Pilot Workload and Acceptability using Data Comm CPDLC Messages in the Terminal Area

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This paper describes a collaborative FAA and NASA experiment using commercial airline pilots to determine the effect of controllers using Data Comm to issue taxi clearance messages in busy, terminal area operations. By the end of Segment 2 (2017-2022) in the Next Generation air transportation system Concept of Operations, the FAA envisions Data Comm between controllers and flight crew to become the primary means of communicating non-time critical information to increase efficiency and capacity. Four conditions were defined that span current day to future equipage levels (voice communication only, Data Comm only, Data Comm with Moving Map Display, Data Comm with Moving Map displaying taxi route), and each condition was used to create an arrival and a departure scenario at Boston Logan Airport. These eight scenarios were repeated twice for each of the ten subject crews, for a total of 16 scenarios per crew. Quantitative data was collected on subject reaction time, flight technical error, operational errors, and eye tracking information. Questionnaires collected subjective feedback on workload, situational awareness, and acceptability to the flight crew for using Data Comm in a busy terminal area. Results from the experiment indicate that ……

Nomenclature

BOS = Boston / General Logan International Airport
CDU = Control Display Unit
CPDLC = Controller Pilot Data Link Communications
D-Taxi = Datalink Taxi
HITL = Human In The Loop
IFD = Integration Flight Deck
MMD = Moving Map Display
ND = Navigation Display
PF = Pilot Flying
PM = Pilot Monitoring

I. Introduction

THE Next Generation Air Transportation System Concept of Operations supports employment of an electronic Data Communications system, to effect communication of non-time critical information and events between flight deck and ground facilities. Transferred information could include expected taxi and flight clearances, weather, and real-time trajectory control. Deploying such a system is intended to sustain expected increase in air traffic by 2025 (Joint Planning and Development Office [JPDO], 2007) and to assist Air Navigation Service

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Providers (ANSPs) in managing air traffic more efficiently (JPDO, 2007). For flight crews, Data Comm serves as a means to share weather, airport surface operations, and Trajectory-Based Operations (TBO) information. Additionally, Data Comm and its automation on the flight deck allows real-time data to be transmitted, thereby improving decision making for controller and pilots (JPDO, 2007).

The FAA plans on implementing this Data Communications (Data Comm) System in three segments. Segment One will occur from the years 2012 – 2016, and will be characterized by current equipage and the use of voice communications as the primary mode. Segment Two will occur in the years 2017 – 2022, and will be characterized by the gradual transition from voice to Data Comm (both in terms of procedures and equipage) during the segment time period. Segment Three will occur the year 2023 and subsequent, and is characterized by Data Comm being the primary mode of communication.

The Federal Aviation Administration (FAA) and National Aeronautics and Space Administration (NASA) have agreed to conduct a Human-in-the-Loop (HITL) simulation to research Data Comm functionality and how it will contribute to the ultimate NextGen goal of increased efficiency and capacity. This paper describes the design and results from the NASA Langley Research Center experiment from February through March 2010 using 20 current, commercial airline pilots. To identify Data Comm operational capabilities, limitations, and system requirements, the experiment used the high-fidelity Integration Flight Deck (IFD) simulator, a complex and operationally realistic simulation of arrivals and departures from Boston Logan Airport, and created high flight crew workload by requiring the simulator be hand-flown in a heavy traffic density scenario

II. Data Comm and Challenges to Flight Crew

Numerous simulation studies and operational evaluations have been conducted recently regarding either the mode of communication between the air traffic controller and the flight crew (voice or datalink), or the display method available in the cockpit (no map, moving map, map with ownship route). These studies have shown communication with datalink can take a significantly longer than with voice, and therefore most recommend only non-time critical messages when using datalink, but also have identified the positive impact of graphically displaying the route on a moving map. With the exception of a study in 2008 at NASA LaRC (Reference 10), there does not appear to have been research regarding the flight crews' workload and situational awareness as a function of both communication mode and display methodology.

