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Evaluation of Pilot and Air Traffic Controller Use of Third Party Call Sign in Voice Communications with Pilot Utilization of Cockpit Display of Traffic Information

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Randall S. Bone
William J. Penhallegon
Leslie M. Benson
Gregory L. Orrell

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McLean, VA

Center for Advanced Aviation System Development

Executive Summary

To take advantage of projected benefits afforded by Automatic Dependent Surveillance-Broadcast (ADS-B) In enabled Aircraft Surveillance Applications (ASAs), the use of call sign has been proposed as the method for pilots and controllers to refer to other (third party) aircraft on a common voice frequency. However, using these “third party call signs” (TPCS) to talk about (rather than talking to) other aircraft on the same frequency introduces a potential for confusion for controllers and pilots. The Federal Aviation Administration (FAA) Surveillance and Broadcast Services (SBS) program office identified TPCS as a program risk and initiated an activity to examine the topic. This Human-in-the-loop (HITL) simulation is part of that effort.

The simulation was intended to evaluate TPCS voice communications alternative candidates proposed by subject matter experts participating in the SBS activity and to provide research results that establish a basis for narrowing down the alternatives. It employed pilots, en route controllers, and terminal controllers as participants and evaluated the TPCS candidates within the context of two ASAs during an arrival and approach operation. Three TPCS formats and two placements were evaluated within the context of a traffic advisory and an Interval Management clearance. The study was framed around three central research objectives. These objectives and a summary of the corresponding results are presented below.

1. The first objective was to determine whether deviating from the use of current day call sign format phraseology was necessary for pilots and controller to reference a Third Party Aircraft (TPA). The simulation found no evidence to suggest that deviating from current phraseology is necessary to reduce Third Party Pilot (TPP) confusion. Additionally, controllers generally preferred the use of current phraseology (Telephonic format), though pilots preferred the pronunciation of the individual letters (Letters format) in the airline designator. In some cases, the Letters format helped pilots more accurately identify the TPA on their Cockpit Display of Traffic Information (CDTI) traffic display than the current Telephonic format. As such, and despite reported controller misgivings, there may be advantages for deviating from the current Telephonic call sign format to convey TPCS.
2. The second objective was to determine whether user acceptability and performance trade-offs existed between the chosen TPCS alternatives. Pilots showed a subjective preference for the Letters format, likely because it helped them better identify the TPA on the CDTI traffic display. A third format, termed “Delimiter,” was evaluated and consisted of placing the word “reference” between the airline designator and numeric flight identification. The Delimiter format was consistently rated poorly and associated with the most performance issues for both pilots and controllers. Overall, the Letters format appeared to be superior to the Delimiter format and it is not recommended that Delimiter formats be explored any further.
3. The third objective was to determine the user acceptability and performance trade-offs related to the placement of TPCS within the controller clearance or advisory (i.e. earlier versus later). Simulation results show that TPCS in the later position was more acceptable and had fewer performance issues than in the earlier position. The improved performance could be because the later position allowed for a more natural and logical

flow, and provided the least deviation from how pilots and controllers currently convey information in voice communications.

An appropriate phraseology solution needs to minimize the potential for TPPs on the frequency to become confused about transmissions referring to them, as well as allow pilots and controllers to establish a clear awareness of the aircraft being referenced. Based on the results of this simulation, two possible approaches with respect to TPCS format are recommended for the next and final activity in the SBS effort. Assuming that TPP confusion will be rare and solvable as it occurs, one approach is to allow controllers to use a Telephonic format as the normal method of conveyance, with the option to use the Letters format when the controller believes there may be pilot confusion about the airline three letter designator. The pilot would be expected to reply with the format used by the controller. However, if situations arise where the controller uses the Telephonic format and the pilot has confusion about which TPA is being referred to, the pilot could reply with a question asking for clarification of the TPA using the Letters format to resolve any ambiguity.

A second approach, that proactively mitigates the potential for TPP confusion, involves a required controller deviation from the current phraseology for TPCS. Despite less controller acceptability than the Telephonic format, simulation results suggest that the Letters format showed performance advantages for pilots and controllers in some instances. For this approach, follow-on research to further explore the acceptability of mandating the use of the Letters format for TPCS, particularly with controllers, is recommended.

For either approach, TPCS placement should be carefully considered to maintain a natural flow and minimize the deviations from current phraseology for the individual clearance, instruction, or advisory in which it is expected to be used. In addition, a safety analysis may be desirable to fully understand the likelihood and impact of TPP confusion, which will always remain a possibility in voice communications.

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1 Introduction

During flight operations, voice over radio is the main communication method between flight crews and Air Traffic Control (ATC) and can include clearances, instructions, and requests. Complete, timely, and unambiguous communications are essential for safe and efficient operations. Flight crews and ATC must receive, comprehend, acknowledge, and act upon their communications.

To take advantage of projected benefits afforded by Automatic Dependent Surveillance-Broadcast (ADS-B) In enabled applications / Aircraft Surveillance Application (ASA) (e.g., Interval Management [IM]), pilots and controllers need to be able to reference a Third Party Aircraft (TPA). The use of a TPA's call sign, referred to as Third Party Call Sign (TPCS), has been proposed as the method for pilots and controllers to refer to other aircraft. The purpose of this traffic identification process differs according to application (Bone and Stanley, 2006). TPCS has been proposed as both an optional element in a communication such as a Traffic Advisory (TA) and as a required element in more advanced operations. When Controller Pilot Data Link Communications (CPDLC) becomes available, it can also be used to convey a TPCS and may overcome most of the concerns associated with TPCS in a voice environment. This is because the TPCS will not be broadcast on a common voice frequency and the TPCS format will match that shown on the Cockpit Display of Traffic Information (CDTI) traffic display.

