NASA Nextgen Flightdeck Research: A Database of Research Areas and Results

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NASA NEXTGEN FLIGHTDECK RESEARCH: A DATABASE OF RESEARCH AREAS AND RESULTS

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This article contains an introduction to a database created to capture important NASA or NASA-sponsored research related to NextGen flightdeck issues and operations. Documents are products of NASA's Airspace and Aviation Safety Program efforts to identify and resolve flightdeck human factors issues in NextGen, challenges to efficient operations, key areas in which technological advances are predicted to facilitate NextGen operations, research findings that can be used to develop NextGen procedures, and the potential impacts of off-nominal events.

NASA and FAA have the greatest number of research and development responsibilities for NextGen, particularly in the area of identifying and responding to human factors-related issues. Information concerning research and findings must be shared across these agencies in order to achieve a seamless integration and handoff of work to achieve the anticipated NextGen Operational Improvements. To this end, we were tasked with creating a database of NASA and/or NASA-sponsored research related to NextGen flightdeck issues and operations.

The resultant NASA NextGen Flightdeck Literature Database includes 339 documents containing the most important NASA or NASA-sponsored research related to NextGen flight deck issues and operations, produced by NASA researchers or NASA-funded researchers in the years 2006-2012. The database delineates attributes of the research in a way that can be easily searched and examined from different perspectives (e.g., by year, by topic, by researcher). It includes presentations, conference proceedings, journal articles, technical reports, and other publications, and is in the form of an Excel spreadsheet. The spreadsheet conveys relevant attributes of each document in terms of research characteristics and findings, and can be used to capture relationships between and among NASA NextGen Flightdeck Human Factors research efforts. It can also be used to identify researchers who are examining specific topics, and topics that are receiving attention in terms of NASA funding.

In the following sections, we introduce a sample of main points in topic areas such as the major changes or enhancements from current operations to planned NextGen operations, the degree of success thus far in implementing an operational concept or technology, the next steps in implementation, research findings and any identified holes in the research including missing methodologies or variables, and human factors issues and/or solutions for the NextGen flightdeck. Topic areas are catagorized as Operations, Technologies, and Human Factors Issues. Only a small number of references is included in this paper due to space limitations; however the **NASA NextGen Flightdeck Literature Database** spreadsheet can be downloaded from http://online.sfsu.edu/kmosier/

Operations

Trajectory-Based Operations (TBO)

The NASA NextGen Flightdeck Literature Database contains documents pertaining to the concept of TBO during flight, as well on surface-based TBOs. The implementation of TBOs involves a ground-based computer system with knowledge of the 4-dimensional trajectories (4D, including a time component) of nearby aircraft that would aid in scheduling and separation of those aircraft (FAA, 2009). Datalink communications technology would enable the uploading of strategic trajectories and trajectory negotiation (e.g., Coppenbarger, Mead, & Sweet, 2007; Mueller & Lozito, 2008). The articles included in this database have demonstrated the concept's potential to increase flight path efficiency and runway throughput through human-in-the-loop simulations involving both flight crews and air traffic controllers. Additionally through the manipulation of an aircraft's 4D trajectory and/or its required time of arrival at a designated waypoint, TBOs can be used to resolve potential conflicts and aid in avoidance of adverse weather conditions. One concern regarding the implementation of TBOs is the technological requirements for participating aircraft. Recent studies have demonstrated that current technologies and procedures, specifically Flight Management Systems, datalink and TCAS (Traffic Alert and Collision Avoidance System), may be sufficient for running TBOs but may not fully realize the potential for increased efficiency without additional technology. Multiple new technologies such as TBO-AID (TBO Adaptive Information Display; Bruni, Jackson,Chang, Carlin, & Tesla, 2011) and the future air navigation system (FANS) have been designed to aid flight crews in the use of TBOs without increasing workload (e.g., Coppenbarger et al., 2007); however many aircraft currently in operation are not equipped with these technologies.

