical and risky situations.

Depending on the diversity of air traffic companies, cultural diversity, diversity through personality and personal characteristics, designing the best solution can be challenging. Variables like mental load, contextual environment, weather conditions can have an influence and impact in element perception and interpretation.

Described influences can be manipulated through visual and audio files and even be deviated or eliminated for correct understanding of perception and solution making. It can help saving lives and prevent significant economic and environmental damages caused to aviation companies.

1.2. Project

For the resolution of overloading, control loss and perception failure it is pretended to do a simulation attending autopilot and ATC system monitor to enhance aircraft automatization and improve auto management capability.

The simulation will provide insights about the developed feature, intended to control traffic variables and solve technology errors during flightpath. The objective of the feature will be focusing on prediction capabilities and control assumption in risk and conflict situation occurring during air traffic.

The results will provide important data and insights for further studies, as well as allow the validation of the experiment next to its end users. It will be developed with air traffic personnel like ATM (Air Traffic Management) and ATC departments to collect valuable information, observations and insights about present system including their features.

1.3. Problem(s), Hypothesis(es) and Objectives of Investigation

How is communication being wrongly applied through ATC and pilots handling risk and conflict situation? How does pilot fail perception understanding? Or What's causing solution gab? They are some problems that this research tries to study, analyze and provide a response to.

Taking in consideration previous research we know there is a perception gab regarding misinformation, information overload and mental load caused by stress, fatigue or health issues from pilots and air traffic controllers.

Automation is being hardly implemented to avoid human errors caused by those perception problems, adopting artificial intelligence applied through machine learning and complex neural network models to assist pilots when they lose their ability to assume the control over the aircraft.

Prediction is an important prop to percept risk and do problem solving. Automation helps creating flight patterns to identify possible events that may occur and solve or avoid possible conflict situations.

By correlating automation to prediction and considering users' needs when dealing with automated systems, interactions between human and machine interfaces can reveal facilities and enhance capabilities that enforce intelligent thinking and actioning.

Adopting machine learning techniques, a new solution can be created to assist air traffic needs and take control of flight conflicts. The objective is the achievement of a fully automated system capable to do a flightpath autonomously and fully independent from human intervention.

1.4. Methodology of Investigation

For the development of this work it was done analysis of existing literature regarding air traffic control operations, air traffic incidents and conflict perception as well as task assessment to reach desired outcomes.

Research regarding traffic management, information transmission, neuron ergonomics, assessment, system design and testing has been conducted to identify gaps and possible solutions.

The research was done using Google Scholar mostly with 2024 tagged to filter new and updated literature. Second source used was Mendeley where literature was also stored and reviewed for further analysis.

Keywords to conduct the research were: air traffic control systems, air traffic management and airplane crashes. Pilot was used to filter research related to perception, risk and management.

Most of the literature was selected among the first or second page of Google Scholar and Mendeley. Priority was selecting updated data about ATC systems and airplane management techniques as well as pilots' perception state regarding objects and information presentation.

This allows an overview through three main categories of air traffic control: ATC stations, Pilots and Systems.

2.Literature Review

In the domain of Industrial Setting, technology has been implemented and used for different purposes. Advancements like artificial intelligence mechanisms, automated systems and augmented features allow tasks to become more accessible for humans and to improve their precision handling complex situations.

Philipp Ortner et al. 2022 identified the need to introduce ATM into the next-generation human-integrated systems with optimized abstraction of airspace and situational awareness levels. They also mentioned the positive impact of augmented air traffic control systems regarding current traffic control procedures.

LSTMs (Long Short-Term Memory) networks are presented to define temporal dynamics its behavior when monitoring air traffic error patterns. They are used to predict weather events, cyberattacks, emergency situations and human factors that may occur during flightpath.

State of the Art has been conducted to investigate current mechanisms of systems for control, management and supervision. Especially for air traffic agents like traffic controllers, crew members and pilots. Not devaluating the crucial paper of passengers and general airport occupants for the study of the environment influences.

Increasing traffic numbers, reveal consequences in the data processing like information overload and consequent stress caused to pilots. It affects participants mental and physical health, reducing their cognitive and decision-making ability.

Jianfeng, X. U. et al. 2021 Issued the importance of correlating information elements, deepen the knowledge about their mutual influence and identifying constrains relating to information metrics and their operation ability.

They recommend that ATCS (Air Traffic Control Systems) should personalize information and practice sustainable information sharing. Mentioning information's relativity of age, flying hours, education, duties and many other influences.

Grabowski et al. 2002 concluded 70% of flight accidents were caused by human factors, majority of them by influence of psychological factors. The surrounding environment according to authors can also affect pilots and controllers' consciousness of risk.

A measure of cognitive dimension called Matching Familiar Figures Test (MFFT) was created by Jerome Kagan and showed that participants who are more reflective tend to perform better regarding tasks that require attention on details. On the other hand, impulsive participants perform better on tasks that require rapid actions (Morris and Rouse 1985; Zelniker and Jeffrey 1976).

These facts allow us to understand the need to create personalized content that fits participants different requisites representing the Trichotomy between matter-energy-information and introducing the Mathematical Theory of Communication.

Regarding technology, Machine Learning has played an important role in the development of automated systems making them even more realistic and close to reality. Driverless cars are example of full automation and replacement of human intervention in the Industrial area.

In the very near future aircraft should become fully automated bringing challenges regarding safety and risk assessment (Jamie P. Brown 2016). For Jiawen Tang et al. 2022 Skill-based errors like memory lapses and attentional failures are some of the current detected problems regarding air traffic control.

ICAO (International Civil Aviation Organization) contrasts the implementation of a Safety Management System (SMS) in ATC services, releasing Annex 19 Safety Management to improve safety management worldwide (Jiawen Tang et al. 2022).

Studies have shown a gap regarding the management of conflict and risk information. An automated feature to prevent human failures and assuming human intervention has been defined as an opportunity for further developments.

2.1. Introduction

Air traffic control is a station occupied with more than one controller per tower equipped with glass windows that allows the overview of the airport road, airplanes, vehicles and personnel. Each controller is responsible to monitor their own route, traffic path, circuit and airport communications.

Human Machine Interaction (HMI) as well as HCI (Human Centered Interaction) have been focus on technology development and system design. They pretend to adapt machine to human components and human to machine requisites. Neurophysiological measures are then applied to assess their effectiveness (Pietro Aricò 2018; Maxime et al. 2010).

Mental workload and mind wandering phenomena are examples where HCI and HMI techniques have been applied to. They focus on the experience of participants regarding workload measures like perception.

Pietro Aricò 2018 and Maxime et al. 2010 said in their work that the sounds being emitted by airplanes play an important role to locate them. They investigated and tested audition stimuli and its influence in perception ability and accuracy ability.

An augmented solution is presented by the researchers to help sound detection with more precision. They perform a comparison between normal and augmented state to evaluate impact of the augmented version.

Results revealed advantage of using augmented version. Jianfeng, X. U. et al. 2021 study message length and conclude it has clear influence over the system's throughput ratio, which means that information volume affects transmission.

Claude E. Shannon and Warren Weaver 1964 proposed the qualitative and quantitative model of communication. They perspective information as the scientific term for transmission corresponding to a specific statistical distribution (Jianfeng, X. U. et al. 2021).

2.2. Perception Errors

Perception is described as the interpretation of stimuli. Errors like the unavailability of data, difficulty finding information and loss of memory may occur during perception (Steven T. Shorrock 2007).

Hear back and distraction are some of the more recurrent issues identified during perception. Regarding radars and monitors errors mostly occur due to lack of detection and delay (Steven T. Shorrock 2007).

Conclusion taken from the analysis of previous research regarding air traffic control and management systems reveal uncertainty, imperceptibility, confusion, misunderstanding as well as generalization and bias.

Jianfeng, X. U. et al. 2021 also notices that fusion of information may reduce errors related to delays in data collection and data transmission.

Perception errors regarding auditory stimuli include not hearing auditory requests or late perception of those requests (Steven T. Shorrock 2007).

Problems relating to radar monitoring include delay regarding the detection of the flight level, direction and speed of an aircraft (Steven T. Shorrock 2007).

2.2.1. Models and Theories

Yanming Miao et al. 2023 mentioned the importance of prediction for advancements on traffic flow systems. They also identify a gap of current research regarding the correlation between spatial and temporal features, proposing GDENet (Graph Differential Equations Network) as solution.

Study of space and time have been done attending to previous data to define patterns and ease prediction. For Yanming Miao et al. 2023 efficient traffic flow planning depends on the precision of the prediction.

Increasing number of features and information lead to a bigger system complexity with longer calculations. GDENet revealed high computational efficiency, good for that purpose.

Other models can be divided into two categories: statistical models (based on probabilistic to model traffic patterns) and artificial intelligence models (machine learning algorithms to extract meaningful insights). Machine learning models help predict traffic flow through regression techniques.

Yanming Miao et al. 2023 noticed although the ability of processing complex data regarding traffic flow, aspects like spatial extraction are still insufficient. Models of deep learning for instance, use graph neural networking to help on the process of such complex data.

Graph neural network models in the other hand, are popular regarding settings of artificial intelligence helping on prevent data loss by improving its robustness and expression ability. It provides enhanced problem-solving and scenario description capability.

Map models created for air traffic interfaces, such as the two-dimensional map giving priority to salience techniques (Giraudet L. et al. 2015) through visual design and attentional features (Nardo et al. 2011).

Giraudet L. et al. 2015 found in several theories that higher cognition causes a higher workload and consequent loss of auditory perception to risk. According to authors, cognition level is affected by its environmental context, reflecting its influence on performance.

They suggest salience as the technique to reduce workload in perception and cognition processes. Improving outcome levels through attentional store and prevention. In parallel revealing an enhancement on ATCs performance and its efficiency.

Jiawen Tang et al. 2022 present the game theory for safety risk assessment of air traffic control systems. They state that ATCs safety is being assessed attending the human and machine component, as well as the environmental influence posted over task management.

According to authors the cloud model's ability to solve the inconsistency between qualitative and quantitative outcomes have a positive impact on the safety measuring. Matter element model is presented to assist the understanding of those inconsistencies.

Game theory combines qualitative and quantitative data to produce actioning through procedural thinking. SHELL model proposed by Friedman and Carterette has been created to study human component and its relationship with aviation systems (Hawkins 1987).

For the study of accidents in the aviation industry several models were created. STAMP (System-Theoretic Accident Model and Processes) for instance pretends to analyze the risk-causality factor of ATC systems (Leveson 2015).

Disturbance Effect Barrier (DEB) analysis, from Ternov and Akselsson 2004 identifies the protection weaknesses of ATC systems. Another model like the proportional hazard from Shyrur 2008 was applied for safety analysis in the aviation industry. Concluding that most accidents occur due to human failure.

Wang et al. 2019 proposed a trajectory-based landing risk assessment method as a predictor of accidents in the landing phase. Hu et al. 2019 presented a risk-based operational safety method for automated procedures.

These techniques are widely used in the aviation industry. They even reveal some limitations regarding the correlation between qualitative and quantitative data, dependency on specific samples, external requirements and lacking accuracy.

Presented models are the representation of changing ATC systems. For Jiawen Tang et al. 2022 information should be reviewed before being applied to the system since previous models tend to devalue critical information.

Pan Ren and Lishuai Li 2018 address aspects of large-scale aircraft tracking data. They claim that ATC and ATM stations need to understand risks related to air traffic before creating strategies and do planning.

As authors observed very less has been done regarding this aspect, mostly due to lack of data availability. To solve this issue, they present a data-driven framework capable of filtering updated data for traffic management.