Using call signs to talk about (rather than talking to) other aircraft on the same frequency introduces a potential for confusion for controllers and pilots. In order to discuss the issues associated with the use of TPCS, the following terms will be used:

- **First Party Aircraft (FPA):** The aircraft to which the controller is directly talking.
  - **First Party Call Sign (FPCS):** The portion of a communications message that includes the airline designator and the numeric flight identification for the FPA.
  - **First Party Pilots (FPPs):** Flight crew members in the FPA.
  - **First Party Loop:** A communication exchange between ATC and a FPA. It includes, at least, the controller message and pilot readback.
- **TPA:** Any aircraft on the common frequency that is not directly involved in a communications exchange between a FPP and ATC.
  - **TPCS:** The portion of a communications message that includes the airline designator and the numeric flight identification of the TPA.
  - **Third Party Pilots (TPPs):** Flight crew members in the TPA.
  - **Third Party Loop:** A communication exchange between ATC and a FPP that has the potential to be overheard by a TPP. It can also be when the TPP contacts the controller to resolve any confusion based on hearing the communication exchange between ATC and a FPP.

Figure 1-1 illustrates these pilot-controller communication loops and shows the First Party Loop information exchange between a controller and FPP when referencing a TPA. Since the communication is over voice on a common frequency, the TPPs can hear their call sign used in the communication. Since call sign normally triggers a flight crew to tune into the communication with ATC, they may not know whether their call sign was being used as a TPCS or not and may start listening to the remainder of the communication. In some cases this could result in a TPP questioning or, worse, accepting an instruction intended for another aircraft. It may also result in extra transmissions to clarify or recover / correct information, which increases frequency congestion and increases pilot and controller workload.

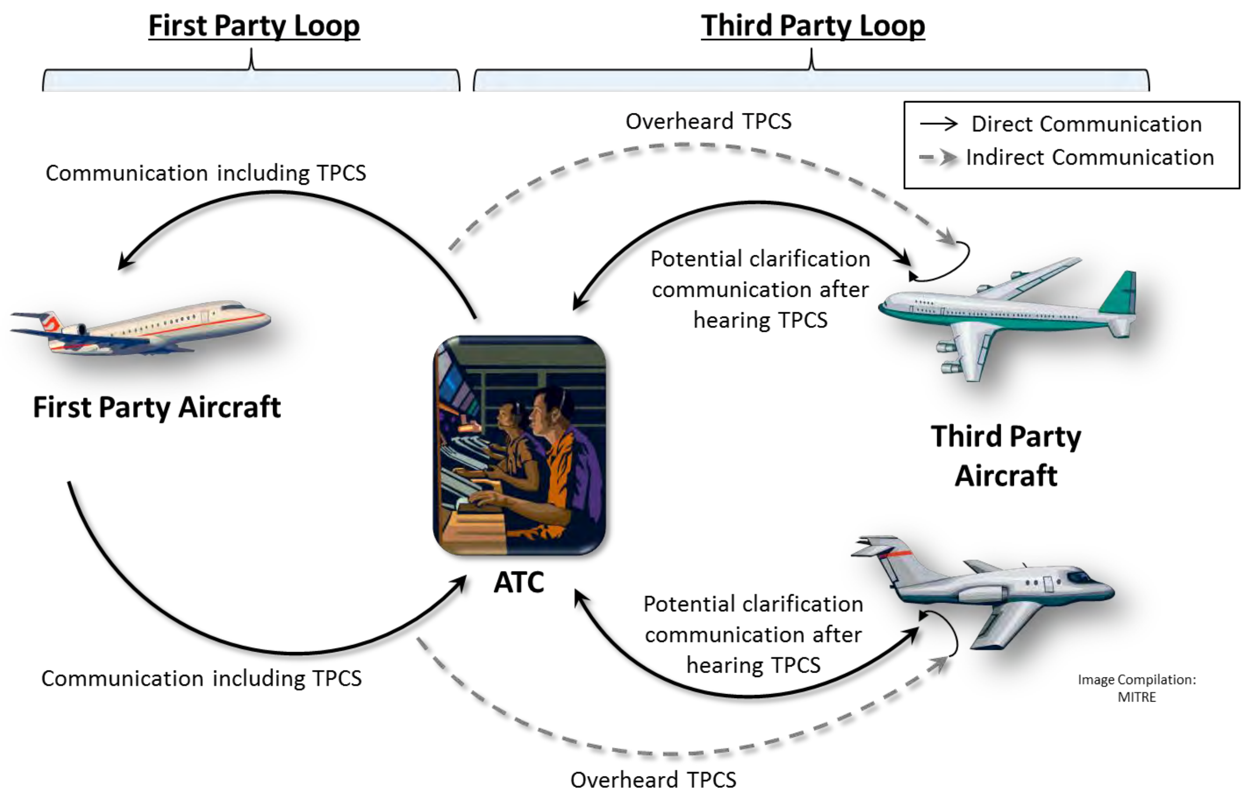

Figure 1-1. Pilot-Controller Communication Loops

Using a method other than current day phraseology to refer to a TPA on the voice frequency may reduce the potential for confusion. An appropriate solution should:

1. Allow controllers and FPPs to establish a clear awareness of the aircraft to which they are referring.
2. Minimize the potential for other aircraft on the frequency to become confused about transmissions referring to them.

The Federal Aviation Administration (FAA) Surveillance and Broadcast Services (SBS) program office identified TPCS as a program risk and the ADS-B In Rulemaking Committee (ARC) recommended that the FAA identify TPCS phraseology standards for FAA Order 7110.65 (FAA, 2012b), the Aeronautical Information Manual (AIM) (FAA, 2012a), and the International Civil Aviation Organization (ICAO). SBS established a Traffic Flight Identification (TFID)[1] Operational

[1] The FAA SBS program office uses the term Third Party Flight Identification (TFID) in its development activity to refer to the use of TPCS. However, the literature uses flight identification to refer to the numeric portion of a “call sign,” which consists of the combination of airline designator and numeric flight identification. Thus, this paper uses the term TPCS instead of TFID. However, TFID is still used when referring to specific SBS related activities and documents.

Focus Group (OFG) group to identify the most effective TPCS phraseology and includes members from the FAA (SBS, Flight Standards Service [AFS], Air Traffic Operations [ATO]), industry (UPS, US Airways, Air Line Pilots Association [ALPA], National Air Traffic Controllers Association [NATCA], United States [US] Airline Pilots Association [USAPA]), and research organizations (such as the National Aeronautics and Space Administration [NASA], and The MITRE Corporation [MITRE]).

