

Cockpit Display Based Visual Separation during an Instrument Approach: Effect of Traffic Display Size and Location

Cockpit Display of Traffic Information (CDTI) Enhanced Flight Rules (CEFR) Simulation 2

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Abstract

At many busy airports maximum efficiency and minimum delay occur when visual approaches are being conducted by pilots using visual separation from traffic for a portion of the approach. Pilot willingness to accept responsibility for visual separation also affords controllers maximum flexibility in traffic management under conditions of high traffic load. It may be possible to extend that efficiency to lower weather conditions if pilots are able to perform similar tasks by reference to a Cockpit Display of Traffic Information (CDTI) in lieu of visual contact out-the-window. This concept is termed CDTI Enhanced Flight Rules (CEFR). CEFR procedures may be applicable during visual or instrument approaches, this study examined the instrument approach application with particular attention to the pilot acceptability of different CDTI locations and sizes.

This study is the second in a series of studies designed to examine whether a CDTI can be used by pilots to monitor their separation in relation to traffic in a manner analogous to visual contact. The previous study indicated pilot acceptance of the CDTI feature set and the CEFR procedure (see Bone, Domino, Helleberg, and Oswald, 2003). The current study increased the realism of the simulation environment by introducing aircraft categories other than large (i.e., Boeing 757 and heavies) as well as introducing real time communication with air traffic controllers.

Eight commercial airline pilots flew coupled approaches, as the pilot flying, in a flight deck simulator, while maintaining a self-determined visual separation from Traffic To Follow (TTF) by mixed reference to a visual scene and a CDTI. Speed management was used to adjust spacing to a pilot-determined value. Independent variables included two CDTI locations and two CDTI sizes, one of which represented a CDTI that may be the initial implementation in actual operations. The results indicate that pilots are willing and able to perform the CEFR procedure via any of the CDTI sizes or locations tested in the simulation while following various aircraft types.

KEYWORDS: Airborne Separation application, Airborne Separation Assurance Systems (ASAS), Automatic Dependent Surveillance-Broadcast (ADS-B), ATM lab, Cockpit Display of Traffic Information (CDTI), CDTI Enhanced Flight Rules (CEFR), flight simulation, MITRE CAASD, Safe Flight 21 (SF-21), spacing, terminal area, visual separation.

Acronyms

ADS-B	Automatic Dependent Surveillance-Broadcast
ANOVA	Analysis of Variance
ARTS	Automated Radar Terminal System
ATC	Air Traffic Control
ATM	Air Traffic Management
CDTI	Cockpit Display of Traffic Information
CEFR	CDTI Enhanced Flight Rules
EFIS	Electronic Flight Instrumentation System
FAA	Federal Aviation Administration
FAF	Final Approach Fix
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
LCD	Liquid Crystal Display
MCP	Mode Control Panel
MSL	Mean Sea Level
ND	Navigation Display
OEP	Operational Evolution Plan
OTW	Out-The-Window
SDF	Louisville International Airport - Standiford
SF-21	Safe Flight 21
TCAS	Traffic alert and Collision Avoidance System
TIS-B	Traffic Information Service -Broadcast
TTF	Traffic To Follow
VMC	Visual Meteorological Conditions

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Section 1

Introduction

Visual separation can be applied to separate aircraft in terminal areas either by the tower controller, who sees the aircraft involved, or by a pilot who sees the other aircraft involved. If the flight crew accepts a clearance by Air Traffic Control (ATC) to maintain visual separation, it must:

- Maintain constant visual surveillance,
- Maneuver the aircraft as necessary to avoid the other aircraft or to maintain in-trail separation,
- Avoid wake,
- Not pass the other aircraft until it is no longer a factor (traffic is no longer a factor when, during approach phase, the other aircraft is in the landing phase of flight or executes a missed approach), and
- Promptly notify ATC “if visual contact with the other aircraft is lost or cannot be maintained or if the pilot cannot accept the responsibility for the separation for any reason” (Federal Aviation Administration (FAA), 2003b, sections 4-4-13 and 5-5-12).

When visual separation is to be used, a traffic advisory is issued by ATC to the flight crew. The crew then visually searches for the traffic and, when sighted, reports it in sight. The search for aircraft in a dense traffic environment or during reduced visibility conditions can be challenging. The flight crew may have difficulty visually identifying aircraft and may even identify the wrong aircraft as the traffic of concern. Such difficulties can be reflected in the number of traffic advisories that must be issued before the traffic is sighted. After reporting the aircraft in sight, the flight crew is assigned responsibility for visual separation and an approach clearance can be issued. Thereafter, the flight crew is responsible for maintaining visual separation from the Traffic To Follow (TTF) to the runway, while ATC continues to provide separation from all other aircraft.

While maintaining visual separation, the flight crew is responsible for adjusting spacing as necessary to maintain a safe arrival interval, and may have to detect and then respond to unexpected deceleration of the TTF, requiring them to adjust speed, reconfigure the aircraft, and in extreme cases perform a go-around (if the flight crew judges the separation to be unsafe). On occasion, the flight crew may lose sight of the preceding aircraft, requiring ATC intervention to establish another form of separation.

The information available on the Cockpit Display of Traffic Information (CDTI) may allow the pilots to make more accurate spacing judgments and enhance the flight crew’s ability to keep the aircraft in sight. If information on a CDTI can be used to perform the visual

separation task, these same procedures could be applied during weather conditions under which visual Out-The-Window (OTW) contact cannot be maintained and visual approaches suspended.

Ideally, a CDTI used for traffic awareness and separation would be placed in the optimum location for each flight crew member and would have the largest display area possible. However, due to space and other constraints, other locations and sizes must be considered (Sanders and McCormick, 1993 and Wickens, Gordon, and Liu, 1998). Therefore, there is a need to determine which CDTI sizes and locations would be acceptable implementations. Furthermore, it would be desirable to use currently certified equipment, if possible, to avoid additional developmental costs.

1.1 Concept Description

CDTI Enhanced Flight Rules (CEFR) is an Airborne Separation application in which delegation of separation responsibility is applied to a designated aircraft (i.e., the TTF) and ATC maintains separation responsibility for all other aircraft (see Federal Aviation Administration / EUROCONTROL Cooperative Research and Development, 2001 and Bone, Domino, Helleberg, and Oswald, 2003 for more details). The concept is similar to the notion of *extended delegation* as proposed by Hoffman, et. al., 2000.

Other terminal spacing or separation applications such as Paired Approaches (Bone, et. al, 2000, Hammer, 1999, Pritchett, 1999 and Stone, 1998) and Approach Spacing (RTCA, in preparation, Abbott, 2002, Olmos, Bone, and Domino, 2001) have also been proposed. These other terminal applications are expected to be implemented in a time frame beyond that envisioned for the implementation of CEFR. In both applications, on-board automation generates speed commands to achieve a specified desired distance or time-in-trail along the final approach. This is in contrast to CEFR where pilots use the CDTI to make their own spacing judgments to achieve self-determined spacing. However, the lessons learned during their development has aided in and led to the development of CEFR.

The operational concept for CEFR is to use the information available from the CDTI for traffic identification and separation monitoring during visual or instrument approaches. CEFR takes the seemingly small, but operationally large, step from pilots using the CDTI to assist with spacing judgments during visual approaches when the aircraft is continuously in sight OTW (see RTCA, 2000), to using information from the CDTI to monitor and maintain visual separation even when that aircraft is not in view OTW. In effect, the operational definition of “visual separation” is expanded to include the use of the CDTI to substitute for OTW visual contact when maintaining pilot-determined separation. The initial implementation of CEFR is expected to be during single runway arrivals. However, later implementations are expected to include parallel runway operations.

The source of traffic information for CEFR is assumed to come from aircraft equipped with Automatic Dependent Surveillance-Broadcast (ADS-B) data link (see RTCA, 2002). A

second potential source of traffic information, that requires further investigation, may be Traffic Information Service-Broadcast (TIS-B), in which ground based surveillance data is up-linked to aircraft via a networked ground infrastructure (see Zeitlin and Strain, 2002 and RTCA, 2003). Combining information from multiple surveillance sources on the same cockpit display will require additional research and evaluation and is not addressed in this study.

In CEFR, pilots use the CDTI in a manner that is functionally equivalent to using the information derived from scanning OTW while performing visual separation. For example, while following another aircraft visually, pilots are expected to detect closure on traffic ahead by changes in the apparent size of the TTF OTW and to adjust ownship speed or path so as to maintain a safe interval. The CDTI provides analogous information in the form of traffic position, range, ground speed, and closure rate (see Figure 1). Changes in distance or speed, therefore, are directly observable on the display in the form of both relative distance and alphanumeric information. Use of CDTI should make it possible to detect such changes well before they would be apparent using visual OTW cues alone. The availability of flight identification on the CDTI can also aid in traffic awareness and allow for reliable and less ambiguous traffic identification.



Figure 1. Inset of CDTI showing an ADS-B target and the associated target information.

Use of the CEFR procedure is expected to occur during either visual or instrument approaches. Although the initial application of CEFR will most likely be during visual approaches (see Bone, Helleberg, Domino, and Johnson, in preparation), the concept was defined initially for use during instrument approach procedures, which is the operational domain used in the present (and previous) study. Requirements for the conduct of the instrument approach remain unchanged except for pilot use of the CDTI for visual

separation. In addition, the flight crew is required to correlate the OTW aircraft with the target on the CDTI prior to using the CDTI for this task.

During instrument approach procedures, current ATC procedures will be used, including the use of visual separation when appropriate. Lateral and vertical path guidance will be required to ensure obstacle clearance, minimize crew workload, and minimize the likelihood of an encounter with the wake of the TTF. Flight crews will be trained on the wake separation criteria set forth in FAA documents (FAA, 2003a and FAA, 2003b). It is expected that the flight crew would use these values as guidance for safe distances to maintain behind other aircraft. However, the flight crew would also be expected to make safe spacing judgments based on the particular conditions of each approach, and the application of other avoidance procedures as specified in the FAA Aeronautical Information Manual (FAA, 2003b). After accepting a clearance to maintain visual separation, flight crews would be responsible for adjusting spacing to maintain a safe interval behind the TTF.

ATC will need to know which aircraft are CDTI equipped and capable of performing CEFR. Ideally, the aircraft's equipment level should be conveniently available on the controller display whenever that information is required.

The aircraft equipment will include the traffic display, a pilot interface, and the associated processing systems. The display feature must allow the flight crew to not only visually acquire but to monitor the position of the TTF using the CDTI during periods of loss of visual contact. The expected CDTI elements include target selection capabilities (highlighting the target and the display of selected target ground speed, weight category, call sign, as well as range and closure rate in regards to ownship).

Flight crews should also be made aware that their traffic picture with respect to the overall traffic flow, while significantly enhanced from that available by visual means, is still incomplete. Air traffic control retains its primary responsibility for traffic flow management and has knowledge of the overall traffic situation, which is necessary in order to develop a comprehensive arrival and departure strategy for the entire airport.

1.2 Purpose

The purpose of CEFR is to maintain visual separation operations, and their associated arrival rates, for as long as feasible, as weather conditions deteriorate. This procedure is expected to enable arrival rates closer to those experienced in visual conditions by allowing the flight crew to use the CDTI to maintain separation from the TTF and by providing ATC the flexibility allowed by visual separation procedures. Use of visual separation by flight crews is an underlying factor for the maintenance of Visual Meteorological Conditions (VMC) arrival rates during periods of high demand at many airports. By expanding the weather conditions under which "visual" separation may be applied, capacity at airports can be improved and delays reduced (Bone, Domino, Hahn, and Narkus-Kramer, 2002 and Management, Consulting, and Research Federal, Inc., 2002). An incremental improvement in

safety is also expected through improved traffic awareness of the flight crew resulting from the improved identification, visual acquisition, and tracking of traffic.

1.3 Maturity

CEFR is currently in a developmental stage. This application is being developed by the FAA Safe Flight 21 (SF-21) program and is being considered for inclusion in a joint United States (i.e., RTCA Special Committee 186) and European (i.e., EUROCAE Working Group 51) ADS-B / CDTI technical requirements document (i.e., a version of RTCA, in preparation). The CEFR application is also identified as a terminal application under the Operational Evolution Plan (OEP)- Airport Weather Conditions: AW-2, Space Closer to Visual Standards (FAA, 2001). It builds from the joint US and European application of Enhanced (Successive) Visual Approaches (Eurocontrol, 2002 and RTCA, 2000). The traffic information is assumed to be from other ADS-B-equipped aircraft. Therefore, implementation of CEFR will require that a sufficient number of aircraft be equipped to broadcast ADS-B or the traffic picture will need to be supplemented by a service such as TIS-B¹ (see Zeitlin and Strain, 2002 and RTCA, 2003).

A series of four medium fidelity cockpit simulations have been conducted to refine the application description, define the associated procedures, and identify required display features. Results of the first simulation are reported in Bone, Domino, Helleberg, and Oswald 2003. The third and fourth simulations in the series examined CEFR during visual approaches under marginal visual weather and night operations, as well as failure conditions. The results of these simulations will be used to refine the application description as well as to assist in decisions on the future development of the concept. The benefits case as well as an initial safety analysis has begun. A CDTI with features and functionality similar to those used in these studies has been certified by the FAA and may be able to support the CEFR procedure. However, CEFR will require additional development and implementation activities such as those outlined in RTCA (1999), including formal approval for use by an operator. Limited field implementation of CEFR could occur in Fiscal Year 2005 or 2006.

¹ It is not clear that TIS-B provides the adequate integrity and accuracy necessary for this application.