Data-driven framework uses new statistical measures and data analysis techniques to summarize availability of airspace, network structure and patterns.

Another framework is the one from Gariel et al. 2010 using density for clustering and pattern creation. Cluster analysis in the other hand allows data mining for identification of groups in a dataset (Pan Ren and Lishuai Li 2018).

Emergency Management (EM) is event driven. RDSS (Recommendation and Decision Support System) support emergency managers to take correct and timely decisions. It is also capable to process a variety of emergencies in a time frame (Vuk Mijović et al. 2019).

CI (Critical Infrastructures) such as airports require high management skills like multitasking. Models have been created to discard bias and provide optimized event overview (Vuk Mijović et al. 2019).

Another challenge is the behavioral bearing of the supporting personnel, that require agent-based models. These models are part of the training sessions and allows trainers to actively participate in a simulation. This reveals to be significant since either simulation is not efficient or there is lack of precision to execute an action.

Shared understanding concept has two models: shared problem models for situation awareness and shared mental models for shared understanding among participants (Young Woo Sohn and Kyeongtae Kim 2006).

Matthew Krebs et al. 1995 mention the conceptual model to control confounding variables. They describe age variable as being one potential confound cause. They highlight that having control of this variable may avoid distortion. Ideas that were discriminated in previous research.

Large-scale and realistic air traffic models are supporting LSTM networks in the identification of patterns among airspace which reveal difficulties due to its complexity.

2.2.2. Technology and System

ATC control uses radio and monitors to manage aircraft and traffic during flightpath. Crew and pilots use same technology to communicate with each other.

Monitors use radars for tracking other aircrafts and detected eventual crashes. They also provide overview of weather conditions and information's about the aircraft.

The system itself provides updated information about flightpath, routes, flight plans and aircraft. It also allows alerting and editing features like change to autopilot function.

Airports use sensors to catch data from airplanes when departing or arriving as well as driving cars that may circulate through the airport. More detailed features like augmented versions, artificial intelligence and use of machine learning techniques have been described in previous sections.

2.3. Summary and Conclusions

Air traffic control need automation and technology resourcing to optimize results regarding risk prevention, conflict detection and emergency resolution. Previous research has shown important insights about management processes and performance during flightpath.

Studies conclude overloading as being a big issue to be solved. Many models have been designed for this purpose to reduce fatigue and stress levels and enhance machine capabilities.

Improving perception by allowing systems to catch, process and implement solutions autonomously have revealed to be an important priority. This allows aircraft to become more efficient handling conflict and daily task as well as to abolish human component from air traffic procedures during the next near future.

Main objective for future research is to strengthen aircraft system to get fully automated like current driverless cars in the transportation industry. It requires replacement of human cognitive network system to create precise instructions and achieve positive results.

3. Air Traffic Control Framework

To solve communication issues between ATC and pilots it was created a framework that substitutes current verbal communication code with a non verbal code. The Framework is a numerical code based on instruction to trigger action.

In the following sections it is presented the literature review, frameworks structure, assessment and results. The objective at the end of this work is to collect positive feedback regarding participants learning process of ATCF's (Air Traffic Control Framework) rules.

Participants should be able to control variables of flight like altitude, velocity and direction using numbers and mental arithmetic through an instructional code without the need of controller's guidance.

Non verbal code should solve problems like transmission delays, communication errors, wrong perception and misunderstandings.

3.1. Automation

Automation represents future air traffic and aviation implementations. It is pretended that soon aircraft turns fully automated without needing human intervention.

Technologies like reactive indicators to detect performance lapses and predictive indicators for system assistance during failure are examples of such implementations. Proactive indicators have been created to adapt system for workload, fatigue and trust (Natalie Griffiths et al. 2024).

In the context of mental load and workload automation helps decrease effort to do better performance and have better outputs. Authors also noted that trust is playing a crucial role for engagement. In the other hand excessive trust may cause overestimation and system misuse.

Natalie Griffiths et al. 2024 also proved that automation solve 80% of air traffic conflicts caused by complex process requirements. Machine learning models are being developed to detect and classify such requirements.

To solve voice communication issues, automatic speech recognizers have been created for speech translation. To solve detection errors digital data is collected to preview conflict occurrence (Helmke, H., and Ohneiser, O. 2024).

Mathematical models show limitations leaving operators unprepared and vulnerable to failure (Allan Hodgson et al. 2013). Authors provide explanation about two types of thinking of performance when doing problem-solving.

Type I is unconscious cognition, effortless and used for automatic and fast response. Type II relates to conscious cognition influenced by culture. ATCF uses Type I to conduct traffic control operations, making it independent from working memory.

Alberto Testolin 2024 mention aspect of mathematical reasoning as being one of human's highest achievements in intellect. Logical reasoning and mathematic are referred to intelligent machine conceptions and high cognitive ability in pattern recognition and abstract thinking.

Regarding acceptability and usability concerns Allan Hodgson et al. 2013 observed pilots' preference for automatized systems and some concerns correlated to skill loss. They prove that high automated aircraft have a negative effect on pilots' manual flying skill along the time.

Passive monitoring is another concern in the context of conflict prevention and risk management caused by system misconceptions like wrong design and non-use of universal protocols.

Jonas Lundberg and Björn J. E. Johansson 2020 concluded that higher levels of automation turn systems less communicative and independent from humans. They also distinguish capabilities of humans and machines when doing task segmentation.

Low communication rates and passive monitoring may increase pilots distraction levels, fatigue and error probability. It is important in such context to engage pilots attention with the system and traffic operations.

Man-Machine-Teaming (MMT) strategies have been implemented to overcome limitation regarding information processing when interacting with autonomous technology. The focus of the project relies on controlling operability rather than mastering it through cognition like CSE (Cognitive System Engineering).

It also tries to approximate machine to human and human to system by matching their interests. It leads to informational processing issues like misunderstandings where there is a need for such strategies.

Overall issues regarding ATC performance due to mismatch of preferences when doing problem-solving like machine learning frameworks are frequent. This solution as explained by Yash Guleria et al. 2023 uses behavioral cloning to predict and learn ATC characteristics.

Authors also describe a series of processes related to cognitive thinking when doing problem-solving and the influence of ATC characteristics through this step. They suggest use of strategies to face such complexity.

Mathematical models replace characteristics with instant problem-solving. Yash Guleria et al. 2023 have observed difficulty analyzing ATC preferences due to the existence of high influence. It may even be impossible to predict it with accuracy, they say.

Neurophysiological measures have been implemented to assess HMI (Human Machine Interaction) values and showed increase in efficiency when adopting augmented technology versions especially with auditory stimuli (Pietro Aricò et al. 2018).

Measures approximate research to operator's mental state during operations and after task completion which lead to higher predictability levels and lower load values. Artificial intelligence has been explored in this context to pattern, model and map system to air traffic needs (Philipp Ortner et al. 2022).

Overall as concluded by Asaf Degani et al. 1997 automation helps reducing procedures and contributes to minimize task load grouping a series of action into one single action.

Other studies as Lance Sherry et al. 2014 notice that probable causes of accidents include fail in components, equipment, procedures or poor training. They also report fail of sensors, automation disengagement or incorrect calculation.

The resolution of the problem according to the authors is to anticipate and detect events and trajectories. Bryan A. Barrows et al. 2024 identify FPM (Flight Path Management) for the functioning of dynamic path planning operations.

Their study show that FPM automation ability improves planning, decreases demands, increases response and causes less criteria separation. They also observe that FPM implementations solved 100% conflicts.

Stewart L. Nelson et al. 2024 mention another flight plan system called AOP (Autonomous Operations Planner) they also observe that strategic AOP can efficiently detect conflicts by using flight intent as variable to generate new 4D routes.

This technologies are helpful in situation where pilots do not have the ability to securely take control of aircraft and do mind-wandering causing distraction, low perceptibility and increased risk.

Anaïs Servais et al. 2023 noted that specially external informational sources are misprecept by pilots when doing mind-wandering. This kind of phenomena happen due to high load and fatigue. In current communication processes with ATC it might lead to miscommunications and wrong interpretations causing possible incidents.

Authors notice that internal attention compared to external attention is biased even occupying half of peoples daily life. In a professional context with increased tasks and demands this levels might increase causing excessive workload.

Such concerns were taken as basis for conception of ATCF by modeling pilots thoughts and attention through the use of a code and arithmetic strategies. It is pretended to reduce redundancy daydreaming, passive fatigue and distraction levels.

Anaïs et al. 2023 explain that human mind often switches from external to internal attention during a day which also costs effort. Those risky variables may cause a wrong change in speed, wrong direction or wrong altitude appliance.

ATCF triggers in the place of cognitive processing the mechanical processing mode stimulating it through low loaded calculations and algorithm combinations to catch pilots internal attention. It pretends the application of logic instead of understanding for task execution.

Pilots should along flightpath calculate, predict, aware and conscious themselves of abstract space and location to make the linkage of concrete marks with final destination.

Mind-wandering is considered a degraded mental state which explains that pilots in such a state are not capable to perform tasks autonomously and with safety.

Matt R. Jardin 2004 identify a series of models developed to simulate conflict scenarios and predict possible risks. They also mention free flight as being one of the methodologies used to achieve better route and traffic operations.

Redding et al. 1992 have analyzed task and psychological components of route planning. They promote the training of controllers knowledge for quick response and prioritization ability. Authors also mention progressive decision making processes for that purpose.

They also describe the progression to become more precise along the time. Pilots mental state, expertise and skills have been focus to determine performance levels. They also distinguish impulse from reflexion stating that impulsive participants perform better quick task compared to reflexive ones that pay more attention to details.

Authors also notice that independent pilots perceive better than those influenced by their cultural and professional background. Prioritization is the set of task priority according to problem solving needs.

Pilots need to be aware in order to percept key elements and act according to risk protocols. They have to adopt a monitoring mind set and be attentive and vigilant in a long-term basis.

3.1.1. Code

Code can be defined as being a system where letters, numbers and symbols have meaning (another letter, number or symbol). Normally characterized as an operation or assigned hidden message. One common example is programming language for computer systems.

Other examples well known are Morse code, Hieroglyphics and Braille. All of them share different rules and serve different purposes. Coding is a process which evolves message processing techniques, encryption and translation.

Codes vary in complexity and can be representative of instruction or information. Their purpose may differ from hiding a message, difficult the access, simplify understanding or exemplify something.

They can also be classified as verbal or nonverbal codes. Verbal codes use words and vocal sounds to communicate, nonverbal codes use signs and symbols to transmit the message.

Abstract coding differs from concrete coding in the way it does not connect to any influence or preference. Like mathematical codes it is universal and can ease communication between members of different communities.

Some codes evoke discussion, deliberation, analysis and others are more suitable for operational, strategical and mechanical use. In a case where mechanic and strategy are required deliberation might be an enemy.

ATCF code uses an old strategy called the Rapid Serial Visual Presentation (RSVP) created to improve reading performance such as speed and perceptibility. It refers to the presentation of single words sequentially in a single location (Rubin 2013).

In the case of ATCF it was used numbers instead of words to reduce grammatical bias. It also pretends with the use of RSVP to simplify representations on display and system pre visualizations to optimize visual noise and functional bias.

It is pretended to transmit information faster, easier and with more accuracy to pilots during flightpath in order for them to reach better performance, more efficiency and become more intelligent and autonomous when facing air traffic conflicts.