The SBS TFID OFG activity consists of three phases. The first phase was to identify TPCS format and phraseology alternatives and narrow-down to three top candidates for further evaluation. This phase is complete and the final report is available (FAA, 2012c). The second phase is intended to evaluate the alternatives in an operational context in a Human-In-The-Loop (HITL) simulation and provide research results that establish a basis for down-selecting to a final alternative. The third phase consists of a follow-on HITL simulation and is intended to validate Phase 2 results in an operational context in high-fidelity workstations. Phase 3 will use the recommendations from Phase 2 and validate the proposed solution to support the updating of FAA guidance material.

The HITL simulation described in this report satisfies Phase 2 of the SBS TFID OFG plan. The simulation completed was intended to evaluate TPCS voice communications alternative candidates proposed by the TFID OFG in a HITL simulation using ASAs during an arrival and approach operation. Its overall goals included:

- Determining the acceptability of each alternative to both flight crews and air traffic controllers.
- Determining phraseology that is reasonably acceptable to both flight crews and controllers.
- Evaluating any potential performance tradeoffs among the candidate alternatives.

This report has seven main sections. This first section introduces the TPCS issue and summarized the FAA's approach to resolving it. **Section 2—Background** summarizes issues and prior research on voice communications and studies involving the use of TPCS. **Section 3—Research Questions and Hypotheses** presents the research questions for this study and their associated hypotheses. **Section 4—Methods** provides details on the how the simulation was conducted. **Section 5—Results** presents the subjective and objective results of the simulation. **Section 6—Discussion** summarizes and starts to synthesize the simulation results. **Section 7—Conclusions and Recommendations** addresses the framing research questions and provides the final recommendations for Phase 3 of the TPCS activity.

2 Background

2.1 Current Voice Communications

Controllers and pilots communicate by a formalized language termed Standard Phraseology, which includes the prescribed words and their sequential order, pronunciation, and enunciation (Kerns, 1991). Controllers in the US have phraseology specified for them in the ATC handbook (FAA, 2012b). Pilots have guidance on communications in the AIM (FAA, 2012a). The Pilot / Controller Glossary (FAA, 2013) contains the terms to be used in pilot and controller communications.

Communication procedures typically involve four steps (McMillan, 1999):

- Sender transmits a message.
- Receiver listens to the message.
- Receiver retransmits the message to the sender.
- Sender listens to the reply for accuracy.

In aviation, a controller message begins with the call sign of the aircraft being addressed followed by message content. The flight crew then provides a “readback” of the original ATC message, including their call sign and the information contained in the ATC message in the same order as issued by the controller. The pilot should read back the elements of the instruction or clearance that are non-advisory such as altitude and runway assignments (FAA, 2012a). This step and the last step (i.e., the controller “hearback”) exist to catch errors if the flight crew misunderstood or misstated the ATC message. It also allows the controller an opportunity to confirm that the originally issued instruction / clearance was correct (i.e., the controller can catch his or her own error).

Aircraft call signs are a means to differentiate between aircraft during radiotelephonic (RTF) communications. For general aviation aircraft, call signs are normally the characters that correspond to the registration number of the aircraft (e.g., N6011T). For airlines, it can be the three character abbreviation of the aircraft operator (termed “airline three letter designator”) followed by the last four characters of the registration number of the aircraft. However, it is typically a three character abbreviation of the aircraft operator followed by a flight number (termed “numeric flight identification”) of up to four characters (e.g., UAL601 refers to United Airlines flight number 601) (ICAO, 2002; United Kingdom [UK] Civil Aviation Authority, 2000a). Certain call signs can be abbreviated or can include an aircraft type after establishing satisfactory communications and after ATC has used the abbreviated call sign. For example, N6011T can be abbreviated to 11T once ATC establishes use of that abbreviation. However, similar call signs that may cause confusion may not be abbreviated.

During the use of call sign by ATC, the aircraft operator is not spelled out phonetically but is stated as the operator that is being abbreviated, e.g., UAL is stated as “United” not “Uniform Alpha Lima” or “U A L.” This spoken format is termed the “airline telephony designator.” See Table 2-1 for sample airline names, airline three letter designator (which is available on controller and flight crew traffic displays), and the telephony designator (spoken format used in voice communications). As can be seen, the spoken format does not always have a clear connection to the three character designator.

Table 2-1. Comparison of Airline Name, Three Character Abbreviation, and Spoken Format

Airline Name	Spoken Format (Airline Telephony Designator)	Displayed Format (Airline Three Letter Designator)
British Airways	Speedbird	BAW
Lufthansa	Lufthansa	DLH
Republic Airlines	Brickyard	RPA
Scandinavian Airlines	Scandinavian	SAS
United Airlines	United	UAL
UPS	UPS	UPS

2.2 Issues with Current Voice Communications

2.2.1 Non-Flight Identification Issues

Miscommunications such as errors and requests for repeats can occur in any of the four steps in the communication procedure. The chances of a miscommunication increase with factors such as high workload, blocked transmissions, non-standard phraseology, and fast rates of speech. Miscommunications, in turn, increase frequency congestion and can lead to increased workload and even an aircraft accepting a message that was intended for another aircraft. Most literature reports that a small percentage (fewer than 1%) of communications that are read back result in miscommunications. This was found for the en route (e.g., Cardosi, 1993), tower / local control (e.g., Cardosi, 1994), and the Terminal Radar Approach Control (TRACON) (e.g., Cardosi, Brett, and Han, 1996; Morrow, Lee, and Rodvold, 1993; Van Es, 2004) environments. Additionally, controllers and pilots correct the majority (60-80%) of the communication problems (Cardosi, 1994) and can often do so without a reduction in communication efficiency (e.g., see Prinzo's [2002] analysis of a Departure Spacing application conducted at an operational evaluation).