Section 2

Method

2.1 Simulation Environment

The MITRE Center for Advanced Aviation System Development's Air Traffic Management (ATM) laboratory hosts the integrated terminal area and flight simulation. This medium fidelity simulation environment supports end-to-end evaluations from both flight deck and ATC perspectives. The main simulation functions used in this study included a cockpit simulator and a traffic generator. All applications ran on networked Sun, Silicon Graphics Incorporated (SGI), and Linux workstations. The simulation was customized to the Louisville International Airport – Standiford (SDF) terminal area.

The cockpit was an enclosed, fixed based, mid-fidelity transport aircraft simulator (see Figure 2). It was configured as a generic, twin-engine jet, large weight category aircraft. It had a CDTI and an autopilot / autothrottle system was used to control flight path and speed. The simulation included audio capabilities supporting aircraft environmental sounds (e.g., slipstream noise, ground proximity warning system) and ATC communication. The cockpit provided for two standard flight crew and observer positions. For aircraft control, both the captain and first officer positions had side-stick controllers. The center pedestal housed the throttle quadrant, flap handle, and speed brake lever. Twenty-one inch touch-screen displays were located in front of the captain and first officer positions. A nineteen inch display occupied the center instrument panel. These comprised the Electronic Flight Instrumentation System (EFIS) displays. A ten inch Liquid Crystal Display (LCD) was mounted in the center console ahead of the throttle quadrant and was used to display the CDTI. A Mode Control Panel (MCP) was used to control the autothrottle and autopilot systems. Approaches were flown using the autocooper.



Figure 2. MITRE ATM lab cockpit simulator.

The following applications permitted the cockpit to fly within the virtual environment, record simulation events and performance data, and share information between other applications.

- *Three dedicated display processes* for the generation of the EFIS display as well as associated data collection.
- *Flight control simulator* for the definition of movement of the aircraft in response to the pilot actions (e.g., autopilot inputs, throttle movement).
- *Traffic handler* for sending traffic data to the CDTI for display.
- *Navigation aid simulator* which modeled radio-navigation equipment (e.g., the Instrument Landing System (ILS)) and sent the course deviation information to the flight displays.
- *OTW visual scene driver* (see the following description).

The OTW visual scene driver created the 3 dimensional display, which gave the flight crew a virtual representation of the outside world. The perception of immersion was supported by a 130-degree curved screen with a darkened and curtained area. The main elements that composed the virtual world were aircraft, airport surface structures, surrounding terrain, various environmental features, and weather (e.g., clouds). To achieve a high level of visual fidelity, a SGI Onyx II output three discrete channels to generate the OTW imagery. The various models contained in the OTW scene were built using MultiGen-Paradigm Creator and the SGI Performer Application Programming Interface rendered the real time imagery. Various data sources were used together to build each database. Numerous aircraft types, buildings, and other structures were placed using actual dimensions with photographic textures. Level-of-detail techniques were applied to allow for the maximum fidelity at any viewpoint in the scene.

Other aircraft in the scenarios were either pre-recorded or generated by a target generator, which created simulated aircraft flights based on airport, airspace, and runway configuration information, as well as aircraft characteristics. The target generator contained several different aircraft performance models for updating aircraft positions. A ground simulation managed all aircraft, besides the cockpit simulator, in the last phases of flight, i.e., the approach, landing, and taxi.

The display available to ATC was a replication of an Automated Radar Terminal System (ARTS) III.

For more detail on the MITRE CAASD ATM simulation facility see Oswald and Bone, 2002.

2.2 Participants

Eight air carrier pilots (mean flight time = 6700 hours) were recruited for the study and were paid for their participation. All had glass cockpit experience and were familiar with the Traffic alert and Collision Avoidance System (TCAS), which includes a rudimentary traffic display. The subject pilots acted as the pilot flying. A confederate acted as the pilot not flying and performed CEFR specific duties such as interaction with the CDTI.

A confederate air traffic controller acted as the final controller for Runway 17 Right. Two individuals were alternated between this position, both had extensive ATC experience. Each controller acted in his position for half of the trials. Controllers were instructed to “run” traffic as they normally would during instrument approaches, with the exception that they were to vector the subject cockpit behind specifically designated TTF.

A confederate pseudo pilot received instructions from ATC for all aircraft in the scenarios except the cockpit. Those instructions were verbally acknowledged and then entered into an interface in order to maneuver the aircraft as instructed.

2.3 Cockpit Display of Traffic Information

Two CDTI locations and two CDTI sizes were evaluated in this simulation. One location was in the primary field-of-view on the Navigation Display (ND) and the other location was in the throttle quadrant forward console area (the same location typically used in some weather radar installations) (see Figure 3). These locations represented two potential implementations, the first simulated a newer generation aircraft and the second a lower cost retrofit location. The two sizes were either a six or seven inch diagonal. The seven inch CDTI was representative of a primary field of view ND on modern glass cockpits and the six inch CDTI was representative of a throttle quadrant location display.



Figure 3. The two CDTI locations examined.

The CDTI features were those required for the Enhanced Visual Approach procedure as defined in RTCA, 2000. Some of the elements related to the CDTI, including the control panel and some of the display features, were based on the United Parcel Service Aviation Technologies (UPSAT) AT2000 CDTI². The CDTI was utilized, as with previous MITRE simulation efforts, since it was a likely initial ADS-B implementation. The Enhanced Visual Approach feature set was shown to be acceptable for CEFR operations by flight crews, even under unexpected and aggressive deceleration behavior by the TTF, in a previous simulation (see Bone, Domino, Helleberg, and Oswald, 2003). Therefore, this same feature set was chosen for this simulation. The traffic information was overlaid on a navigation display either in the primary field-of-view or in the throttle quadrant forward console. Targets appearing on the CDTI were correlated with visible traffic in the OTW visual scene. CDTI traffic symbols were shown as cyan chevrons when airborne and brown chevrons when on the ground. One of the available features was target selection, which displayed additional information available on the target in a data block in the lower left portion of the display. Selected targets were surrounded with an enhancing outline and depicted in green when airborne and brown when on the ground. The datablock information included selected target ground speed, range from ownship, flight identification, and weight category (see Figure 1). Additionally, closure rate to TTF was automatically displayed when certain geometry constraints were met. Ownship ground speed was also shown. Target range alerting was not provided.

The CDTI feature set examined was available on a currently certified CDTI, which would allow for an acceptable early implementation of the concept without additional development time. However, potential display changes could be proposed. For example, a display element to aid in the task of monitoring could be imagined, such as an analog representation of the changing closure rate (Wickens, Gordon, and Liu, 1998). However, the examination of such changes was not the priority of the simulation efforts.

2.4 Procedure

The experiment was 2 x 2 factorial design with two within subjects independent variables (CDTI size and location). The CDTI size was either a six or seven inch diagonal while the location was either in the primary field-of-view or forward of the throttle quadrant (see Figure 3). Subjects flew all combinations in a counterbalanced order.

At the beginning of the simulation, subjects were briefed on the purpose of the study and provided some basic guidelines for judging separation using the CDTI information. Subjects were advised that they could use any combination of visual or CDTI data to maintain their desired spacing as they do in normal visual separation operations.

² UPS Aviation Technologies asserts proprietary rights in certain concepts embodied in or represented by this simulation, including concepts claimed in one or both of U.S. Patents 6,469,660 and 6,473,003.

Each pilot conducted three practice approaches to become familiar with the simulation characteristics, the CEFR procedure, and the CDTI features. Following training, subjects flew two blocks of six approaches. Each block of approaches used one of the two display sizes. CDTI location varied within each block.

On each trial, subjects flew an ILS approach to runway 17 Right at SDF using the autopilot and approach coupler. Each trial began with ownship and TTF in VMC on top of an overcast cloud layer. The cloud layer began at 3500 ± 200 feet (ft) Mean Sea Level (MSL) and continued to 2000 ± 200 ft MSL (1500 ft above ground level). This single cloud layer thickness was used since the results from the previous simulation indicated that the time spent on the CDTI for separation was not an issue for pilots conducting the CEFR procedure through several cloud thicknesses (Bone, Domino, Helleberg, and Oswald, 2003). Furthermore, this cloud layer allowed for the visual acquisition of traffic above and below the cloud layer and a reasonable length of the final approach segment.

Ownship began each approach from one of three initial set-up positions (downwind, dogleg to final, or extended final) within the continuous traffic flow. The TTF for the approach was either a large, Boeing 757, or heavy aircraft. This mix of aircraft allowed for different radar (and wake) separation requirements. The TTF also varied by its final approach speed and when it slowed to that speed. The final approach speeds varied between 111 and 149 knots, which represented an average ± 2 sigma of an actual distribution of speeds (Warren, Ulrey, and Ebrahimi, 2000). The aircraft slowed to this speed at the final approach fix (FAF), 1 mile outside the FAF, or 1 mile inside the FAF. All TTF exited at the same high speed exit with a runway occupancy time of 50 ± 5 seconds.

The instrument approach clearance included an instruction to maintain “visual separation,” which authorized use of the CDTI to monitor separation when the traffic was not in view OTW.

Aircraft call sign use was an option for air traffic controllers. It could be appended to the standard traffic advisory phraseology (see FAA, 2003a for standard phraseology) to permit pilots to correlate the aircraft seen visually OTW with its target on the CDTI. Flight crews could also use call sign in their response to the advisory. A sample follows.

Louisville Approach Control: “Abaco two thirty five, Louisville Approach, traffic twelve o’clock, six miles, southbound, Boeing seven thirty seven at four thousand, **Defiant one twelve.**”

Abaco 235: “Louisville, Abaco two thirty five, roger, **Defiant one twelve** in sight.”

Once cleared, pilots could use any combination of OTW cues or the CDTI to monitor separation. Pre-recorded traffic arrived and landed on 17 Left and provided targets on the CDTI but was independent of the arrival flow to 17 Right. This traffic was included to increase the simulation realism; however, pilots had no spacing or separation tasks associated with the traffic inbound to the parallel runway. Communication to traffic inbound to 17 Left

was assumed to be using a different approach control frequency. Communications to other traffic in-bound to 17 Right occurred between the confederate controller and a pseudo pilot.

After each approach, pilots taxied clear of the landing runway and completed a workload form. The cockpit was then reset to one of three positions (downwind, dogleg to final, or extended final) to begin the next approach. Each approach spanned approximately ten minutes. After the simulation, pilots completed a questionnaire and participated in an informal debrief.

2.5 Data

One of the main purposes of this study was to assess pilot spacing behavior while using a CDTI to monitor spacing in a manner similar to that used while maintaining separation under a visual separation clearance. Accordingly, each approach was divided into three phases for data collection using the OTW visibility of the TTF as the dividing line between phases. Phase 1 began with initialization of the approach (and initial visual acquisition of TTF) and ended when TTF entered the cloud layer. Phase 2 began when the TTF entered the cloud layer and ended when ownship broke out underneath the cloud layer. During this phase, the TTF was not visible OTW and pilots used only the CDTI to monitor and adjust their separation from TTF. Phase 3 began when ownship broke out underneath (which allowed for visual re-acquisition of traffic) and ended when the TTF crossed the runway threshold (see Figure 4). During each of these phases, spacing between TTF and ownship was collected at a rate of once per second (as objective data).

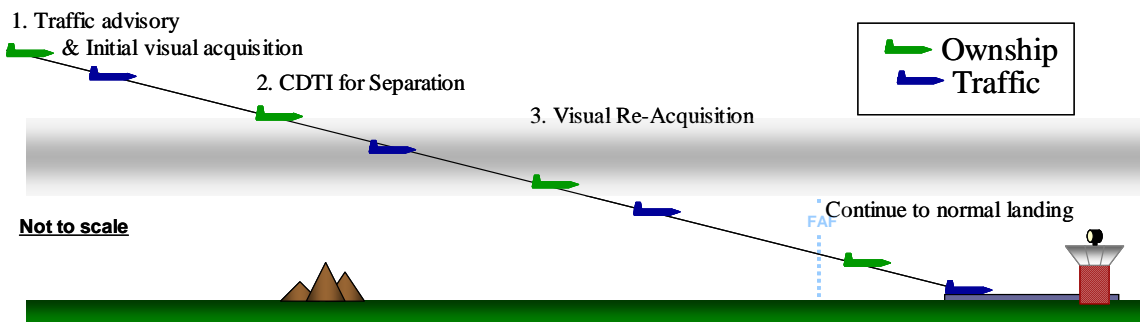


Figure 4. Approach progression and data collection phases.

In flight, pilots were asked to perform duties as they would in normal aircraft operations with the exception of verbalizing their thought processes when interacting with the CDTI. This was done for the benefit of the observer who collected cockpit data by direct observation of pilot-CDTI interaction (Joseph, Domino, Battiste, Bone, and Olmos, 2003).

After each approach, pilots completed a Bedford Workload Rating Scale (Roscoe and Ellis, 1990) (see appendix B). The Bedford workload form is a modification of the Cooper-Harper

measure of handling qualities of test aircraft (Cooper and Harper, 1969). Modified versions of the Cooper-Harper measure have indicated that it can be a statistically reliable indicator of overall mental workload (Wierwille and Casali, 1983).

Additionally, pilots completed a written questionnaire at the conclusion of the study. The questionnaire consisted of Likert scale (i.e., a one-dimensional scale measuring agreement with a topic), multiple choice, yes / no, and open-ended questions. Pilots also participated in an informal oral debrief as a means to discuss topics of interest or a specific topic that was not captured elsewhere.

