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Reflections on automation and the need for new competencies in the civil pilot training

Abstract

Although automation is an increasingly present reality in aircraft control systems, the absence of adequate systems training and pilot training has been a worrying factor that may affect performance. Based on the studies developed by Machado,[1] Hollnagel et al.[2] Henriqson et al.[3] Bent,[4] Fontes[5] and others, the paper discusses the complexity of technological tools currently being used in automated systems of modern Aircraft and the pilot training challenges confronted with new demands of the highly complex technological world, where psychomotor skills alone are no longer enough for the safe performance of the profession. The following paper proposes an innovative training that emphasizes the development of new competencies requiring pilot cognitive control skills in a new human-machine interface. The paper presents two new competencies to be integrated into the main competency framework proposed by ICAO: single-pilot resource management and commitment to learning..

Keywords: automation, human-machine interaction, cognitive control, competency-based training

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'System control' as an essential tool

The results of some investigations on aircraft accidents point to the crew's unpreparedness in properly monitoring the aircraft`s automation systems as one of the contributing factors to accidents[3] in other words, increased volumes of information regarding the conditions of a given flight without proper analytical and solution training may lead to more accidents.

Although measurements and data are necessary to control, understand and predict technological systems' behavior, the data themselves are not enough. The belief that more data or information automatically leads to better decisions which is probably one of the greatest mistakes made by the information society.[2]

The idea of an information society has its origins in the scientific and technological advances of the post-industrial revolution. This has created a "new reality that demands competencies and skills from individuals to deal with the computerization of knowledge".[6]

In this regard, it is important to highlight that the concept of knowledge is not reduced to information itself, which is its raw material. It is necessary to elaborate access, analyze and relate the information so it can be transformed into knowledge. Currently, the possibility to access information is infinitely greater than it was in the past due to the new information production sources, such as the internet, interactive cell phones, applications that reproduce real-time data, dynamic production in the network, flexibility, flow, etc. However, they only produce information, not knowledge.

The information constitutes the knowledge's foundation, but first, its acquisition implies the triggering of a series of intellectual operations, which relate the newer data with the information previously stored by the individual. Knowledge is acquired when many information mutually interconnect themselves, creating a network of meanings that interiorize themselves. Currently, one of the disturbances provoked by the media is the fact that modern human beings believe they have access to the meaning of events, simply because they have received information on it.[7]

Currently, given the advanced technologies present on the latest-generation aircraft, whose data and information production is shown to be more complex when compared to the past, it is necessary to rethink the preparation, the professional activities and the knowledge the pilot has regarding these complex technologies in this new worldwide scenario.

Hollnagel & Woods[2] mention three significant consequences arising from the growth of the new technological systems' complexity:

A. **First consequence:** The search for greater efficiency inevitably brings systems closer to their limits of safe performance. Even having different concepts about risks or training safety concerns, or taking the public opinion or the Aeronautics Industry's business purpose into account, it is possible to accept an increase in risks in an operation that involves automated systems, when an efficiency gain is aimed.

Greater risks are reduced by applying automated security and warning systems. However, these may increase the complexity of technological systems and lead to even greater risks, thus creating a vicious cycle that spins around the search for safer ways to fly and more direct means to have systems with safer operations.

It is necessary to emphasize the authors indicate the fact that the increase in the use of complex technological systems may keep or even contribute to a reduction in the number of accidents. On the other hand, future accidents that occur may have even more severe consequences, because operators of modern equipment need to better understand the new complexity of the systems.

B. **Second consequence:** An increase in the dependency on the proper performance of the technological systems. A system failure may lead to consequences far beyond the working natural environment in which the operator/pilot is used to live and work in.

The increase in the interdependency between the various flight control systems creates the need for issues related to the man-technology interaction to be also extended to subjects linked to the design of the technological systems on the several environments, to the deployment of systems on the activities, and to the management and maintenance of these systems.[8]

C. **Third consequence**: Finally, the significant increase in the amount of generated data. The number of systems has increased and, with that, the amount of data that may be obtained has also increased. Thanks to these and other improvements, the measurement systems and the transmission capacity have improved too. Computers have contributed to managing increases in data generation as well as greater flexibility in the storage, transformation, transmission, and presentation of these data.

These notes express new demands for the models and methods that describe the man-machine interaction, as well as a new paradigm for the science that supports this process. The digital paradigm has modified in significant ways the human relationship with the various machines they interact with. New competencies are required to address the demands presented by these complex systems.[9,10]

Thus, from the digital paradigm perspective, the ability to make decisions and the experience are intrinsically related to the operationalization of new competencies. Competencies can only be put into practice based on knowledge, flying skills, and attitudes acquired by the pilot. It is necessary for pilots to learn what the purpose of the knowledge is, and when and how to apply it to the management of different technological variables present during the performance of a flight, both inside and outside an aircraft's control systems.