Nevertheless, the consequences of even a single miscommunication can be significant. Perhaps the most dramatic example of this was the runway collision between two Boeing 747s in 1977 at Tenerife, Canary Islands. The accident had the highest number of passenger fatalities of any aviation accident. Low visibility was a factor but radio frequency issues, blocked communications, and misunderstandings during ATC and flight crew communications contributed to a flight crew taking off without a clearance and hitting another aircraft taxiing on the runway. Issues such as runway incursions can be caused by miscommunications and the outcome can be hazardous (Van Es, 2004).

In high density environments, frequency congestion can be an issue. In such environments, pilot and controller transmissions can be truncated or non-existent due to the workload of both parties. For example, several studies found high partial readback rates (e.g., 12% in the en route [Cardosi, 1993], 37% in the tower / local control environment [Cardosi, 1994], and 26% in the TRACON [Cardosi et al., 1996]).

Additionally, frequency congestion creates other problems such as inability to access the frequency and stepped on transmissions (Carlson, Jacobs, Kelly, Rhodes, 1998; Van Es, 2004). Further exacerbating the problem, controllers tend to increase their speech rate to correct pilot errors in readbacks or provide clarification during periods of congestion (Cardosi and Boole, 1991).

In an issue related to expectations during “hearbacks” and “readbacks” pilots expect to get affirmation of a request and controllers expect correct acknowledgement of the given clearance. Expectations based on past experiences help pilots and controllers process information more quickly and more accurately (Wickens, Lee, Liu, and Becker, 2004). However, this can lead to problems such as pilots and controllers hearing what they expect to hear as opposed to what was actually said. Although readback errors are low and the majority are caught by ATC, 65% of Aviation Safety Reporting System (ASRS) reports on communication errors analyzed by Cardosi, Falzarano, and Han (1999) involved controllers either failing to catch incorrect pilot readbacks or correct pilot readbacks based on incorrect information initially provided by the controller. Van Es (2004) also found that readback / hearback was the most common type of communication problem category based on analyses of safety reports.

Past research on voice communications also indicates that as the number of elements in a communication increase, so does the potential for errors. Elements have been defined as “each word, or set of words… [that was] critical to the understanding of the message” (Cardosi, 1993, p. 3). Each element can be considered an opportunity for an error. As an example, “Delta 1 3 5, turn **right** heading **180.**” Both “right” and “180” are considered one element each. In the body of Cardosi work (e.g., Cardosi, 1993; Cardosi, 1994), the FPCS was not considered an element.

Cardosi (1993) found a doubling of readback errors as the complexity of the instruction or clearance increased from three to four elements in an en route environment. Cardosi (1993) also found that in the few very complex cases where the communications included five or more elements, the number of errors increased dramatically. In the TRACON environment, instructions / clearances that contained four or more elements comprised only about one fourth of the readbacks but accounted for about half of the total readback errors (Cardosi et al., 1996). On the local / tower frequency, Cardosi (1994) found the complex communications with five or more elements to be more frequent (31% of the communications), but did not find an increase in readback errors with increasing complexity, even up to 9 or more elements. All complexity levels were very similar and below 1% (with a slight spike at 8 elements). These tower results were inconsistent with research in en route and the TRACON. The authors suggested this was due to predictability in the terminal environment, the information available on Automated Terminal Information Service (ATIS) and the common frequency, and pilot’s expectations of communications from ATC.

Bürki-Cohen (1995) also found that there was a relationship between readback errors and message complexity: errors increased as complexity increased. The number of errors spiked at 7 elements to approximately twice (to about 2.0%) that of the other complexities. Morrow et al. (1993) found an increase in incorrect readback when the “speech acts” (a measure of length and complexity) increased from one to two or more.

Past research also shows that when there is an increase in message complexity or number of elements, there is also a chance for an increase in the number of repeat requests from pilots.

These requests indicate some confusion within the flight deck and can use up valuable frequency time. Cardosi (1993) found that as the complexity of the messages increase to five or more elements, the rate for pilots asking for a repeat of all or part of a transmission increased about 1.5 to 3% in an en route environment. Cardosi (1994) found a slight (0 to 1%) increase in pilot requests for repeats with an increase in message complexity beyond five elements. Bürki-Cohen (1995) found the number of pilot requests for repeats on the ground control frequency increased with message complexity. Eight elements showed a spike that more than doubled the number of readback requests (to about 3.6%). However, there were no repeat requests when there were 9, 10, or 11+ elements.

Past research also shows that when there is an increase in message complexity or number of elements, there is a chance for incomplete readbacks from flight crews. Cardosi (1993) found that the more complex the message, the less likely pilots would give a full readback. The percentage of full readbacks drops significantly with a complexity rating of five elements. Without a full readback, it is unclear whether the pilot received all the information and just didn't read it all back or whether the pilot didn't receive all the information but read back what was received. In either case, the controller does not have the opportunity to catch an error. Cardosi (1994) found in tower operations that the more complex a controller's communication was (four or more elements seemed to be a breakpoint), the more likely the pilot would reply with a partial or full readback versus a simple acknowledgement. Bürki-Cohen (1995) found the number of partial readbacks and acknowledgments only increased (as compared to full readbacks) with increased message complexity or number of elements. Bürki-Cohen (1995) also found the number of partial readbacks increased (as compared to full readbacks and acknowledgments only) with increased message complexity or number of elements. Partial readbacks increased from about 4% (for 1 element) to 13% (for 3 elements) to about 30% (for 6 elements) to about 64% (for 11+ elements). Morrow et al. (1993) found an increase in partial readbacks when the "speech acts" (a measure of length and complexity) increased from two to three or more.

With increasing complexity of the messages, the memory load on the pilot is higher and therefore is expected to lead to more errors and confusion. With several items in the transmission, it seems likely that more elements will have the potential to contain an error in the readback. It may be more difficult for the controller to catch multiple errors in a readback than it is to catch one error due to both expectations of a correct readback and the memory load demands. Therefore, not only do more complex messages introduce the potential for more readback errors, they also reduce the possibility of controllers catching the errors in their hearback.