Section 3

Results

3.1 Subjective

The results presented are based on the pilot responses to the Bedford Workload Rating Scale, the informal debrief, and multiple choice and five-point Likert scale questions from the pilot debrief questionnaire. The Likert scale had the following options: “strongly disagree,” “somewhat disagree,” “neither disagree nor agree,” “somewhat agree,” and “strongly agree” (with a sixth option of “not applicable / did not use”). The pilot responses are reported based on the following mean ranges: 1.00 – 1.49 (strongly disagree), 1.50 – 2.49 (somewhat disagree), 2.50 – 3.49 (neither disagree nor agree), 3.50 – 4.49 (somewhat agree), and 4.50 – 5.00 (strongly agree). Three different style graphs are used in the presentation of the subjective results as a depiction of a:

- Summary of a set of questions.
- Distribution and frequencies of a particular question with high variability.
- Partition by CDTI size and / or location of a particular question.

Note that one pilot, for unknown reasons, did not complete the questions based on the smaller size CDTIs. Therefore, that data is not represented.

The air traffic controllers were “in” on the simulation and were not requested to provide any formal subjective feedback. However, informal data was collected that aided in concept and future simulation development, but is not reported in this document.

3.1.1 CEFR Concept

3.1.1.1 Acceptability and General Conduct of the Procedure

Pilots “strongly agree(d)” or “somewhat agree(d)” that they would be willing to routinely perform CEFR with the appropriate training. Results for the CDTIs were the following: large primary ($M = 5.00$, $SD = 0.00$), small primary ($M = 5.00$, $SD = 0.00$), large throttle ($M = 4.63$, $SD = 0.55$), small throttle ($M = 4.29$, $SD = 0.57$) (see Figure 5).

Pilots “strongly agree(d)” or “somewhat agree(d)” that they were comfortable using the CDTI when traffic was not visually in sight OTW. Results for the CDTIs were the following: large primary ($M = 5.00$, $SD = 0.00$), small primary ($M = 5.00$, $SD = 0.00$), large throttle ($M = 4.38$, $SD = 0.27$), small throttle ($M = 4.29$, $SD = 0.24$) (see Figure 6).

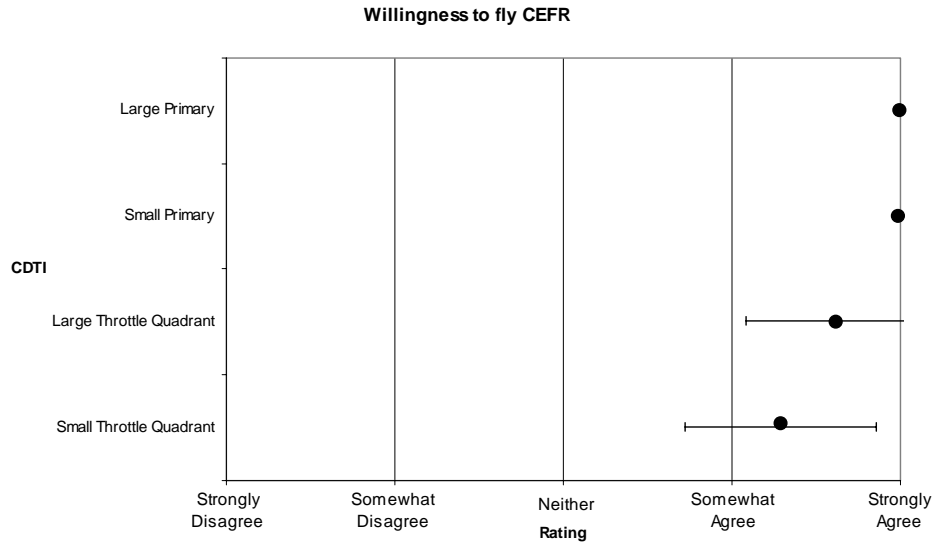


Figure 5. Average pilot rating on their willingness to routinely perform CEFR by CDTI.

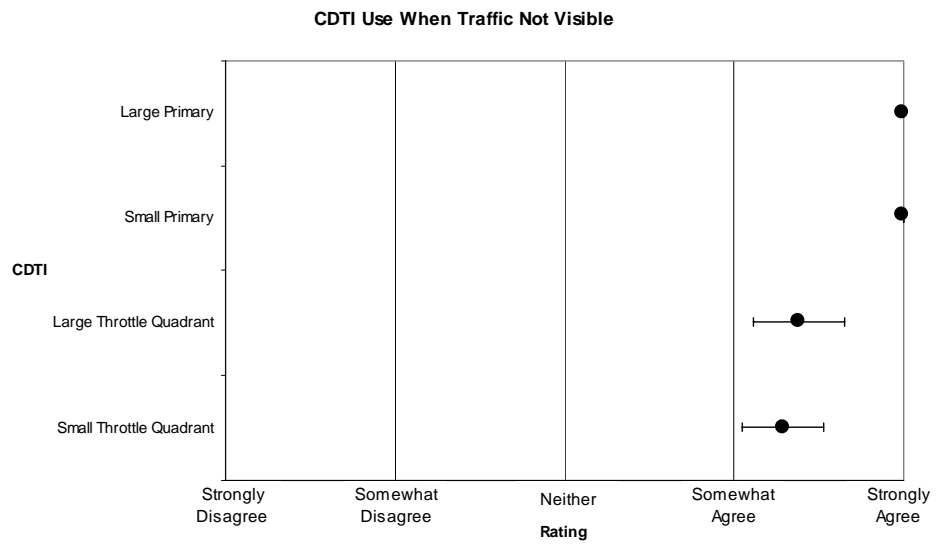


Figure 6. Average pilot rating on comfort when using CDTI for separation when traffic was not visible.

Pilots “strongly agree(d)” or “somewhat agree(d)” with the statement, “Overall, use of the CDTI enhanced the safety of ILS approach operations” (see Figure 7). Results for the CDTIs were the following: large primary ($M = 5.00, SD = 0.00$), small primary ($M = 5.00, SD = 0.00$), large throttle ($M = 4.38, SD = 0.27$), small throttle ($M = 4.29, SD = 0.57$)

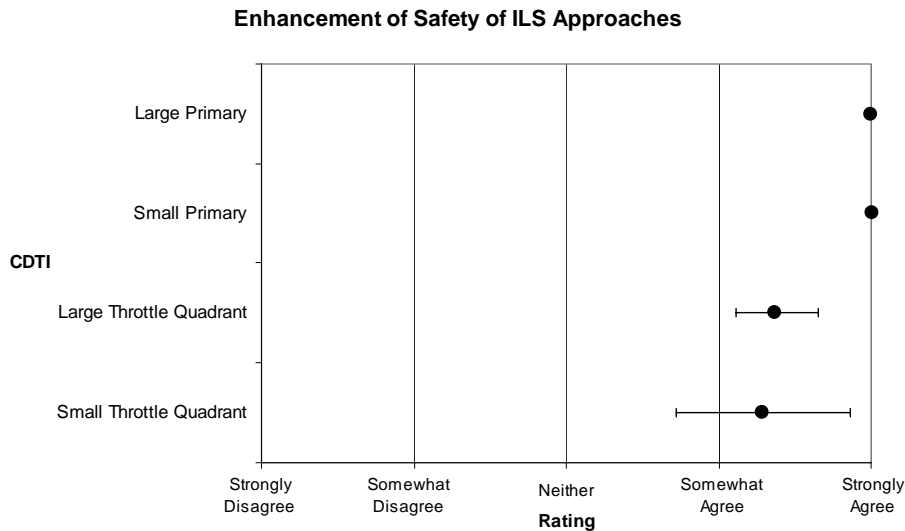


Figure 7. Average pilot response regarding the enhancement of safety during ILS approach operations with the use of a CDTI.

Pilots “strongly agree(d)” that they were more confident with the use of the CDTI as compared to the OTW visual scan for establishing appropriate spacing ($M = 4.50, SD = 0.29$). Pilots “strongly agree(d)” that the use of the CDTI was acceptable for separation in the 1500 ft cloud layers presented ($M = 5.00, SD = 0.00$). Pilots “strongly agree(d)” that they were able to perform CEFR regardless of CDTI size ($M = 4.86, SD = 0.14$) or location ($M = 4.50, SD = 1.14$). Pilots “strongly agree(d)” that it would be acceptable to modify the meaning of visual separation to include use of the CDTI ($M = 4.88, SD = 0.13$). Pilots also “strongly agree(d)” that closure to final spacing occurred at a comfortable and appropriate rate when using the CDTI ($M = 4.63, SD = 0.27$). See Figure 8 for a summary. Pilot opinions varied on whether initial visual acquisition of traffic was required prior to using the CDTI for separation (see Figure 9).

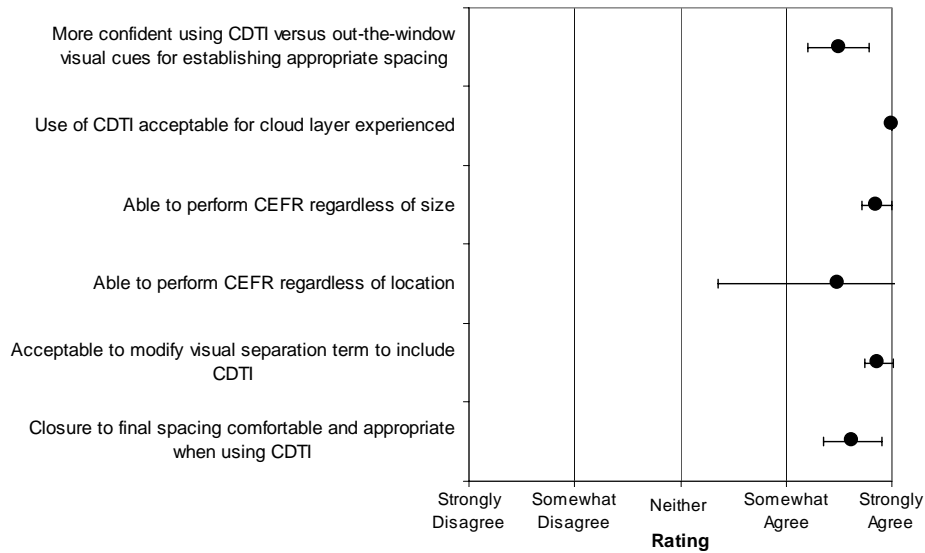


Figure 8. Summary of questions on the general conduct of the CEFR procedure.

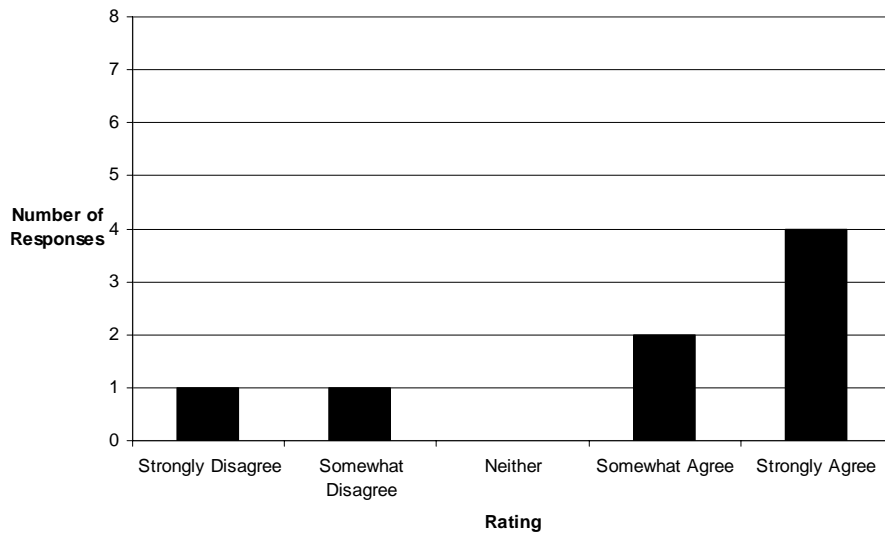


Figure 9. Distribution and frequency of pilot responses to question of whether initial visual acquisition is required prior to using the CDTI for separation.

In regards to difficulty, pilots were asked to choose the most representative statement from the following list (one pilot did not answer). The procedure is:

- No more difficult than most precision approaches (62.5% of the responses).
- More difficult than most precision approaches but the average pilot can do it (31.3%).
- Very difficult with respect to most precision approaches. The average line pilot will have difficulty with it (0%).
- Extremely difficult with respect to most precision approaches. Most pilots will be unable to perform the procedure (0%).
- Too difficult to be safely flown by any pilot (0%).

Ninety percent of the answers in the “More difficult...” option were based on the throttle quadrant display (see Figure 10).

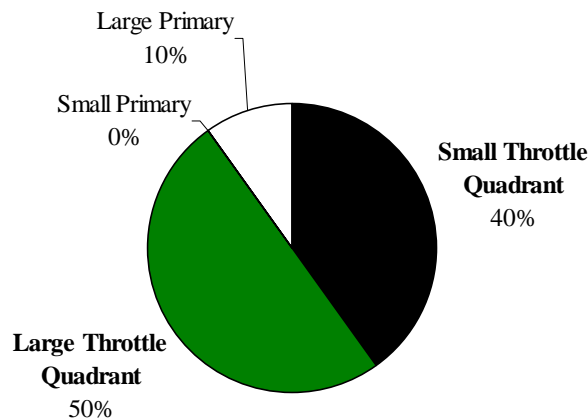


Figure 10. Percentage of responses in the CEFR is “More difficult than most precision approaches but the average pilot can do it” option.

During the debrief, pilots were asked if loss of visual contact with the TTF affected their behavior. All pilots reported that their behavior was not affected (see Figure 11). When discussing wake turbulence in the debrief, subjects generally agreed that some type of

prescribed spacing guidance should be adapted and included in company training. The prescribed spacing should be standard across the industry and should be instituted as guidelines only and not as a regulation.