Thanks to the increasing use of complex technological systems by the aeronautics industry and to the use of automation as a control philosophy for air operations, changes in the pilots' working environment, including their cockpits, indicate a progressive and continuous shift on the type of activities performed by those professionals. Whereas flying was traditionally considered as a typically physical or mechanical task, nowadays, it is increasingly considered as a mental or cognitive activity.[11]

Nine main categories were described by ICAO (1998) in a study performed by the subcommittee G-10, from the Automotive Engineering Society, which approached the deficiencies of information systems and the possible reasons for those deficiencies in some accident 'reports'. The categories identify some important concerns to be analyzed:

i. Situational awareness;
ii. Complacency with automation;
iii. Intimidation by automation;
iv. Conservation of the pilot-in-command authority;
v. Design of the aircraft's pilot-systems interface;
vi. Pilot selection;
vii. Training and procedures;
viii. Pilot 'relation' to the aircraft's automation; and
ix. Other issues.

These study categories cover the concerns of those responsible for the system involved in the activity aspect modification. The nine categories refer, directly or indirectly, to the mental or cognitive nature of the air experience. The systems operator's attention must be directed towards a better interaction between those and the technological machines and equipment.

As stated by Ribeiro,[10] the evolution of automation systems has made air operations safer and more efficient over time, severely reducing the number of accidents due to equipment failure. These systems support pilots on aircraft performance, flight security and fuel economy. Nevertheless, the complexity of the current automation systems demands decisions that require knowledge and command of all the available automated resources in the cockpits.

Although the statistics point to human error as the main reason for aircraft accidents, it is important to emphasize that, as stated by Ribeiro[10] it is also known that these errors are a result from scenarios which involve, besides the pilots, the pilot training, airlines and the engineering behind the automation systems.

Considering the complexity of current technological systems, some aspects must be observed that may improve the man-machine relationship. As mentioned by Hollnagel & Woods,[2] complexity is understood as a more structural way, which involves the development of systems and control systems aiming for safer operations over time. The complexity issue and the factors that affect it can be viewed in Figure 1.

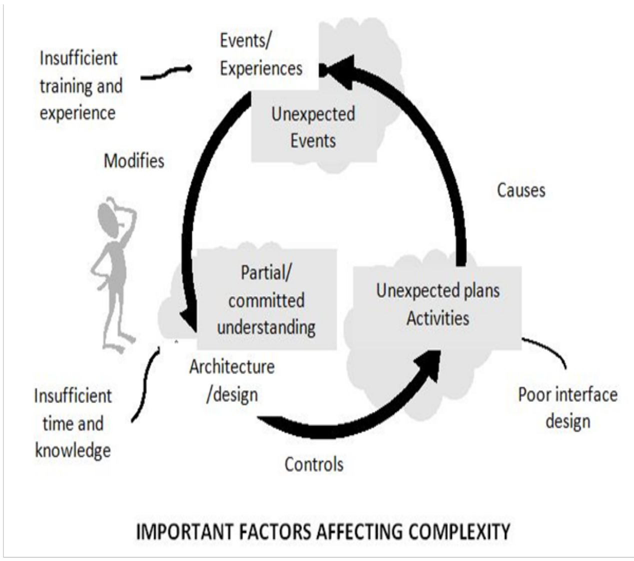

Figure 1 Crucial factors that affect the complexity of modern systems.

In the above diagram, Hollnagel & Woods[2] aim to identify three relevant models of man-machine communication. The first one is perceived as the identification and assessment of events that occur during a certain activity. Two important factors to be noticed are the insufficient training and lack of experience; these event assessment and interpretation deficiencies may result in an incomplete, partial or improper comprehension of the situation.

The second factor is time and insufficient knowledge; even if it is possible to identify a problem, it is very difficult to keep a correct execution attitude of a specific task if the time for a specific context and/or the knowledge of a specific reaction are not sufficiently satisfying. These factors are paramount, especially for abnormal moments, emergency situations or for understanding confusing responses from onboard equipment.

Finally, the third factor present in the figure is the system's complexity, which combined with the lack of knowledge for its proper management makes it difficult the interaction of pilots with the information produced by equipment or the interaction devices, especially after analyzing data obtained from the several aircraft sensors, which show the operator what the better attitude to be taken is, in a specific situation, when operating in a proper way and without any breakdowns in the system.

However, as stated by Hollnagel & Woods,[2] if the pilot-machine interaction devices are difficult to be interpreted or comprehended, the implementation of a corrective or directive action may be incomplete or even incorrect.

ICAO[12] states that several issues may be observed when the use of automation is not promoted with an adequate interaction between man and machine in order to support the needs and particularities of a specific situation during flight. For Hollnagel & Woods,[2] these deficiencies, listed in several studies, characterize a certain loss of control by the operators, justified by a lack of time to act quickly, a lack of knowledge regarding the onboard equipment and their modus operandi, and even a lack of essential competencies required for the comprehension of advanced cognitive systems.

This absence of skills, knowledge, and attitudes involved in the handling of highly advanced equipment may cause the sensation of loss of systems control by the operator. Among the several reasons that would justify the sensation of loss of control and incorrect interpretation of equipment readings, one can mention: the unexpected or unknown events that occur during operations, the pressure to act in a short period of time during emergencies or abnormal situations, the inability to comprehend or recognize what occurs during specific moments in operations, not knowing what to do in a specific context, and not knowing how to use resources, materials or cognitive skills, especially in abnormal situations or during moments when the absence of automated systems is inevitable.