An important summary of datalink research was conducted by the MITRE Corporation and noted several issues. The operating environments (airport, terminal, enroute, oceanic) have different characteristics in terms of what information is to be transferred, its criticality, and the expected time of response. The time spent by the crew to process a datalinked message was less than an aural message, but total transaction time using datalink was significantly longer. A time of 22 seconds was determined to be the longest useable response time in departure and final approach sectors. Overall there was no change in workload for pilots or controllers, however it was important to be able to "auto-load" clearances into the FMS and minimize switching between communication modes. Finally, graphical presentation of the datalinked message improved the ability of the crew to detect errors, and the subject pilots felt datalinked messages prepared and issued in advance of the final approach should be acceptable in the terminal area.

The survey of datalink research by Navarro had similar findings. Datalinked messages have the potential for higher efficiency than voice, to place less demand on pilots' working memory, reduce error and confusion, and improve message delivery time. However datalink is not as flexible as voice, and therefore should only be used for non-time critical communication. Of note, datalink requires pilots to use the visual channel and other tasks cannot be performed in parallel, unlike voice communication.

The D-TAXI studies in Brussels from Aug 2006 through Feb 2007 used in revenue service flights with operational flight crew, certified controllers, and existing technology to asses if data link can be used to deliver taxi information to the flight crew in order to improve efficiency. Limited to sending non-time critical messages prior to the aircraft pushing back from the gate and a requirement that pilots read back all datalinked messages ("supplement" mode for this study), the study measured workload, safety, and changes in voice communication usage. The results indicate that data link provided a concise and permanent message, with pilots not having any safety incidents and reporting high acceptance despite longer response times and increased heads-down time (self-reported). Controllers reported the system as implemented had a very negative impact on workload (controllers required to respond to both voice and datalink), and did not improve the control process or efficiency. Not analyzed in this particular study was the impact on the pilot's workload if taxi clearances were "auto-loaded" from the CPDLC into the FMS, the impact of having to taxi the aircraft while receiving a datalink clearance, and the impact on the pilot if the clearance was shown graphically on a moving map.

EMMA and EMMA2 were tests conducted from 2004 - 2009 throughout Europe that introduced new technology in the tower and cockpit to assess using datalink for transmission of non-time critical and non-safety related messages (taxi routes by datalink, but clearance onto a runway or for takeoff was done by voice). This study also limited datalink to non-time critical and non-critical messages, however pilots only had to respond for clarification or abnormal situations ("exception" mode for this study). Some of the new technology for controllers included automatic taxi route generation coupled to a departure management program, and transmission via datalink of that digitized route. New for the pilots was a moving map display that included own ship position, graphical display of the datalinked route, and other surface traffic displayed on the map. The results from the numerous simulations and three operational evaluations showed that taxi time and voice communications were reduced, workload for pilots and controllers was maintained while situation awareness improved, and there were no operational or safety errors.

A NASA Langley study in 2009 used a full-scale, high-fidelity simulator with commercial pilots to explore four different communication modes between pilots and controllers for NextGen surface operations. This study found when controllers communicated via datalink and pilots responded with datalink and voice read back of clearances, the pilots committed the fewest errors and had significantly higher situational awareness than the other three conditions (datalink and voice by both ATC and pilot for all messages, datalink only from ATC and pilot with voice-by-exception, and datalink only). This study included a Head-Up-Display (HUD), which may have altered the pilot's workload and acceptability rating, and did not correlate various display methods (moving map with and without own ship route) to the communication mode. Of note is the only significant pilot errors committed occurred when using the datalink only mode of communication. (Reference 10)

Another study of interest to this particular research work was published in 1995 by the FAA WJHTC. The Dutch Nationaal Lucht- en Ruimtevaartlaboratorium (NLR) conducted a simulation using European and American commercial pilots flying into Schiphol International Airport using different datalink interfaces. It noted that datalinked messages from ATC "… had an effect on the scanning behavior of the crew member not responsible for the communication task." This study concluded that no datalink interface was suitable for high workload environments, such as terminal area operations, however it did not include the ability to "auto-load" a clearance into the FMS nor did it include moving maps with the route graphically displayed. (Reference 11)