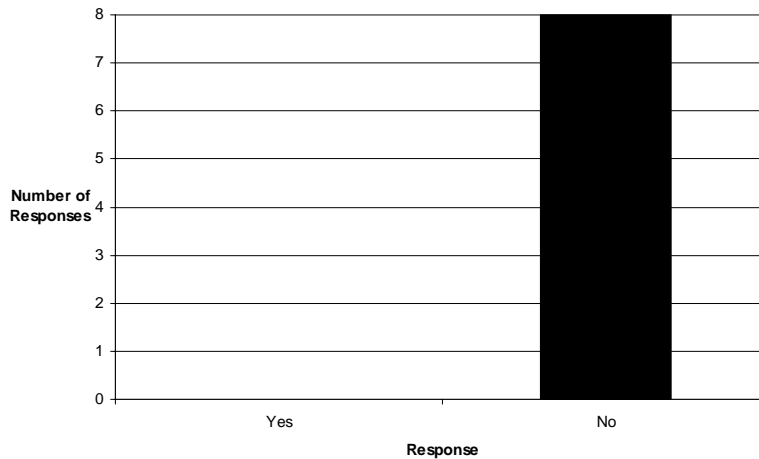


Figure 11. Distribution and frequency of pilot responses when asked if loss of visual contact with the TTF affected their behavior.

3.1.1.2 Head Down Time

Pilots “strongly agree(d)” that the large ($M = 4.88, SD = 0.13$) and small ($M = 4.71, SD = 0.24$) primary CDTIs were easy to integrate in the instrument scan without excessive fixation (see Figure 12). For the same question regarding the large ($M = 2.88, SD = 1.27$) and small ($M = 3.00, SD = 0.67$) throttle quadrant CDTIs, the results were varied and are shown in Figures 13 and 14.

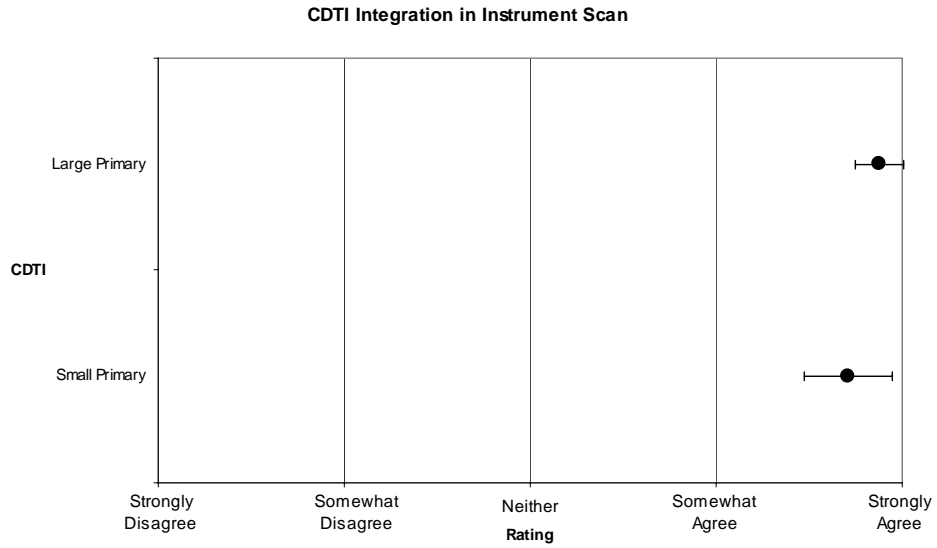


Figure 12. Average pilot ratings on question of integration of the primary CDTIs into the instrument scan.

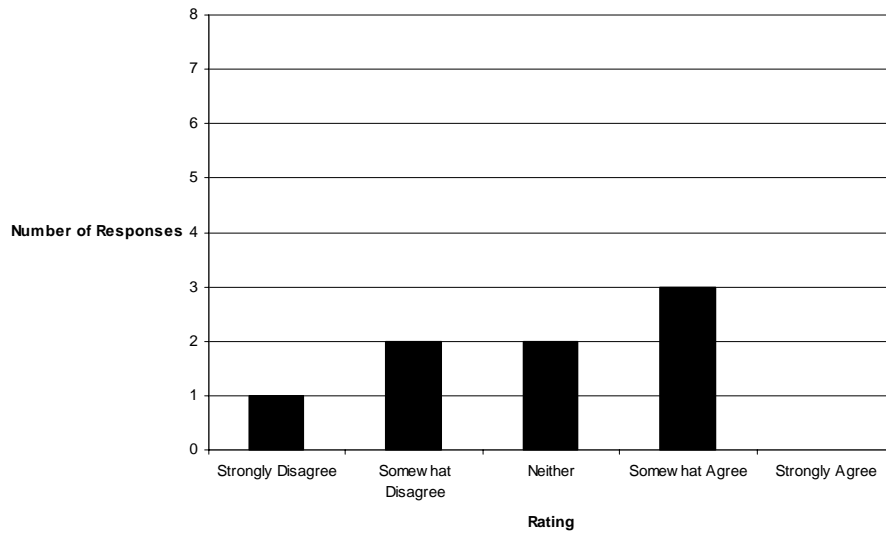


Figure 13. Distribution and frequency of pilot responses to question of integration of the large throttle quadrant CDTI into the instrument scan.

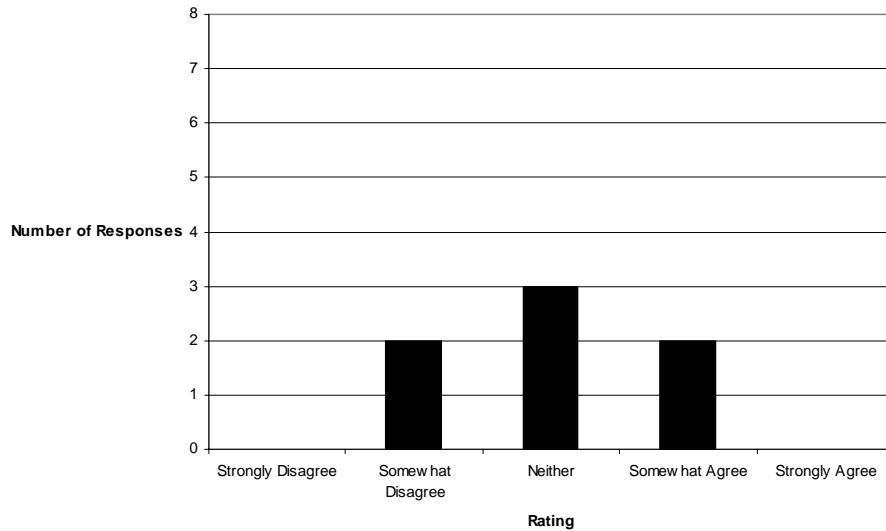


Figure 14. Distribution and frequency of pilot responses to question of integration of the small throttle quadrant CDTI into the instrument scan.

Pilots “strongly agree(d)” that the large primary CDTI was easy to integrate in the OTW scan without excessive fixation ($M = 4.50$, $SD = 0.57$). Pilots “somewhat agree(d)” that the small primary CDTI was easy to integrate in the OTW scan without excessive fixation ($M = 4.43$, $SD = 0.62$) (see Figure 15). For the same question regarding the large ($M = 3.13$, $SD = 1.84$) and small ($M = 3.14$, $SD = 1.48$) throttle quadrant CDTIs, the results were varied and are shown in Figures 16 and 17.

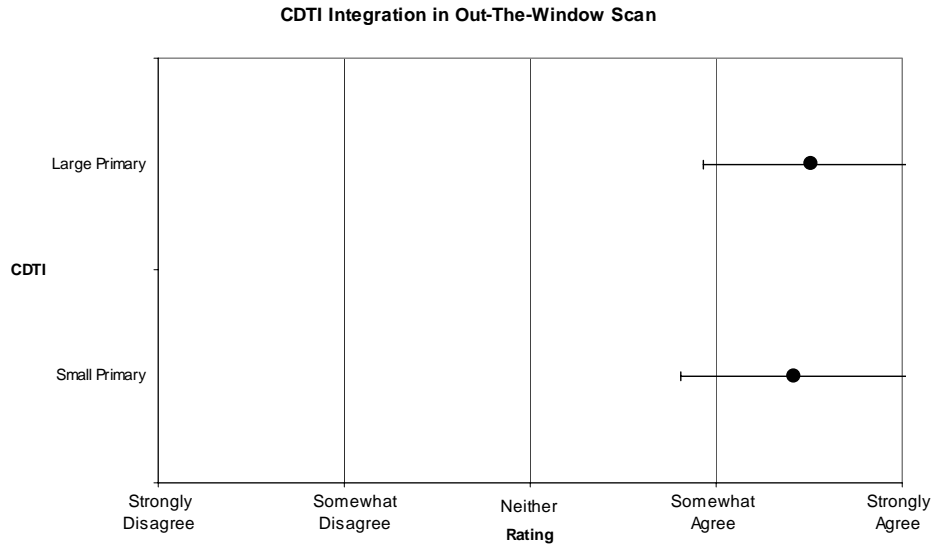


Figure 15. Average pilot ratings on question of integration of the primary CDTIs into the out-the-window scan.

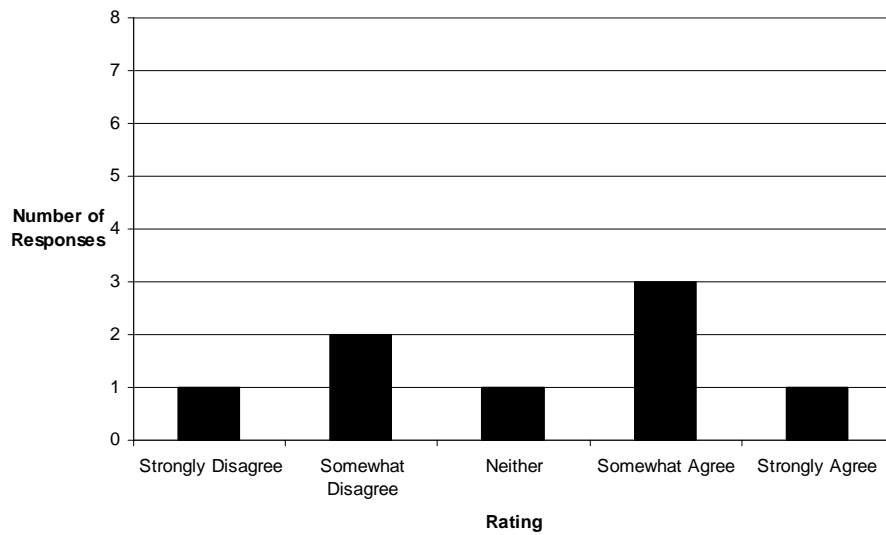


Figure 16. Distribution and frequency of pilot responses to question of integration of the large throttle quadrant CDTI into the out-the-window scan.

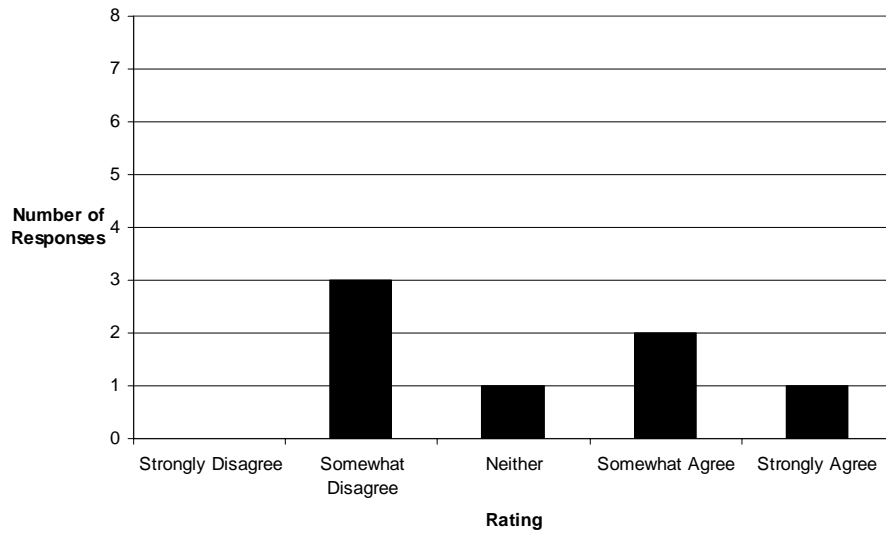


Figure 17. Distribution and frequency of pilot responses to question of integration of the small throttle quadrant CDTI into the out-the-window scan.

3.1.1.3 Workload

The average workload ratings on the Bedford Workload Rating Scale provided by pilots at the end of each approach were the following (by CDTI type): large primary ($M = 1.50$, $SD = 0.51$), small primary ($M = 1.67$, $SD = 0.56$), large throttle ($M = 2.21$, $SD = 0.72$), small throttle ($M = 1.96$, $SD = 0.62$). All means are a rating of “workload is low” on the Bedford Workload Rating Scale. These results were subjected to a 2 (CDTI size) x 2 (CDTI location) within-subjects analysis of variance (ANOVA). The results revealed a significant main effect of display location, $F(1, 7) = 5.86$, $p < .05$. Figure 18 shows that workload ratings increased when pilots used the throttle quadrant CDTI. However, the effect of display size on pilot workload ratings was not significant, $F(1, 7) = 0.08$, ns . Although some workload effects were seen, the pilots “strongly agree(d)” that all cockpit tasks were completed while performing the CEFR procedure ($M = 4.88$, $SD = 0.13$).