The process of keeping control over equipment occurs by knowing and comprehending what happens (constant supervision), what happened (feedback) and what will happen (feed forward), in a certain moment, for a certain reason, within a specific context.

To help the comprehension of a process and keep control through constant supervision, Hollnagel & Woods[2] present the river metaphor in order to recognize the feedback and feed forward elements, as it can be seen in Figure 2.

Other important factors that help pilots to keep control over cognitive systems clearly understand the alternatives of actions and procedures and the ability to plan and assess certain situations, which are skills that should and must be developed in an operator/pilot who is using advanced cognitive systems.

The increasing complexity surrounding the cognitive systems may result in an incompatibility between the demand of these systems tasks and the operating capacity of system 'controllers'. This deficiency may be reduced or even extinguished by simplifying the cognitive systems or improving the preparation and qualification of its operators, or even both.

Concerning the training, Hollnagel & Woods[2] argue that the development and improvement of essential competencies are paramount to keep or retake control of several technologically-advanced operator/pilot systems.

The Federal Aviation Administration[13] has already stated that the pilot preparation and training methods are inadequate and do not promote the development of skills to operate an aircraft safely. The study has demonstrated that the development of training in aircraft environments with a high degree of automation does not favor the development of the fundamental cognitive skills to perform a safe flight.

In order to overcome this issue, the report has suggested exploring additional opportunities for security of new technologies or operating within the limitations of such technologies in the training programs, including the development of competencies that lead the pilot to make more accurate assessments of flight risk as well as to know how to properly manage the flight risk in situations that traditionally cause fatal accidents, such as abnormal operations.

The competency-based training is geared towards mobilizing, integrating and transferring the knowledge, attitudes, and skills required to perform a given activity or task effectively. The correct mobilization of knowledge and skills to perform a given task provides subsidies for proper decision-making in unexpected situations that may occur in the exercise of an air operation.

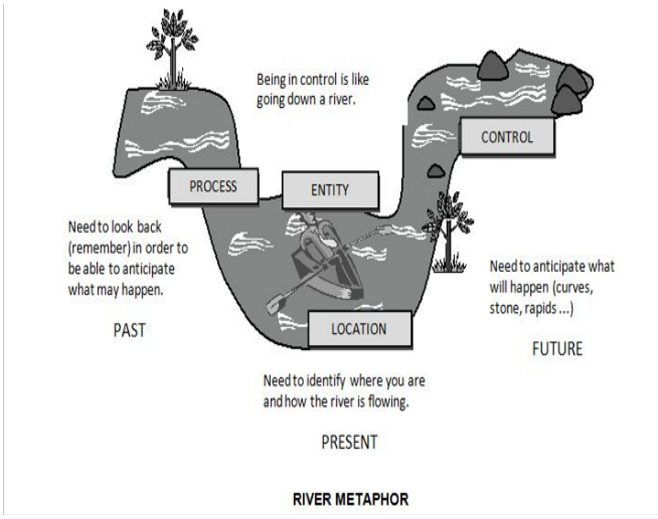

Figure 2 River metaphor.

The 'cognitive control' for the highly-advanced systems

According to Reason,[14] the automation has not eliminated the human error; rather, it has only modified its nature. In the introduction of automation, the human error had as advantages, among others, the reduction of its physical workload during some moments of a flight, and the reduction of fatigue due to the elimination of some repetitive tasks on the aircraft's control.

However, the mental workload has increased during the several phases of a flight. Today, the cognitive control is necessary from the pilots for a safer and more effective maintenance of operational relationships between pilots and advanced technological systems.[3]

The cognitive capacities to be considered are the perception of specific information, the comprehension of data produced by various systems and the pilots' ability to analyze and comprehend that information (knowledge) for future application.

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Endsley[15] support this implication by stating that the comprehension arising from several situations or the positive keeping of the situational awareness is cognitively processed in three levels:

1st level - the perception of the current situation's elements;

2nd level - the comprehension of elements perceived through the activation of mechanisms from memory and direct or indirect association with mental models (mindsets and plans) closer to the perceived situation; and

3rd level - the manifestation of anticipation mechanisms, which is, as pointed by Hollnagel and Woods (2005), the feedforward, a future state of the system.

This cognitive control, controlled by the situational awareness kept by the pilot during flight performance is what indicates the level of cognitive effort made by the professional, which is an effort classified in three control levels established by Rasmussen.[16]

To Rasmussen,[16] cognitive control can occur in a conscious, unconscious or mixed way, depending on the type of cognitive requirement derived from the most varied situations processed during a flight.

The levels of cognitive control presented by Rasmussen[16] are:

1st level - Skill-based behavior - SBB: a moment in which there is a higher predictability degree of the situations, and the pilot will be able to rely on his/her skills or basic psychomotor skills to respond to the different situations;

2nd level - Rule-based behavior - RBB: situations pre-determined by procedures established by or present in the current regulation; and

3rd level - Knowledge-based behavior - KBB: unforeseen situations that will need the acquired knowledge, practical or theoretical, to be solved.