Code monitor representation according to RSVP strategy:

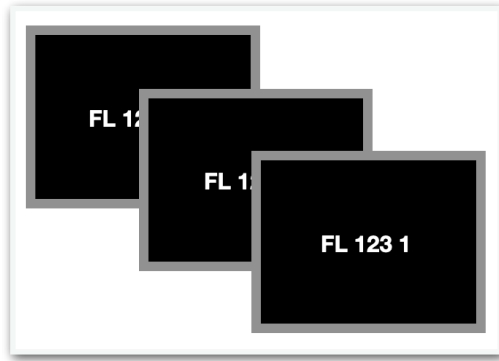


Figure 1: ATCF Display Review.

The code plays an important role for the removal of noise caused on wireless communication systems. Solutions like LDPC coding (Low-Density-Parity-Check-Codes), VMD (Variation Modal Decomposition), WPD (Wavelet Packet Decomposition) and some other noise reduction systems were created for that purpose too (Gang Zhang et al. 2024).

It is part of digital intelligence projects giving use of high tech technology, share of real time security, information sharing and risk suppression through improved transmission sharing (Xiaoyan Zhu et al. 2023).

Removing controllers from traffic control operations and replacing current verbal code with numbers cause risk suppression and risk prevention from disturbances in communications and delayed information transmissions.

Jean-Yves Béziau 1999 appointed that logical syntax are part of the language build through formulas and expressions of linguistic intuition. At the time there was a gab between mathematical language concepts and its natural conception.

Numbers and mathematics have been applied to solve a variety of communication issues and to reach suitable message sizes, phrase lengths and speech times for optimized transmissions.

Main researchers of the filed are philosophers, linguists and logicians. In verbal communication systems punctuation is considered an additional sign to the alphabet or noise. Logicians in the other hand think symbols are more suitable than signs to communicate.

Mainly they search for abstraction of meaning or a symbolic logic to construct message and communicate means. They adopted the so called formalist approach where meaning is rejected (Jean-Yves Béziau 1999).

They are the opposite thinking of logicians who think that the symbolisms has meaning and signs are blind. For Morton Wiener et al. 1972 communication is described as the gestures and movements of body language that act as transmissions. They also appoint to the usefulness of a formal signal system consisted by a code, encoder and decoder.

Decoder is described as the agent who respond to the code through behavior and where behaviors or movements are expressiveness. They respond through signs, expressions and

emotions. Most communication systems include more decoders than encoders as for example children's where the process of decoding information overlays the encoding process.

Source of information is important to determine participants encoding ability. In the context of aviation process studies as Timothy J. Etherington et al. 2018 reveal that many experienced pilots receive information from redundant sources that might affect outcomes and performance.

Authors observe for example a difficulty regarding speed issues demonstrating confusion, low processing and translation ability. Automated system to support reading sensibility are created to help detect such errors like CAD (Computer Aided Detection).

David Lyell and Enrico Coiera 2016 have noticed that errors mainly occur due to no previous preparation, lack of information or notion of the probability of failure occurrence. Literature also reveal that errors occur more frequently when doing multi tasking than single task operations.

This is also called automation bias and happens because there are a variety of elements calling for participants attention at same time causing confusion and disorientation. Authors relate such aspects to task characterization as by complexity and execution difficulty. Single task methodology as the one used in ATCF reduces workload and complexity. It also promotes participants autonomy towards automated systems.

David Lyell and Enrico Coiera 2016 also observed that there are distortions and disturbances detected when doing intrinsic cognition by external information sources. It is important to clean visuospatial space after making translation in order to prevent intersections and bias.

Authors defend that non-interruption zones and elimination of distractions should be applied to reduce such effort. Another measure to prevent mistakes is the adoption of safety standards and regulated protocols. This helps prevent loss of function or malfunctioning (Reece A. Clothier and Paul Wu 2012).

By providing ATCF with a psychological layer it is possible to manipulate pilots outcome through inner emotional state, personality and thoughts (Morton Wiener et al. 1972). Behavioral modulation is used to activate in the neural circuits sensory stimuli for informational transformation and reach of outcomes.

Physical layer or visual code play with response modulation where pilots emotions are stimulated to reach quality of response and performance. Modulation with mathematic strategies are used to avoid ambiguity caused by verbal codes and intersections of different interpretations and understandings.

Researchers also highlight physical attractiveness such as environmental context as being important to avoid oversimplification of non verbal communication systems (Mark L. Knapp and Judith A. Hall 2010).

Strategies like arithmetical number representation and informational transformation are usually difficult to acquire and take years to understand its symbolism especially in Children's.

Adults in the other hands activate a non symbolic approach when dealing with mental arithmetic number representations. This makes task easier to perform and more understandable (Camilla K. Gilmore et al. 2007).

Arithmetic instruction is often used to deal with small numbers and help map number into non symbolic representations. Authors appoint that only accuracy is needed in such contexts and conclude ease of participants facing large number arithmetic problems when mastering this technique.

This means small number arithmetic representations such as those used in ATCF for operational instruction should be easy to perform and be accurate reaching desired outcomes. Characteristics in parallel with abstraction pretend to reach system simplification through compression and generalization. Authors like Mark K Ho et al. 2019 recommend use of less, obvious and undifferentiated details to become faster and easier to percept.

In their work they explore the qualities of unity to make decisions. They note the value of macro actions and low level actioning as being crucial for the achievement of performance. Such ideas have been discussed in contexts of Reinforcement Learning (RL) and DL (Deep Learning) techniques.

Such theories refer to details like color as being noisy and redundant and look at space and time as a general sequence of actions also called options. Research reveal effectiveness of such strategies in both human and machines.

By doing so problems such as overfit, excessive mental load, congestion and data limitations are solved. ATCF also pretends to resolve issues regarding controllers and pilots communication issues mainly done in English language.

Studies such as the from Qiong Wu et al. 2019 have been comparing accented speaking and native speakers for errors when communicating in English language. Study conclude accented speakers do more errors than native speakers.

They also observe that error mainly occur when using letters and words rather than numbers. At this stage communication between ATC and pilots are already characterized as being highly scripted, coded, and precise.

Qiong Wu et al. 2019 note however that current verbal code is not perfect and demonstrates vulnerability when talking fast or counting data volume. They also notice some competition from pilots to communicate with ATC due to high congestions.

When analyzing participants opinion of flight study demonstrated that cockpit environment generally is classified as a worse and unpleasant place to stay. It is also described as a small and noisy place. In parallel pilots often operate various tasks simultaneously causing high stress levels.

Authors conclude that the more items a message has the more errors probability exists especially for accented English speakers. They also mention read backs as being the variable of measure communications accuracy through feedback.

ICAO recommended three items for transmission instead of average eight items used in a message. ATCF uses one single item (equivalent of a word) to communicate each instruction through algorithms.

Aligned with the mathematical theories of communication are the representational theory of information from Vigo and informational geometry theory as discussed by Shun-ichi Amari and Hiroshi Nagaoka 2000. At this time with society changing from an industrial era to the informational era.

XU Jianfeng et al. 2021 identify two ways of describing the world, one concrete and other subjective. Concrete referring to the matter and subjective to the emotional. They also observe matter-energy-information Trichotomy characterizing information as being an independent discipline from energy and objection.

Authors also mention the capacity of energy to create motion and connect to objective world through matter or moving objects. It is proved that informational system affect lifestyles and influence objective worlds functioning.

In that way information or data transmission can be understood as a series of processes composed as a system with structure and hierarchy. It can be represented like ATCF as a framework with diagrams showing their flow, networking and navigation along requisites.

XU Jianfeng et al. 2021 state information as being representational of moving objects in their objective and subjective matter. It might even be a link between imagination of motion and real object movements along space.

By modeling pilots flight conscious and awareness to abstract air space it is possible to model trajectories, movements and motion mechanics. Authors describe the existence of motion parameters reflecting pilots operational intention through consciousness.

Studies have shown that main incidents in the aviation industry happen precisely due to psychological events and phenomenas. Intend to flight may translate trajectories and even judge predictions depending on pilots conscious and emotional state.

For the authors volume and message length are crucial for achieving informational and transmission performance. It influences collection time, significance and quality values of transmitted data. Other quality strategies are MACS (Multi Aircraft Control Systems) created to multitasks and speed up monitoring operations (Thomas Prevot 2002).

ATCF codes search not to involve more participants in the processes of air traffic control operations but to minimize and filter interventions and interaction in the context of cockpit and flight path performability. It is pretended to avoid intersection from any source of sound, visual or physical sensorial matter.

Adopting this strategy pilots emotional, conscious and attentional state should be focusing on operation ability and functioning of aircrafts operations towards flightpath. It should optimize data collection, translation and execution of task.

Excessive technical and systematic interventions proved to overload softwares causing delays and malfunctions. Simplifying and reducing technical affordances to the system will help insertion rates between pilots and technology, reducing load, complexity and stress levels.

This should lead to better outcomes when solving air traffic conflicts and performing daily traffic tasks as well as using and creating self outcomes, solutions and surveillance plans and strategies.

Previous research show adoption of checking lists, to do list, plans to face probability scenarios of possible conflicts. ATCF promotes reduction of such tasks providing pilots with self esteem, self confidence and capacity to deal and face air traffic conflict with more autonomy and accuracy.

It is supposed to reduce confusions, abstractness, low knowledge, low conscious and low awareness levels. Pilots should better preview mentally air space without help of physical maps, marks or guidance assistants.

They should be able to imagine objective world and transform it psychologically into mental images and reference points to travel abstract space. It is needed to transform flight experience for intrinsic experience rather than a physical and extraneous experience.

ATCF not only pretends pilots to execute a tasks but to act intelligently and systematically to achieve outcomes and performance. Such results should be achieved with arithmetic and rhythmic characteristics of modeling human brain to physical phenomena that occur during flight.

It does not afford any cognitive effort, calculation or understanding of any kind from pilots. It does afford memorization of short rules representational of instruction for operation performance.

The higher the knowledge of pilots about airspace dimension and measure as well as aircraft typology and functioning the better he will perform the tasks. It reduces time spent analyzing, studying and understanding materials fostering problem-solving and enhancing resolution and accuracy rate.

ATCF does not create dependence like automation technology allowing pilots to stay independently in the air traffic environment. Code allows pilots to travel according to time, speed and trajectory requiring good awareness of actual location and desired destination to complete the path.

Pilots need three measures- time, speed and direction data as well as maneuvering ability and experience to complete flight. ATCF prevents pilots to lose the control of aircraft, to get lost or to feel powerless regarding conflicts and risky situations. It should help them face daily tasks with more confidence and also more freedom handling required operations not making them dependent from controllers and traffic managers.

Independence given by ATCF should increase resolution and optimize action time expanding goal achievement probability. Pilots should have good mental mathematical preparedness and be like to imagine concrete spacings towards abstract space.

They should have load to be willing to measure, predict and model flight according to affordances. Code needs for that reason to be short, quick to understand and ease to execute. He should also not vary too much and keep a pattern show difference with the less characters possible being ease to distinguish and segment along flight categories.

ATCF should link pilots intuition, natural behavioral knowledge of function to relate to task and requirements for problem solving. It is required pilots to know encrypted data about ATC procedures to complete the tasks such as basic knowledge about aircraft acceleration characteristics and overall maneuvering capabilities.

3D Technologies as described in the study from Büşra Tuzlupinar 2019 and augment versions of systems should be an accessory and not a dependency from pilots to solve a conflict or a daily task.

3.1.2. Fundamentals

Framework constitutes some fundamentals that characterize the code and its message. One fundamental is the use of numbers to communicate, propose and composite. Main component is its mathematical grounding which composes a physical and psychological layer.

Presented code uses arithmetic and algorithmic compositions to instruct and trigger an action. Its physical layer or visual component is the instruction received by pilots and understood as a sign for action. Psychological layer is the calculation and subjacent mean behind arithmetic and messaging.