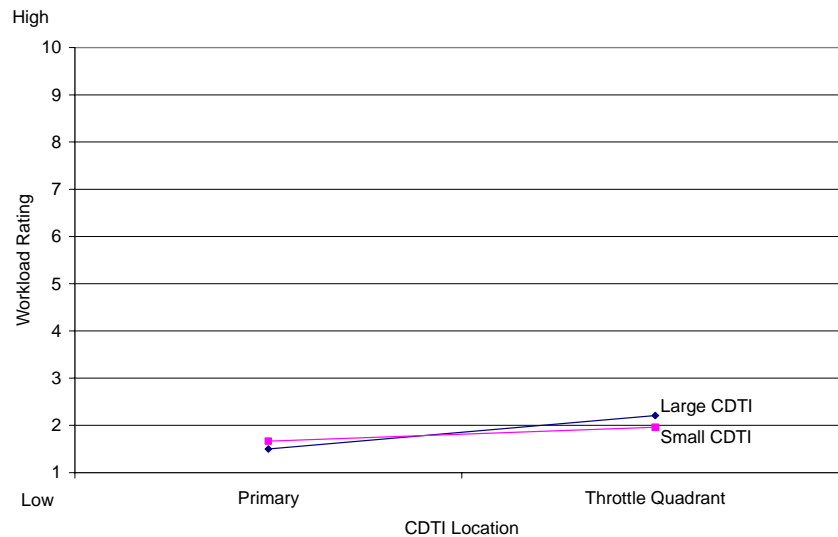


Figure 18. Pilot mean workload ratings by display location and display size.

3.1.2 CDTI Features

Pilots “strongly agree(d)” that the necessary CDTI features for performing visual separation were available ($M = 5.00$, $SD = 0.00$) and that those features were beneficial for acquiring and tracking traffic ($M = 5.00$, $SD = 0.00$). Pilots “strongly agree(d)” that the traffic symbols, i.e., chevrons, ($M = 4.88$, $SD = 0.13$) and the traffic colors, i.e., cyan when airborne and brown when on the ground, ($M = 5.00$, $SD = 0.00$) were acceptable. See Figure 19 for a summary. During the debrief, pilots were asked which display features they found

most useful. Those responses are shown in Figure 20. None of the subjects found any of the display features to be totally unusable or disruptive to completing the assigned task.

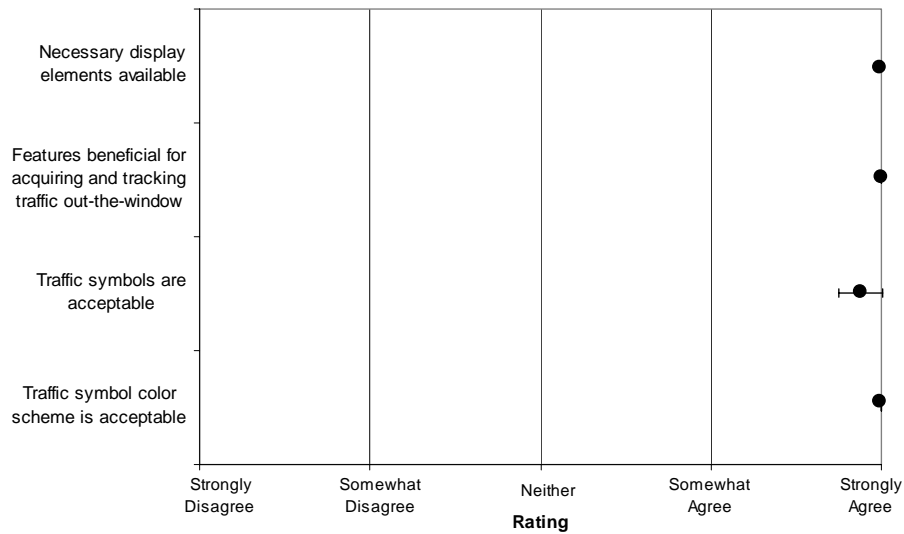


Figure 19. Average pilot rating for CDTI feature questions.

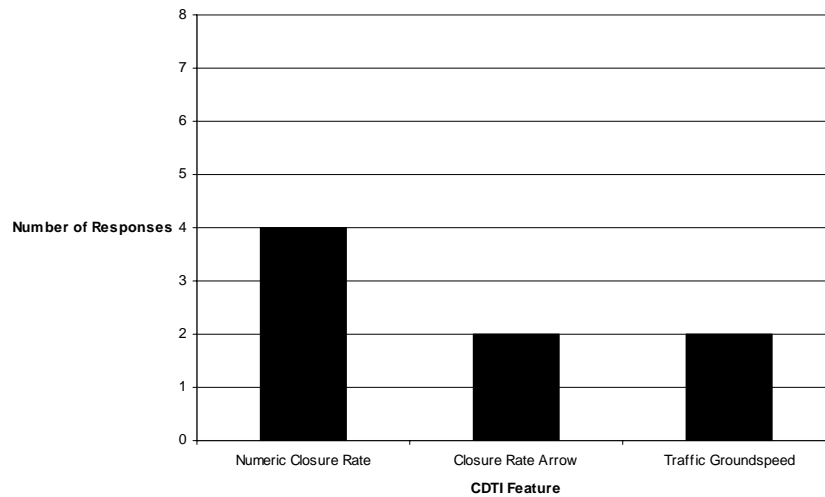


Figure 20. CDTI features that pilots reported were the most useful (Note: Although not represented, pilots also reported that the numeric range was very useful).

Cockpit observer data indicated that it was clear, from subject comments, that the CDTI enabled enhanced crew performance for achieving visual separation. The CDTI also provided the crew with significantly more traffic information to aid in their decision making. The following comments were noted.

- “It (CDTI) would be very useful in Chicago or New York.”
- “That’s very nice, I can see that he’s turned off (the runway).”

Additionally, numerous comments indicated that the CDTI greatly enhanced the overall traffic awareness of the pilots. The following comments were noted.

- “Interesting...I can follow his deceleration on the runway.”
- “It gives a great mental picture of what’s there and what to expect.”

3.1.3 Aircraft Call Sign Use in Traffic Advisories

Pilots “somewhat agree(d)” that use of call sign aids in positive identification ($M = 4.00$, $SD = 0.57$) and the benefits involved in the use of call sign are worthwhile ($M = 4.13$, $SD = 0.70$) (See Figure 21). Pilots responses were in opposition on whether the use of call sign in a reply to ATC was unacceptable ($M = 3.00$, $SD = 2.86$) and whether it was confusing to hear their ownship call sign in a traffic advisory to another aircraft ($M = 2.88$, $SD = 2.41$) (See Figures 22 and 23, respectively).

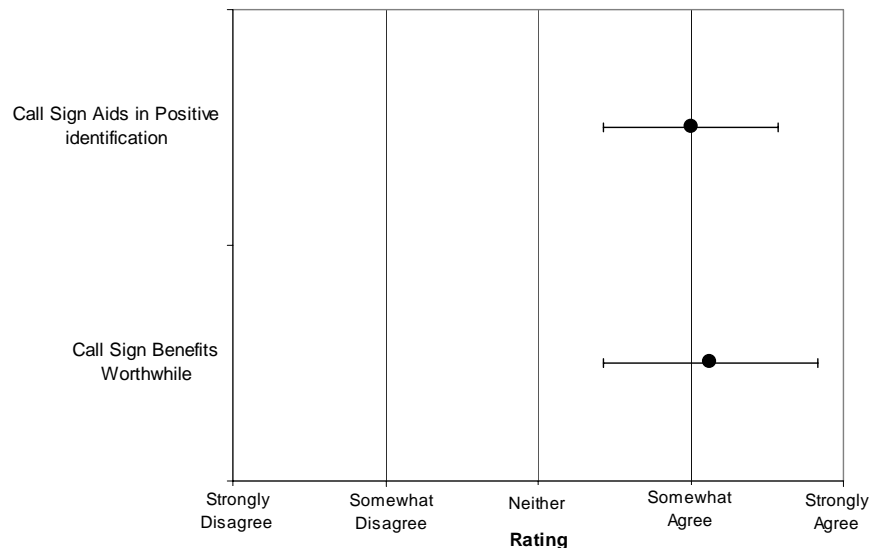


Figure 21. Average pilot rating for call sign procedure questions.

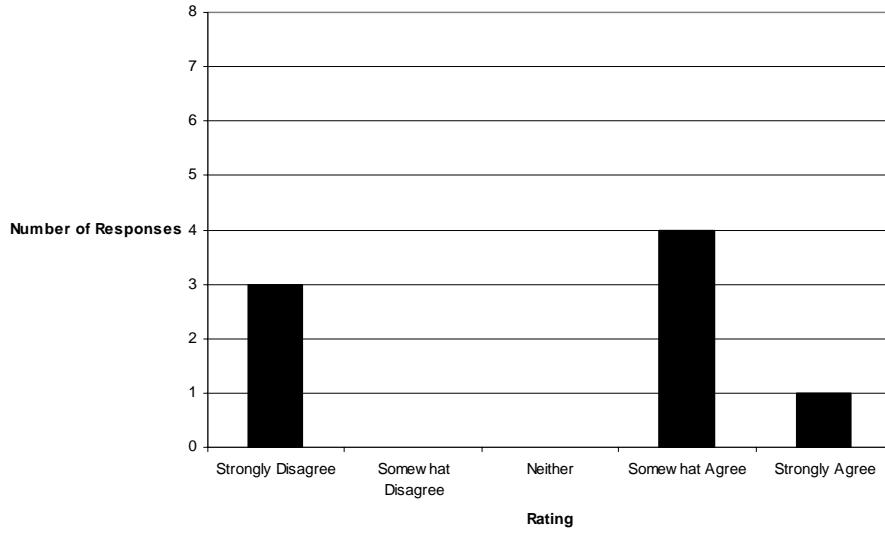


Figure 22. Distribution and frequency of pilot responses to the question on whether call sign use in the reply to ATC was unacceptable.

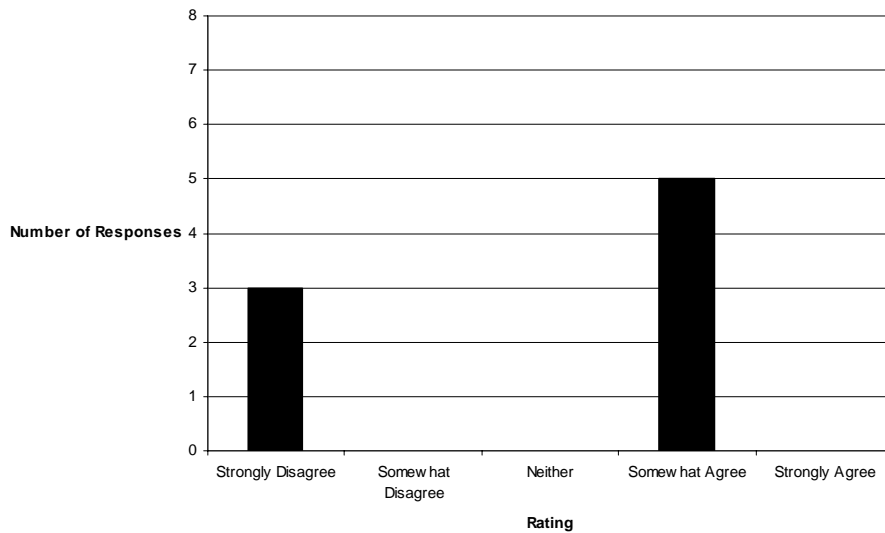


Figure 23. Distribution and frequency of pilot responses to the question on whether it was confusing to hear ownship call sign in a traffic advisory to another aircraft.

3.1.4 Crew Resource Management

In the debrief, pilots were asked what crew procedures (pilot flying and pilot not flying duties) should be developed for CEFR (e.g., related to the CDTI location, distance / closure rate callouts). The pilots consistently felt that manipulation and scanning of the CDTI should be the duty of the pilot not flying. Most felt that standardized callouts (based on company procedures for spacing, closure rate, etc) should be developed. If flying in instrument meteorological conditions (IMC), the pilot flying could prompt for information in lieu of callouts, especially if using the throttle quadrant display.

3.1.5 Simulation Environment

Pilots “strongly agree(d)” ($M = 4.63, SD = 0.27$) that the autopilot performance was acceptable. Pilots “strongly agree(d)” that the primary field of view display ($M = 5.00, SD = 0.00$) and the throttle quadrant display ($M = 4.50, SD = 0.29$) were useable. Pilots also “strongly agree(d)” that the depiction of the OTW world ($M = 4.88, SD = 0.13$) as well as the traffic ($M = 4.88, SD = 0.13$) were an acceptable representation of the real world. Finally, pilots “strongly agree(d)” ($M = 4.63, SD = 0.27$) that their performance during the simulation reasonably reflected how they would fly the procedure in actual operations. See Figure 24 for a summary.