Several experiments conducted at NASA Ames explored various modes of communication and display methodology. In 2002 a study showed datalink reduced the pilots' time and need to write clearances, improved understanding the message the first time, and providing the taxi route during descent reduced delays after runway turn-off. However a low rate of verbalizing the message to the other crew member was noted, and clearance transactions took longer in either datalink mode (Reference 15). In 2001, another Ames study using 18 professional pilot crews in a high-fidelity B-757 simulator showed that datalinked messages graphically displayed on a moving map significantly enhanced situational awareness and reduced both intra- and inter-flight deck communications. This particular study is pertinent since it incorporated moving maps with cleared taxi route, and examined the feasibility of issuing taxi clearances while the crew was on approach. Results showed datalink helped the crew understand the taxi clearance the first time, however there was a low rate of verbalizing the datalink messages, possibly since the clearance was issued while the crew was on a 12 nmi final and therefore other tasks took precedence. Furthermore, the availability of a moving map with the cleared route shown graphically offset to a large degree the increased heads-down time needed by the Pilot Not Flying for datalink communication, and also significantly reduced that pilot's workload. The study also indicated "…that the loss of traffic awareness from not monitoring the radio frequency in the datalink only environment may largely be replaced through the depiction of traffic on the moving map." [In addition to issuing a taxi clearance on a 12 nmi final, this research also included a HUD for the Captain, which significantly alters the workload and acceptability of operations for a Segment 2 equipped aircraft.] (Reference 19)

In summary, the literature review indicates that:

- Known: compared to voice transmissions, datalinked messages tend to have higher efficiency, place less demand on a pilots' working memory, reduce error and confusion, provide a persistent record, and improve message delivery time. However datalink is not as flexible as voice, generally takes longer for the crew to respond, causes a loss of situational awareness (no party-line comm), and seems most appropriate for non-time critical communication

- Known: datalinked messages of non-time critical information may improve comprehension for the pilots, however scan patterns are significantly altered and how the message is shared is sometimes still an issue
- Known: graphically displaying the clearance on a moving map enhances awareness and comprehension
- Unknown: will non-time critical datalinked messages be acceptable to a flight crew during a high workload environment when the aircraft has Segment 2 equipage? (Moving Map Display, auto-load of a taxi clearance to the Navigation Display)

III. Experiment Design Overview

The FAA uses the term Data Comm to describe a range of electronic messages, to include the messages required to exchange log-on information (aircraft name, flight data, application, etc), system connection management messages for establishing and terminating sessions, aircraft state information (e.g., ADS-C and FIS), and Controller Pilot Data Link Communications (CPDLC) messages. The FAA/NASA Interagency Agreement for this experiment specified the focus of research was CPDLC uplink messages (ATC to flight crew), in particular, should controllers be inhibited from sending taxi or expected taxi clearances due to high flight crew workload in a busy terminal area.

A. Experiment Hypothesis

To determine if datalinked messages are acceptable to flight crew in a high workload environment such as arrivals and departures in Boston Logan International Airport, the research team defined three key hypotheses:

H1: Pilot Workload and Situational Awareness will not vary according to the modality of the communication (Voice or Data Comm).

H2: Pilot Workload and Situational Awareness will not vary according to the presence of display attributes in conjunction with Data Comm (no display, ownship position on MMD, and ownship plus route on MMD).

H3: Pilots will find Data Comm communications within this experiment operationally acceptable.