Overall, as messages increase in complexity so do communication issues. In recommendations similar to others, Barshi and Farris (2013) recommend no more than three "aviation topics" in one ATC message. If more than three are necessary, they recommend using two separate messages or provide a warning (an "advanced organizer") to the pilot that a long clearance will be given so that the pilot can prepare to write it down.

2.2.2 Call Sign Issues

Within the context of general issues with current voice communication, call signs can play a role. Call signs can be visually or aurally similar and can be confusing in either format (Cardosi, Lennertz, and Eon, 2011; UK Civil Aviation Authority, 2000a). Visual confusion can occur for the controller when reading things like flight strips or surveillance displays. The flight crew can also have visual confusion when looking at a CDTI traffic display. Aural confusion can happen during pilot and controller voice communication exchanges. The issues discussed in this section are related to aural confusion.

Call sign issues exist today with similar sounding call signs being confused, especially during periods of high traffic volumes when ATC and flight crews are very busy, frequencies are congested, and transmissions can be blocked (Monan, 1991; Grayson and Billings, 1981; Bürki-Cohen, 1995; Cardosi et al., 1999; Canadian Aviation Safety Board, 1990; Van Es, 2004). Stepped on transmissions are closely connected to the flight crew hearing a similar call sign or accepting a clearance for another aircraft since not all of the communication is heard (Van Es, 2004). At least one accident (Los Angeles, CA, 1991) has been cited with controller call sign confusion as a contributing factor (Maurino, Reason, Johnson, and Lee, 1995).

When using airline call signs such as UAL213, UAL123, and DAL123, the numeric flight identifications are more likely to mislead the controller (e.g., into picking up the wrong flight strip or issuing a clearance to the wrong aircraft); however the latter two call signs can also be confused to a lesser degree (UK Civil Aviation Authority, 2000a; Bürki-Cohen, 1995; Cardosi et al., 2011). Transposed alphanumerics can also be an issue (Monan, 1983). Cardosi et al. (2011) also reported that it is more problematic when the call sign has four numbers than when the call sign has three numbers.

Bone and Stanley (2006) report that Civil Aviation Authorities worldwide are focusing efforts in reducing the call sign confusion problem. In an effort to examine this topic, the UK Civil Aviation Authority requested that pilots and controllers submit reports on call sign confusion incidents. A total of 482 reports were submitted. Sixty-six percent of the reports involved confusion between call signs from the same airline (A EUROCONTROL [2013] study also reported a high percentage: 74%.). Most of the occurrences involved (the typical) numeric-only call sign flight identifications (e.g., 344). Eighty five percent of the 482 reports collected from pilots and controllers resulted in no deviations from operational procedures (UK Civil Aviation Authority, 2000a). Of the remaining reports, 0.6% resulted in loss of ATC separation while 73% involved increased workload for ATC and flight crews. In response to this, the UK released Aeronautical Information Circular (AIC) 107/2000 to address the issue of call sign confusion in voice communications (UK Civil Aviation Authority, 2000b). Although this AIC was released in 2000 based on a 1998 study, there is anecdotal evidence that the problem still exists (UK Civil Aviation Authority, 2005).

As noted earlier, expectation can be a contributing factor to both pilot and controller confusion. For the pilot, expectations can lead to thinking a clearance was for ownship when it was actually intended for another aircraft. Similar call signs can exacerbate the problem. For pilots, expectancy for certain instructions may be more of a factor than similar call signs when incorrectly replying to a controller message (Bürki-Cohen, 1995). However, similar call signs on the same frequency was cited as a contributing factor in 54% of the ASRS reports of a wrong aircraft accepting a clearance for another aircraft (Cardosi et al., 1999). Van Es (2004) also found that a high number of consequences (70 of 496 = 14%) of 444 occurrences were attributed to a wrong aircraft accepting a clearance and that similar call signs were the most common factor (87 of 506 = 17%) contributing to the problem. Of the readback / hearback incidents examined by Van Es (2004), similar call signs were the most common contributing factor (59 of 166 = 36%) with a resulting likely consequence (74%) of either an altitude deviation or a wrong aircraft accepting a clearance. Similarly, Cardosi et al. (1999) found that similar call signs, pilot expectancy, and controller workload were the most commonly cited factors contributing to communication errors found in ASRS reports. Similar call signs were noted as contributing to 15% of the reports. Cardosi (1994) and Cardosi et al. (1996) reported that similar call signs were the most common coincident factor in miscommunications in the local / tower and TRACON environments. In Cardosi (1994), similar call signs and the physical proximity of two aircraft led to a flight crew accepting a clearance intended for another aircraft. In Cardosi et al. (1996), there were seven instances where a flight crew accepted a clearance intended for another aircraft in the TRACON environment. All were caught and corrected by the controller.

Accepting a clearance intended for another aircraft is not the only communication error involving call signs. Cardosi et al. (2011) reported that past studies found about 1% of en route, ground, and local / tower communications involved call sign discrepancies in which the pilot used a different call sign in the response than the controller used in the transmission. Less than half were corrected, but none resulted in any serious effect. The author noted that even with call sign discrepancies, the context and the pilot's voice kept the resulting effects minimal.

2.3 TPCS Addition to Current Voice Communications

The transmission of aircraft identification and position via ADS-B, and subsequent display on a CDTI traffic display, allows TPCS to be utilized by the flight crew and the controller when communicating over the voice frequency. It allows controllers and pilots to conduct ADS-B In / CDTI applications that are commonly known as ASAs. The TPCS will be communicated by the controller to the flight crew who will then correlate the TPCS with the information displayed on the CDTI traffic display. The traffic displays of both the flight crew and controller use the airline three letter designator. Note that the airline three letter designator may not correspond exactly to the spoken form used in the communication to identify the traffic.

The purpose of this traffic identification process differs according to application (Bone and Stanley, 2006). TPCS has been proposed as both an optional element in basic ASAs and as a required element in more advanced ASAs.

