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Eye-Tracking Analysis of Next Generation Air Transportation (NextGen) Taxiing and Departure Concepts

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EYE-TRACKING ANALYSIS OF NEXT GENERATION AIR TRANSPORTATION
SYSTEM (NEXTGEN) TAXIING AND DEPARTURE CONCEPTS

A Thesis

Presented to

The Faculty of the Department of Psychology

San José State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

Christina L. Kunkle

December 2012

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The Designated Thesis Committee Approves the Thesis Titled
EYE-TRACKING ANALYSIS OF NEXT GENERATION AIR TRANSPORTATION
SYSTEM (NEXTGEN) TAXIING AND DEPARTURE CONCEPTS

by

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ABSTRACT

Eye-Tracking Analysis of Next Generation Air Transportation System (NextGen)

Taxiing and Departure Concepts

by Christina L. Kunkle

The Next Generation Air Transportation System (NextGen) is comprised of concepts and technology that will help change the national airspace system. In the current experiment, we analyzed eye-tracking in a NextGen experiment that examined a concept of taxi-out operations that are commonly referred to as surface trajectory-based operation (STBO). This study was built on previous research investigating taxiing from the gate to the runway based on speed and time commands to include speed-based taxiing with bounds. Commercial airline pilots, both current and recently retired, participated in this study at the Human-Centered Systems Lab at NASA Ames Research Center. This study showed that pilots viewed the primary flight display more than when taxiing in the defined condition than the undefined condition. This resulted in more head down time on the primary flight display. Future studies should examine different STBO concepts that prevent more head down time while keeping safety a priority.

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Additional data from this same experiment was published in the following:

Bakowski, D. L., Foyle, D. C., Kunkle, C. L., Hooey, B. L., & Jordan, K. P. (2011). *NextGen flight deck surface trajectory-based operations: Speed-based taxi clearances*. Proceedings of the 16th International Symposium on Aviation Psychology. Dayton, OH: Wright State University. May 2-5, 2011.

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Introduction

The Next Generation Air Transportation System (NextGen) is comprised of concepts and technology that will help change the national airspace system (NAS). Air traffic is expected to increase dramatically by 2025 (JPDO, 2012). The goals of NextGen include increasing safety, security, and capacity of the air transportation system. These goals will be achieved by implementing new procedures as well as technological advances in the near and far terms (JPDO). Presently, taxi-out and departure are the busiest phase of flight for the flight deck crew (Foyle, Hooey, Bakowski, Williams, & Kunkle, 2011). The taxi-out departure environment encompasses operations from the ramp area to the runway. Taxi operations include communication with air traffic control (ATC) regarding clearance information, maneuvering the aircraft, navigating the taxi clearance using airport signage and an airport taxi chart, maintaining separation from other aircraft, and other tasks associated with departure.

Surface Traffic Management Systems

Surface traffic management (STM) systems are being developed to help in the NextGen effort for ATC to provide optimized taxi clearances that will eliminate active runway crossing delays (Foyle et al., 2011). This will, in return, enable more efficient use of runways and ensure the delivery of departing aircraft to

the runways at precise times. Pilots will be required to comply with taxi clearances that have a speed- or time- based component. These NextGen taxi operations are commonly referred to as surface trajectory-based operation (STBO). STM systems are envisioned to use dynamic algorithms to produce speed- or time-based taxi clearances for aircraft in order to calculate the most efficient movement of all surface traffic and enable precise surface coordination (Cheng, Yeh, Diaz, & Foyle 2004; Rathinam, Montoya, & Jung, 2008).

In order to achieve the required accuracy, STM systems provide speed and time commands to the pilots throughout the taxi route, requiring arrival at particular “traffic flow points” (e.g., traffic merge points, active runway crossings, etc.) at specific times; however, this is only one STBO concept, and there are other approaches. If the pilot is unable to comply with the STBO command, or if other traffic is unable to comply thus creating a reduction in aircraft separation or to meet the needs of the dynamic airport surface (e.g., runway crossings), then the aircraft’s speed may need to be adjusted in order to account for these events (Bakowski, Foyle, Hooey, Kunkle, & Jordan, 2011; Foyle et al, 2011). Research is being done to support the effort of ATC STM algorithms to ensure resulting STM systems do not exceed pilot and aircraft performance capabilities (i.e., to ensure pilots are not required to accept a time-based taxi clearance that cannot be safely executed) (e.g., Bakowski et al., 2011; Foyle et al., 2011).