The composition of the code relies on the use of algorithms 1, 2, 3, 4 and 5. Different combinations of those algorithms allow the transmission of diverse signs and means for operational intend. Combinations can be classified into three categories: altitude, speed and trajectory.

Main instruction given by ATC to pilots are related to flight level change, direction change or changes in velocity and airspeed. Framework focuses on these components using a block and box strategy.

Framework has a strong psychological impact more than physical proving to be less loaded than currently implemented verbal code. The psychological layer is protected with math logic and memory to avoid overload, fatigue and stress during problem solving.

Rules based on syntax composition and semantic integration are applied to avoid bias, errors and deviations regarding pilots' awareness and attentional level. They create order for an effective and efficient operation.

Mathematic code activates important mental states to trigger mechanics and cognitive systematics which allow situational control and successful instruction making. Representation of the code on display should respect reading guidances such as lightning, viewing distance, character size, and contrast (Rubin 2013).

Previous research have been focusing on read back errors from pilots when reading back ATCo (Air Traffic Controller) instruction. ASRU (Automatic Speech Recognition and Understanding) for detection of wrong trajectories and translation of speech to text and text to meaning operations has been created.

Hartmut Helmke and Oliver Ohneiser 2024 also noted that current air traffic control operations are executed quickly through VHF in challenging environments with heavy accents and noise that lead to transmission losses and message distortion.

By replacing monitoring with instructional strategy to control air traffic operations it is removed bias caused by external environmental factors as those listed above. This prevents wrong information and misunderstanding that cause majority of incidents.

Complexity and stress levels increase pilots workload which contribute to fatigue that consequently reduces pitch speech signal causing difficulty encoding information.

Study of Hartmut Helmke and Oliver Ohneiser 2024 also show an influence of those components on pilots visual ability. They also mention the use of entropy to determine dispersion rates.

Other studies observe that tasks assisted by technology cause less errors than those entered manually. One example is ASR (Automatic Speech Recognition) technology that reduces input errors in radar labels.

By making ATC tasks independent from controllers the operations turn automatically between system and pilots. Risk probability and error rate are so reduced through ATCF code.

Heinz Erzberger et al. 1997 concluded that trajectory prediction models are inexact and that variables affect technology data accuracy and validity due to its variance. In consequence systems do not correctly prevent occurrence of conflict situations. As a response to the permanent need to optimize models to predict traffic ATCF presents a solution based on mental capacity to make predictions through visualization and memory.

Pilots can concrete abstract air space fulfilling it with memory data representations based on their experience of flight and calculate distance and trajectories through basic arithmetic techniques without needing assistance of technology.

Authors also observe that the higher the prediction the less the probability of conflict like tracking and rating activities. The later pilots respond to a desired task the more evident its solution become and the more difficult it becomes to maneuver it.

By equipping pilots psychological layer during flight such as personality, mental state, presupposition, expectancy it is possible to train its physical ability to respond to conflict more easily and with more autonomy and accuracy.

Heinz Erzberger et al. 1997 list current two sub problems associated to conflict resolution operations such as decision of what time to act and what task to execute.

ATCF removes such sub tasks linked to the cognitive layer by only instructing and stimulating pilots neuron circuits to act according to required task without needing to think about it or what to do with it. Removing those components from pilots workload prevent the

occurrence of wrong alerting and anticipated wrong actioning leading to unnecessary effort and risk enhancement.

Other models as those described by Hatim Elhassan et al. 2021 use machine learning and clustering technique to define Standard Errors (SE). They also highlight requirement elicitation as being an important step during software development.

Authors also observe that most failures of IS (Information System) happen due to issues in the context of requirements conflict which cause big money loss. By simplifying the display appearance and transmission as well as shorten the message and data it is removed complexity caused by excessive requirements and demands for operations.

The objective is to get as close as possible to conflict-free requirements (Hatim Elhassan et al. 2021). Systems accuracy is important in situations like collisions. Avoidance systems have been developed to reduce such failures and incidents (Skoog et al. 2014).

By training and optimizing pilots navigation skill towards space and ground it is pretended to reduce dependence on systems data and reduce transmission errors.

Skoog et al. 2014 also noted lack of storage capacity from systems to support prevention models. They worry about compression of data to execute safety and prevention models. Specially map and terrain scans, 3D technology and ground elevation are being simplified to fit operation requirements.

Technologies like CPDL (Controller Pilot Data Link) have already been replacing ATC operations to modernize and secure digital assets such as spoofing, eavesdropping and message reply (Suleman Khan et al. 2023).

ERC (Emergency Risk Communication) studies focus on message length and amount transacted. Risk according to Elena Savoia et al. 2017 must be prepared through risk communication and planning.

Risk communication for example pretends to ease understanding of complex messages and conquer participants trust. It is measured by the time it takes to be transmitted and how accurate the message is. Authors also explain that results might be affected by participants believes.

In order to predict risk to occur clustering and data mining are applied to achieve behavioral pattern and regularity. Mainly they are extracted from movements and local informations (Omnia Ossama et al. 2011).

In the other hand communication has to be transmitted and understood by participants in order for predictions of systems to be useful when doing problem-solving. Usually those concerns relate to semantic problems that might be affected by language syntax and phraseology (Claude E. Shannon and Warren Weaver 1964).

By using a code like ATCF semantic issues are removed and syntax simplified into guided rules of operability and function. When communicating through digital channel information is transformed into a signal. It can be a sound, an image or any other source of meaning.

ATCF uses algorithms as signal to do something operational and work as a message of measure and calculation. It can be a change in distance, speed or altitude levels. Claude E. Shannon and Warren Weaver 1964 mention that every signal usually requires a code.

Characteristics of the code will define what process it will become. ATCF has a physical layer and a psychological layer that compose the instructional code and its functionality.

Authors also notice that communication process as those shared in an air traffic ambience are vulnerable to distortions caused by noise. Noise may even add redundancy to the transmitted data and influence transmissions outcome.

In their study they also observe a tendency for English vocabulary to become bias and redundant relating to crosswords causing constraints and chaos to communication.

Physical component

Rules

Rule 1: Acceleration

In this rule space represents lower values of speed and altitude. And repetition represents higher values. Two-time same number is fast and three times is very fast.

E.g.

Speed

1 1 3 (slow)

113 (normal)

11 11 33 (fast)

111 111 333 (very fast)

E.g.

Altitude

1 2 3 (slow)

123 (normal)

11 22 33 (fast)

111 222 333 (very fast)

Real Combination:

E.g.

FL 123 1 (normal)

FL 123 11 (fast)

FL 123 111 (very fast)

FL 123 12 (normal)

FL 123 11 22 (fast)

FL 123 1 2 (slow)

When combining 123 with another algorithm the rule applies only to the number in front of that combination. For ground levels the rule does not apply (—, — — and — — —).

E.g.

Turn Left

1 1 1 1 1 (slow)

111 111 111 (fast)

111 11 1 (normal)

Rule 2: Direction

This rule represents the turn to left (1) and the turn to right (3) with different speed variances. Very fast acceleration level does not apply to this rule.

E.g.

Left

111 11 1 (normal)

111 111 111 (fast)

1 1 1 1 1 1 (slow)

E.g.

Right

3 33 333 (normal)

333 333 333 (fast)

3 3 3 3 3 3 (slow)

Rule 3: Altitude

In this rule scale goes from 1 to 5 and after that combinations are created to build bigger numbers, starting always on 1. For FL 300 we combine 12 and not 3 since there is no real 1 or real 2 representation. 123 represents random maximum high altitudes 10 000 feet. 54 is the maximum combination after that we use 123 for higher values.

E.g.

Over 100 FL

FL 123 (100 FL)

FL 123 1 (200 FL)

FL 123 12 (300 FL)

FL123 4 (400 FL)

Under 100 FL

FL 54 (90 FL)

FL 53 (80 FL)

FL 51 (60 FL)

FL 5 (50 FL)

Starting at FL 1 till 54 and then 123 till 123 54 after that 123 123 (maximum) that equals 100 000 feet.

Rule 4: Ground proximity

In this rule altitude is measured starting from the ground. — is the first level in hight — — the second and — — — the third. Over this we are disclosed from ground and start count from FL1.

E.g.

Altitude

FL 1

0,5 FL (— — —)

0,3 FL (— —)

0,1 FL (—)

Ground, Landed or Crashed

E.g.

Altitude Recovery

FL 2

FL 1

0,5 (— — —)

0,3 (— —)

0,1 (—)

Ground, Landed or Crashed

Rule 5: Speed

In this rule we apply proximity to ground rule for Landing and Ascend velocity. V — stands for minimum speed of ascendance and corresponds to — FL. 113 is standard for random maximum speed.

E.g.

113 (1000 Km/h)

112 (800 Km/h)

111 (600 Km/h)

— — — (400 Km/h)

— — (200 Km/h)

— (50 Km/h)

Landed or Crashed

Rule 6: Classification

In this rule we state V for velocity and speed instruction, FL to represent altitude values and D for direction.

E.g.

V (Velocity)

FL (Flight Level)

D (Direction)

Instruction example.

FL 52, V 111, D 111 11 1

Rule 7: Instruction

In this rule we state instruction composition to appear on display. We represent FL, V and D from left to right separated by comma.

E.g. 1. FL 123 12, V 11 11 22, D 3 33 333. (Combination FL, V and Direction)

E.g. 2. V — —. (Velocity)

E.g. 3. D 3 33 333. (Direction)

Rule 8: Block

This rule defines how instruction should be written. There is a total of three blocks or six individual boxes. Block are read as one grouped data; boxes represent additional single data.

E.g.

123	1	2
-----	---	---

123 12: 123 is written as a block with three algorithms. Plus, two individual boxes with one algorithm each

E.g.

11	11	33
----	----	----

113 with acceleration rule is read as a block

E.g.

1	1	3
---	---	---

Same with different acceleration rule

E.g.

333	333	333
-----	-----	-----

3 representing right with maximum acceleration is read as single block

E.g.

1	1	1	1	1	1
---	---	---	---	---	---

Same for left with lowest acceleration

A block transmits one instruction:

E.g.

123 = go 10 000 feet

1 1 1 1 1 1 = go left slowly

A box added to the block represents a calculation:

E.g.

123 1 = go 10 000 feet + 1 (where 1 stands for an extra block of 10 000 feet) = 20 000 feet

123 51 again there is a block (123) and two single boxes (5 and 1):

E.g.

123 51 = go 50 000 + 10 000 = 60 000 feet

Starting from 123 5 we do not calculate block of 123 (10 000 feet) but only the value of the block with the box included (50 000 feet), then 123 51 turns 50 000 (5) plus 10 000 (1) and so one.

Rule 8.1: Box

This rule determines how a box is read when added to a block. This rule applies only to block 123 and represents a calculus (+) till 123 1 (10 000 + 10 000) after that like 123 12 or 123 4 or 123 52 it represents only itself as calculus and the block turns a mark in space.

E.g.

123 12 = 1 + 2 = 10 000 + 20 000 = 30 000 feet

123 4 = 40 000 feet

123 52 = 5 + 2 = 50 000 + 20 000 = 70 000 feet

Rule 8.1.1: Box calculation

This rule explains when and how to do calculation between boxes. Calculation is done when there are two boxes added to each block (*+*). When there is only one box, box is calculated as a single block (+*).

E.g.

123 52 = 5 + 2 = 7 = 70 000 feet (*+*)

123 4 = 4 = 40 000 feet (+*)

Rule 9: Box lecture

This rule explains how boxes are read and interpreted as instruction to block.