In the case of basic or situation awareness ASAs, TPCS will be utilized as an aid to visual acquisition of traffic, helping the flight crew to identify the traffic communicated by the controllers. TPCS could be used in this manner for applications such as:

- Enhanced Visual Acquisition or Enhanced Traffic Situation Awareness during Flight Operations (ATSA-AIRB) (RTCA, 2003; RTCA, 2010).
- Enhanced Visual Approach / Enhanced Visual Separation on Approach (ATSA-VSA) (RTCA, 2003; RFG, 2004; North European ADS-B Network [NEAN] Update Programme, Phase II (NUP II), 2002).
- CDTI Assisted Visual Separation (CAVS) (Bone, Helleberg, Domino, Johnson, 2003b).
- Enhanced Traffic Situational Awareness on the Airport Surface (ASSA / FAROA / ATSA-SURF) (RTCA, 2003; RFG, 2004).

For more advanced ASAs, the TPCS will be used to aid the positive and unambiguous identification of a designated aircraft on the CDTI traffic display prior to the initiation of a procedure with respect to that aircraft, e.g., IM (Barmore, Abbott, and Capron, 2005; Hebraud, Hoffman, Papin, et al., 2004; Bone, Penhallegon, and Stassen, 2008) and Paired Approach (Bone et. al., 2000; Pritchett, 1999; Stone, 1998).

The following two sections provide additional detail on the two uses of TPCS.

2.3.1 TPCS use in Visual Acquisition / Traffic Advisories

Pilots have reported that monitoring the common frequency is the usual means for them to establish their traffic picture (Grayson and Billings, 1981). A traffic display can help further build that picture. Various studies have shown that a display such as Traffic alert and Collision Avoidance System (TCAS), with traffic information but not TPCS, is an effective enhancement to visual acquisition (Moore, 1997; Andrews, 1984; Andrews, 1991). In fact, the concept of using a traffic display for enhanced visual acquisition is currently being practiced effectively in TCAS-equipped aircraft every day (FAA, 1993). The availability of call sign and aircraft type from the CDTI traffic display should assist flight crews even more when listening to the common frequency and hearing instructions to other aircraft.

Use of TPCS could be useful in helping flight crews to more efficiently search for aircraft when ATC issues a TA. These advisories serve two purposes: alerting the flight crew of the existence of an aircraft as well as focusing the flight crew search. The ATC issued advisory can include range, bearing, direction of travel, and other information such as aircraft type (see FAA, 2012b for standard TA phraseology). TAs can present difficulties for flight crews and controllers. During approach operations, controllers use certain geometries, such as altitude step-downs, to allow for flight crew visual acquisition time prior to initiating visual separation operations. Since the relative positions of the aircraft may change, the controller may be required to issue TAs with each step-down. Environmental restrictions may require such step-downs to begin at fairly long distances on final. These instructions are of high priority since they are meant for aircraft on final approach. This reduces the time the controller can devote to the rest of the traffic pattern, such as turns to base or final. Eventually, as the operation becomes workload intensive, the controller may be forced to suspend the visual operation.

After hearing an ATC TA, the flight crew visually searches for the traffic and, when sighted, reports it in sight. The search for aircraft especially in a dense traffic environment, during reduced visibility, or at night can be challenging and workload intensive (FAA, 1983; Hopkin, 1995; Popp, 1995; Krause, 1997; Stassen, 1998). The flight crew may have difficulty visually identifying aircraft and may even identify the wrong aircraft as the traffic of concern. The flight crew must not only detect, but also discriminate between aircraft and judge distance, speed, and trajectory. The difficulties of this task can be reflected in the number of TAs that must be issued by ATC before the traffic is sighted. After the flight crew reports the aircraft in sight, it could be assigned responsibility for visual separation. However, ATC can never have full confidence that the intended aircraft was acquired by the flight crew, unless the flight crew initiates a maneuver based on that traffic. At this point, the controller can determine whether the appropriate aircraft has been sighted and followed.

Several simulations have shown the advantages of the CDTI for traffic awareness and traffic acquisition. Authors of an operational evaluation report noted that when a CDTI was used to enhance airborne traffic awareness during day (with poor visibility) and night (with good visibility) operations, it was normally the first method used, followed by an ATC advisory or visual out-the-window sighting. In this operational evaluation, approximately 75% of the traffic events involved use of the CDTI (Joseph, Domino, Battiste, Bone, and Olmos, 2003).

At another operational evaluation, it was reported that the CDTI traffic display was used in 54% of the traffic acquisition events with an ATC advisory and 76% of the traffic acquisition events without an air traffic control advisory (Battiste, Ashford, and Olmos, 2000). Flight crews also reported that the CDTI traffic display aided in traffic awareness and visual acquisition.

Olmos, Mundra, Cieplak, Domino, Stassen (1998) found a tendency for acquisition time to be reduced during single versus dual stream approaches when pilots had a CDTI with call sign and listened to the common frequency. The longer time for acquisition on the dual stream was likely due to high density of traffic and the difficulty of discriminating between the two streams of aircraft to closely spaced parallel runways. When examining solely the parallel runway operations, they found that with a CDTI traffic display with call sign, acquisition time was reduced when compared to a standard TCAS display (without call sign), indicating that call sign is useful during acquisition. Overall, pilots reported that the CDTI traffic display with call sign greatly enhanced their situation awareness.

To further support the flight crew with traffic identification, controllers may find it useful to use TPCS in TAs to CDTI equipped aircraft. The rationale for the use of TPCS is to enable better discrimination between several aircraft, quicker correlation between the sighted and displayed aircraft, thus increasing the likelihood of visual acquisition, as well as a more positive confirmation of the acquisition of the appropriate aircraft. Better correlation has been shown in simulation and flight test to permit pilots to effectively monitor the position of relevant traffic even when visual contact is temporarily lost (Bone et al., 2003b; Battiste et al., 2000). This may occur while attending to other flight deck tasks, encountering an intermittent obstruction to visibility, or merging of the visual target with other objects or terrain in the visual scene.

The use of TPCS by controllers may reduce the number of TAs required to establish visual contact and may reduce the number of flight crew requests for traffic position (Battiste et al., 2000). This reduction in controller workload may provide more time for the management of traffic and more time to provide additional TAs due to decreased workload. Lack of TAs has been noted as an issue during busy periods in the terminal environment (Grayson and Billings, 1981).