B. Scenario Environment

Approximately ten crews (20 subject pilots) were used in the Integration Flight Deck (IFD) to conduct arrival and taxi operations during simulated day, Visual Meteorological Conditions (VMC) in a complex and busy environment. Scenarios were created to match those used in a controller HITL conducted by the Research Development and Human Factors Laboratory (RDHFL) located at the FAA's William J. Hughes Technical Center. In particular, arrivals and departures to Runways 27 and 33L were chosen, with airborne routes that provided realistic profiles and workload from 18,000 feet to landing, and taxi routes that to the maximum extent practicable matched those used at RDHFL. (See Figure 1)

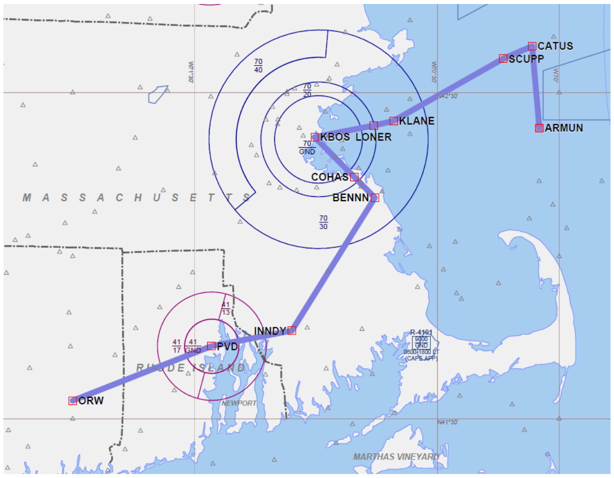


Figure 1. Arrival Procedures and Airspace

Traffic levels consisted of approximately 20 other aircraft during each of the 15 – 20 minute scenarios (approximately 70 aircraft per hour), and included accurate out-the-window and audio emulation of that traffic. During the departure scenarios when the subject flight crew waited to begin their taxi operations, they would see other aircraft clearing the runway and hear two-way communication between the aircraft and ATC. Furthermore, to maximize realism and task-loading, ATC would also issue the subject flight crew voice instructions that required them to interact with the out-the-window traffic. For example, "NASA 557, Runway 27, taxi via your datalink route. Remain behind the CRJ-200 at your 12:00 o'clock turning on Bravo. Hold Short Runway 33 Left." ATIS and voice communication from other aircraft were pre-recorded, requiring approximately 170 dynamic aircraft and 1240 wave files.

A ten-camera oculometer system will be used to record eye and head tracking data for both subject pilots during the runs. The particular SmartEye system to be used in this experiment does not require the subjects to wear anything on their head or attach anything to their body.

Real-world procedures and operations were simulated or emulated to the maximum extent possible, to include the use of checklists (Approach, Before Landing, After Landing, Taxi, etc). Four arrival scenarios will have the crews flying into Boston Logan International Airport and then taxing to a gate, and four departure scenarios will have the crew taxi from the gate to the departure end of the runway. The crews will fly two replicates of these scenarios, plus two additional scenarios to incorporate rare events to investigate the issue of trust of datalink. This paper discusses the experiment and results of the 16 nominal arrival and departure scenarios, with the results of the 2 off-nominal scenarios to be reported in a separate paper.

The baseline scenario will use voice only communication and no moving map display, with display methodology the variable in three runs with datalink. Display methodology variations will consist of no Moving Map, a Moving Map with ownship position, and a Moving Map with ownship position and inclusion of ownship expected and cleared routing. Datalink messages will be received and sent via the CDU, and the CDU will also provide the ability to load them into the Moving Map Display as graphical routes.

C. Research Facilities

The IFD full-workload simulator shown in Figure 2 is a duplicate of a standard Boeing 757-200 aircraft cockpit and is driven by a Boeing 757-200 aircraft dynamics mathematical model. The cockpit includes standard ship's instruments representative of a line operations Boeing 757-200 aircraft. The Main Instrument Panel contains Primary Flight Displays (PFD) and Navigation Displays (ND), the EICAS, flight instruments (airspeed, altitude, attitude, etc), as well as standby altimeter and gear lever. The Center Control Stand consists of a typical B-757 throttle quadrant, flap and speed brake controls, reverse thrust, spoiler handles, dual FMS CDUs, and several electronic panels for controlling the PFD and ND, as well as researcher specified systems. The IFD houses a standard Mode Control Panel under the glare shield, and a complete Overhead Panel.