E.g.

123 52: 52 is the calculation of $5 + 2$ and is read as 7 that equals 70 000 feet

123 4: 4 is a box and read like a block that equals 40 000 feet

123 1: is read as $10\ 000 + 1\ (10\ 000)$ that equals 20 000 feet

or

FL 123 1 = $100 + 1 = 200$ FL (original format)

Rule 10: Measures

This rule determines how altitude, speed and direction is measured through airspace. For altitude the code uses FL to measure feet and 1 (left) and 3 (right) for direction and a special code with acceleration rules for velocity and speed in Km/h.

E.g.

FL 123 1 (flight level) altitude

D 111 11 1 (left) direction

V 113 (1000 Km/h) velocity

V 11 11 33 (1000 Km/h + fast) velocity + acceleration rule

Rule 11: Code language

This rule explains how the code transmits data, in which manner and with what intuition. The code itself is an instruction given to the pilot to trigger an action. Code communicates actions with number and algorithm combination through calculations and measurements.

Process: The Pilot reads a number, an algorithmic distribution, data blocks with algorithms and boxes. They also read syntax, and semantic. Perceive colors, intensity (through scale), density (through repetition) and complexity (through combination).

Code has a physical layer and an intrinsic value (message). Value is purely psychological and represent a cognitive instruction to brain through passive stimuli. Active stimuli are given by instruction set as final action with physical interaction on cockpit ambience.

E.g.

123 1 2 = 123 12 = 300 FL

Code physical layer: The physical layer of the code is the representation of the block and its possible boxes containing algorithms.

E.g.

123 12

Code psychological layer: The psychological layer of the code is the mechanic triggered by the physical layer when read.

E.g.

123 (block read) 1 (box read) 2 (box read), 300 FL (result of calculation)

Intrinsic value: Intrinsic value is the message associated to instruction given.

E.g.

123 12 = Go to 300 FL or go to 30 000 feet (message)

Extrinsic value: Extrinsic value is the action after instruction is read.

E.g.

Altitude maneuver (physical interaction)

Internal stimuli: Internal stimuli is given to brain passively when instruction is read for its understanding.

E.g.

123 12 (stimulates for calculation, scaling and measurement)

External stimuli: External stimuli is the active stimulation of actioning.

E.g.

Pilot is stimulated to maneuver altitude level

Code represents a mental scale for psycho space measurement. Psycho space or virtual mental space is a representation of real space given by real measures and scale techniques.

Mental scale is provided by imagination, experience and long term and short-term memory and gives the brain a realistic virtual representation of real space in psycho space.

Pilots can preview location, trajectory, and measure through scale of airspace without physical need of real numbers or measurement techniques.

Code stimulates the brain and activates needed attentional resource to complete desired task. It is read in English (one, two, three, one, two = 123 12) and able to trigger rhythm through calculation and algorithmic scale.

Scale is attribute to algorithm (one - lowest, two - mid and three - highest) one is easier to spell psychologically then two and three, two is easier than three and three is the most difficult to spell.

When extending the scale to four and five difficulty level increases. When combined five and two for seven the same. Brain knows scale is raising with this passive stimulus.

Passive stimuli do not create complexity or add emergency, stress and difficulty levels to instruction.

E.g.

123 51, 123 52, 123 53, 123 54

By reaching maximum level five when wanting to go higher to six, seven, eight or nine code starts with algorithm one again. Four iteration is the heaviest algorithm to spell after five (54).

The code contains a syntax rule like spacing that separates data blocks from boxes helping pilot getting correct lecture of instruction. In normal representation like 123 12 spaces only separates block from the boxes without any extra meaning.

When applied a rule like 1 1 1 1 1 space indicates acceleration level. In this case space is time and represents slow compared to 111 111 111 where there is less space and higher speed.

Ciphers like V, D and FL classify blocks. V velocity, D for direction and FL flight level.

Code controls mental workload, complexity and difficulty level as well as psychological stress levels through iteration techniques, ending at five first and second at four. Starting from one each time the scale increases.

Rule 12: Code lecture

This rule explains how the code is read when becoming instruction. Code is spelt in single algorithms.

E.g.

123 1 (spelt like one, two, three, one with counting)

113 (spelt like one, one, three with counting)

— — (visual symbol spell without words with counting)

1 1 1 1 1 (spelt like one, one, one, one, one, one without counting with visual block translation)

This rule does not invalid previous rules like, speed, trajectory or rhythm provoked through space technique.

Additional to the way the code is spelt there is the rhythm and tempo that apply other characteristics to the lecture. Interpretation is also divided in boxes and blocks.

E.g.

123 (block) and 1 (box) lecture is done in single algorithms but perceived as a block with a box added.

Space is not spelt but like trace perceived as a visual symbol with or without meaning depending on the context of the rules.

Lecture and composition

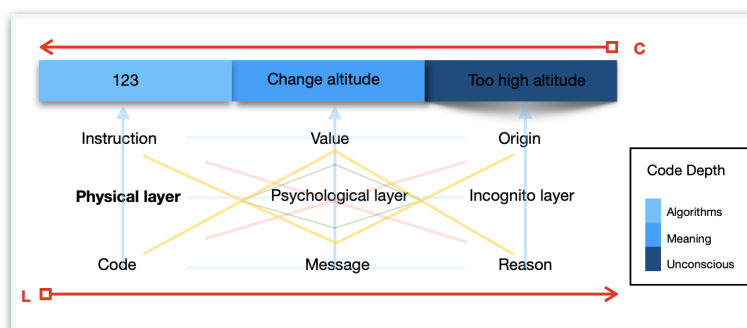


Figure 2: Instruction Interpretation Layers.

When starting an instruction, we start with the cause or the problem that will be the origin, e.g. Wrong trajectory. System will check aircraft location and calculate solution to solve wrong location problem.

He will then generate the right output e.g. Turning right fast. In the display of the airplane a message is presented as instruction saying 333 333 333. This number is the code.

According to following diagram message is created from depth at dark blue and ending at light blue (C). In parallel the lecture is done from light blue to dark blue (L).

Psychological layer drives the success key for instruction pilots to make the right action when facing a problem. It relates value, physics, incognito and message. Code is set as a psychological message with physical value and incognito message.

It can be said that pilots do not perceive a message or does not perceive the meaning or a value but only a code with physical stimuli.

Psychological layer also relates the code with its origin and instruction with its reason. Origin of message defines reason which leads to instruction itself in the other hand code represents the cause that led to its conception.

It can as well be related message to origin and instruction to value of the message and the code to its reason. In that way message stands for the value linked to the instruction.

Diagram

In the following section it is presented Frameworks diagram for code conception/ writing based on real variables like altitude, speed/velocity and direction. For each situation there is a different structure based on algorithm combinations that transmit desired output from each category.

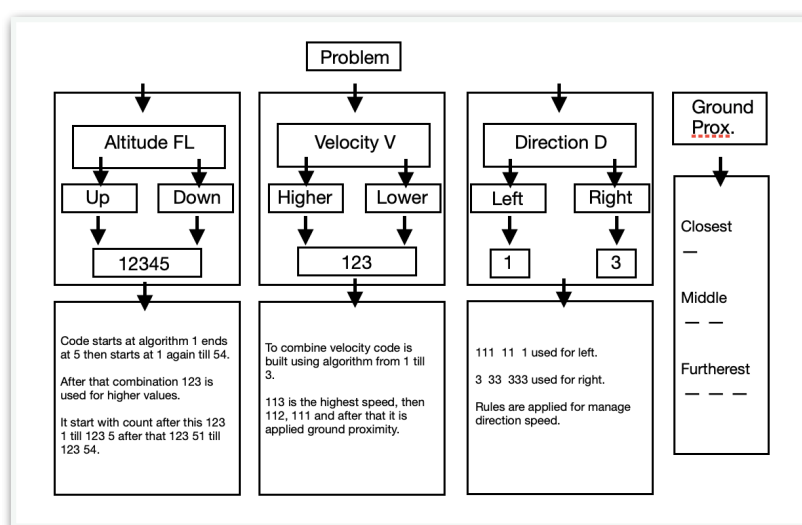


Figure 3: ATCF Diagram.

Problem: Air traffic control problem can relate to altitude, velocity, direction, weather, system or mechanical issues.

First step to create Framework is to define origin of the problem.

FL, V or D. Second step is to define subcategory of detected problem.

Altitude problems can relate to up or down aircraft nose operation.

Velocity is defined by higher acceleration or lower acceleration operation.

Direction relates to left or right operation.

Code: For each subcategory of main problem an algorithmic combination is provided to represent instructional operation.

Up and down is represented with 1, 2, 3, 4, 5, 123 combinations for 10 000 feet representation and 1 for 1000 feet.

Higher and Lower uses 1, 2 and 3 for acceleration representation. 113 for average high altitude velocity.

Left and right uses two algorithms to represent each directional operation. 1 represents left and right is represented with 3. A scale is applied to facilitate direction speed of the maneuver.

Ground Proximity is a measure of altitude and velocity levels. — represents closest proximity to the ground, — — represents the second closest and — — — the furthest.

E.g.

Problem: Need to change altitude, aircraft must go up 1000 feet

Instruction: FL 123 1.

Psychological component

In the following section it is described psychological mechanism triggered by code when reading instruction. Interpretation is done through rhythmic and arithmetic during lecture and processing.

Anna Fiveash and Barbara Tillmann 2024 noticed a rise in perception level when applying rhythm technique. Heard and Lee 2020; Patel 2008 also noted that music and speech share similar mental processing characteristics.

Psychological component refers to the internal process and strategy of the code when messaging pilots through aircraft displays. It defines effectiveness of final outcomes and operations.

Arithmetic

Spatial thinking as mentioned by Jérôme Prado and André Knops 2024 play an important role in modern mathematics by associating numbers to space mappings through geometry and measurement.

Authors reveal that numbers often represent themselves as spatial meanings to human mind as for example the theory of the Mental Number Line (MNL) which reveal a range of effect regarding numerical cognition.

This theory is adopted in code conception and explores the possibilities of number magnitude in psychological events. Gianelli et al. 2012 explained potential of MNL in the occurrence of cognition effects like hallmarks related to size, distance and spatial awareness.

Literature concludes there is a relation between space and numbers triggering cognitive mechanisms to achieve attentional movements along MNL conceptualized as mental arithmetic also called SAA (Space–Arithmetic Association).

Some of the listed phenomena in SAA are cueing effect, operational momentum effect and attentional biases measured through eye and hand tracking effect during arithmetic calculation.

McCrink Dehaene and Dehaene-Lambertz 2007 noticed a preference of participants to choose a higher number when doing addition and smaller numbers when doing subtractions.

All those phenomena represent codes psychological layer by triggering cognitive mechanism in participants mind when dealing air traffic control tasks.

Visually in the physical layer researchers conclude a preference for participants to choose an entire number (e.g. 20) instead of an arithmetic equation (e.g. $15 + 5$) which is hidden in codes psychological layer.

Liu D et al. 2024 also stated that mental arithmetic has a positive effect on participants future computation ability. They also mention the bias related to traditional numerical teaching compared to mental arithmetic ability to achieve calculation speed and performance.

Mental arithmetic is described as the operation of working memory and thinking activity used to do calculus without the use of external tools and by promoting participants autonomy towards measurement techniques.

Performance is automatic when working with memory which removes bias related to external influences caused by distraction operands also called a single-act process triggered by ATCF instructional component (Compton B. J., and Logan G. D 1988, 1991).

Studies also prove that smaller arithmetic problems like $1 + 2$ are quicker to solve than higher one's what justify the use of small MNL scale from 1 to 5. Same happen when applying iteration to operands or using similarity (e.g. $1 + 1$ and $2 + 2$).