Previous research. Previous research has been completed that examined requirements of future STBO taxi clearances and new information that will be needed on the flight deck (i.e., advanced displays to support pilots during taxi operations). The impact on the flight deck and surface operations was crucial in the previous research. Previous research examined speed/time information and commanded speed without speed conformance (e.g., Williams, Hooey, & Foyle, 2006; Bakowski et al., 2011).

Speed and time information. The objective of the Williams et al. (2006) study was to determine whether pilots were able to comply more accurately with 4-D commands given in a speed, time, or speed/time format. Also of interest was variability of ground speed in order to determine how consistent pilots' speed was within the taxi routes. Pilots completed taxi routes while attaining specific average speeds or completion times when speed, time or both were available. Also, a head-mounted eye tracker was used to gain insight about what percentage of the trial pilots looked at display information. This information from the eye tracker was used to determine how pilots used the different formats.

Eighteen current commercial airline captains or first officers, with a minimum of 500 hours as captains within the last four years, participated in the experiment conducted by Williams, et al. (2006). The mean age of the pilots was 49 years, and the mean number of flight hours as captain was 8,383 hours.

Their study was conducted at the NASA Ames Research Center in a medium-fidelity part-task simulator with Boeing 737 modeled dynamics in the Human-Centered Systems Laboratory (HCSL). The simulated environment modeled Dallas Fort-Worth International Airport with 1,200 feet visibility. Displays included the forward out-the-window scene, side window views displayed on two monitors, and a monitor in front of the pilot below the out-the-window scene displaying a static, north-up airport chart and text taxi clearances. Pilots controlled the simulated aircraft using a tiller, throttle, and rudder toe-brakes. Pilots wore an Applied Science Laboratory Model 501, head-mounted eye tracker, while taxiing.

Superimposed graphically over the out-the-window scene simulating a Head-Up Display (HUD) was the current instantaneous ground speed indicator, elapsed time, required taxi speed, and required time of arrival (RTA). Their experiment was a 3 (format) x 3 (distance) x 4 (required speed) within-subjects design. The three levels of command format were speed, time, and speed/time. For the speed format, pilots were to taxi to a specific runway crossing at a commanded average speed, and for the time format they were instructed to taxi to a specific runway crossing by a commanded RTA. For the format with both speed and time, pilots were given a commanded speed with its corresponding commanded RTA, and they were instructed to comply with both of these.

Required commanded speeds were combinations of 10, 14, 18, and 22 knots (kts) and route distances were 3,000, 6,000, and 12,000 feet.

Williams et al. (2006) calculated RTA absolute error, which is the absolute value of the difference between commanded RTA and pilots' actual arrival time at the designated runway crossing. RTA absolute error assesses the accuracy of compliance with the STBO commands. They found a main effect of format and a significant interaction between distance and required speed on the RTA absolute error. Overall, pilots' RTA error was the lowest with the speed/time format, and pilots taxied more accurately with shorter routes and faster required speeds. It was also revealed that pilots arrived equally early regardless of format but arrived earlier with slower commanded speeds and longer distances. The eye tracking data showed that pilots looked at the speed and speed/time displays more than the time display (i.e., high percent dwell time).

Commanded speed without bounds. Foyle, Hooey, Kunkle, Schwirzke, and Bakowski (2009) conducted a study that replicated the Williams, Hooey, and Foyle study with the addition of intermediate time constraint points and higher fidelity flight deck displays. There were two NextGen implementations given in this study, Limited and Advanced. Limited is defined as providing a taxi clearance with a commanded average speed to the pilot and did not have error-nulling avionics (i.e., as was presented to the pilots in the Williams et al., 2006 study). In the Advanced implementation, advanced avionics allowed for time-

based taxi operations to be conducted with speed error-algorithms and arrival time information. Pilots received a taxi clearance with a required speed to maintain from Ground Control. However, in their study no eye tracking data was gathered.

Sixteen commercial pilots, both current and recently retired, participated in their study. The mean age was 45.5 years with a mean of 5,585 hours of flight hours. Again, this study was conducted in a medium-fidelity part-task simulator with Boeing 737 modeled dynamics in the HCSL located at NASA Ames Research Center. The simulated airport environment was Dallas Fort-Worth International Airport with high visibility and distant fog/haze conditions. Pilots controlled the simulated aircraft with a tiller, throttle, and toe brakes. Displays included a forward out-the-window scene, side window scenes, and the simulator flight deck. The flight deck included a Primary Flight Display (PFD), Navigation Display (ND), Tax Navigation Display, Datalink Display, and an Electronic Checklist.