The cockpit's visual system is a panorama system using five video projectors that provide 200° horizontal by 40° vertical field-of-view, with 1440 x 1024 resolution. A Rockwell Collins EP-1000 Boston Logan (BOS) database will be used for the out-the-window projection of the airport surface, taxiways, runways, buildings, obstructions, signs, and airport terrain and cultural features in a day, VMC setting. Up to 20 aircraft will be required in the arrival and surface taxi scenarios, and this traffic will be accurately projected in the out-the-window displays, and shown on the moving map display if appropriate for that run condition.

Figure 2. Integration Flight Deck (IFD)

D. Independent and Dependant Variables

The Independent Variables are:

- communication modality: (1) voice, (2) Data Comm
- display methodology: (1) no MMD, (2) MMD with ownship position, (3) MMD with ownship and route

The Dependent Variables are:

- Is it acceptable to the flight crew (in terms of workload, situation awareness, intrusiveness, and potential performance degradation) to use Data Comm in the Terminal Maneuvering Area for non-critical messages, during arrival and departure (surface) operations?
- What identifiable segments on arrival and departure are associated with pilot non-acceptance of Data Comm (if any)?

E. Experiment Matrix

Table 1 presents the Experimental Design Matrix used in this study. The order of scenarios were randomized within each replicate, to allow for analysis within crew and between crews. This section will be completed in April 2010.

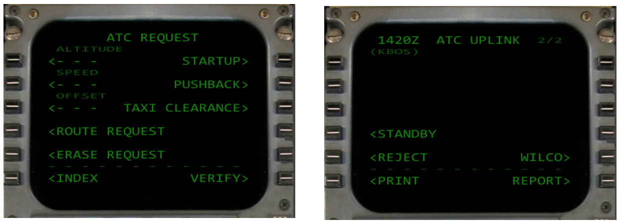
Table 1: Data Comm Experiment Design Matrix

Phase	**Comm Mode**	**Display Method**
Arrival	Voice	None
Arrival	Data Comm	None
Arrival	Data Comm	MMD, ownship
Arrival	Data Comm	MMD, ownship, route
Departure	Voice	None
Departure	Data Comm	None
Departure	Data Comm	MMD, ownship
Departure	Data Comm	MMD, ownship, route

F. Data Comm Messages and Graphical Display

Data Comm messages were formatted in accordance with RTCA DO-305, DO-219, and DO-269, and based on a Boeing 747 FANS 1/A implementation. This experiment focused primarily on two specific CPDLC uplink messages (ATC to flight crew):

- taxi clearances (both from terminal to departure runway, and from landing roll-out to the terminal area)
- expected taxi clearances (operational given by ATC for flight crew planning purposes, expected to be 15 minutes prior to pushback from the terminal area, or prior to Top Of Descent for arriving aircraft)

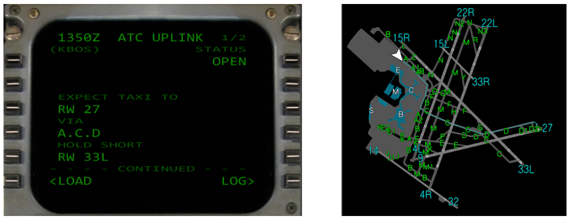


```
        ATC REQUEST
 ALTITUDE
<- - -                 STARTUP>
 SPEED
<- - -                PUSHBACK>
 OFFSET
<- - -         TAXI CLEARANCE>

<ROUTE REQUEST

<ERASE REQUEST
- - - - - - - - - - - - - - - -
<INDEX                  VERIFY>
```

```
 1420Z   ATC UPLINK   2/2
(KBOS)




<STANDBY

<REJECT                  WILCO>
- - - - - - - - - - - - - - - -
<PRINT                  REPORT>
```

Figure 3. ATC Request and Acknowledge Pages

To retain the realism of the of the scenarios and preclude the subject pilots from always expecting these messages, other CPDLC uplink messages were included in the scenarios, such as changes to altimeter settings, notification of a new ATIS recording, and issuing a frequency change to the next controller (e.g., from Approach Control to Tower controller). In addition to responding to all uplink messages appropriately (ROGER, WILCO, UNABLE, or STANDBY), the subject pilots were required to use CPDLC downlink messages such as requesting pushback, requesting engine start, and requesting their taxi clearance.