As a complement to the codes physical component of arithmetic there is a symbolism behind it that leads to knowledge (Camilla K. Gilmore et al. 2007).

Mainly as explained by authors arithmetic is done without symbolism and more with use of intuition and logic. Especially adults do abstraction when making mental calculations.

Andreas Nieder 2016 provided a definition of numerosity by classifying it as a property of quantity, meaningless and abstract. He also mentions importance of number processing for the detection of cognitive control functions.

In its study he finds that numbers in the mental space often relate to estimation practices and physical stimulus. It also proved that numerosity is acquired by human without the need to learn.

Arithmetic makes part of abstraction by reducing and compressing irrelevant informations (Mark K Ho et al. 2019). Wim Gevers et al. 2010 noticed an evident relation between small and big number and hand movements.

Smaller number are faster to operate with left hand and bigger number with the right hand. This possibility opens new perspectives regarding behavioral modeling through mathematic strategies and arithmetic.

Authors also observed a tendency related to human memory and intuition when asking to predict a location in MNL.

Eg.

Whats the middle number between 1 and 5. Average people would respond 3 without recurring to calculations or any other measurement techniques.

Such experiments reveal human capacity to map a mental space model by providing it with locations, trajectories and measures.

Rhythm

Claude E. Shannon and Warren Weaver 1964 defines the communication process as the influence of one mind to another through different arts such as theatre, music, ballet or oral speech.

ATCF uses rhythm skills to do mental code lecture. It applies an amplitude, a melody and timber to constitute a mental beat for awareness and triggering of neural mechanisms.

Rhythm has been explored in studies of neuroscience and psychoacoustics related to music activities. Jonathan Fritz et al. 2024 refer to musical memory used in ATCF for spatial awareness. Authors also mention healing ability and refer to music as a medicine and describe the different degrees of musical syntax by tonality that relate to code arithmetic component.

Beat has shown to be main element for behavior and synchronization of movements responsible for neural changes in the auditory and motor circuit of human brain (Jonathan Fritz et al. 2024).

Study also prove a correlation between neuron imaging and tonality processing. Which reveal to be helpful when doing mental mapping of air space and flight path planing tasks.

Zhongju Yuan et al. 2024 have defined rhythm as a series of periodic patterns in a time interval meaning the ability to stimulate human behavior through temporal cognitive task modeling.

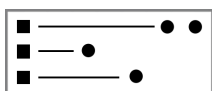
Rhythm production or modular information transfer as referred by authors give code the ability to be translated in another language like symbolic, verbal or musical sequences.

E.g.



Translation of 123 1 into symbolic sequence

E.g.



123 51, 123 12, 123 4

- This is a musical and time representation of the instructional code version. Rules 8 and 9 represent the physical component of the instruction translated into a square and sphere and line represents the sound projection.

There is a distance related to rhythm and it differs from the physical world, mental lecture and imagined projection are different. Imagination works as a tool for mental mapping to associate real world measures to psychological space distances.

E.g.

123 12 may look the same when doing lecture as 123 54 but projection provided by imagination is longer for 54 than for 12. Amplitude adds in this context distance to the inner voice projection.

Set of described rules compose the Frameworks' structure, hierarchy and modular conception. It combines mathematical syntax components with linguistics and secures codes effective interpretation process such as reading, mental transformation or termini, application of logic and response (Roland Friedrich and Angela D. Friederici 2009).

Mathematical logic has been defended by authors in the promotion of brain-imaging they also observe that information organized by hierarchy is frequent in daily tasks.

The use of hierarchy as for example applied in mathematical expressions obeys rules and principles to work accordingly. Studies also conclude that decision based on rules like calculations enhance human processing capabilities to understand complex systems (Roland Friedrich and Angela D. Friederici 2009).

Such complexity can derive from a variety of operational errors like disruptions in weather, traffic volume or political factors to which pilot need to respond in a quick and correct form.

There are other issues related to aircrafts weight, length and typology that affect performance and outcomes when handling conflict situations. A A Ayu Diah Windusari 2023 found that larger and heavier aircrafts cause more delays than smaller aircrafts.

Such informations are important to pilots when facing congestion os system failures where prediction and natural intuition through experience and operational knowledge are required.

Knowledge about each aircrafts typology might affect maneuver performance when executing ATCF being important pilots to have experience maneuvering a specific type of airplane to reach operational performance and outcome accuracy.

It is known that delays of big aircrafts can take from 2 hours to 15 minutes. In a context of conflict pilots should use mental calculation to predict possible incidents regarding such delays. To do so he will need to apply mental arithmetic and rhythmic components to conduct the calculation.

Rhythmic and arithmetic provide the pilot with neuron-image marks and patterns to map airspace and identify conflict scenarios so there can be processed a decision to solve the problem.

Consequently problems may arise if conflict does not solve efficiently as for example fuel consumption, route and traffic disruptions, airport capacity and ground service affecting the security of passengers and crew members (A A Ayu Diah Windusari 2023).

Jingbo Liu 2024 observed that there is a psycho-spiritual layer provided by rhythm, frequency and regularity of sound. It has a medical effect causing physical and psychological response outcomes.

Literature have shown the human body's complexity and refer to it as a celestial body capable of containing vibrating energy and own frequency. Its physics can be improved through sound when interacting with the inner self creating harmony and improvement in the functional system (Wang, L. et al. 2019).

Inner voice is proved to have an effect on human mind similar to that ones caused by external sounds sources (Stephane Massoud et al. 2021). It triggers brain activity from the temporal and spatial cortices.

Authors also call inner voice or silent speech as egocentric speech putting focus on the self instead of the surrounding space. However there is proved spatial awareness that happens in the mind.

Stephane Massoud et al. 2021 found that overall inner speech has better time performance than reading aloud activities (Rubin 2013). Voice or sound also plays an important role to control emotional state.

Jingbo Liu 2024 have been studying the emotional performance and its relation toward objective things. Author defines emotion as an automatic process resulting form experience, grouped into categories or also called moods that represent personality's versatility.

He presents different types of emotional types: basic, personality, attitude, expression and behavioral. They can be positive moods and negative moods depending on psychological phenomenas.

Rhythm is able to model diversities and challenges regarding pilots emotional journey during flightpath such as preferences, desires, excitement, bipolarity, stability, regularity and interest.

In its study Jingbo Liu 2024 mention sentiment calculators and modeling methods created to control such metrics. One method described is rhythmic pattern applied to music modulation techniques.

Rubin 2013 found that majority of visual difficulties detected by people with vision problems relate to reading activities in opposite to watching TV which was the less difficult task.

Studies regarding reading performance measurement and assessment have been discussed to overcome difficulty. For ATCF it was selected a preview strategy pretending pilots to memorize short codes and relate them to operations by simply watching them on display.

Mentioned strategy might be helpful in emergency cases such as those ones related to pilots health issues that can cause visual disfunction, cerebral disfunction and control loss.

In worst case it can cause crashes and high number of fatalities as well as monetary loss and environmental damage. Strategy also protects memory by not overloading it with new and different content every path and by not requiring excessive load and effort to understand and deal daily task and conflict situations during flight.

Anna Fiveash and Barbara Tillmann 2024 conclude a correlational effect of rhythmic production with durational cues. They also noticed influence on processing mechanisms, perception and awareness. Temporal processing is proved to enhance communication sensitivity. Authors observed that rhythmic cue can optimize response to sentence from neural system.

Working memory

Working memory represents the visuospatial stimuli also called as visual memories part of the mental transformation process. Memory plays an important role when operating and making decisions by providing control and function mechanisms for cognition.

Levels of cognition according to Wim Gevers et al. 2010 are related to sensorimotor. They also observe that abstract space of numbers are noticed according to the concrete dimension of space. MNL also showed to link left and right mechanisms providing coordination skills in external space and number representation.

Working memory allows participants to calculate, think and measure by saving representations in the mental sketchpad used when do processing. Arithmetic is an example of the use of memory to conduct calculation (Andreas Nieder 2016).

Authors define the term as a temporary store of information for guidance and operations. Research have demonstrated a positive effect of working memory on mental arithmetic processes of speed and functions (Liu D et al. 2024).

Concepts such as mathematical mental computation have been used to introduce schema methodology and prove its positive impact on learning through instructions with chunking information into schemas.

Schema teaching increase students' ability during arithmetic calculation and lowers stress levels with a multi-sensory and five sensed strategy to engage students into learning activities.

It is also called a method to solve continued issues since it allows correlation between working memory and long-term memory increasing connection and retention. Schemas also proved to be effective in enhancing participants autonomy toward external tools (Liu D et al. 2024). Other aspect act with working memory such as legibility and design.

Brady 1988 defined legibility as the processing time and recognition. All parts of a cipher are important for its legibility in order to promote reading and visualization (Caglar Okur 2017). Regrading graphic design principles it was recently adopted a marketing strategy where letter got replaced by numbers to attract attention and enable logo memorization.

They are part of creative practices and play with aspects like contrast, color, size, typology, form, alignment, spacing and robustness. They all work for memory to facilitate operation with iteration processing.

Design principles also play an important role to do mental calculation not only when measuring distances or trajectories but also when mapping spaces and visualizing or making predictions.

Characteristics of the elements when entering memory should be impactful, recognizable and familiar for assimilation. By doing so participants when reading instruction will engage, understand and execute more quickly and efficiently desired task for operation.

ATCF uses a strategy of block and box representation of data to promote legibility, memorization and recognition when measuring hight and distances.

For Caglar Okur 2017 legibility is defined as being the basis for readability. He also concludes that numbers used in design strategy add depth to the representation and consequently attractiveness to the represented object.

Author recognizes that numbers have not only a quantitative meaning but also a qualitative which can relate to other signs such as sounds and shapes. By assimilating number to other meanings it is possible to communicate a variety of messages in one single representation.

It optimizes processing techniques and transmission by fostering those steps. Message should be short and compact and be represented as a unity to the mind in order to be successful (Caglar Okur 2017).

3.2. Assessment

Following assessment is to evaluate knowledge about code and air traffic control mental map rules and composition. Assessment will be a online quiz further discussed on the research methodology and results section.

Inquiry

a. Please select whether sentences are true or false.

1 1 1 1 1 1 represents a slow turn to right. ☐ True ☐ False

Green in the instruction section stands for positive flight state. ☐ True ☐ False

V — — represents a change in velocity to 200 Km/h. ☐ True ☐ False

FL 123 12 represents a fast change in altitude to 30000 feet. ☐ True ☐ False

3 33 333 in red represents a turn to right with urgency. ☐ True ☐ False

V 112 mean aircraft has currently 800 Km/h speed. ☐ True ☐ False

FL 123 11 has no rule applied. ☐ True ☐ False

Airspace is divided by level 1 till FL 3, level 2 till FL 51 and level 3 till FL 123. ☐ True ☐

False

FL 123 52 represents two different instructions. ☐ True ☐ False

FL 52, V 111, D 111 11 1 is correct format. ☐ True ☐ False

FL 53 is part of Level 2 in airspace. ☐ True ☐ False

— — — is the closest level to ground. ☐ True ☐ False

FL 123 is faster than 1 2 3. ☐ True ☐ False

White represents first level of airspace. ☐ True ☐ False

V 113 1 is a valid instruction. ☐ True ☐ False

Code is written from left to right. ☐ True ☐ False

123 12 represent slow acceleration. ☐ True ☐ False

— is used for velocity and altitude measure. ☐ True ☐ False

— — represents FL 0,3. ☐ True ☐ False

V 123 1 represents 20000 feet. ☐ True ☐ False

123 is an ascendent scale. ☐ True ☐ False

Mental airspace map is divided into 3 areas with 6 divisions each. ☐ True ☐ False

Distance does not depend on vertical measure to calculate flight time. ☐ True ☐ False

One area in straight line takes around 10 flight hours to be crossed. ☐ True ☐ False

Australia is part of area A. ☐ True ☐ False

B3 has 11200 miles. ☐ True ☐ False

3.3. Mental Calculation Model

To help calculate distance and trajectory in space it was created a mental map divided into three air spaces A, B and C. Each space division is measured attending a scale of five algorithms. Map is observed horizontally from left to right and measured into miles along equator.