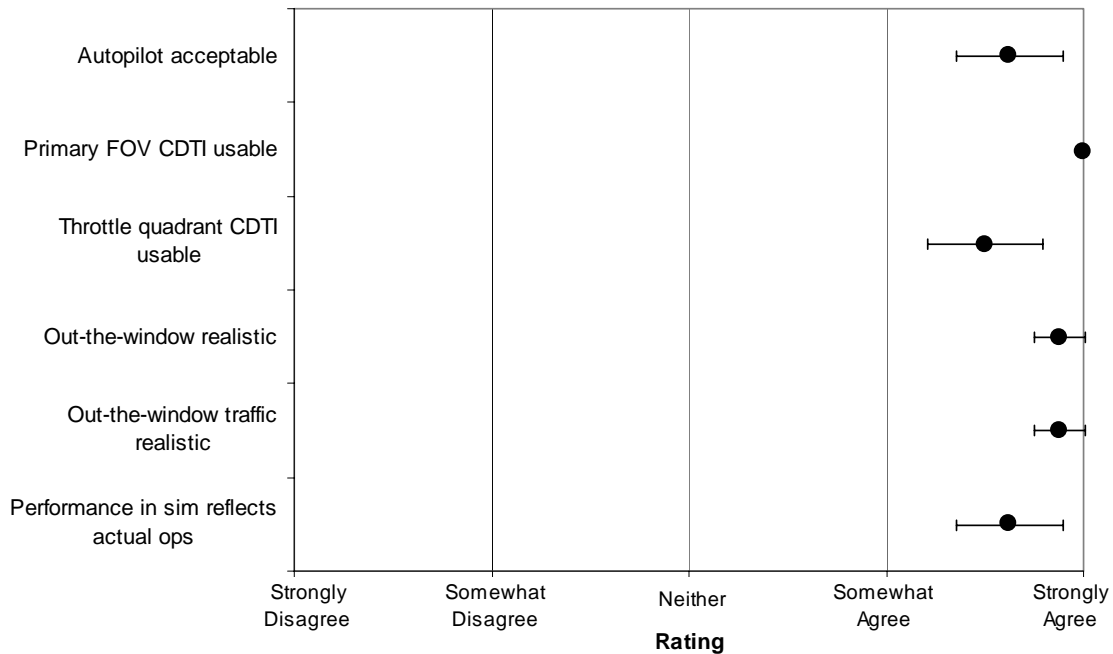


Figure 24. Average pilot rating for simulation environment questions.

3.2 Objective

3.2.1 Spacing

The phase 2 final spacing data represented in-trail separation after using only the CDTI for separation. The phase 3 data represented the in-trail separation as the TTF crossed the threshold, which is commonly used as one measure of throughput efficiency. To increase power and allow comparisons across aircraft types with a single ANOVA, the spacing data was converted into a relative measure of the distance between ownship and the radar separation minima (including wake turbulence applications). It should be noted that the radar separation numbers were used as a reference point and are not separation figures required for use by flight crews during visual separation.

In order to assess the effects of display size and display location, two separate 2 (CDTI size) x 2 (CDTI location) within-subjects ANOVAs were conducted on the spacing between ownship and the TTF at the end of phase 2 and phase 3. The spacing between TTF and ownship at the end of phase 2 was not significantly affected by display size $F(1, 7) = 0.40$, *ns* or display location $F(1, 7) = 0.37$, *ns*. Correspondingly the spacing between TTF and ownship at the end of phase 3 was also not significantly affected by display size $F(1, 7) = 0.18$, *ns* or display location $F(1, 7) = 0.83$, *ns*.

Pearson product-moment correlations between the initial spacing at the beginning of phase 1 (the point at which pilots began the spacing task) and the final spacing at the end of phase 2 (the point at which pilots could use OTW visual separation) were performed separately for each aircraft type (i.e., large, 757, and heavy categories). The correlation was not significant for large TTF types $r(30) = .06$, *ns*. However, there was a significant positive correlation for 757 TTF types $r(30) = .37$, $p < .05$ and for heavy TTF types $r(29) = .56$, $p < .01$ indicating that spacing at the end of phase 2 increased as the initial spacing increased. Figures 25, 26, and 27 depict the relationship between initial spacing and final spacing at the end of phase 2 by TTF category.

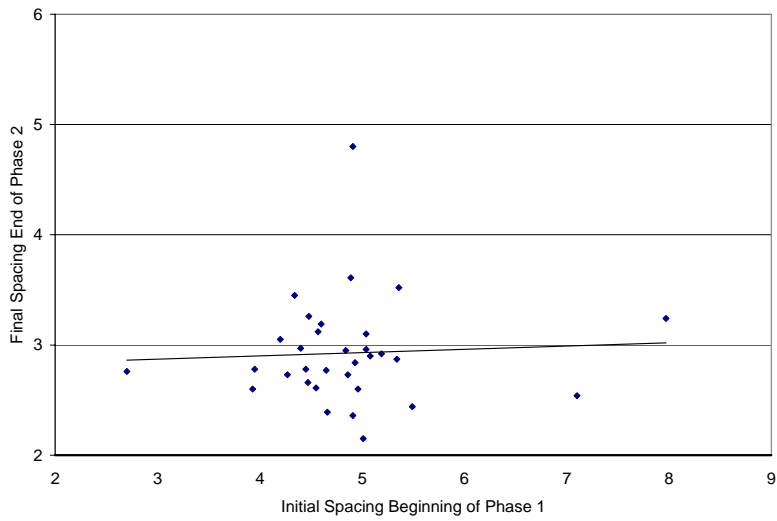


Figure 25. Relationship between initial spacing and spacing at the end of phase 2 when following large aircraft.

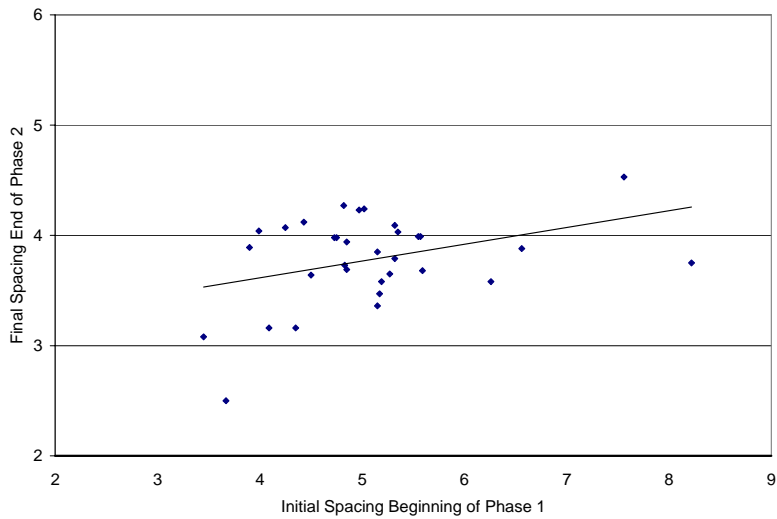


Figure 26. Relationship between initial spacing and spacing at the end of phase 2 when following 757 aircraft.

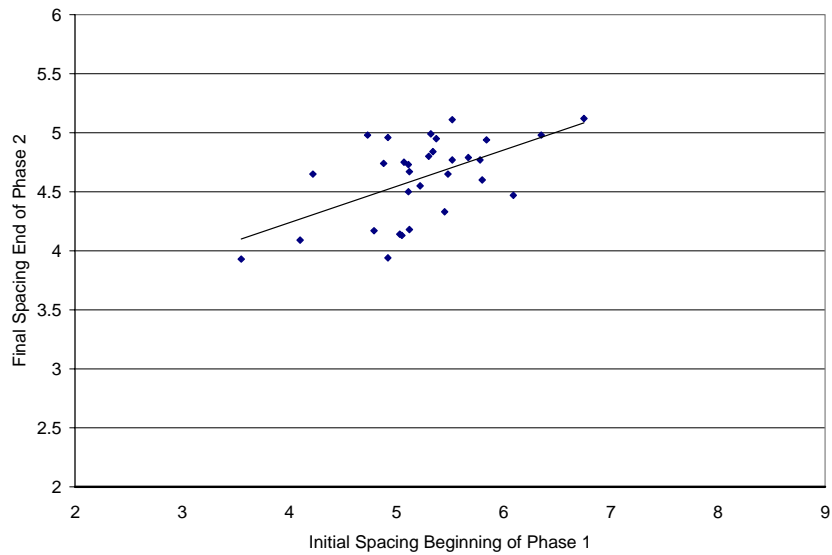


Figure 27. Relationship between initial spacing and spacing at the end of phase 2 when following heavy aircraft.

A similar set of Pearson product-moment correlations between the initial spacing at the beginning of phase 1 (the point at which pilots began the spacing task) and the final spacing at the end of phase 3 (the point at which the TTF crossed the threshold) were performed separately for each aircraft type (i.e. large, 757, and heavy categories). The correlation was not significant for large TTF types $r(30) = .00$, ns or for 757 TTF types $r(30) = .27$, ns. However, there was a significant positive correlation for heavy TTF types $r(29) = .52$, $p < .01$ indicating that spacing at the end of phase 3 increased as the initial spacing increased. Figures 28, 29, and 30 depict the relationship between initial spacing and final spacing at the end of phase 3 by TTF category.

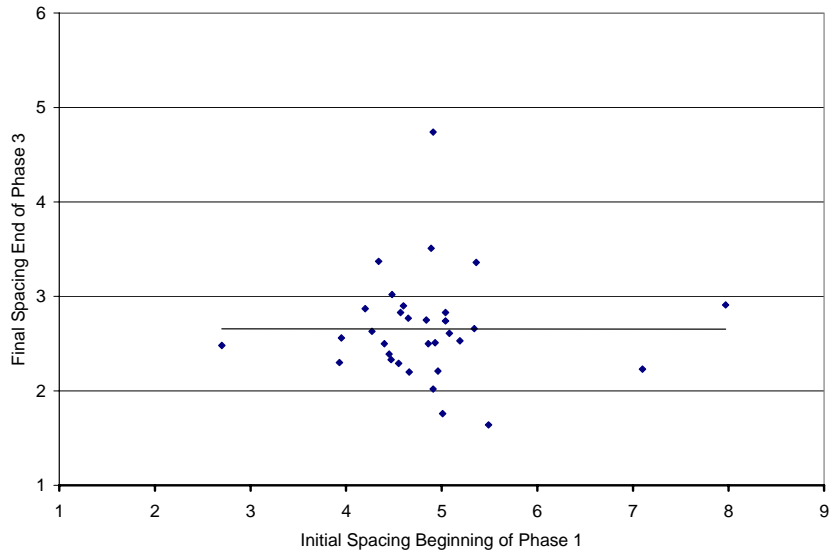


Figure 28. Relationship between initial spacing and spacing at the end of phase 3 when following large aircraft.

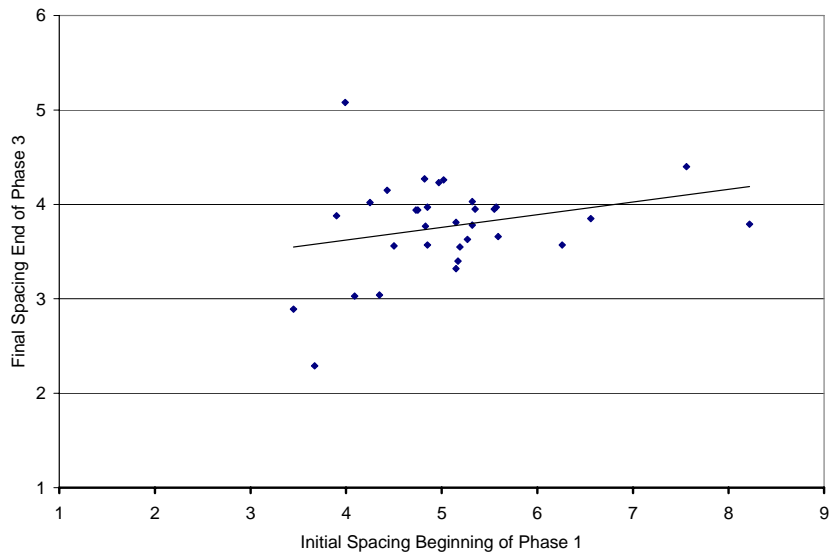


Figure 29. Relationship between initial spacing and spacing at the end of phase 3 when following a 757 aircraft.

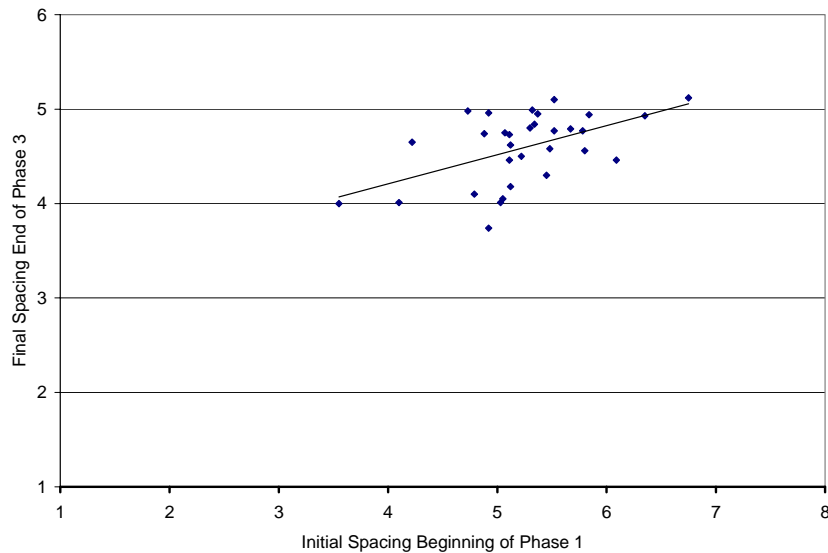


Figure 30. Relationship between initial spacing and spacing at the end of phase 3 when following a heavy aircraft.

3.2.2 Closure Rate

The minimum and maximum closure rates that occurred were calculated separately during each of the phases. In order to assess the effects of display size and display location, three separate 2 (CDTI size) x 2 (CDTI location) within-subjects ANOVAs were conducted on the minimum closure rate between ownship and the TTF across phase 1, phase 2, and phase 3. A similar set of ANOVAs was conducted on the maximum closure rate.

The minimum closure rate between TTF and ownship across phase 1 was not significantly affected by display size $F(1, 7) = 1.52, ns$ or display location $F(1, 7) = 0.02, ns$.