Their study was a mixed-subjects design with one between-subject factor, NextGen Implementation (Limited and Advanced) and two within-subject factors, Number of traffic flow points (1, 3, or 5) and Commanded speed (10, 14, 18, or 22 kts). There were a total of 24 identical taxi trials given to the pilots (3 flow points values x 4 speeds x 2 repetitions) comprising each of the NextGen implementations, and a “current-day taxi” trial was presented after the first 12

experimental trials were completed. The “current-day taxi” trial was given in order to allow a comparison between NextGen time-based operations and what pilots do in current day taxiing operations.

As with the previous study by Williams, et al. (2006), pilots tended to be most accurate with moderate taxi speeds (e.g., 14 kts) and tended to arrive at traffic flow points early for slower commanded speeds and late for faster commanded speeds. Also consistent with the previous study, it was found that time of arrival (TOA) error was largest with only a single taxi route and improving when more traffic flow points were added (i.e., in the Limited NextGen implementation). In the Advanced NextGen implementation, the error-nulling algorithm reduced TOA error. However, the advanced implementation may have increased overall workload, as indicated by pilot responses on a post-study questionnaire. Therefore, the results of the Foyle, et al. (2009) study indicated that the challenge is to implement these algorithms without resulting in adverse effects on pilot workload, situation awareness, and other flight deck tasks. Their study led into the current study, which examined eye tracking among pilots who participated in a NextGen concepts study with the introduction of conformance bounds.

Current Study

The current study examined pilots' situation awareness and workload while performing NextGen taxiing and departure concepts through eye tracking data. This study was built on previous research investigating taxiing from the gate to the runway based on speed and time commands (e.g., Williams et al, 2006; Foyle et al, 2009) to include speed-based taxiing with bounds. This study adds the important element of eye tracking, which Foyle et al. lacked in their study.

Speed-based commands typically require the pilot to follow a commanded speed throughout the taxi phase. This reduces the variability of taxi speed and has the potential to increase throughput on the airport surface. However, speed bounds allow the pilot room to work around a commanded speed such that while there may be some minor variability in taxiing speed, on average the pilot maintains the commanded speed across taxiing. It was proposed that with no alerts (i.e., undefined condition) the performance of the pilot would be similar to that of current day performance, and in the alert condition (i.e., defined condition, ± 1.5 kts) the pilot would allocate more visual attention to the Primary Flight Display (PFD) to make sure he or she was within in the bounds because there would be more of a chance he or she may go out of the bound limits. For the no alert condition there would be less dwell time on the PFD in the 14 kt speed segment because this was approximately nominal, and the 22 kt speed

segment would have more dwell time because it was expected the participant would tend to drift away from this speed. The same effect was expected for the alert condition but the difference between the two speed conditions would be larger than in the no alert condition.

Method

Participants

Twenty commercial pilots, ages 25 to 65 participated in the study ($M=44.7$, $SD=12.1$). Fifteen were Captains and five were First Officers. Pilots were recruited through the Test Subject Recruitment Office of the Human Systems Integration Division at NASA Ames Research Center. Nine pilots were excluded from the eye-tracking analyses due to technical difficulties with the eye tracker system (i.e., the experimenter could not obtain the quality eye calibration that was needed or the participant wore prescription reading eyeglasses). A total of 11 participants' data were included in the eye data analyses ($M=37.1$, $SD=7.2$). One participant wore soft contact lenses, and her data were included in the analyses, as eye tracker calibration was not affected.

Apparatus

The experiment was conducted at the Human-Centered Systems Lab at the NASA Ames Research Center in a medium-fidelity simulator with Boeing 737 modeled dynamics. The simulated environment was Dallas Fort-Worth International Airport (DFW). Pilots controlled the simulator using a tiller, throttle,

and set of toe-breaks; see Figure 1 for an overview of the simulator. Pilots wore an Applied Science Laboratory Mobile Eye eye tracker with eye-head integration.

Figure 1. Overview of B737 modeled dynamics simulator

At the beginning of the experiment, participants read and signed informed consent forms for San Jose State University and NASA Ames Research Center and completed a demographic questionnaire. After each trial, participants completed a questionnaire assessing their subjective assessment of a range of variables (e.g., workload, situation awareness). At the end of the study, participants completed a questionnaire regarding the study as a whole and were debriefed as well.

