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BEYOND MULTITASKING: HUMAN FACTORS IMPLICATIONS FOR SINGLE-PILOT OPERATIONS IN THE NEXTGEN ENVIRONMENT

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Operations within the Next Generation Air Transportation System (NextGen) will be a source of new complexities and unique challenges for the single pilot. Human factors research and development will be required to ensure safe single-pilot operations. New avionics, the increase in procedural complexity, and the elevated standards for required navigation performance are the source of many issues that need to be identified before they become a threat to safety. This paper presents a taxonomy developed to identify the potential human factors issues that could impact single pilots flying within NextGen. A series of NextGen capabilities, scenarios, and Automatic Dependent Surveillance-Broadcast (ADS-B) applications were extracted from the literature and examined to determine potential single-pilot human factors issues. A priority list was created to emphasize the issues that constitute the biggest threat to single pilots. The implications of the results are discussed in this paper, and recommendations are given for future research.

The Federal Aviation Administration (FAA) has defined the Next Generation Air Transportation System (NextGen) as a set of technologies, and actions enabled by those technologies, that represents the most significant overhaul of the National Airspace System (NAS) in U.S. history (Federal Aviation Administration [FAA], 2011). This overhaul consists of the transformation of the air traffic control system from a ground-based system to a satellite-based system. A satellite-based system allows for the use of Global Positioning System (GPS) technology to shorten routes, reduce traffic delays, increase airspace capacity, and save time and fuel (FAA, 2007). Operations within NextGen will be a source of new complexities and unique challenges for the single pilot. The introduction of new avionics, the increase in procedural complexity, and the elevated standards for required navigation performance (FAA, 2011) will generate a series of issues that will need to be identified before they become a threat to operational safety for the single pilot. These issues will be system wide, for they will affect both pilots and air traffic controllers. However, the lower amount of resources available to single pilots, in comparison to larger crews, makes them a research priority.

The single pilot is already responsible for many different tasks and procedures, often concurrent, in the current NAS. These tasks can range from visually scanning out the window, monitoring the instruments, and gathering information from the displays, to processing all of the received information, using it to make decisions, and ultimately flying the airplane in a safe manner (FAA, 2008). Therefore, it is crucial to determine any potential increase in such task demands that NextGen will impose on the single pilot in order to avoid potential overload.

Previous research (FAA, 2009b) suggests that mental workload will play a very important role in the success or failure of the single pilot when operating in the NextGen environment. Furthermore, the single pilot's ability to achieve and maintain a safe level of situation awareness (SA) will also be heavily dependent on the level of workload required to process the information made available in the cockpit. Thus, this presents a research gap that requires further study in order to determine the best solution, or approach, for any potential human factors issues that may arise in this area.

Methodology

This research supports the previous work done by the FAA (FAA, 2009b). The research goal of this project was to develop a complete list of significant human factors issues and challenges that represented the main potential problems with single-pilot operations in NextGen. This goal was divided into three steps: a) a literature review of

NextGen-related documents, b) the examination of specific human factors research that addressed human factors issues in multi-person crews in NextGen, and extracting single-pilot related information, and c) the development of a taxonomy that related human factors issues to several NextGen areas. As a result of this project, recommendations were presented for the focus of future research studies, which included the particular single pilot human factors issues that could represent a threat for single-pilot operations.

NextGen Single-Pilot Items

Several Federal Aviation Administration (FAA) and Joint Planning and Development Office (JPDO) documents were reviewed that included NextGen scenarios, capabilities and Automatic Dependent Surveillance-Broadcast (ADS-B) applications (JPDO, 2007; FAA, 2009a; FAA, 2010a; FAA, 2010b). Overall, 24 scenarios, capabilities and applications were initially extracted from the NextGen documents. For the sake of simplicity, the NextGen scenarios, capabilities and ADS-B applications were combined into a broader category named NextGen Single-Pilot Items. After the Subject Matter Experts (SMEs) reviewed the 24 items, and considered their potential impact on the single pilot, the list was reduced to 18. The rationale for the elimination of some of these items was two-fold. On the one hand, some of the items were found by the SMEs to have many similarities, which would have created redundancy in the results. On the other hand, the SMEs believed that the human factors issues generated in some items would not be unique to the single pilot; but rather independent of the size of the crew, thus making them irrelevant for this research. As shown in Table 1, the remaining 18 items were then categorized according to the phase of flight (i.e., departure, enroute, arrival, approach, surface, or overlaying all phases).

Table 1.
Finalized List of 18 NextGen Single-Pilot Items Extracted from the NextGen Literature and Organized by Phase of Flight.

Departure
RNAV/RNP Departure Procedures
Equivalent Visual Operations for Departure
Enroute
Flight-Deck Based Interval Management-Spacing
Delegated Responsibility for Horizontal Separation
Flight-Deck Based Interval Management with Delegated Separation
Independent Closely Spaced Routes
Time-Based Metering Using RNAV and RNP Route Assignments
Arrival
Point in Space Metering
Approach
Paired Closely Spaced Parallel Approaches
Traffic Situation Awareness for Visual Approach
Improved Operations to Closely Spaced Parallel Runways
Use Optimized Profile Descent
Equivalent Visual Operations for Approach
Surface
Enhanced Surface Traffic Operations
Airport Traffic Situation Awareness
Overlay All Phases
ADS-B Integrated Collision Avoidance
Use of Data Communications
Network-Enabled Information Access / Aeronautical Information Services

Note. NextGen Single-Pilot Items consist of NextGen scenarios, capabilities, and ADS-B applications.