Map

GPS (Global Positioning System), radars and other surveillance systems such as Auto-GCAS (Automatic Ground Collision Avoidance Systems) were created to help pilots fly safely through airspace and ground stations.

Challenges arise regarding transmission capacity and storage as well as information processing. Systems and maps need to become more compressed and flexible in order for that technologies to be used correctly.

One strategy is to provide pilots with a mental capacity to navigate airspace and ground stations without help of technology. It requires training of pilots predictive ability and conscious of actual traffic network and its behavior along space and time.

By providing them with mental calculation and measurement techniques and guidance to preview, analyze and understand airspace it will become more easily for participants to take a decision and trust in operation.

It also balances participants self confidence when interacting with high automated systems not removing their ability to autonomously solve a problem. Commonly prediction tasks are done by sensors and models that design behavioral patterns to avoid obstacles and possible conflict zones (Patrick Doherty 2004).

For UAV (Unmanned Aerial Vehicles) the main challenge is to take pilots responsibility and execute their operations like watching obstacles or operating an emergency (Suraj G. Gupta et al. 2013).

Pilots needs to perform systems capacity when it fails providing them with understanding of automated systems functional protocol and teaching them how to behave without guidance of technology.

As said by Suraj G. Gupta et al. 2013 UAV need to know their location and position towards airspace at any point on earth in order to correctly reach a destination for landing.

Same happens in opposite for pilots without assistance of the system. Authors also mention that navigation accuracy, guidance and flight control capabilities are key to reach successful automation.

Knowing the environment around their location and having a flight plan and conscious tracking of the path is also crucial to reach the destination point.

ATCF mental map secret is to think short-medium term and have clear overview of the trajectory being done, time estimated to complete it and location in altitude.

For automated systems it is more important to think long term and have a prediction for long distances believing that small distance disturbance will easily be detected and avoided.

Mental map as presented above will help participants have better notion of abstract airspace providing them with a shape for better perception and understanding. The shape will in the place of a physical map be a mental pre visualization of altitude levels and distance areas.

Pilots will not navigate in a satellite based map with physical instruction of trajectory and location but rather navigate according to ruled map division strategy based on awareness of space, time and flight experience.

This supports issues regarding data transmission delays, wrong transmission, data hacking and information distortion that lead to disorientation and monitor dependence taking out participants ability to face and solve a conflict incident in case of system failure.

Training and stimulating pilots senses and ability to maneuver according to their intuition and natural surveillance capacity is important to avoid other problems like hard-landing where aircrafts pressure during landing is higher than normal causing serious damages (Dr.K. Rama Krishna et al. 2023).

According to the study of Dr.K. Rama Krishna et al. 2023 70 to 90 flight crashes happen worldwide revealing gab in system capacity to track traffic flow and monitor vehicles along airspace. Research also reveal lack on pilots capacity to deal conflict situations and loss of awareness.

Traffic code

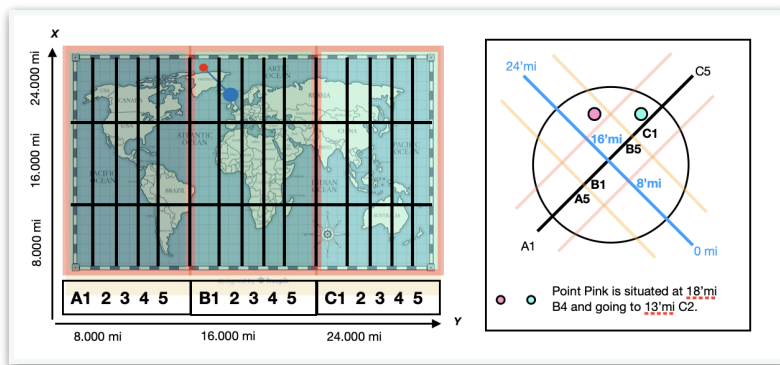


Figure 4: Air Space Calculation Model.

In this section it is presented a code for guidance during flightpath. It represents trajectory and distance in space.

Rule 1: Distance

Distance is measured along earth equator with a total of approx. 24 000 miles represented as 24'mi. This measure is divided into three areas A, B and C.

Each area has a scale that goes from 1 to 5. Area A goes from 0 miles to 8000 miles; area B goes from 8000 miles to 16 000 miles and C goes from 16 000 miles to 24 000 miles.

To measure distance, it is used black axis that goes from A1 till C5. Blue axis (x) provides vertical location of aircraft between 0 miles and 24 000 miles. While black axis (y) provides measure in length from right to left among the three areas.

E.g.

An aircraft is located at FL 200 at V 113 and located at B3 20'mi. It is pretended to reduce speed to two lower levels and go B3 17'mi.

Instruction: V 111, B3 17'mi.

Rule 2: Time

To estimate time of distance during flight it is used the average time an airplane needs to cross equator at an average speed of 900 Km/h. It would take around 45 h to complete 24'mi.

Time that goes from A1 till C5 is equal to 45 h at approximately 900 Km/h. So, distance from A1 to A5 in a total of 8000 miles represent approximately 15 flight hours. Same happen for B1 to B5 and C1 to C5. From A1 to A2 there is 1600 miles which represent approximately 3 flight hours when trajectory is done in a straight line.

E.g.

Aircraft is going from Airport Pink to Airport Turquoise. Airplane is going from B4 18'mi to C2 13'mi. From the perspective of the presented map airplane is going down and right in trajectory. He will go down 5'mi. Airplane will take around 8 flight hours to complete trajectory.

If trajectory from B1 to B2 would be linear (horizontal) it would represent 1,6'mi and approximately 3 flight hours to complete. So:

24'mi = 45 h;

1 h = approx. 0,5'mi = approx. 804 m or 0,804 Km; and

1 Km is approx. 0,6'mi.

Distance measurement patterns

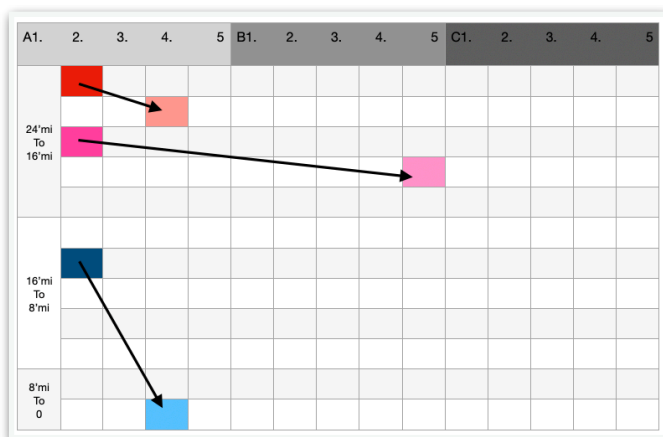


Figure 5: Distance Variation Patterns.

In the following table we present three distance patterns with different duration in time using variable length and depth for variance calculation.

Light gray represents area A1 to A5, medium gray B1 to B5 and dark gray C1 to C5. All examples start at A2 and end at A4 or B5.

Considering following table starting from the same point in light gray A2 trajectories can vary in length and depth. First red combination has the lowest depth and smallest length. Pink has the same depth than red but more length. Blue has same length than red but is deeper.

When looking to the arrows and taken into count that distance represents time, pink trajectory is longer in time than red and blue ones. For blue, even length is the same as red we can see trajectory is longer in time through its deep.

So red has the smallest trajectory, blue longer than red and smaller then pink and pink the longest trajectory.

Rule 3: Trajectory

Trajectory can be measured through miles. If I say aircraft goes from 24'mi to 20'mi, then I know aircraft according to map is going down vertically.

If I say aircraft goes from 24'mi A2 to 20'mi A3 then I know aircraft goes down in diagonal with a deviation to the right.

Opposite happens if I say that aircraft goes from 20'mi to 24'mi and from A3 to A2. Then trajectory reveal that aircraft goes up and there is a deviation to the left.

4. Research Methodology

Online assessment

For assessment of ATCF it was conducted research on Google with key” Free Online Assessment tools” to test the code and its rules. There was a total of seven websites analyzed.

A total of 33 tools were collected, most cited one was Quizlet with four mentions along the seven websites. Due to limitations second option with three mentions was selected to conduct the assessment – Google Forms.

Tool

Google Forms is a free survey tool that allow to create online quizzes and questionnaires with features like multiple choice and selection box. For this study it was selected multiple choice with true or false answer options.

Quiz contains 26 questions about ATCF instruction. Each question equals 1 point from a total of 26 points a participant can collect. In the end of the assessment responder can check their results.

Training

Before starting the quiz, it was asked participants to study ATCF rules by providing them with a PDF (Portable Document Format) containing examples and detailed explanation of code’s functionalities. After that a link to Google Forms was shared for participants to access the quiz.

Sample size

For development of research, it was selected target of young pilots (male and females) ranging ages of 28 and 48 years and trainees or students aspiring to become pilots.

According to studies as age increases pilots tend to perform less mistake handling critical flight situations compared to younger ones. Exposure to flight increase probability of error and most errors are conducted by men compared those made by woman's (Matthew Krebs and Guohua Li 1995).

Flight hours and experience do not relate to pilots and may create bias when considered together. Young pilots can reveal higher experience with less flight hours than older pilots. Studies indicate higher flight time may increase probability of incidents.

Exposure diverges from flight time being linked to flight experience and not its duration. Exposed pilots are those who experienced different flight situations and have reach overview of flight probability. Opposite to flight time which can be collected always in the same flight scenario.

Overall, it is proved that increased flight time decrease accident probability. According to similar studies a range of about 50 and 100 samples were collected to conduct research. Studies were focusing on air traffic control measures, assessment, validation and analysis. This range will also be used to conduct present research on ATCF.

It was done research using strings “pilot school”, “airports” and “pilot association” to collect contacts of pilots or future pilots from schools and training centers. It was used Google and LinkedIn to do the collection of 364 contacts.

More than 200 contacts are schools, forums, groups and associations from different countries and localities. Rest of the contacts represent private persons like pilots collected from LinkedIn.

Disclosure and collection

Collection of the result was done online by automatically saving participants answers to questionnaire. Outcomes of the answers were transformed by the used application into statistics for further analysis.

Graphs are generated to preview collected data and organize them according to desired results. Informations about wrong and correct data and points collected can be seen in the statistics. There is the possibility to see answered questions one by one or in a feed.

Only one response was collected from the sample size other participants either felt unconfident answering the quiz saying not being able or not having enough knowledge to answer it or felt uncomfortable answering quiz due to unknown source stating not being a professional request for participation.

Other participants, main of them said having no time, being busy, answering later or demonstrated confusion about the responding procedure and gave up at the middle of it. Some said they would answer but they didn't.

It was given possibility for participants to make questions about the learning material and questionnaire. Non of them demonstrated any doubt about questions presented. There were participants that had some difficulties accessing quiz link demonstrating issues opening the website.

Result collected is from unknowns respondent with 10 correct responses from a total of 26 questions. Analysis of responses given is provided in section 5 of this research.