Merging and Spacing (M&S)

The research on merging and spacing suggests that airport throughput can be dramatically increased over today's capacity by use of aircraft pairs (Barmore, Bone, & Penhallegon, 2009). The use of new merging and spacing techniques will also be essential in future Continuous Descent Arrival (CDA) techniques. Emphasis is being placed on pilot involvement in the process, much more so than is the case presently. Studies have found that when the flight crew is kept in the loop of merging and spacing procedures, there is a greater degree of efficiency and potential throughput for airports. Research concerning this topic area from the flightdeck perspective is relatively sparse, and different merging and spacing techniques involving the flight crew need to be explored and tested. Additionally, more controlled studies that are amenable to statistical analysis are needed, and the effect of new merging and spacing procedures on flight crew and ATC workload needs to be measured.

Departures and Arrivals

An estimated 5% increase in runway throughput can be achieved using airborne spacing techniques. Literature on arrivals and departures focuses on Area Navigation (RNAV) Departure and Arrival Procedures and CDAs (e.g., Barmore et al., 2009). Recent NASA research also focuses on integrated arrival operations along efficient descent profiles using advanced scheduling automation, tools to aid air traffic controllers, and airborne precision-spacing automation to enable fuel-efficient arrivals at busy airports during peak traffic periods. Some articles also document characteristics of aircraft that are both on and vectored from routes in the execution of area navigation (RNAV) precision departures to support precision modeling and provide for NextGen super density operations research. The Collaborative Virtual Queue (CVQ; Burgain, Feron, & Clarke, 2009) concept, which uses virtual queuing to keep aircraft away from runway queues and enable last-minute flight swapping, proposes to create departure pushback slots to enable flight departure swapping and prevent overloading the taxiway system. CVQ implementation can shorten the average departure taxiing time, reduce emissions, provide flexibility for airlines to reorder pushbacks, and increase predictability of wheels-off times by decreasing taxiway queuing. Some of the research in this area is in the operational and modeling stages. Assumed in models is that the aircraft arrive at specified locations on their prescribed paths precisely when the ATC expects them. Modeling simulations may not accurately reflect circumstances with higher traffic and poor weather conditions.

Next steps for departure and arrival studies include ongoing industry and government activities to address air-ground communication terminology, design improvements, and chart-database commonality for arrivals and departures.

Runway, Surface, and Taxi Operations

Many research efforts on runway, surface, and/or taxi operations were geared toward increasing runway throughput through improved aircraft spacing precision at landing. The Airborne Precision Spacing (Barmore, Abbot, Capron, & Baxley, 2008) concept of operations has been developed to support the precise delivery of aircraft landing successively on the same runway. Some of the latest concepts are aimed at supporting more fuel efficient and lower community noise operations while maintaining or increasing runway throughput efficiency. It has been estimated that surface surveillance information could improve optimization of departure operations by reducing emissions and the number of taxiing aircraft by 5.7%.

Taxi operations articles generally mentioned new ways to improve precision taxiing, using for instance a prototype surface automation tool (Ground Operations Situation Awareness and Efficiency Tool – GoSAFE; Verma, Kozon, Lozito, Martin, Bllinger, & Cheng, 2010) or a CVQ to shorten the average departure taxiing time. One issue in autonomous taxiing is the uncertainty about intentions of other aircraft, and some work assessed the efficacy of head-worn display (HWD) and head-up display (HUD) concepts (e.g., Arthur et al., 20008) for surface operations, to determine whether greater visibility increased situational awareness. Issues with these displays included some nausea experienced by pilots, as well as issues with latency, alignment, comfort ergonomics, color and other display rendering.

Other reseach focuses on technology and safety issues in surface operations. The Runway Safety Monitor (RSM; Jones & Prinzel, 2007), for instance, detects runway incursion conflicts and generates alerts in time for the crew to avoid collisions. Its detection algorithm has been found to be effective in reducing all types of runway incursions and eliminating the most severe incursions. The Runway Incursion Prevention System (RIPS; Jones & Prinzel, 2006)) has been designed to enhance surface situation awareness and provide cockpit alerts of potential runway conflicts in order to prevent runway incidents. However, some results indicated that most pilots were able to acquire incurring traffic looking out the cockpit windows (in VMC conditions), even before incursion alerting was activated.

Next steps in this area include implementing an alerting system for runway incursions, and refining display systems to aid the flight crews,

Closely-Spaced and Very-Closely-Spaced Parallel Runway Operations (CSPR and VCSPR)

A major issue facing NextGen operations is airport capacity. Even with the increased efficiency enabled by other proposed NextGen concepts, many airports are simply not large enough to handle the expected increase in traffic. With many of the nation's major airports located within cities expansion is not always an option. One proposed solution is to insert additional runways near or between existing ones creating (very) closely spaced parallel runways (VCSPR).