As mentioned by Dekker et al.[17] one of the most important challenges the current commercial aviation faces is the pilots' training on the transition from a traditional cockpit analog paradigm with mechanical thought to a highly automated and sophisticated environment, such as those seen in glass cockpit aircraft. The introduction of concepts related to automation and its use must occur during the first moments of a pilot's training.

As already shown, the technology brings two sides with it.[18] At the same time it enhances the pilot's and the aircraft's potential and capabilities, it significantly increases the pilot's mental workload and thus requires further investments in pilot training and preparation.[5,8,12,17]

New competencies for effective 'cognitive control'

Due to new requirements on the technological world, the preparation of civil aviation pilots must assume a position in which it supports the demands of a world where the complex socio-technological systems are more present over time, being necessary to redefine features and purposes of the preparation, as well as the demanded competencies for a 'new' pilot.

The need for changing the structure of the civil pilot training and preparation due to the constant and continuous evolution of new aviation technologies generates the need to rethink the educational policies regarding the improvement of commercial pilots, especially on the use of new tools suitable for newer and more complex flight environments in which they are being introduced, from the moment they begin their pilot training and preparation.[19]

On the aviation sector, which is not different from other sectors that had an increase on automation for the execution of their tasks, the pilots have been experiencing the reflexes of this new situation present in the spheres that use the technology with the goal of increasing the safety and reducing the operational costs, among others.

As stated by Pezzi,[20] the worker of a sector with a high technological use must develop some skills, such as being creative and adaptable to new situations, know-how to execute multitasks, taking proactive attitudes, trusting their own decision-making capacities, having a humanistic education, finding solutions in risky situations, and ability to keep interpersonal relationships.

Knowing how to be engaged in a dialogue on a specific subject means to receive specific information and process it in such a level that it can be transformed into tacit knowledge and from it into an express action or knowledge, enabled by the creation of new relationships with the articulation between the several studied contents.[21]

When it comes to competency, some points must be considered. Primarily, it is necessary to conceptualize the 'competency' term. For Alessandrini,[21] "competency is the capacity of a person to understand a situation and to act reasonably". In other words, it is a group of resources (background) constituted by knowledge, attitudes, and skills, through which an individual's performance is assessed by showing a specific knowledge at practice.

Therefore, competency can be comprehended as the capacity to assess experienced situations, establish a parameter with what was experienced, identify abnormalities, react in a proportional way to the moment and to suggest/act in order to perform as better as possible, with the intention of clarifying or solving any existing issues.

Machado[1] states that: [...] for some time, the transformation of the tasks' structure occurs at a fast pace. Nowadays, it is not learned how to handle a certain type of machine that will soon become obsolete. It is only learned how to read and understand the instruction manual of a new equipment, learn general standards of operation from several types of equipment, or even to search fundamental elements for a competent use on the new software's help area.

Therefore, it is extremely important that the school education must provide conditions for the professionals so they can have the basic competencies for a better acting in face of the new requirements from the different sectors.

Among the several competencies, it is possible to highlight:

[...] capacity of expression, comprehension about what is being read, interpretation of representations, mobilization capacity for progressively more complex and significant action schemes at different contexts, capacity to create relevance maps of the available information, aiming in the decision-making, ability of collaborating, of team working and, mainly, the ability to project the new, to create a scenario of problems, values and circumstances in which one is inserted and must mutually act.[1]

According to the DeSeCo report,[22] "competency is a holistic concept that integrates the existence of external demands, personal attributes (ethics and values included), as well as the context".

For the report, competency becomes the group of knowledge, skills, and proper attitudes to face a certain situation and also, "the skill to successfully satisfy the demands of a context or situation, providing the required psychological resources (from a cognitive and metacognitive aspect)".

As stated by Sacristán,[22] the basic competencies are those which empower the individuals to participate in multiple contexts or social scopes in an active way.

It is important to develop the aspects related to competency - knowledge, skills, and attitudes - in the professionals so they are able to respond to the social demands according to the needs of a given problem, either from a technical or personal range.

As reported on the final report of the Organization for Economic Co-operation and Development - OECD, explained on DeSeCo, the basic competencies can be grouped in three categories:

a. Interacting at the core of socially heterogenic groups.
   i. Ability to properly engage with others;
   ii. Ability to cooperate; and
   iii. Ability to handle and solve conflicts.
b. Working autonomously
   i. Ability to act within a general goal; and
   ii. Ability to plan and execute personal plans and projects.
c. Using interactive resources or instruments
   i. Ability to use language, symbols, and texts in an interactive way;
   ii. Ability to use the knowledge and information in an interactive way; and
   iii. Use of technology.

Consequently, competency may be understood, among so many possibilities, as the capacity to mobilize the acquired knowledge on the use of essential skills with a certain attitude, aiming to face any situations arising from trainings, or standardized situations, to enable the acquisition of satisfactory results on the most different situations experienced on the operational environment, especially the unexpected ones.

More important than learning the content from the several subjects in school, it is essential that the preparation of a pilot provides conditions for them to use their potential.