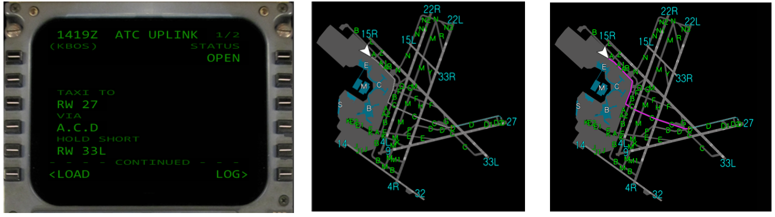
```
1350Z  ATC UPLINK  1/2
(KBOS)             STATUS
                     OPEN


 EXPECT TAXI TO
 RW 27
 VIA
 A.C.D
 HOLD SHORT
 RW 33L
- - - - CONTINUED - - -
<LOAD                LOG>
```

Figure 4. Expected Taxi Message and Display

Shown in Figure 4 is an example of a Data Comm "Expected Taxi" message displayed on the CDU and on the Moving Map Display. When the CPDLC uplink is received, a chime sounds in the cockpit and the Pilot Monitoring (PM, always the First Officer in this experiment) depresses the ATC button on the CDU to read the message. On page one of the message, the PM loads the text clearance onto the MMD as a graphical route (if the scenario is the one condition that includes displaying the taxi route graphically). The "Expected Taxi" message is displayed as a dotted cyan line from the terminal gate to the departure runway, with no red hold short lines for any runway (a decision made to reinforce visually that an "Expected Taxi" message is not a taxi clearance, and is for planning purposes only). The same procedure applies for an arrival scenario where ATC sends an uplink message of the taxi route from runway to terminal for planning purposes, the PM loads the route onto the MMD (if appropriate for that condition), then sends a downlink of "ROGER" to acknowledge the

"Expected Taxi" clearance. (ROGER automatically replaces WILCO shown in Figure 3 for informational type CPDLC messages such as expected taxi clearances, changes to the ATIS or altimeter settings, etc.)

The actual "Taxi" clearance is accessed in a similar fashion by the PM. A chime sounds when the uplink is received, the PM reads the message and loads the graphical representation on the MMD (if appropriate) from page one. The taxi clearance is shown as a dotted white line from ownship position to the first active runway, where it ends in a solid red bar representing the Hold Short line (not clearly visible in these pictures at the intersection of Taxiway D and Runway 33L, however very visible in the IFD during the experiment). The rest of the route past the red Hold Short bar remains dotted cyan. When the PM acknowledges the taxi clearance with a WILCO on page 2 of the message, the dotted white line turns to a solid magenta.



```
 1419Z  ATC UPLINK  1/2
(KBOS)          STATUS
                  OPEN

 TAXI TO
 RW 27
 VIA
 A.C.D
 HOLD SHORT
 RW 33L
- - - - CONTINUED - - -
<LOAD              LOG>
```

Figure 5. Taxi Message, Proposed and Accepted Route Displays

In the voice condition used to simulate operational procedures in effect today, the subject flight crew were cleared to begin taxing the aircraft once they acknowledged and read back the ATC taxi clearance. However the Data Comm environment is slightly different. A Data Comm taxi clearance is just the route, and not permission to being taxing the aircraft. The flight crew in Data Comm scenarios received the route via Data Comm, but then required a voice instruction from the ground controller to begin taxing the aircraft. The voice message exchange might be: "Ground, NASA557 ready to taxi", "NASA557, Ground, taxi via data link route", "NASA557, Roger."