Some airports, such as San Francisco International Airport, currently conduct CSPR operations; however paired approaches are only permitted under visual meteorological conditions (VMC). Thus when weather conditions degrade, as they often do in San Francisco, the benefit of the extra runway is negated. Thus one of the major topics in VCSPR research is achieving VMC performance capabilities in instrument meteorological conditions (IMC). Multiple human-in-the-loop studies have shown that with the advancements in vision and conflict detection technology this performance goal is achievable, even with the occurrence of off-nominal events such as aircraft incursions (Verma et al., 2009). Additionally, analytical models for calculating the ultimate arrival, departure, and potential mixed operation capacity of closely-spaced parallel runways have demonstrated that the use of closely spaced parallel runways in all weather conditions can provide stable and predictable arrival capacity (Janic, 2008).

Approaches to (V)CSPRs would involve pairing aircraft with one in a slightly offset trail position; thus another major concern for (V)CSPR operations is the potential disturbance caused by the lead aircraft's wake-vortex. Multiple efforts have been made to model the behavior of the wake-vortex and establish a wake-free safe zone (Guerreiro, Neitzke, Johnson, Stough, McKissick, & Syed, 2010). HWDs and HUDs have been introduced in the context of CSPR approaches as a way to enhance situation awareness.

Off-Nominal Events

Off-nominal events pose a significant challenge to NextGen operations, and have been examined in general discussion and model development papers, human-in-the-loop simulations, Monte Carlo and other simulation techniques, meta-analyses looking at pilot performance. Methods such as Trajectory-Based Route Analysis and Control (TRAC; Callentine, 2011) have been used to model off-nominal events and recovery plans. Analyses address characteristics of the off-nominal events, situation (e.g., phase of flight), and the efficacy of new cockpit technologies such as highway-in the sky displays, datalink, or HUDs in helping pilots deal with events (e.g., Hooey, Wickens, Salud, Sebok, Hutchins, & Gore, 2009). The database includes studies looking at how pilots handle off-nominal events using enhanced and synthetic vision systems, off-nominal events in conjunction with VCSPR operations, in merging and spacing, future vehicles, and the effects of pilots' responses to off-nominal events in future trajectory based operations (e.g., Wickens, Hooey, Gore, Sebok, & Koenecke, 2009). Of particular importance are events that may occur during high-workload and high-traffic phases of flight (e.g., approach and landing, especially to VCSPRs), as they may disrupt CDAs. One caveat with some research is that pilots in many of the human-in-the-loop simulations were aware that they were going to experience off-nominal events, potentially limiting generalizability of their results to operational settings.

Technologies

ADS-B

Automatic Dependent Surveillance-Broadcast (ADS-B) is a satellite-based surveillance technology intended to enable increased capacity and efficiency by supporting enhanced visual approaches, CSPR approaches, reduced spacing on final approach, reduced separation in other flight phases, surface operations in lower visibility conditions, improved situational awareness, improved visibility, and reduced environmental impact by allowing controllers to guide aircraft into and out of crowded airspace with smaller separation standards than currently possible. Many documents in the database include ADS-B capabilities as a variable, but in a support capacity rather than as a focus of study. Those that focus specifically on ADS-B have typically looked at its impact on performance in conjunction with other display technologies such as Cockpit Display of Traffic Information (CDTI), or the Traffic Alert and Collision Avoidance System (TCAS; Romli, King, Li, & Clarke, 2008). So far, the addition of ADS-B has proven to provide small improvements over current conflict detection technologies. Aircraft performance capability was the main predictor of response time, rather than the speed or quality of the external data inputs.

ALARMS

Implementation of ALARMS (Alerting and Reasoning Management System) will consist of placing advanced sensor technologies into the cockpit to convey a large number of potentially complex alerts (Daiker & Schnell, 2010). The ALARMS technology will prioritize aircraft sensor alerts in a quick and efficient manner, essentially determining when and how to alert the pilot. The research thus far has mainly focused on the theoretical implications of the new ALARMS system and the challenges that will be associated with implementing it, as well as on creating human motor models to test different ALARMS scenarios.