As affirmed by Machado,[1] the professional training must enable an "incorporation of the awareness provided by the construction of emergency channels with a mobilization of what was learned and what is known". Thus, it is necessary to provide affective-cognitive opportunities for the professional to explain what they would only have as a tacit or implicit knowledge in the past.

The spectrum of competencies Machado[1] denominated as 'personal' is not developed in a methodology in which there is only the technical aspects and the independent appreciation of the content. As stated by Machado,[1] the technical education makes the tacit knowledge retention non-feasible, disabling the professional's ability to articulate a theoretical knowledge with the practical ability; in other words, putting into practice what was learned on theory.

For Machado,[1] this retention may be made feasible by inserting the entire subject, content, fixed and technical knowledge in a broader context, and it may be characterized as a contextualization on the teaching-learning process.

Contextualizing means "to retain a reference from a text from which it was extracted that loses a substantial part of its meaning when separated from the text". For the author, this is a fundamental strategy for the construction of meanings.

What can be said about an environment with a high use of technology?

Would it not be necessary basic competencies that would allow the resolution of conflicts between information every time they are needed?

For example, is it not expected that the pilot's knowledge should be 'retained/contextualized' so they can have conditions to put into practice the things he or she has learned on theory?

As already stated in the relationships based on knowledge,[16] the pilot must have physical, psychological, and cognitive conditions to properly respond to an unexpected situation during any moment of a flight. Therefore, would the use of modern technologies not require the 'contextualization' of several pieces of knowledge for its proper use at a certain moment?

For Machado[1]: [...] the professional training that aims the working world, as it is set today, must necessarily position the attention focus in something that is not new and has always existed, but that produced its effects in a supporting or collateral way: the basic competencies to be developed are related to the personal education, the personal capacities that transcend the studied subjects, which survive the transformations that are growing rapidly on the equipment and material production scenarios.

New challenges for the preparation of pilots

Despite all efforts to keep the high safety levels in the aeronautic system in general, and even knowing that the pilots' performance is a critical point for the aviation safety, their training remains more reactive and focused on motor aspects rather than proactive and concerned to creating and developing a better preparation for the pilot to act as an operator of complex technological systems.[4] A study performed by the Center for Asia Pacific Aviation - CAPA, in 2009, reported that the training is considered by the airline companies as a cost that can be avoided rather than a priority for company policies.[4]

However, the technological shift on the aeronautic environment requires a more active judgment from the training policies in order to transform it into a critical point for the safe development of the aviation sector, providing more favorable aspects for the automation use on the air environment.[13]

As stated by Bent,[4] the current aircraft have such complex flight management systems that it is hardly expected that pilots know or comprehend all systems with the depth that would be considered ideal to operate them in a safe and effective way. This already considering a proper preparation. Despite the complexity of a system, it is expected that a pilot knows how to competently operate an aircraft in all situations, especially in abnormal situations when the technology 'transfers' the responsibility for the pilot Bent.[4]

The aeronautic industry, in the attempt to keep its activities in high-security levels, creates software to surround all sides of the human fallibility. Technology has been evolving at an exponential rate over time, whereas the pilots, as human beings, keep their limitations, expand their skills and cognition, at least in what concerns the technical issues, according to their training, even if in a limited manner Bent.[4]

It is proven that the insertion of automation on aviation has reduced the number of accidents and incidents. Yet, failures and mistakes still remain, either due to the project design, the systems programming or even due to failures in the sector's regulation. To preserve the aviation security, more complex systems are created as a barrier so it can be certified that mistakes will not occur, increasing the systems' complexity and, with it, the pilots' demands for the interaction with the machines.[2]

By improving the systems with the aim to reduce latent and potential failures, the complexity of the tasks and comprehension required from the pilots are increased, besides an increase on the cognitive engagement in an air operation, creating a cycle without an established beginning and end, expressing the automation paradox.

In Figure 3 below, it is possible to identify the 'automation paradox'. Aimed to reduce the possibility of failures, the system is increased or receives adaptations to improve its functionalities. With it, the complexity of several available tasks is expanded, increasing the requirements from the operators/pilots at the same rate. If these individuals do not have the necessary preparation to deal with the applications from the complex systems, they are subject to not being able to handle unexpected failures, which will cause consequences that are also unexpected, leading to a new reassessment of the system and to a possible increase in its functionalities.

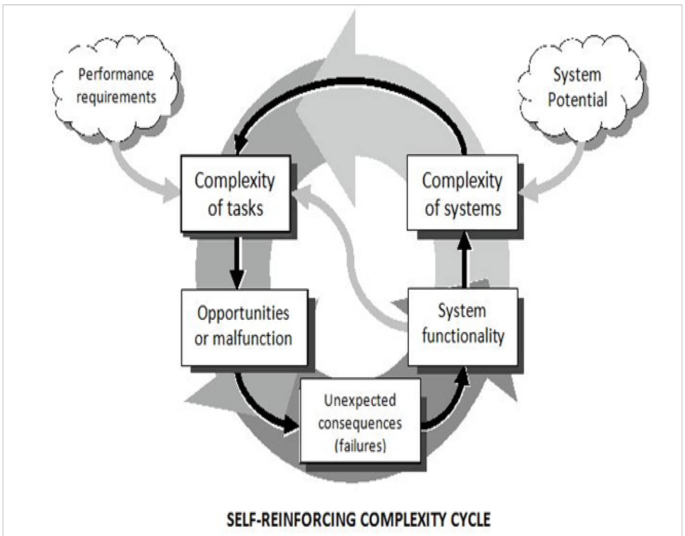

Figure 3 Self-reinforcing complexity cycle.