Surface situation awareness may also be enhanced in situations requiring discrimination among several aircraft. Raynaud et al. (2007) reported that TPCS use by ATC during TAs when pilots had a CDTI on the airport surface (using the ATSA-SURF application) was found to be useful for out-the-window correlation.

Another potential use of TPCS is would allow ATC to provide a TA on a time permitting basis, regardless of whether the flight crew can acquire the aircraft at the moment (Olmos and Mundra, 1999). If this were authorized, the flight crew could report “CDTI contact” if the aircraft is not in sight and then subsequently report the aircraft in sight out-the-window once visually acquired. Raynaud et al. (2007) tested this concept under ATSA-AIRB and reported that pilots found the use of “CDTI contact” to be easy to use but of limited operational interest when visual acquisition is still required.

If TPCS can be used by the flight crew in a reply to an ATC TA, the identification process is further improved. ATC can use the pilot TPCS report and their surveillance display to confirm the intended aircraft was more likely acquired by the flight crew. Therefore, ATC can capture errors either initiated from the initial advisory or flight crew misidentification (Cieplak, Hahn, Olmos, 2000).

TPCS use in TAs would be one additional piece of information to positively identify the aircraft and would not require any new procedures. In other words, ATC would not be required to use TPCS and the flight crews would not be required to use TPCS in their reply nor correlate it with the CDTI, if time does not permit such a correlation. However, TPCS use is expected to be operationally advantageous to pilots and / or controllers if they choose to use it.

2.3.2 TPCS use in Advanced ASAs

Similar to the visual acquisition task, for advanced ASAs such as IM, ATC must advise the flight crew and the flight crew must identify a reference aircraft on the CDTI traffic display. For an operation like IM, that may involve searching manually on the CDTI for traffic or using automation support to identify the reference aircraft. Either way, the TPCS is a required element to initiate an operation like IM. When identifying the traffic for advanced ASAs, the TPCS may be used alone or additional positioning information may also be included in the message (e.g., clock position and distance).

2.4 TPCS Options

Several different methods for introducing TPCS into TA communications are possible. This section will provide examples of potential uses of TPCS and presents both advantages and disadvantages of each option.

TPCS could be used in current communications without additional changes (e.g., normal TA with TPCS added to the end), or it could introduced with a new method to truncate the current TA (e.g., “Traffic U P S one two three, twelve o’clock”). A reduced TA may be desirable since lengthy, complex messages have been shown to create problems in correct readbacks (Morrow, and Rodvold, 1993; Bürki-Cohen, 1995; Cardosi, 1994). With regard to introducing a new, truncated TA, 59% of controllers in a survey said shortening current required phraseology would be an acceptable way to reduce frequency congestion during tower and surface operations (Carlson et al., 1998).

The TPCS could be presented in different locations of the communications and also could be spoken differently in each of those locations. The following sections describe some of these options.

2.4.1 TPCS Location within a Transmission

TPCS may be able to be placed in one of several locations within the overall transmission. It can be near the beginning (but not the first element), in the middle, or at the very end. The placement of TPCS in the communications needs to be considered to prevent the potential for errors.

The following text will show some options for TPCS location within the context of flight crew and controllers transmissions and provide potential advantages and disadvantages of the specified location. Table 2-2, Table 2-3, and Table 2-4 show three potential locations for a TPCS: earlier, mid-communication, or at the end.

Table 2-2. TPCS Location Earlier in an ATC Communication

Receiver	TPCS	Concept	Action / Clearance
UPS 123	United 456	Is Traffic	Cross FIXX 120 seconds behind that traffic

Table 2-3. TPCS Location Mid-ATC Communication

Receiver	Message type- Acknowledgement	Action / Clearance	TPCS	Action / Clearance
UPS 123	Roger	Follow	United 456	Cleared visual approach three six left

Table 2-4. TPCS Location at the End of an ATC Communication

Receiver	Message type- Traffic	Clock position	Range	Direction of flight	Type	Altitude	TPCS
UPS 123	Traffic	Ten o’clock	Eight miles	Westbound	Airbus	Six thousand	United 456

As shown in the examples, the TPCS cannot be the first element in the ATC transmission since that slot is reserved for FPCS. However, as shown in Table 2-2, the TPCS could be after the FPCS and still be earlier in the communication. Potential advantages and disadvantages of an earlier placement are presented next.

- **Earlier advantages:** Provides immediate notification to crew on which aircraft to find on display. More straightforward position for standardization; does not depend on other message content.
- **Earlier disadvantages:** May be followed by clearance / instruction information that could be “stolen” by third party. May also require “traffic is” verbiage that could be avoided in other positions and cases.
    - For TAs, clock position and range coming later may not, in some CDTI traffic display implementations, help pilots find the aircraft on the display.

- **Other sample ATC communications with earlier uses.**
    - **IM:** For [interval spacing], traffic is [United 123], [cross WAYPT 180 seconds behind that traffic, terminate at STOPP].
    - **TA:** Traffic is [U A L 914], three o'clock, eight miles, westbound, Boeing 737, flight level 220.

The TPCS can also be later in the ATC transmission or be the final element in some communications. This option also has potential advantages and disadvantages that are presented next.

- **Later advantages:** TPCS not followed by a full instruction / clearance that could be stolen by TPP. May allow optimization of TPCS within message context and reduce extraneous verbiage. May allow for more "natural" flow.
    - For TA, clock position and range coming first may help pilots find the aircraft on the CDTI traffic display.
    - May also allow for greater message separation between FPCS and TPCS.
- **Later disadvantages:** May be left "dangling" if it is the last element and may lead flight crews to ask if the communication was for them. If not at very end of message, may be followed by clearance / instruction information that could be stolen by TPP (as would be possible in the communication in Table 2-3).
- **Other sample ATC communications with later uses.**
    - **IM:** For [interval spacing], [cross WAYPT 180 seconds behind [U A L 123], terminate at STOPP].
    - **TA:** Traffic three o'clock, eight miles, westbound, Boeing 737, flight level 220, [United 914].