Single-Pilot Human Factors Taxonomy and Issues

The second step in the development of the list of human factors issues was examination of work by Funk, Mauro, and Barshi (n.d.) of a research study that addressed human factors issues in multi-person crews in NextGen. In their final report, Funk et al. (n.d.), included a database with 236 specific human factors issues, organized into 10 categories, that could potentially affect any type of crew in a NextGen environment. Due to the narrower focus of this single-pilot study, this step extracted a set of human factors issues tailored specifically to single-pilot operations.

The extraction process consisted of determining which human factors issues a) were not exclusively related to crews with more than one person, b) maintained a relationship to single-pilot operations, c) were not so similar to others that would cause the results to be duplicative, and d) were measurable by a previously developed and validated scale. A total of 23 NextGen human factors issues were extracted from Funk et al. and organized into 6 broader categories (see Table 2). The extracted issues became the foundation for a taxonomy that further linked single-pilot human factors issues to the previously established 18 NextGen Single-Pilot Items.

The third and final step of the analytical process was a more detailed examination the human factors issues by two SMEs. This detailed examination determined which of the human factors issues in the list (see Table 2) could potentially manifest itself within the different NextGen Single-Pilot Items. A series of comments and questions regarding the impact of each of the human factors issues on the NextGen Single-Pilot Items were developed.

Table 2.
List of 23 Human Factors Issues Related to NextGen Single Pilots.

Pilot Characteristics	Controls Interaction
Aeronautical Decision Making	Feedback
Single Pilot Resource Management	Manual Skill
Situation Awareness	System Interface
Allocation of Attention	Representation & Processing
Risk Assessment	Interface Functionality (System Access)
Memory	Complexity
Other Mental Workload	Cues & Alarms
Physical Workload	Delay
Stress	ATM
Fatigue	Communication & Collaboration
Error Management	Other
Automation Interaction	Training
Complacency	
Monitoring	
Managing Automation Failure	

Results

The results obtained from the comparison of the NextGen Single-Pilot Items with the individual human factors issues were synthesized into a taxonomy table (see Figure 1). In this taxonomy, human factors issues are matched to those NextGen Single-Pilot Items in which they have an impact for the single pilot. Using the taxonomy, researchers identified the most prevalent issues across the different NextGen Single-Pilot Items (see Table 3). Then conclusions were extracted regarding the criticality of specific human factors issues and recommendations were made regarding which of these issues should have research priority above the others.

Figure 1. Taxonomy table of NextGen Single-Pilot Items vs. single-pilot human factors issues.

Conclusion and Recommendation

This research supports that additional research is needed to allow the single pilot to safely fly in the NextGen environment. Future research will need to identify a) factors that could affect the single pilot's situation awareness, b) guidelines that could aid the pilot in prioritizing tasks under high levels of stress, c) requirements for cues and alarms that can inform the pilot about deviations or procedure errors, and d) best methods for presenting the necessary information and interfacing with the avionics in a way that maintains a reasonable level of physical and mental workload while avoiding complacency.

Future avionics design should consider the single pilot's challenges in monitoring and interfacing with instruments and displays inside the cockpit while also maintaining a visual scan outside the cockpit. Proper cues, alarms, and pre-processing will be essential to offload some of the monitoring and workload requirements, and to mitigate issues with allocation of attention that NextGen applications will impose on the single pilot. Furthermore, new information needed by pilots as a result of NextGen applications needs to be presented in a clear and concise manner. The single pilot should be able to perceive the needed information, easily interpret it, and use it to make projections into the future.

Thus, research goals for future studies are a) the balance between clarity and conciseness within new NextGen displays; and b) interface functionality (i.e., system access). The single pilot must be able to navigate through the different interfaces and access whatever information is needed in a way that is not only easy to learn and remember, but also time efficient. Considering all of the other tasks that must be completed by this one person, no time can be wasted trying to locate the required information needed at any point in time. This could also impact the single pilot's level of situation awareness in that, if too much time is wasted trying to obtain information, not enough will be available for the perception and further processing of that information.

Table 3.
Prioritized List of 23 Human Factors Issues Based on Their Number of Appearances Across the 18 NextGen Single-Pilot Items.

Human Factors Issues	Number of Appearances
Situation Awareness	18
Allocation of Attention	18
Monitoring	18
Representation & Processing	18
Interface Functionality (System Access)	18
Cues & Alarms	18
Training	18
Other Mental Workload	17
Complacency	17
Managing Automation Failure	17
Feedback	17
Aeronautical Decision Making	16
Error Management	16
Communication & Collaboration	16
Physical Workload	14
Stress	14
Complexity	14
Delay	14
Risk Assessment	13
Memory	13
Fatigue	13
Single Pilot Resource Management	12
Manual Skill	9

Note. No prioritization exists between those human factors issues with the same number of appearances.

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