Correspondingly, the minimum closure rate between TTF and ownship across phase 2 was also not significantly affected by display size $F(1, 7) = 0.13, ns$ or display location $F(1, 7) = 0.42, ns$. Correspondingly, the minimum closure rate between TTF and ownship across phase 3 was also not significantly affected by display size $F(1, 7) = 0.00, ns$ or display location $F(1, 7) = 0.05, ns$. A similar pattern was found for the maximum closure rates.

The maximum closure rate between TTF and ownship across phase 1 was not significantly affected by display size $F(1, 7) = 0.13, ns$ or display location $F(1, 7) = 0.01, ns$.

Correspondingly, the maximum closure rate between TTF and ownship across phase 2 was also not significantly affected by display size $F(1, 7) = 0.09, ns$ or display location $F(1, 7) = 0.07, ns$. Correspondingly, the maximum closure rate between TTF and ownship across

phase 3 was also not significantly affected by display size $F(1, 7) = 1.99, ns$ or display location $F(1, 7) = 0.02, ns$.

In order to examine the relationship between closure rate and the distance from TTF, the spacing data was converted into a relative measure of the distance between ownship and the radar separation minima (including wake turbulence applications). It should be noted that the radar separation numbers were used as a reference point and are not separation figures required for use by flight crews during visual separation. These derived spacing values were used in the following analyses.

Pearson product-moment correlations were performed between minimum and maximum closure rate and the derived spacing values described above at the end of phase 1, at the end of phase 2, and at the end of phase 3. The correlation between minimum closure rate and distance from the spacing reference across phase 1, 2, and 3 was significant $r(266) = .52, p < .01$. The correlation between maximum closure rate and distance from the spacing reference across phase 1, 2, and 3 was also significant $r(266) = .25, p < .01$. Figures 31 and 32 depict the relationship between minimum and maximum closure rate and distance from the spacing reference across phase 1, 2, and 3. It is clear from the figures that pilots utilized higher closure rates when the spacing between aircraft was greater and lower closure rates when spacing was reduced.

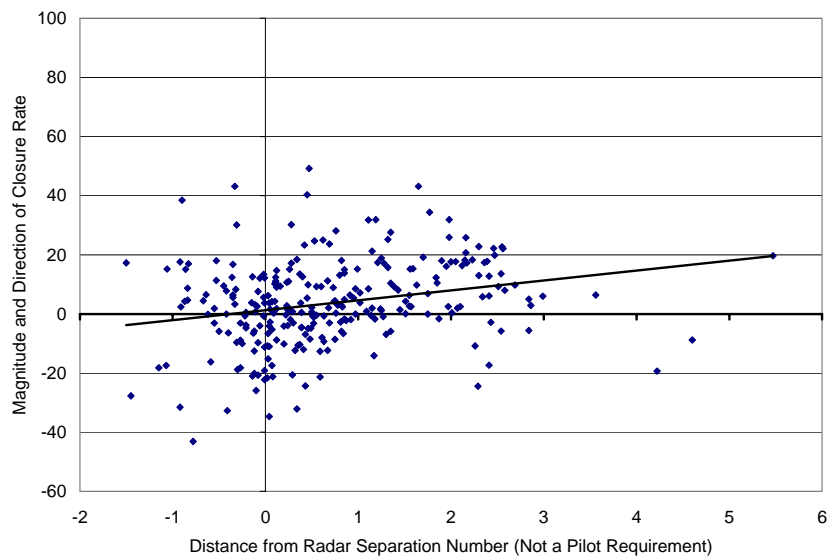


Figure 31. Relationship between derived distance from spacing reference and minimum closure rate across the entire approach.

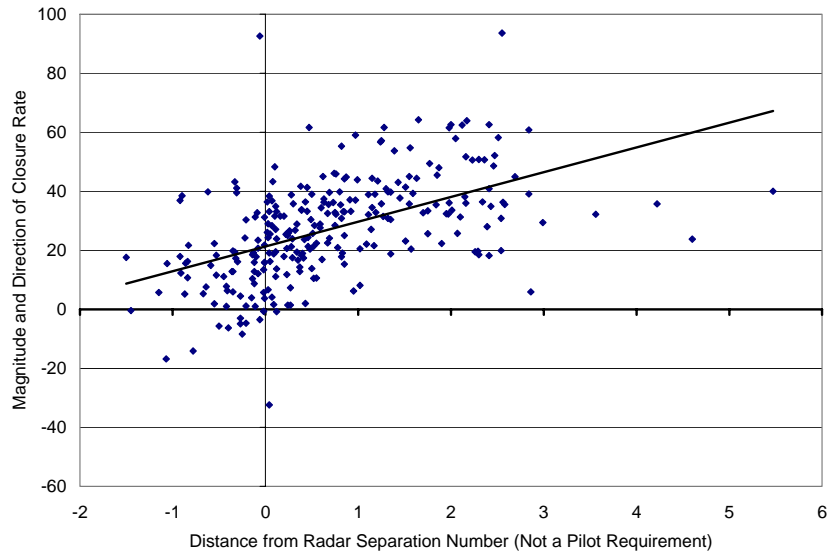


Figure 32. Relationship between derived distance from spacing reference and maximum closure rate across the entire approach.

Section 4

Discussion

This second evaluation of the CEFR procedure validated the findings from the first study and indicated that pilots were able to adequately perform separation monitoring during instrument approach operations by reference to the CDTI. Pilots reported being comfortable with the simulation environment and that their conduct in the simulation reasonably reflected real world operations. Pilot responses on the CEFR procedure indicated strong acceptance of the CDTI features (especially closure rate data, relative numeric distance, and ground speed of the TTF) and their use for CEFR and for traffic awareness. In fact, pilots reported being more confident with the use of the CDTI as compared to the OTW visual cues for establishing the appropriate spacing. Pilots also reported that the loss of visual cues did not affect their behavior, indicating that the CDTI is used in the same manner regardless of whether or not the traffic is in sight OTW. Objective closure rate data indicated that pilots were able to use the information available on the CDTI to allow for higher closure rates when spacing between aircraft was greater and lower closure rates when spacing between aircraft was reduced.

Spacing after using only the CDTI for separation increased as initial spacing increased for both 757 and heavy aircraft (but not for large). Similar trends were seen for final spacing between aircraft. These results indicate, as with the initial simulation (Bone, Domino, Helleberg, and Oswald, 2003), that controllers will continue to have a key role in the successful implementation of CEFR procedures. Tighter initial spacing or an instruction to maintain a certain speed or greater³ will permit pilots to “fine tune” their spacing interval.

Pilots indicated that the call sign procedure could be beneficial and that it aided in the positive identification of aircraft. However, opinions were in opposition on the actual use and potential confusion. Nevertheless, call sign use is optional for CEFR and other visual acquisition procedures and is not a required element.

With regard to CDTI size and location, size difference was minimal and was less of an issue than location. Pilot responses were more variable on head down time associated with the throttle quadrant forward console implementations. Head down time with regard to the throttle quadrant forward console implementation needs further examination in future simulations, in part to determine if learning and experience have an effect. While workload

³ Air traffic control issuing a speed to maintain for spacing to the flight crew, when the flight crew is responsible for separation, can seem contradictory. However, this is a common current practice during visual separation and / or visual approaches to achieve a desired operational spacing to the same runway. If necessary, pilots are able to initially refuse or subsequently report unable.

was statistically significant for CDTI location, it was not operationally significant since the workload rating on the Bedford Workload Rating Scale was still, “workload is low.” As another indication of acceptable workload, pilots reported that all cockpit tasks were successfully completed. However, it should be noted that the pilot not flying, which was a confederate in this simulation, may have additional duties associated with CEFR and therefore could have a higher workload. Finally, pilots reported being willing to perform CEFR with any of the CDTI sizes or locations examined in this simulation. As for the objective data, no effect was found for either CDTI size or location either on spacing or closure rates between ownship and the TTF, whether traffic was visible or not. Therefore, the CDTI size and location data indicate that any of the examined implementations are acceptable.

The CEFR procedure is in the preliminary stages of development and evaluation. Future simulations will incrementally increase the realism of the operating environment, include line air traffic controllers as participants, and examine the visual approach application. The operating environment will also be expanded to include marginal visual weather conditions and night operations. These conditions commonly create demanding visual acquisition environments, under which CEFR may provide benefits.

Procedural issues that still need to be addressed in future discussions and simulations include: crew coordination requirements for CDTIs forward of the throttle quadrant, alerting requirements to support the spacing task, and pilot and ATC actions under failure conditions. These issues are being identified and examined in Safe Flight 21.

List of References

- Abbott, Terence S. (2002). *Speed Control Law for Precision Terminal Area In-Trail Self Spacing*, NASA TM 2002-211742, NASA Langley Research Center, Hampton, VA.
- Bone, R., Domino, D., Hahn, E., and Narkus-Kramer, M. (2002). Cockpit Display Of Traffic Information (CDTI) Enhanced Flight Rules (CEFR). *Proceedings of the 2002 IEEE/AIAA 21st Digital Avionics Systems Conference*, Oct. 2002, Irvine, CA: IEEE Press, 2002.
- Bone, R. S., Domino, D. A., Helleberg, J., and Oswald, A. (2003). *Cockpit Display Based Visual Separation During an Instrument Approach: Pilot Performance and Acceptability. An Implementation of Cockpit Display of Traffic Information (CDTI) Enhanced Flight Rules (CEFR)*. MITRE Technical Report (MTR 03W0000011), The MITRE Corporation Center for Advanced Aviation System Development, McLean, VA.
- Bone, R. S., Helleberg, J., Domino, D. A., and Johnson, N. (in preparation). *Pilot Use of a Traffic Display for Visual Separation during Visual Approaches: Cockpit Display of Traffic Information (CDTI) Enhanced Flight Rules (CEFR) Simulation 3*. MITRE Technical Report (number forthcoming), The MITRE Corporation Center for Advanced Aviation System Development, McLean, VA.
- Bone, R., Olmos, O., Mundra, A., Hammer, J., Stassen, H. P., and Pollack, M. (2000). *Paired Approach Operational Concept*. MITRE Paper 00W0000210, The MITRE Corporation Center for Advanced Aviation System Development, McLean, VA.
- Cooper, G. E., and Harper, R. P., Jr. (1969). *The Use of Pilot Rating in the Evaluation of Aircrafts Handling Qualities* (NASA TN-D-5153). Moffett Field, CA: NASA Ames Research Center.
- Eurocontrol (2002). *CARE/ASAS Activity 5. Proposal for a first package of GS/AS applications*, Brussels, Belgium.
- Federal Aviation Administration (2001). *Operational Evolution Plan*. Available URL: <http://www.faa.gov/programs/oep/AW-2.htm>, Department of Transportation Federal Aviation Administration, Washington, DC.
- Federal Aviation Administration (2003a). *7110.65 Air Traffic Control*, Department of Transportation Federal Aviation Administration ATO-100, Washington, DC.
- Federal Aviation Administration (2003b). *Aeronautical Information Manual*, Department of Transportation Federal Aviation Administration, Washington, DC.
- Federal Aviation Administration / EUROCONTROL Cooperative R&D, (2001). *Principles of Operation for the Use of Airborne Separation Assurance Systems*, Version 7.1, 19 June 2001 [http://human-factors.arc.nasa.gov/ihh/cdti/DAG_TM_WEB/Documents/ASAS_report\(0601\).pdf](http://human-factors.arc.nasa.gov/ihh/cdti/DAG_TM_WEB/Documents/ASAS_report(0601).pdf).

- Hammer, J. (1999). Study of the Geometry of a Dependent Approach Procedure to Closely Spaced Parallel Runways. *Proceedings of 18th Digital Avionics Systems Conference*, October 24-29, 1999, St. Louis, MO.
- Hoffman, E., Zeghal, K., Cloerec, A., Grimaud, I., and Nicolaon, J. (2000). Is limited delegation of separation assurance promising? *Proceeding of 3rd USA / Europe ATM R& D Seminar*, Napoli, 2000.
- Joseph, K. M., Domino, D. A., Battiste, V. , Bone, R. S., and Olmos, B. O. (2003). *A Summary of Flightdeck Observer Data from SafeFlight 21 OpEval-2*. DOT/FAA/AM-03/2 FAA CAMI, Oklahoma City, OK.
- Management, Consulting, and Research Federal, Inc. (2002). *CDTI Enhanced Flight Rules (CEFR) Benefits Analysis [Draft]*. Arlington, VA.
- Olmos, B. O., Bone, R. S., and Domino, D. A. (2001). *Cargo Airline Association & Safe Flight 21 Operational Evaluation-2 (OpEval-2)*. *Proceedings of Proceeding of the 4th USA / Europe ATM R& D Seminar*, Orlando, 2001.
- Oswald, A. and Bone, R. S. (2002). Integrated Terminal Area And Flight Simulation Capabilities, *Proceedings of the AIAA Modeling and Simulation Technologies Conference*, Monterey, California 2002.
- Pritchett, A. (1999). Pilot Performance at Collision Avoidance During Closely Spaced Parallel Approaches, *Air Traffic Control Quarterly*, Vol. 7, No. 1, p. 47-75, Arlington, VA.
- Roscoe, A. H., and Ellis, G. A. (1990). *A Subjective Rating Scale for Assessing Workload in Flight. A Decade of Use*. Royal Aerospace Establishment Technical Report TR90019, Farnborough, U.K.
- RTCA (in preparation). *Minimum Aviation System Performance Standards (MASPS) For Airborne Separation Assurance (ASA)*, Washington, DC.
- RTCA (1999). *Development and Implementation Planning Guide for Automatic Dependent Surveillance – Broadcast (ADS-B) Applications RTCA/DO-249*, RTCA, Washington, DC.
- RTCA (2000). *Application Descriptions for Initial Cockpit Display of Traffic Information (CDTI) Applications*, Document No. RTCA/DO-259, Washington, DC.
- RTCA (2002). *Minimum Aviation System Performance Standards for Automatic Dependent Surveillance – Broadcast (ADS-B)*, Document No. RTCA/DO-242a, Washington, DC.
- RTCA (2003). *Minimum Aviation System Performance Standards (MASPS) For Traffic Information Service-Broadcast (TIS-B)*, Document No. RTCA/DO-286, Washington, DC.
- Sanders, M. S., and McCormick, E. J. (1993). *Human Factors in Engineering and Design* (7th ed.) New York: McGraw-Hill.