Experimental Design

This study was a within-participant design, with three independent variables-- Commanded speed (14, 18, and 22 kts), Segment size (1, 3, and 5 segments), and Speed conformance condition (Undefined—no alert and Defined—alert). In the defined condition, participants were told to taxi within +/- 1.5 kts of commanded speed and if he or she went above or below the +/- 1.5 kts, he or she received an auditory “Check speed” message. Dependent measures were conformance to speed on straight-aways and turns, workload, and situation awareness as measured and analyzed through the eye tracking data (e.g., percent dwell time).

There were two blocks of nine nominal trials each—one block for each of the two sizes of alerts (undefined and defined). The undefined block was always presented first due to potential learning effects. The nine nominal trials within each of these two blocks resulted from the factorial combination of the three levels of commanded speed (14, 18, and 22 kts) and the three levels of segment size (1, 3, and 5 segments). The defined condition also contained nine nominal trials with a factorial combination of the commanded speeds and segment sizes. Three practice trials were placed in the beginning of the experiment in order for the participant to become familiarized with the simulator controls, and one practice trial was placed before the start of the alert condition block in order for the participant to become familiar with how the bounded speed alert worked. A

baseline trial to measure current day operations was placed between the last undefined and first alert condition practice trials. Refer to Figure 2 to view the order in which trials were presented.

Speed Conformance Condition	Trial Type	Segment Size	Commanded Speed(s)
Undefined	Practice	1	14
		3	14,22,18
		5	22,14,18,14,22
	9 Nominal Trials	1	14
		1	18
		5	22,14,18,14,22
		3	14,22,18
		1	22
		3	18,14,22
		5	14,18,22,18,14
		5	18,22,14,22,18
		3	22,18,14
B	B	1	—
Defined	P	3	18, 22, 14
	9 Nominal Trials	1	14
		1	18
		3	14,22,18
		5	22,14,18,14,22
		5	14,18,22,18,14
		3	22,18,14
		1	22
		3	18,14,22
		5	18,22,14,22,18

Figure 2. Conditions and trial blocks

The experiment was conducted over a one-day period. Experimental testing was approximately 8 hrs, which included training and instructional period in the morning and post-experiment questionnaires and debrief later in the day.

Within and after each block were several 10-15 min breaks; also, a 1 hr lunch break was given.

Procedure

After they completed two informed consent forms and a demographic questionnaire, pilots were given a set of general instructions regarding the experiment. The experimenter went over these instructions with the participants and gave a timeline of the day's activities (i.e., breaks, eye-tracking calibration, simulator procedures).

After the initial instructions were given regarding the simulation, the experimenter familiarized the pilot with the simulator (i.e., tiller, throttle, toe breaks; see Figure 3). The experimenter then asked the pilot to wear the Mobile Eye eye tracker, and the eye-head integration calibration was begun. After the eye tracker calibration was completed, a series of practice trials were completed to familiarize the pilot with the simulator controls. The experimenter pointed out the information displayed on the screens. The experimenter was present in the room with the pilot during these practice trials in case he or she had questions. After each trial, the pilot completed a post-trial questionnaire. At the conclusion of the experiment, the pilot completed a post-study questionnaire and was debriefed by the experimenter. Breaks were given throughout the experiment.

Figure 3. B737 Simulator showing Tiller (A); Throttle (B); Toe Brakes (C) labeled
Eye Tracking

Scene planes and areas of interest were determined before the experiment began. Figure 4 presents a layout of the scene planes and areas of interest (AOIs). Eye tracking calibration was performed at the beginning of the experiment and approximately after every 2-3 trials or when needed (i.e., if the pilot bumped the eye tracker glasses). Participants were calibrated to Scene Plane 1 (see Figure 4) because this was the area the experimenters were most interested investigating the hypotheses for this study. A breakdown of the AOIs in scene plane one will be discussed below.

Figure 4. Scene planes and areas of interest (AOIs)

Variables in the eye tracking data included pupil size and percent dwell time. Pupil size was used to validate the data and will be discussed in the section below. Percent dwell time is the percentage of time the participant was looking at a particular area over an entire trial. Percent dwell was used in the data analyses.

Areas of Interest

Areas of interest (AOIs) were defined within scene planes throughout the physical environment located in front of the participant (see Figure 4 for the

overall view). The AOI this paper is most interested in is 1A or the speed tape area on the primary flight display located in scene plane one (see Figure 5). The electronic checklist, located in scene plane one, was also of used in determining the validity of the eye tracking data; that will be discussed further in the next section.