4.1. Challenges

Cybersecurity

Cybersecurity is one of the main challenges regarding air traffic control due to increase in automatization of computer software's.

They need to become more protected against cyberattacks to aircraft IP (Internet Protocol) networks, digital air traffic controls and Flight-By-Wire systems (Bashar Ahmed Alohalil 2023).

Interconnectivity, supply chain and digitalization are challenging and reveal cybersecurity vulnerabilities. With an increase in cyber threats author suggests a standardized, integrative and neutral operation strategy.

Accessible learning and regulated access to information and understanding are some important topics of discussion within the Cybersecurity community. Encryption such as use of unique commands and controllers are a way to protect the system from cyberattacks.

Sontan Adewale Daniel and Samuel Segun Victor 2024 have been studying trends on cybersecurity for critical infrastructures like aviation industry and air traffic control.

Main concerns are connectivity, network complexity and digitalization. Modern technologies like AI (Artificial Intelligence) and ML (Machine Learning) have been applied to optimize those processes.

Warning system, gab identification and preempting attacks are examples where AI and ML are implemented. Also they allow use of smart authentication and encryption tools (Sontan Adewale Daniel and Samuel Segun Victor 2024).

Other technologies are identified by authors such as VR (Virtual Reality) and AR (Artificial Reality) to automatize and enhance cybersecurity trainings and simulations.

Wesley Murisa and Marijke Coetzee 2024 listed some of the main vulnerabilities of ATM services regarding security measures. Signal modification, flooding, data injections and GPS spoofing are some of them.

CNS (Communication, Navigation and Surveillance) systems compromise main ATM and ATC services. They are essential to track location, traffic and landing operations. Any interception on those systems can cause serious damages.

Other compromised technologies are VHF (Very High Frequency) and CPDLC (Controller Pilot Data Link Communication) done through wireless connection.

System intelligence

System must become more self-efficient due to increasing automation of aircrafts. Several models and frameworks have been developed to optimize prediction and perception rate to avoid accidents and put system closer to cognitive abilities offered by humans.

Passive fatigue

By reducing workload passive fatigue occurs associated to low stress levels. Reducing tasks, increase importance of maintaining pilots' attention and interest in flight.

Autonomy

As studies indicate, automation can create dependency and reduce pilots' ability to solve air traffic problems. It is important to maintain pilots' awareness and safeguard its independency and capability handling air traffic conflicts.

Complexity

As air traffic increases, complexity reveal new challenges for safety and management operations. Human role in safety is higher when systems complexity increases (Jamie P. Brown 2016) giving focus on what tasks should be automated.

Mark L Knapp et al. 1978 notice the fact that nonverbal often is underestimated and excessively simplified. Aspects such as nonverbal communication attractiveness or contexts are very important for its effectiveness.

Expressions should obey an hierarchy and be ruled to be effective and organized (Roland Friedrich and Angela D. Friederici 2009). Authors also mention mathematical syntax for the activation of processing modules and task performance.

They also proved that ruled-based and decision processes are effective when compressing and reading information in complex systems.

4.2. Objectives

Main objective is to simplify air traffic control tasks by reducing bias and communication errors caused by current implemented verbal code used between controllers and pilots.

Abolishing grammatical complexity, cultural influences and verbal distortion from transmissions with instructional code solve main communication error detected.

With ATCF it is pretended to contribute to aircraft automatization and same time promote pilots' autonomy and independency handling traffic conflicts.

As previous studies pretend to increase system intelligence, ATCF focuses on contributing to pilots' awareness, autonomy and operation ability.

Studies like Shawn R., et al. 2009 show that it is estimated air traffic flow to double or triple until 2025 in consequence there will be increased flight delays.

They also explain that aircraft should maintain an average speed to cover fuel costs. In addition there is a decrease in airspace capacity that cause traffic constrains.

Authors also notice in their study that airlines often don't worry about each other but only care about their own strategies which strains traffic management and monitoring operations. They describe that airlines act only according to their own business model not attending models or solutions form the others.

As mentioned by Eirini Balta et al. 2024 time is an important measure of performance linked to cognitive demand and modulated by workload. They also describe workload as a basis of ergonomic parameterization through task-operator interactions.

The use of English as common language increases mental load for native and non native speakers. Non native speakers because they need more effort to communicate with native speakers and native speakers to communicate and understand non native speakers.

ATC strategies and choices for decision making attend to mental load and try to minimize it as much as possible to achieve a positive load balance. Workload has as well an influence on pilots psychological and physical health and can cause heart, visual and respiratory problem if excessive.

4.3. Advantages

Delay

Short message is key to communicate efficiently with ATCF using a code to translate ideas, symbols and meanings.

Content is transmit more quickly and with more ease to understand reducing delays related to perception difficulties, wrong translations, miscommunications and rectifications.

Code should help further research for automation features promoting more mechanical thinking and operational abilities to deal traffic and air congestions.

ATCF should help reducing delay caused by system failures, monitoring, assistance issues providing pilots with more autonomy and knowledge about air space to deal air traffic problems.

Interference

Removal of controller's presence in air traffic control tasks is the technique used to reduce bias caused by interferences during flightpath.

Difficulties relating to communication or informational understanding are reduced between participants by removing dialogs, interactions and information sharing between them.

Pilots through ATCF should face monitoring alone by only receiving instruction. It will not be required them to think, give opinion or take decision about air traffic control tasks.

Participants should only be able to understand code and operate desired tasks for problem solving.

Redundancy

No use of grammatical is the strategy adopted to solve issues regarding excessive information's, redundancy and delays during transmission.

Redundancy also characterizes main communication issues between pilots and controllers. Knowing there exists biased and unnecessary informations, excessive verbal details and too much abstract elements such as punctuation.

Redundant information are frequent in common communications and they had in cases of emergency, and conflict situations to delays that may affect resolution outcomes.

Such redundancies are for example the use of colors, sizes, dramatic, syntax or semantics that are unnecessary for the transmission of an idea. ATCF replaced verbal alphabet by a algorithmic combination that represents a communication code based on numeral code.

This strategy pretends to remove bias of same letter or word having different meanings, non understanding of letters due to non native speakers and complexity of composition of words, phrases and dialogs. Code does not use such components reducing interactions to a more simplified representation.

Mental load

By using instruction, it is solved the problem related to cultural influences and understanding errors caused during interpretation processes. Excessive cognition, perception and translation tasks cause mental load that opposite from work load cause psychological effort.

This may cause fatigue, mind wandering and other problems affecting operational performance from pilots during conflict situation of air traffic control. It does not allow safety, accuracy and perfection essential from the resolution of a problem.

Techniques such as those used in ATCF pretend to reduce such levels to optimize pilots ability and skill set during flightpath. The lower the mental load is the more attentive and active

pilots mind is to predict and detected problems. It also increases its ability to solve the problem with more flexibility and accuracy.

Pilots mental state turn more positive, trustworthy and exact making decisions with more correctness then in a loaded, tired, bored or sick mode. It is important to train mind at same time when reducing load to stay active, interested and involved in flight maneuverings.

This will allow to avoid passive fatigue, non interest or other consequences from low loaded work environments. Pilots should be stimulated even not being in a loaded context to stay interested in operations needed to be executed further.

5.Results

As a result from the sample size collected and experiment conducted it is possible to observe a low participation rate. However there was engagement, interest and appreciation for from participants.

Their profile as a participant of the research is similar to the one described in air traffic control literature. Analysis is based on behavioral, communication and reaction of participants when being presented with ATCF.

They showed low trust, low ability to access online assessment independently, need for monitoring, unconfident when answering and learning new tasks as well as applying their knowledge. They felt un responsible and recommend others, fear for participation due to policy concerns, tendency to suggest rather than acting, oblivion, rush and avoidance of responsibility.

Participants have shown through their responses low urgency, low availability, self-scheduling, fake promises, curiosity and enthusiasm. From the sample size collected only a few participants, the equivalent of 10 people, provided a response.

The participants that respond to the assessment collected 10 points from a total of 26 possible as observed in previous section. Wrong answers relate to acceleration rules, velocity, composition, hierarchy and appearance.

Participant also failed questions related to measure, amplitude and projection and shown difficulties regarding code representation questions, layers and areas. It is possible to notice low levels of modulated thinking and spacial awareness.

According to current air traffic control tasks it is not used a specific protocol to conduct the monitoring of traffic operations. The presentation of a ruled code with standard operations can be something new to participants.

They will require training, mental preparedness, mental modulation to face new traffic control operations with implementation of ATCF code.

They will require to be more self confident, trained, have mental ability to preview and predict concrete measures into abstract space, have modulated thinking and be organized and think hierarchically.

They should become aware of space, maneuvering like speed control, acceleration and directional mastering to be more autonomous and conscious of operations in order to reach performance.

It can be concluded what previous research observed, dependence on technology or controllers guidance towards tasks removes pilots confidence. Pilots are also not willing to participate, demonstrating low trust, no interest, stress and redundancy as well as rejection of cooperation and communication quit.

Participants shown to be lazy, not aware of need for cooperation as well as not interest to learn or adopt measures to prevent air traffic communication problems. They need to be modulated according to ATCF instruction to be more attentive, informed, aware and active demonstrating willing and operability.

Trust levels should be stronger by demonstrating and showing pilots wrong examples of current communication code and resolution of them through ATCF code. They should become trust on system, as well as themselves.

They should as well feel confident by staying informed, feeling comfortable with system interaction, learn tasks and its features. It should be taken control of maneuvers of air traffic control operations what they do not have currently with ATC monitoring.

Their answer to invitation of cooperations revealed complexity, high workload and mental load, confusion and low perceptibility. Pilots should be introduced to the new version provided by ATCF with more facilities, ease and compact functionalities.

New communication code designed should facilitate perception, translation and understanding of desired tasks to be executed during air traffic control.

5.1. Conclusions

Study has shown efforts in the past and present to reach operational accuracy along air traffic control tasks. Researchers have been creating models and frameworks to help systems turn more efficiently and precise predicting possible risk situations and providing quick and accurate solutions for it.

Main objective is to reduce the much possible air traffic incident rate that cause losses in human lives, economy and environment. Mental models, cognitive and behavioral studies have been conducted to incorporate human intelligence into systems and machines.

It is pretended to kit system with basic human natural and hereditary knowledge in order to replace their main abilities and skills when doing problem-solving. Machine should be able to replace humans intelligent acting and thinking to optimize technological models based on artificial intelligence.

Predictors and reactors are used to obtain positive and accurate data about locations, trajectories and behavioral patterns. They think long term and search preventive outcomes. ATCF is short term based focusing on small and quick instructions of monitoring air space problems.

It is also proved that there is a possibility to reach desired solutions through techniques like arithmetic application, rhythm, modulation and representation through schemas. They collect participants natural skills and use them to reach outcome and performance.

Technology developed to automate system is also proved to work for optimization of prediction tasks in conflicts and possible communication errors or transmission failures. Together it is possible to reduce incidents both from machine and human side.

As observed in literature review main mistakes detected in air traffic control are conducted by humans which caused a need for ATCF creation with the objective to provide pilots with more mental ability, memory capacity and physical accuracy to operate and reach objectives.

ATCF should fix through strategies listed above and proved to be efficient in different contexts problems such as aviation disorientation, confusion, low perceptibility of features, measure and calculation difficulty. Should as well create more trust, control of fatigue, reduce system misuse, solve personality biases, mind wandering and align intention of operation.

By doing this there will be a fix in main errors detected during communication between ATC stations and pilots as well as issues regarding aircraft maneuver during conflict and emergency situations.

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