The pilot, more than an aircraft operator, becomes a manager and supervisor of modern and complex systems.[23] Thus, the challenge is to promote an efficient, useful and effective training in order to enable a pilot to comprehend and foresee the automation peculiarities, its nuances and limitations, and to incorporate this wide range of knowledge to the series of cockpit designs, the different features of each type of aircraft, the integrated control systems of the aircraft and to the procedures standardized by companies, and also to group these features to the fact of operating in an environment other than the natural one - the air environment.

In order to respond to such complexity, the pilots' training must include elements that benefit the development of competencies that help them to perform the activities of an air operation with safety and efficiency. But how should the model for a pilot's competencies training is? Based on the technological and social complexity, what would be the most proper training to be applied by an institution? How can one understand the competencies in the highly technological world as the aeronautical sector? Which are the necessary competencies for a safer operation of the complex technological systems in a cockpit?

The competency-based training in the pilot preparation builds on the idea that it is not possible to train for emergencies and unexpected events. However, it is possible to prepare the pilot for these situations through scenario-based (problem-solving) instruction, where key competencies must be focused in the training of the 21st century pilot. Learning is thus based on the mobilization of superior mindsets in the face of real or simulated challenges imposed by the environment, which would result in meaningful professional learning.

With severe criticisms on the adoption of the competency-based training model in pilots' training in Australia, by understanding it as a method that privileges the product rather than the process, that emphasizes skills at the expense of knowledge, reduces the assessment of observable behaviors and modulates the curriculum by scoring the minimum competencies to be achieved by the student as opposed to the development of more complex skills necessary for the safe operation of an aircraft, Franks et al.[24] mentioned "the need for CBT to be used in a more holistic and integrated way of what the current practice in the pilots training is" (page 143). The authors argue for the importance of adding the competency concept to problem-solving and decision-making in aviation contexts/scenarios to promote higher-order cognitive skills from the beginning of the pilot training, integrating skills and knowledge, theory and practice and reinforcing the ability to transfer skills to real flight situations.

The ability to make decisions and the experience are closely related in a competency's operationalization. Making a decision often involves some degree of improvisation, but an improvisation guided by experience and knowledge. The main elements of competency to be covered in the multi-crew pilot training can be defined as follows: application of procedures; communication; aircraft flight path management, automation; aircraft flight path management, manual control; leadership and teamwork; problem-solving and decision-making; situational awareness and workload management. These competencies and their respective performance criteria constitute a set of observable behaviors for a safe, efficient and effective multi-crew flight operation, according to the table below, formulated by ICAO.[25]

The essential competencies presented in the table above define the pilot's profile for flying automated aircraft, who must also demonstrate manual control of the aircraft. In summary, the training should emphasize the need for the pilot to recognize a divergence as soon as possible and immediately take the corrective measures and decisions required to return the aircraft to the planned path, either by managing the automated system or by manually operating the aircraft.

Analyzing the competency table, it is possible to verify that the presented competencies no longer distinguish between technical (operational) and non-technical (human factor) skills, seeking to align the training content with the challenges of the automated aviation environment, such as the management of threats and errors as an advanced discussion within the CRM concept.[26]

Those competencies demonstrate more than the transition from the "stick-and-rudder" aviation (analog paradigm) to the automated aviation (digital paradigm). They evidence the incorporation of the piloting concept from a manual aviation to a more technological one and impose new challenges on the pilot, who has a greater intellectual workload, requiring him/her constant vigilance and a high degree of judgment for unequivocal decision-making.

In addition, the development of technologically-advanced small aircraft, known as VLJ (very light jets), has introduced a new demand in the field of pilot training in the world. Also known as single-pilot aircraft, the VLJ can be operated with a single pilot that needs to control complex systems and decision-making alone. The VLJ has a maximum takeoff weight of up to 10,000lbs. (4,540kg) and adds technological features of larger jets such as: satellite navigation with one or more integrated GPS; flight management system and instrument panel with digital technology, which includes: moving map with information on the navigation, ground and onboard weather radar, traffic information, engine instrumentation, electronic checklist, instrument approach procedure data, etc. Moreover, these aircraft are available in the aeronautical market at affordable prices and carry up to seven passengers, which makes them an attractive option for newly qualified private or commercial pilots, or pilots with little flight experience and precarious knowledge on advanced avionics, which may contribute for faulty judgments and mistaken decision-making in emergency situations.

To that end, the VLJ have created a specific competency requirement not provided in Table 1, which is the Single-pilot Resource Management or SRM. In this concept, the pilot must develop the competency to individually manage a set of tasks effectively, becoming responsible for assessing, judging and making decisions unilaterally, which is not different from actions to be taken in class aircraft that have less complex operations but are also operated by a single pilot. Therefore, the pilot training should lead students to learn how to learn, to properly gather the most important data available, both inside and outside the cockpit, to identify possible courses of action, to assess the inherent risk of each maneuver, and to make proper decisions.