Figure 5. Scene Plane 1 and areas of interest (AOIs)

Data Validation

Three data validation tests were used to determine whether the data from each participant for each trial were valid. First, the data were filtered for pupil

size. Pupil size was considered valid and “good” if it was at least 30mm or greater for a minimum of 0.25 seconds. If the size was less than 30mm or was not at the size requirement for at least 0.25 seconds, it was considered invalid or “bad” pupil size. The next criterion for inclusion in the data set were one of the following—for the first ten seconds of the trial (i.e., the first ten seconds started when the ownship’s speed was greater than 10 knots), the participant should have been looking at the speed tape (i.e., AOI 1A, see figure 4) for 50 percent of the time. The third criterion was that the pilot had to have at least one fixation on the electronic checklist (i.e., AOI 1G; see Figure 4) because if the pilot “checked” then he or she had to have been looking at it. The trials for each participant that were not included in the data set are presented in Table 1 below

Table 1

<i>Excluded Trials Per Participant</i>	
Participant	Trial(s)
2	4 & 5
6	5
17	26

Results

Eye Tracking Analyses

Mean percent dwells were calculated for the overall, one segment, three segments, and five segments among the undefined and defined conditions.

Refer to Figures 6-9 to view the mean percent dwells and standard error of the mean for the speed conformance conditions (including the baseline condition) by segment size.

Figure 6. Overall Mean Percent Dwell of the speed tape area. Error bars represent +/- one standard error of the mean.

Figure 7. 1 Segment Mean Percent Dwell of the speed tape area. Error bars represent +/- one standard error of the mean.

Figure 8. 3 Segments Mean Percent Dwell of the speed tape area. Error bars represent +/- one standard error of the mean.

Figure 9. 5 Segments Mean Percent Dwell of the speed tape area. Error bars represent +/- one standard error of the mean.

To investigate the relationship among the three independent variables, a 2 (speed conformance condition) x 3 (segment size) x 3 (speed) within-subjects analysis of variance (ANOVA) was performed on the nine nominal trials for each speed conformance condition. A significant effect was found for speed conformance condition (i.e., undefined and defined), $F(1, 9)=22.73$, $p<.01$, segment size (1, 3 and 5), $F(2, 18)=18.64$, $p<.01$, and speed (14, 18, and 22 kts), $F(2, 18)=7.08$, $p<.01$. However, no significant interactions were found between speed conformance and segment size, $F(2, 18)=0.93$, $p=.4$, segment

size and speed, $F(4, 36)=1.381$, $p=.26$, and all three conditions, $F(4, 36)= 1.32$, $p=.28$. The interaction of speed conformance and speed approached significance, $F(2, 18)=3.34$, $p=.058$

A one-way ANOVA was performed on only the one segment speed conformance and baseline conditions. Here, a significant difference was found, $F(2, 20)=31.71$, $p<.001$. Follow-up paired sample t -tests were conducted for pairings of undefined, defined, and baseline conditions with one segment. Significant differences were found between undefined and baseline conditions, $t(10)=5.37$, $p<.001$, defined and baseline, $t(10)=6.24$, $p<.001$, and undefined and defined, $t(10)=4.11$, $p<.01$.

When participants were not looking at the speed tape (i.e., AOI 1A), they were looking out-the-window (i.e. Scene plane 2, see Figure 4). In the undefined condition, overall pilots averaged 31.8 percent dwell time when they viewed the external taxiway, and in the defined condition had 29.7 percent dwell time. In the baseline condition (i.e., current day operations trial), pilots viewed the out-the-window scene an average of 38.4% of the time.

Time of Arrival (TOA) Data

Bakowski et al. (2011) previously reported TOA results from the current study experiment. TOA error was the primary measure of pilot performance on the taxi task. This was calculated by subtracting required time of arrival (RTA) from the observed arrival time, and the RTA was calculated for each segment

using taxi route segment length, ATC-commanded speed for straight segments, 2-kts/sec acceleration/deceleration, and a turn speed of 14 kts.

There was a significant interaction ($p=.013$) between number of traffic flow points (i.e., number of segments) and commanded taxi speed. This suggests that TOA error increased as commanded speed increased from 14 kts to 22 kts, and decreased as the number of segments or traffic flow points increased from one to five. Further analyses showed an interaction ($p=.019$) between speed conformance condition and number of segments, and a simple main effect of number of segments in the defined speed conformance condition ($p=.002$). It was also shown that TOA error was higher for one-segment trials than for three- and five-segment trials.