Head-up Displays (HUD), Enhanced Vision Systems (EVS), Synthetic Vision Systems (SVS)

Many documents in the database address various display configurations, including but not limited to cockpit situation displays (CSD), heads-down displays (HDD), HUDs, enhanced vision systems (EVS), synthetic vision systems (SVS), head-worn or helmet-mounted displays (HMD), and external visions systems (XVS), as well as monocular and biocular displays. These new display technologies, and configurations of existing display technologies, are intended to provide increased visibility, symbology, and information for enhanced situational awareness and reduced pilot error, improvements in low-visibility operations, and overall enhanced pilot performance, particularly in terminal operations (e.g., Arthur et al., 2011). Display advancements are used to investigate Better Than Visual operations and Better Than Visual technologies for all-weather capabilities in NextGen such as below-minimum landings, suggesting potential changes in current FAA landing requirements. Experiments using these and other display technologies have been geared toward identifying pilot perceptions and characterizations of display clutter and influences of display clutter on pilot performance (e.g., Kaber, Alexander, Stelzer, Kim, & Hsiang, 2007). Some results suggest there may be a clutter “threshold” beyond which pilot performance degrades. This suggests that advanced technologies that include increasing display clutter may be counter-productive, which points to the need for both eliminating clutter and improving the salience of critical symbology and information. Several articles were overviews of new technologies rather than experiments or investigations into their utility and effectiveness, suggesting a need for further investigation of new flight deck display technologies, including issues such as readability in daylight (color, brightness, contrast) and disorientation and illusion issues.

Conflict Detection and Resolution (CD/R)

A major research focus for CD/R is improving the algorithms of conflict detection tools in order to create more effective vertical and horizontal resolutions with fewer secondary conflicts. Pilots will become increasingly more active in the conflict resolution decision-making process; however this may be at the cost of increasing their workload. As the amount of air traffic increases, creating conflict resolutions that avoid secondary or cascading conflicts is becoming more of a concern, and this is reflected in the amount of research that is dedicated to this concept. Some research focuses on pilot acceptance of CD/R automation (e.g., Battiste et al., 2008). New algorithms have been generally successful at creating more effective and efficient conflict resolutions with more accurate predictions of future conflicts and recovery from loss of separation (e.g, Butler & Munoz, 2009). The next step will be to test the new algorithms in more diverse and dynamic environments. A consistent drawback of most of these studies is that certain variables (aircraft location, altitude etc.) were held constant in order to test the experimental variable. Therefore, the algorithms may not perform as well in a more dynamic and realistic scenario.

Haptic Control

The main feature of haptic control technology is the ability of a control surface or system to provide tactile feedback to the pilot. The additional feedback has been demonstrated to improve pilot situational awareness of aircraft state and overall pilot performance (Goodrich, Schutte & Williams, 2011). Additionally, pilots seem to prefer the Haptic Flight Control System to traditional systems. The research regarding the haptic control has been promising with human-in-the-loop simulations showing positive effects.

Human Factors Issues

Attention

Much of the research addressing attention for NextGen applications concerns noticing and perceiving events in a situation. The N-SEEV (Noticing - Salience, Effort, Expectancy, Value) model has been a primary means to examine human attention on the flight deck, and has demonstrated success in predicting variance in pilot response to off-nominal situations (e.g., McCarley et al., 2007). Another area of attention research concerns checklist monitoring and checking, exploring factors that cause pilots skip or miss items (Dismukes & Berman, 2010). Additionally, the relationship between attention and pilot engagement and fatigue has been investigated through brain imaging techniques that provide feedback on how much attention the pilot is paying, as well as the level of fatigue experienced.

Roles and Responsibilities

Implementation of NextGen will entail collaborative decision making between air and ground, and some reallocation of roles and responsibilities. Flight crews are expected to have increased responsibility for flight paths, especially with respect to spacing and separation from other aircraft. With the expected increase in air traffic, the potential increase in ATC workload figures to be a limiting factor in the number of aircraft the system can handle. One proposed solution to this problem is to assign some of the spacing responsibilities to the flight crews themselves. Assigning aircraft to self-separation is seen to be an effective solution to the inevitable increase in traffic, particularly when there is some flexibility (Idris & Shen, 2010), lowering ATC workload substantially while maintaining an acceptable workload for the flight crews (Johnson et al., 2010). Human-in-the-loop and computer simulations have demonstrated that self-separation is able to accommodate 2-5x increases in traffic in en route operations. Self-spacing has also demonstrated the capability to increase runway throughput and facilitate the use of continuous descent arrivals through increasing spacing precision and arrival accuracy. Increased efficiency due to self-separation also is projected to decrease noise and emissions. A major obstacle to the self-separation concept is the accuracy (or lack thereof) of wind forecasts. The lack of realistic wind forecast errors was a significant limitation in the existing research. Additionally, implementation of self-separation will entail additional training, enhanced crew resource management, and tailored procedures within the flight deck.