G. Subject Requirements, Schedule, and Training Program

The requirements and desired criteria for subject pilots in this simulation experiment were:

- to have a valid FAA Airline Transport Pilot certificate
- be currently employed by a Part 121 Air Carrier or manufacturer
- have a Boeing 757/767 type-rating (other ratings with similar CDU/FMS incorporations are acceptable)
- preference for pilots familiar with FANS-1/A CDU controls, displays, and functionality
- preference that subject volunteers be from the same flight organization
- preference for recent flight experience in the role they will be assigned (i.e., Captain or First Officer)
- one pilot will be designated the role of Captain (left seat, Pilot Flying) and the other of First Officer (right seat, Pilot Monitoring) for the duration of the simulation experiment

Three crews meeting the above criteria assisted the researchers in January 2010 to validate the experiment design and ensure the scenarios were operationally realistic and demanding. Ten crews came to NASA Langley in February and March 2010 to participate in the Data Comm experiment as subjects. Their schedule on the morning of the first day included two hours of academic training and oculometer calibration and two hours of training runs in the IFD, then eight scenarios flown and post-scenario questionnaires completed in the afternoon. The remainder of the scenarios and questionnaires would be completed the morning of the second day, with the subject pilots finishing the post-experiment questionnaire by noon.

A training program was developed describing the FAA's vision for Segment 2 by 2022, the research issues being addressed, the simulation scenarios at Boston Logan, relevant Data Comm CPDLC messages and responses, and part-task training in the briefing room and IFD itself.

H. Questionnaires

A post-scenario questionnaire was given to both crew members after each scenario to ask questions specific to that run, and a post-experiment questionnaire given at the end of the experiment to make comparisons between the runs and capture issues not previously identified.

The post-scenario questionnaire given to both the Captain (PF) and First Officer (PM):

- flight crew workload using a Modified Cooper-Harper (MCH) scale (1 – 10)
- Situation Awareness using Situation Awareness Rating Technique (SART) on a Likert scale (1 – 7)
- Data Comm acceptability (comparative rating)

The post-experiment questionnaire asked about:

- comparison of workload across all scenarios
- Situation Awareness across all scenarios
- acceptability of Data Comm messages by various phases of flight
- open-ended questions about realism of the experiment, display formats, etc

I. Data Collection Metrics

A range of quantitative and qualitative data collection metrics were used to support the three hypotheses. Two 5-camera oculometer systems were installed to collect head position and eye gaze vector of the Captain and First Officer to provide independent and quantitative inferences of crew tasking and workload. (More detailed explanation and oculometer data results published separately.)

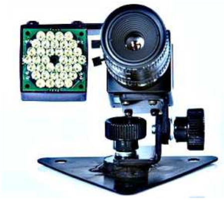


Figure 6. SmartEye Oculometer

- pairwise comparisons of MCH and SART ratings
- crew response metrics (responsiveness to message, understanding message, responding to message)
- crew interaction (directing other crew member to message, cross-cockpit verification, etc)
- flight technical error (lateral and vertical deviation from Flight Director bars while hand-flying)
- operational errors (incorrect taxi routes, missed altitude or speed assignments, etc)
- percent of time each member was heads down, percent time spent looking at a particular display, etc
- pairwise comparisons of MCH and SART ratings
- crew response metrics (responsiveness to message, understanding message, responding to message)
- crew interaction (directing other crew member to message, cross-cockpit verification, etc)
- flight technical error (lateral and vertical deviation from Flight Director bars while hand-flying)
- operational errors (incorrect taxi routes, missed altitude or speed assignments, etc)
- eye gaze vector and percent of time each member was heads down, time spent looking at a display, etc

IV. Experiment Results

Section IV to be written in April 2010 after data analysis.

A. Flight Crew Workload

B. Situational Awareness of Flight Crew

C. Acceptability to Flight Crew

D. Other Observations and Recommendations

V. Conclusion

To be written in April 2010.

Appendix

An appendix, if needed, should appear before the acknowledgements.

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References