Questionnaire Data

Pilots completed a post-questionnaire asking a variety of questions regarding their experience and importance of situation awareness. Using a 5-point scale, where 1 = Rarely and 5 = Most of the Time, participants were asked, 'How often did you find yourself focusing on the PFD speed tape when you have preferred to have been paying to the external taxiway environment?' As reported previously by Bakowski et al. (2011), their results showed a significant effect of speed conformance condition, $F(2, 34)=69.19$, $p<.001$. Participants reported they focused on the speed tape more in the defined speed conformance

condition than they would have preferred. This was more pronounced in the undefined speed conformance and baseline conditions.

Discussion

In conclusion, this study demonstrated that giving pilots more information to help them conform to speed limits while taxiing in order to make a set time slot to the runway can help increase their accuracy in obtaining this goal. However, providing this information may hinder safety. When pilots were in the defined speed conformance condition with alerts (± 1.5 kts), their head-down time increased because they were focusing on making sure they stayed within the bounds by looking at the speed display on the PFD. An increase in head down time can be confirmed by the post-questionnaire in which pilots reported they would have preferred to have spent less time on the speed tape and more time viewing the external taxiway. However, in the undefined speed conformance condition (no alerts), performance in making the allocated time slot to the runway decreased because pilots were less focused on the speed display and spent more time looking out-the-window. This increase in head-down time looking at the speed tape on the PFD decreased surface operations safety because the pilots should have been using the increased time to maintain navigation, situation awareness, and separation from other aircraft on the airport surface. When compared with current day operations (i.e., the baseline condition in this study),

pilots viewed the head-down speed display two to three times more. Again, this is a large amount of time to spend head-down during surface taxi operations.

It was also found that there was no significant difference in percent dwell time between 14 kt and 22 kt speed segments in either speed conformance condition, however; results indicated an approach to significance. It was assumed there would be more percent dwell time as speeds increase from 14 kts to 22 kts because it is more difficult for pilots to keep a consistent speed when taxiing at higher commanded speeds. This is indicated by TOA error results Bakowski et al. (2011) describe in which TOA error increased as commanded speed increased from 14 kts to 22 kts in their study. However, consistent with Bakowski et al.'s findings on taxiing long distances (i.e., one-segment) percent dwell time did increase between undefined and defined speed conformance conditions. One possible cause may be due to the fact it is harder for the pilot to keep a consistent speed during longer taxi routes so they are checking their speed tape more often.

To help ease the workload on the pilot, while maintaining good taxi time performance, a flight deck display aid may help as suggested by Foyle et al. (2009). Future studies should examine possible flight deck display aids and their impact on surface operations. One important focus on future studies should be sustaining safety (i.e., separation from other aircraft and situational awareness) when trying to achieve on time taxi performance from pilots with NextGen speed

algorithms. A possible aid may be to incorporate the information into a graphical representation, possibly on the electronic moving map. This feature would update to accommodate the ownship's speed, traffic crossings, and new runway RTA commands from ATC. If a new change comes in, that could be an auditory beep to alert the pilot of the change and he or she could adjust accordingly; otherwise, the pilot could spend more time being head-up out-the-window and maintaining separation from other aircraft.

Another possible flight deck display aid would be to provide the speed information on a head-up display (HUD). That way, if the pilot goes out of bounds, he or she will not have to be head-down for a long period of time. Instead, it could be displayed on the HUD with possibly something that flashes next to the speed to get the pilot's attention. Something other than a sound may be better to alert the pilot when he or she is out of bound because the pilot is already listening to ATC and the first officer.

A limitation of this study was the absence of a co-pilot due to the simulator setup. Co-pilots relay information to the Captain; however, all of the information the Captain may have needed was located on the PFD in the study. Future studies should include co-pilots to include more current day operation procedures.

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Appendix A: IRB approval

**SAN JOSÉ STATE
UNIVERSITY**

To: Christina Kunkle

From: Pamela Stacks, Ph.D.
Associate Vice President
Graduate Studies and Research

Date: September 30, 2009

Office of the Provost

Associate Vice President
Graduate Studies & Research

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Voice: 408-924-2427
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gradestudies@sjsu.edu

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The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"Eye Tracking Analysis of Next Generation Air Transportation System (NextGen) Taxiing and Departure Concepts"

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Dr. Pamela Stacks, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subject's portion of your project is in effect for one year, and data collection beyond September 30, 2010 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2427.

Protocol #S0904024

cc. Kevin Jordan 0120