Adding this new focus to Table 1, the list of core competencies proposed by this paper would be established as follows Table 2:

Table 1 Description of core competencies and behavioral indicators.[25]

Competency	Competency description	Behavioral Indicator
Application of Procedures	Identifies and applies procedures in accordance with published operating instructions and applicable regulations, using the appropriate knowledge.	Identifies the source of operating instructions
		Follows SOPs unless a higher degree of safety dictates an appropriate deviation
		Identifies and follows all operating instructions in a timely manner
		Correctly operates aircraft systems and associated equipment
		Complies with applicable regulations
		Applies relevant procedural knowledge
Communication	Demonstrates effective oral, non-verbal and written communications, in normal and abnormal situations.	Ensures the recipient is ready and able to receive the information
		Selects appropriately what, when, how and with whom to communicate
		Conveys messages clearly, accurately and concisely
		Confirms that the recipient correctly understands important information
		Listens actively and demonstrates understanding when receiving Information
		Asks relevant and effective questions
		Adheres to standard radiotelephone phraseology and procedures
		Accurately reads and interprets required company and flight documentation
		Accurately reads, interprets, constructs and responds to datalink messages in English

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Table Continued...

Competency	Competency description	Behavioral Indicator
Aircraft Flight Path Management, automation	Controls the aircraft flight path through automation, including appropriate use of flight management system(s) and guidance.	Controls the aircraft using automation with accuracy and smoothness as appropriate to the situation
		Detects deviations from the desired aircraft trajectory and takes appropriate actions
		Contains the aircraft within the normal flight envelope
		Manages the flight path to achieve optimum operational performance
		Maintains the desired flight path during flight using automation whilst managing other tasks and distractions
		Selects appropriate level and mode of automation in a timely manner considering phase of flight and workload
		Effectively monitors automation, including engagement and automatic mode transitions
Aircraft Flight Path Management, manual control	Controls the aircraft flight path through manual flight, including appropriate use of flight management system(s) and flight guidance systems.	Controls the aircraft manually with accuracy and smoothness as appropriate to the situation
		Detects deviations from the desired aircraft trajectory and takes appropriate action
		Contains the aircraft within the normal flight envelope
		Controls the aircraft safely using only the relationship between aircraft attitude, speed, and thrust
		Manages the flight path to achieve optimum operational performance
		Maintains the desired flight path during manual flight whilst managing other tasks and distractions
		Selects appropriate level and mode of flight guidance systems in a timely manner considering phase of flight and workload
		Effectively monitors flight guidance systems including engagement and automatic mode transitions
Leadership and Teamwork	Demonstrates effective leadership and team working.	Understands and agrees with the crew's roles and objectives
		Creates an atmosphere of open communication and encourages team participation
		Uses initiative and gives directions when required
		Admits mistakes and takes responsibility
		Anticipates and responds appropriately to other crew members' needs
		Carries out instructions when directed
		Communicates relevant concerns and intentions
		Gives and receives feedback constructively
		Confidently intervenes when important for safety
		Demonstrates empathy and shows respect and tolerance for other people
		Engages others in planning and allocates activities fairly and appropriately according to abilities
		Addresses and resolves conflicts and disagreements in a constructive manner
		Projects self-control in all situations

Table Continued..

Competency	Competency description	Behavioral Indicator
Problem Solving and Decision-making	Accurately identifies risks and resolves problems. Uses the appropriate decision-making processes.	Seeks accurate and adequate information from appropriate sources
		Identifies and verifies what and why things have gone wrong
		Employ(s) proper problem-solving strategies
		Perseveres in working through problems without reducing safety
		Uses appropriate and timely decision-making processes
		Sets priorities appropriately
		Identifies and considers options effectively
		Monitors, reviews, and adapts decisions as required
		Identifies and manages risks effectively
		Improvises when faced with unforeseeable circumstances to achieve the safest outcome
Situational Awareness	Perceives and comprehends all of the relevant information available and anticipates what could happen that may affect the operation.	Identifies and assesses accurately the state of the aircraft and its systems
		Identifies and assesses accurately the aircraft's vertical and lateral position, and its anticipated flight path
		Identifies and assesses accurately the general environment as it may affect the operation
		Keeps track of time and fuel
		Maintains awareness of the people involved in or affected by the operation and their capacity to perform as expected
		Anticipates accurately what could happen, plans and stays ahead of the situation
		Develops effective contingency plans based upon potential threats
		Identifies and manages threats to the safety of the aircraft and people
		Recognizes and effectively responds to indications of reduced situation awareness
Workload Management	Manages available resources efficiently to prioritize and perform tasks in a timely manner under all circumstances.	Maintains self-control in all situations
		Plans, prioritizes and schedules tasks effectively
		Manages time efficiently when carrying out tasks
		Offers and accepts assistance, delegates when necessary and asks for help early
		Reviews, monitors and cross-checks actions conscientiously
		Verifies that tasks are completed to the expected outcome
		Manages and recovers from interruptions, distractions, variations, and failures effectively