Operator Performance

Operator performance is a large area that covers all aspects of pilot behavior and encompasses human factors variables such as workload, situation awareness (SA), and decision-making. A common methodological trend in this area is the modeling of pilot performance in these areas, particularly with respect to new technologies or off-nominal events. NextGen operations such as CDA and technologies such as EVS/SFS or other displays typically focus on increasing SA and maintaining manageable workload (e.g., Johnson et al., 2010). Other research in this area includes human-in-the-loop simulations as well as meta-analyses that compare the results of the model against previously published articles. In the future the topic of operator performance will become increasingly important as we try to predict pilot behavior under new NextGen operational conditions.

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References

Arthur J. J. III., Prinzel, L. J. III., Bailey, R. E., Shelton, K. J., Williams, S. P., Kramer, L. J., & Norman, R. M. (2008). *Head-worn display concepts for surface operations for commercial aircraft.* (NASA/TP-2008-215321). Langley, VA: NASA.

Arthur, J. J., Prinzel, L. J., Williams, S. P., Bailey, R. E., Shelton, K. J., & Norman, R. M. (2011). Enhanced/synthetic vision and head-worn display technologies for terminal maneuvering area NextGen operations. Proceedings of the *SPIE Defense, Security, and Sensing Conference* (pp. 25-29). Orlando, FL.

Barmore, B., Abbott, T., Capron, W., Baxley, B. (2008, September). *Simulation Results for Airborne Precision Spacing Along Continuous Descent Arrivals*. Presented at the 26th Congress of International Council of the Aeronautical Sciences, Anchorage, AK.

Barmore, B., Bone, R., & Penhallegon, W. (2009). Flight deck-based merging and spacing operations. *Air Traffic Control Quarterly, Vol. 17(1) 5-37.*

Battiste, V., Johnson, W. W., Dao, A. Q., Brandt, S., Johnson, N., & Granada, S. (2008). Assessment of flight crew acceptance of automated resolution suggestions and manual resolution tools. *Proceedings of the 26th International Congress of the Aeronautical Sciences*, Anchorage, AK: ICAS.

Bruni, S., Chang, A., Carlin, A., Swanson, L., & Pratt, S. (2012). Designing an adaptive flight deck display for trajectory-based operations in NextGen. In S. J. Landry (Eds.), *Advances in human aspects of aviation* (23-32). Boca Raton, FL: CRC Press.

Burgain, P., Feron, E., & Clarke, J. (2009). Collaborative virtual queue: Benefit analysis of a collaborative decision making concept applied to congested airport departure operations. *Air Traffic Control Association Institute, Incorporated, 17(2)*, 195-222.