Stone, R. (1998). *Paired Approach Concept, Increasing IFR Capacity to Closely Spaced Parallel Runways*. United Airlines World Headquarters, Chicago, IL.

Warren, A., Ulrey, M., and Ebrahimi, Y. (2000). Final Approach Throughput Analysis for Conventional and Enhanced Air Traffic Management. *Proceedings of the 2000 IEEE/AIAA 19th Digital Avionics Systems Conference*, Oct. 2000, Philadelphia, PA: IEEE Press, 2000.

Wickens, C. D., Gordon, S. E., and Liu, Y. (1998). *Human Factors Engineering*. New York: Longman.

Wierwille, W. W., and Casali, J. G. (1983). A Validated Rating Scale for Global Mental Workload Measurement Applications. *Proceedings of the human factors Society 27th Annual Meeting, 1983* (pp. 129-133). Santa Monica, CA: Human Factors Society.

Zeitlin, A. D. and Strain, R. C. (2002). Augmenting ADS-B with Traffic Information Service – Broadcast. *Proceedings of the 2002 IEEE/AIAA 21st Digital Avionics Systems Conference*, Oct. 2002, Irvine, CA: IEEE Press, 2002.

Appendix A

Post Flight Questionnaire

Post Flight

CEFR Concept- CDTI Use for Separation		Not applicable/ Did not use	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
1.	Using the CDTI to maintain separation was acceptable for the cloud layer thickness experienced in this simulation.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2.	The ceiling of 1500ft that was used in this simulation would be acceptable when using the CEFR procedure, while conducting an ILS approach.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3.	I was comfortable using the CDTI for separation when traffic was NOT visible.						
	Large Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Large Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4.	I was comfortable using the CDTI for separation when traffic WAS visible.						
	Large Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Large Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5.	I would be willing to accept responsibility for separation from the traffic I am following by reference to the CDTI.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6.	Provided the necessary rule or guidance changes were made, it would be acceptable to modify the meaning of "visual separation" to include the use of the CDTI in addition to out-the-window visual contact.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7.	Initial visual acquisition of traffic to follow should be required prior to using the CDTI for separation.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8.	Sufficient time was available to reacquire traffic after descending through the cloud layer.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9.	The CDTI was helpful in the re-acquisition of traffic below the cloud layer.						
	Large Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Large Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10.	After descending through the cloud layer, visual acquisition of the traffic-to-follow should be required prior to it landing.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11.	After descending through the cloud layer, I need to visually acquire the traffic-to-follow only to determine if it is clear of the runway.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12.	When using the CDTI for separation, closure to final spacing occurred at what seemed a comfortable and appropriate rate.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

CEFR Concept- General		Not applicable/ Did not use	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
13.	This procedure would be acceptable in a two pilot crew environment using						
	Large Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Large Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14.	With appropriate training, I would be willing to routinely fly this procedure using						
	Large Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Large Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15.	I gained comfort in the procedure as the simulation progressed and I flew more approaches.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16.	Flying this procedure with the ILS coupled and auto-throttle engaged was acceptable.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
17.	I would predict that, it would be acceptable to hand fly this procedure without the ILS coupled or auto-throttle engaged using						
	Large Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Large Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
18.	The performance of the CEFR procedure interfered with other crew duties during final approach operations.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
19.	The performance of the CEFR procedure interfered with checklist completion during final approach operations.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
20.	Whether or not the CEFR procedure interfered with other tasks, the CDTI information provided was useful.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
21.	While performing the CEFR procedure, all cockpit tasks were successfully completed.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
22..	The performance of the CEFR procedure increased head-down time to a degree that compromised safety during approach operations when using						
	Large Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Large Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
23.	It was easy to integrate the CDTI into my normal instrument scan pattern, without excessive fixation, when using						
	Large Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Large Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

24.	It was easy to integrate the CDTI into my normal out-the-window scan pattern, without excessive fixation, when using						
	Large Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Large Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
25.	I am more confident in the use of the CDTI as compared to using out-the-window visual cues for establishing appropriate spacing behind an aircraft during an approach to a runway.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
26.	If necessary, it would be acceptable to require that pilots learn the wake separation criteria associated with different aircraft weight categories.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
27.	The number of go-arounds will increase if this procedure is implemented.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
28.	Overall, use of the CDTI enhanced the safety of ILS approach operations.						
	Large Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Large Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
29.	Overall, use of the CDTI would also enhance the safety of visual approach operations.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

30. Are there any additional cockpit based or ground based (i.e., ATC) capabilities that should be provided to help increase your acceptance of this procedure?

31. While using the CDTI for separation and considering the cockpit capabilities that were simulated, please choose the most representative statement for each combination of display size and location listed below.

The CEFR procedure is:

- A) No more difficult than most precision approaches.
- B) More difficult than most precision approaches but the average pilot can do it.
- C) Very difficult with respect to most precision approaches. The average line pilot will have difficulty with it.
- D) Extremely difficult with respect to most precision approaches. Most pilots will be unable to perform the procedure.
- E) Too difficult to be safely flown by any pilot.

Circle the appropriate letter for each combination of display size and location

Large Primary	A	B	C	D	E
Large Throttle Quadrant	A	B	C	D	E
Small Primary	A	B	C	D	E
Small Throttle Quadrant	A	B	C	D	E

32. Did you adjust your personal minimum separation standard during this simulation? Yes / No

If yes, what spacing standard did you apply, and what caused you to adjust the standard for this simulation?

33. Was the spacing you flew today typical of your normal spacing during visual approaches in normal line operations?

Yes / No

If not, what caused you to adjust for this simulation?

34. What type of training do you believe would be required for this procedure?

Cockpit Display of Traffic Information Features		Not applicable/ Did not use	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
35.	The traffic symbols are acceptable.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
36.	The traffic symbol color scheme is acceptable.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
37.	I could easily find the information I needed on the CDTI.						
	Large Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Large Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Primary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Small Throttle Quadrant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
38.	The target select feature and its associated information were useful tools for performing the task.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
39.	Closure rate is useful information.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
40.	The display provided the information I needed to perform the “visual” separation task.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
41.	Some available display features were unnecessary to perform the procedure.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
42.	Rank the following display features in order of importance for performing this procedure (1- Most important → 7- Least important) Target Highlighting _____ Numeric Closure Rate _____ Graphic Closure Rate Arrow _____ Traffic Ground Speed _____ Range scale indicator _____ Numeric Range to Traffic _____ Traffic Position _____						
43.	Do you have any additional comments regarding the CDTI features used today or additional feature that may be necessary? _____ _____ _____						
44.	The CDTI would be useful during visual approaches during temporary loss of visual contact with traffic.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
45.	Do you have any additional comments regarding potential CDTI use during visual approaches? _____ _____ _____						
46.	The CDTI features were beneficial for acquiring and tracking the traffic out-the-window.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
47.	I was able to perform the procedure regardless of CDTI <i>size</i> .	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
48.	I would be willing to perform the procedure with the smaller <i>size</i> CDTI I used today (ignore simulation issues if any existed. e.g. readability of text on small displays, etc).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
49.	I would be willing to perform the procedure with the larger <i>size</i> CDTI I used today (ignore simulation issues if any existed. e.g. readability of text on small displays, etc).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

50.	I was able to perform the procedure regardless of CDTI <i>location</i> .	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
51.	I would be willing to perform the procedure with the primary field of view <i>location</i> CDTI I used today (ignore simulation issues if any existed, e.g. readability of text on small displays, etc).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
52.	I would be willing to perform the procedure with the throttle quadrant <i>location</i> CDTI I used today (ignore simulation issues if any existed, e.g. readability of text on small displays, etc).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Simulation Environment		Not applicable/ Did not use	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
53.	The “look and feel” of the autopilot was acceptable.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
54.	As implemented in this simulation, the smaller size CDTI was useable.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
55.	As implemented in this simulation, the larger size CDTI was useable.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
56.	As implemented in this simulation, the primary field of view location CDTI was useable.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
57.	As implemented in this simulation, the throttle quadrant location CDTI was useable.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
58.	The out-the-window view was an acceptable representation of the real world.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
59.	The depiction of traffic out-the-window was an acceptable representation of the real world.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
60.	I believe my performance during the simulation reasonably reflects how I would fly the procedure in actual operations.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

61. Were there aspects of the simulation environment that made the procedure artificially difficult or easy? Yes / No

If yes, please comment.

62. Please provide an overall assessment of the use of the simulation environment.

Aircraft call sign communication procedure		Not applicable/ Did not use	Strongly disagree	Somewhat disagree	Neither disagree nor agree	Somewhat agree	Strongly agree
63.	It was confusing to hear my own call sign in a traffic call out to another aircraft.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
64.	Using call sign in the reply to an ATC traffic to follow call out was unacceptable.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
65.	Use of call sign in traffic advisories improves the ability to positively identify aircraft when using the CDTI.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
66.	The additional of call sign made communications difficult.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
67.	The benefits involved in the use of call sign when added to current communications are worthwhile.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
68.	Adding call sign to traffic call outs will be beneficial.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

69. Please provide an overall assessment of the use of call sign in traffic advisories.

Overall Comments

70. During the course of the study, what techniques did you find effective to achieve your desired spacing along the approach?

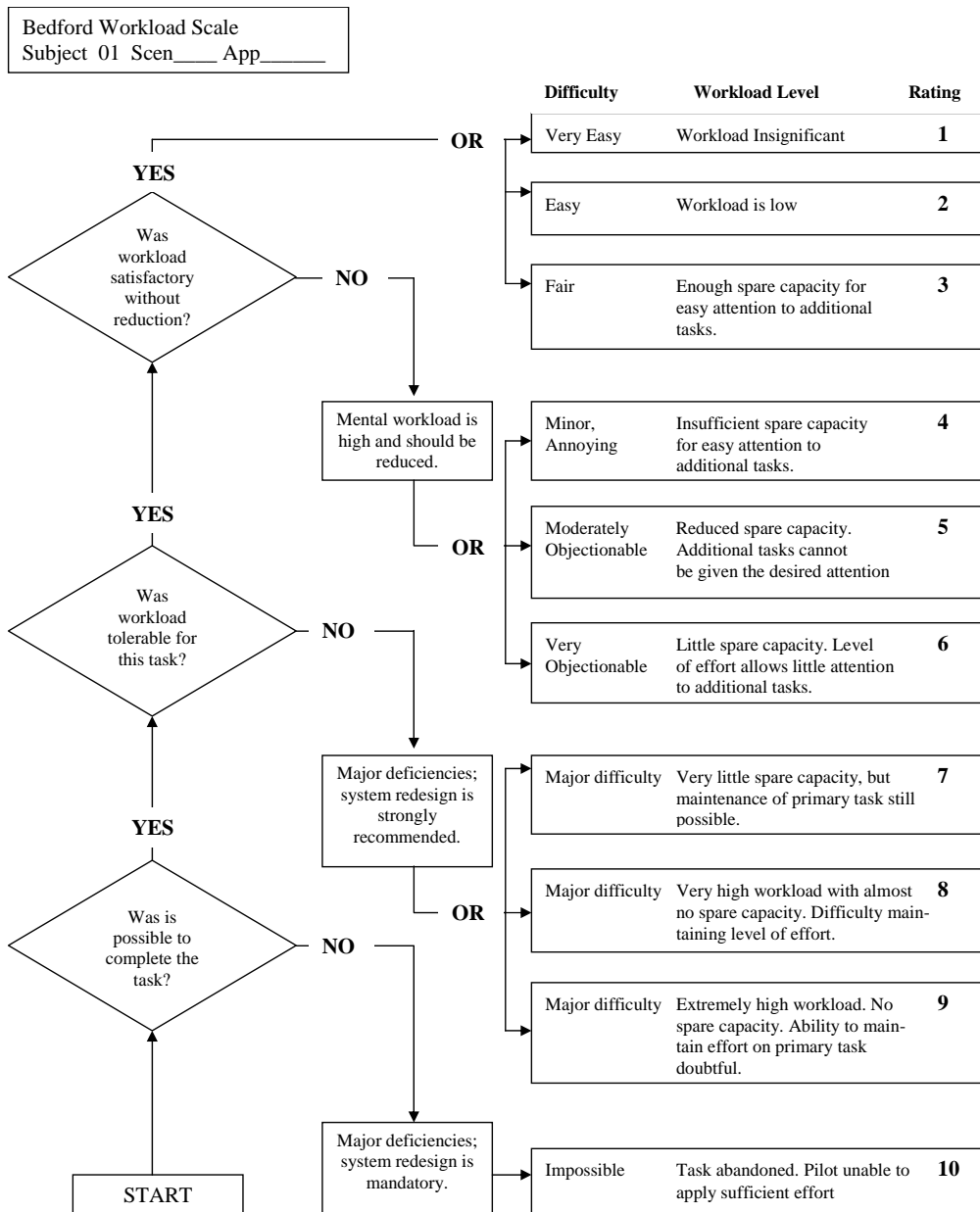
71. In general, is this procedure acceptable to you? Yes / No
Please comment.

72. What recommendations would you make for *improving the procedure?*

73. In your opinion, what rules or procedures need to be developed and / or implemented to support the efficient use of CDTI for the CEFR procedure?

Appendix B

Bedford Workload Rating Scale



Rating _____