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Table 2 New focus to description of core competencies and behavioral indicators

Competency	Competency description	Behavioral indicator
Application of Procedures	(See Table 1)	(See Table 1)
Communication		
Aircraft Flight Path Management, automation		
Aircraft Flight Path Management, manual control		
Leadership and Teamwork		
Problem Solving and Decision-making		
Situational Awareness		
Workload Management		
Single-pilot Resource Management	Manages available resources, establishing assessment, judgment and decision-making unilaterally.	Plans the actions efficiently
		Manages the time available for the execution of the actions
		Performs the actions cautiously and efficiently
		Checks whether the actions have been performed correctly
		Identifies and corrects possible mistakes
		Manages risks and threats as required
		Assesses, judges and makes decisions properly
Commitment to learning	Demonstrates availability and discipline to learn and develop studies in their field.	Searches for information in different reference sources
		Remains in a continuous process of training
		Has a certain curiosity and thirst for knowledge
		Is receptive to new knowledge and ideas
		Proposes and develops studies in their field

The "Single Pilot Resource Management" was initially proposed by the FAA[13] as a flight instruction technique, defined as "the art and science of managing all resources (both on board the aircraft and from external sources) available to a single pilot (prior and during flight) to ensure the successful outcome of the flight" (9-11). The single pilot resource management includes concepts such as: decision-making, risk management, task management, ground collision in controlled flight, automation, and situational awareness. However, due to the inherent characteristics of this type of instruction, it was concluded that this is, in fact, a competency whose development and training help the pilot to keep the situational awareness through the management of automation and related aircraft and navigation control tasks.[5]

Regarding the "commitment to learning" or "learning to learn" competency, it is intrinsically related to the "learning to do" that is present in the working world, where the knowledge capacity has become the main appreciation currency of the worker. In a world in which machines have become increasingly intelligent and the work has dematerialized itself, the workers have had to reinvent themselves, entering into a continuous process of training and developing competencies to replace traditional skills.

It is important to emphasize that this competency covers two important areas of development that are both distinct and complementary: the ability to self-learning and the ability to remain in a continuous learning process. The first is related to an individual's ability to create learning strategies and establish connections between knowledge due to the situations experienced. The second concerns an individual's ability to remain in a continuous training process, either through self-learning or periodic participation in qualification/training courses.

The commitment to learning may be the most valuable competency for the professional in the contemporary world, especially for those whose activities are being profoundly transformed by technology.

Final considerations

It will be difficult to find a professional training where so many sciences are involved as it occurs with the pilot profession. Physics with aerodynamics and transportation theory; math with its logical reasoning; cartography and geography through navigation; meteorology and climatology; management of people and conflicts, either from people or machines.

The Greeks were used to working with the idea of 'integral man', a concept where the subjects, as they are known today, were developed in a natural and integrated way. Without discussing the definitions and parameters of the 'integral man', as mentioned over the text, being a pilot requires a training so global that it allows the professional to have conditions to perform a flight valuing the technique and observing latent failures from the several systems involved in an air operation, either being related to complex technological systems or to human factors.

As observed on the aviation instruction culture, a pilot's training is based on a paradigm linked to the number of flying hours required to develop the necessary psychomotor skills to operate an aircraft with safety and efficiency. And, for a certain reason, the so-called analog paradigm might have been considered enough for the training of these professionals.

On the other hand, with the progressive and inevitable use of technological tools for a safer, more effective and more economic aircraft operation, only the 'stick-and-rudder' - psychomotor - skill does not attend the needs of a profession that involves the safety of so many lives anymore.

Former documents point for minimal requirements judged as adequate for a pilot's training, in which the motor practice was necessary and was considered enough. In an environment filled with a high technological complexity, the psychomotor skills are being shown to be inefficient, but still necessary.

Several investigations on aeronautical accidents or incidents indicate the lack of preparation from the crew in response to the malfunctioning of the flight management systems, or even the incomprehension or incorrect reading of the data provided by that equipment as the reason for these incidents or accidents. The traditional training undoubtedly does not attend the needs of a technological reality of high complexity, such as the one configured on the aeronautical system.

Several studies, as well as the agents involved in the air system (pilots, companies' training sectors, coordinators of the aeronautical science course, study centers linked to aviation), indicate the existence of new competencies to be developed by the pilots due to the automation present on the modern aircraft. These new competencies require cognitive skills from the pilots, added to the motor and perceptual skills, which would enable a higher safety on the flying operations.

Competency is more than a knowledge and skill. It involves opportunities for the professional to use psychological and cognitive resources to respond to contexts, either involved in personal, organizational, technological or social conflicts. Therefore, it becomes critical to review the subject program regarding pilots' training, as well as to implement efforts to elaborate a national curriculum which contemplates the basic competencies required to operate with control and safety in an increasingly automated aviation environment. It is believed that technological advances in aviation will continue to happen on a large scale in this century. Therefore, research in the pilot training area must also go hand in hand with the aviation industry's development. In this sense, this paper should only be considered as the first draft of a study that can contribute to flight safety in Brazil and in the world.

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Conflict of interest

Author declares that there is no conflict of interest.

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