Butler, R. W., & Munoz, C. A. (2009). *Formally verified practical algorithms for recovery from loss of separation* (NASA TM-2009-215726). Hampton, VA: NASA Langley Research Center.
Callantine, T. (2011, August). *Modeling Off-nominal Recovery in NextGen Terminal-area Operations.* Presented at the 2011 AIAA Modeling and Simulation Technologies Conference, Portland, OR
Coppenbarger, R. A., Mead, R. W., & Sweet, D. N. (2007). Field evaluation of the tailored arrivals concept for datalink-enabled continuous descent approach. *Proceedings of the 7th AIAA integrations and Operations Conference (ATI),* Belfast, Northern Ireland: AIAA.
Daiker, R., & Schnell, T. (2010). Development of a human motor model for the evaluation of an integrated alerting and notification flight deck system. *Proceedings of the MODSIM World 2009 Conference and Expo* (pp. 157-162), Hampton, VA.
Dismukes, R.K. & Berman, B. (2010). *Checklists and monitoring in the cockpit: Why crucial defenses sometimes fail.* (NASA Technical Memorandum-2010-216396). Moffett Field, CA: NASA Ames Research Center.
FAA (2009). *NextGen Mid-Term Concept of Operations for the National Airspace System, Version 1.0*. Washington, DC: FAA Air Traffic Organization NextGen & Operations Planning, Research & Technology Development, Air Traffic Systems Concept Development.
Goodrich, K. H. Schutte, P. C., & Williams, R. A. (2011). Haptic-multimodal flight control system update. *Proceedings of the 11th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference*, Virginia Beach, VA.
Guerreiro, N., Neitzke, K., Johnso, S., Stough, H., McKissick, B., & Syed, H. (2010). Characterizing a wake-free safe zone for the simplified aircraft-based paired approach concept*. Proceedings of the AIAA Atmospheric and Space Environments Conference*, Toronto, Ontario, Canada: AIAA.
Hooey, B. L., Wickens, C. D., Salud, E., Sebok, A., Hutchins, S., & Gore, B. F. (2009). Predicting the unpredictable: Estimating human performance parameters for off-nominal events. *Proceedings of the 15th International Symposium on Aviation Psychology,* Dayton, OH: Wright State University.
Idris, H., & Shen, N. (2010). Improving separation assurance stability through trajectory flexibility preservation. *Proceedings of the 10th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference*, Fort Worth, ID: AIAA.
Janic, M. (2008). Modelling the capacity of closely spaced parallel runways using innovative approach procedures. *Transportation Research. Part C: Emerging Technologies, Volume 16, Issue 6.*
Johnson, W., Ho, N., Battiste, V., Kim-Phuong, V., Lachter, J., Ligda, S., ... & Martin, P. (2010). Management of Continuous Descent Approach During Interval Management Operation. *Digital Avionics Systems Conference.*
Jones, D. R., & Prinzel, L. J. (2006, October). Runway incursion prevention for general aviation operations. In 25th Digital Avionics Systems Conference, 2006 IEEE/AIAA (pp. 1-12). IEEE.
Jones, D. B., & Prinzel, J. III. (2007). Cockpit technology for prevention of general aviation runway incursions. *Proceedings of the 14th International Symposium on Aviation Psychology,* Dayton, OH; Wright State University.
Kaber, D. B., Alexander, A., Stelzer, E., Kim, S-H., & Hsiang, S. (2007). *Psychophysical Modeling of Perceived Clutter in Advanced Head-Up Displays* Technical presentation at the 2007 NASA Aviation Safety Technical Conference. St. Louis, MO.
McCarley, J., Wickens, C., Sebok, A., Steelman-Allen, K., Bzostek, J., & Koenecke, C. (2009). Control of Attention: Modeling the Effects of Stimulus Characteristics, Task Demands, and Individual Differences. NASA Final Report, ROA 2007, NRA NNX07AV97A (2007).
Mueller, E., & Lozito, S. (2008). *Flight Deck Procedural Guidelines for Datalink Trajectory Negotiation.* Paper presented at the American Institute of Aeronautics and Astronautics (AIAA) Aviation Technology, Integration, and Operations (ATIO) Conference, Anchorage, AK .
Romli, F. I., King, J. D., Li, L., & Clarke, J. P. (2008). Impact of Automatic Dependent Surveillance – Broadcast (ADS-B) on Traffic Alert and Collision Avoidance System (TCAS) performance. *Proceedings of the AIAA Guidance, Navigation and Control Conference and Exhibit,* Honolulu, HI: AIAA.
Verma, S., Kozon, T., Lozito, S., Martin, L., Ballinger, D., & Cheng., V. (2010). Human factors of precision taxiing under two levels of automation. *Air Traffic Control Quarterly*, *18*(2), 113-141.
Verma, S., Lozito, S., Ballinger, D., Kozon, T., Panda, R., Carpenter, D.... Resnick, H. (2009). Evaluation of triple closely spaced parallel runway procedures for off-nominal cases. *Proceedings of the Eighth USA Europe Air Traffic Management Research and Developement Seminar,* Napa, CA.
Wickens, C. D., Hooey, B. L., Gore, B. F., Sebok, A., & Koenecke, C. (2009). Identifying black swans in nextgen: Predicting human performance in off-nominal conditions. *Human Factors, 51(5)*, 638-651