When examining these options, one needs to consider how TPCS is being used. If TPCS is to be used optionally by the controller, it may be advantageous to include TPCS at the end of the communication, as seen Table 2-4. This would allow the controller to add the information when it was operationally advantageous or to not include the information at all. It would be the equivalent of adding information such as "company traffic."

As noted previously, flight crews can use TPCS in a reply to ATC. This reply could either be used when ATC initiated TPCS use or when ATC has not used TPCS. The location of the TPCS could vary for flight crews also. However, when ATC issues an instruction or clearance, they would be expected to read it back as the controller stated (per FAA, 2012a).

2.4.2 TPCS Format

When choosing a format to refer to a TPA, the solution should: 1) Allow pilots and controllers to establish a clear awareness of the aircraft they are referring to, including traffic with carrier three letter designators that are difficult to intuitively determine from the spoken airline telephony designator, and 2) minimize the potential for TPPs on the frequency to become confused about transmissions referring to them.

There are several options for the manner in which TPCS is stated in ASA RTF communications. For example, TPCS can be stated as the currently used call signs (e.g., United Four Five Six), or at the other extreme, it can be a randomly generated code (i.e., IGOBJ). Both of these sample formats have advantages and disadvantages. Utilizing and building upon current phraseology for identification is advantageous since controllers and pilots only have to remember one format. However, it may create additional risks such as crews becoming unnecessarily alert and confused upon hearing their call sign in a voice communication to another aircraft with a subsequent increase in workload in the air and on the ground.

A strategy for differentiating a TPCS is to add language or a word that differentiates it from the FPCS. This language, termed a "delimiter" by the subject matter experts participating in the SBS TPCS activity, can either come before the TPCS, placed between the airline designator and numeric flight identification, or even come afterwards. A delimiter could also be used in conjunction with a format change, such as letters. Ideally, the choice of delimiter and its placement would be salient enough such that the TPP would detect it and recognize that their call sign is being used as the TPCS.

If the TPCS is a format other than that used for call signs today, it could negate any potential confusion with current call signs. However, it could introduce difficulties such as the requirement to remember two different methods of identifying aircraft: one for the FPA and another for the TPA. A new format also may not convey information such as aircraft company, a parameter which is expected to help in the visual search at relatively close ranges (e.g., when on the airport surface or in the terminal area on approach) and some formats may not work well with all aircraft identifications, e.g., general aviation aircraft.

Although different formats have been proposed, most do not modify the numeric flight identification. The majority of the options discussed only modify the airline designator or add text between them. Each option has its own benefits and issues. Several examples follow:

- Telephonic / conventional (United one two three).
    - **Advantage:** Same as conveyed today, which may make it easier for ATC since no change in the manner in which aircraft are identified.
    - **Disadvantage:** Same as conveyed today, which may lead to confusion on the flight deck since flight crew hears ownship call sign stated in same manner.
- Letters (U A L one two three).
    - **Advantages:** Different than today so potentially less pilot confusion; overcomes potential issue of flight crew confusion over three letter abbreviation and the telephonic / conventional spoken format of TPCS. Requires less time to say as compared to Phonetic (see below).
    - **Disadvantages:** Different than today so potentially more difficult to require ATC to differentiate between referenced traffic and other traffic; does not work well for general aviation and business aircraft with all numbers in call sign or those without airline designators. May require more time to say as compared to one or two syllable telephonic designators.

- Phonetic letters (Uniform Alpha Lima one two three).
    - **Advantages:** Different than today so potentially less pilot confusion; overcomes potential issue of flight crew confusion over three letter abbreviation and the telephonic / conventional spoken format of TPCS. Can result in a greater distinction between designator letters, especially as compared to the letters format.
    - **Disadvantages:** Different than today so potentially more difficult to require ATC to differentiate between referenced traffic and other traffic; may not work well for general aviation and business aircraft with all numbers in call sign or those without airline designators. Can require longer time to state, especially as compared to the letters format.
- Internal delimiter (United *Flight* one two three or United *Flight Number* one two three).
    - **Advantages:** Different than today so potentially less pilot confusion; delimiter breaks up call sign.
    - **Disadvantages:** New word(s) added to communication; different than today so potentially more workload for ATC to communicate FPCS and TPCS differently; does not work well for general aviation and business aircraft with no clear insertion point for "flight" or "flight number".
- External delimiter (Call sign United one two three).
    - **Advantages:** Different than today so potentially less pilot confusion; functional for general aviation and business aircraft.
    - **Disadvantages:** Delimiter does not break up airline designator and flight numeric identification; words added to communication; different than today so potentially more workload for ATC to communicate FPCS and TPCS differently; since it is before the call sign, the pilots may not hear it.
- Reversal with telephonic / conventional, letters, or phonetic letters (One two three [United, U A L, or Uniform Alpha Lima]).
    - **Advantages:** Different than today so potentially less pilot confusion.
    - **Disadvantages:** Different than today so potentially more workload for ATC to communicate FPCS and TPCS differently; may not work well for general aviation and business aircraft with all numbers in call sign or no clear reversal point.
- ICAO 24-bit address.
    - **Advantages:** Different than today so potentially less pilot confusion; functional for all aircraft broadcasting this address.
    - **Disadvantages:** Does not assist pilot in initial visual acquisition; not displayed on current CDTI traffic displays; different than today so potentially more workload for ATC to communicate FPCS and TPCS differently.

- Transponder code.
    - **Advantages:** Different than today so potentially less pilot confusion; functional for all aircraft broadcasting the code.
    - **Disadvantages:** Does not assist pilot in initial visual acquisition; not displayed on current CDTI traffic displays; different than today so potentially more workload for ATC to communicate FPCS and TPCS differently.
- Randomly generated characters.
    - **Advantages:** Different than today so potentially less pilot confusion.
    - **Disadvantages:** Does not assist pilot in initial visual acquisition; not displayed on current CDTI traffic display and ATC displays; different than today so potentially more workload for ATC to communicate FPCS and TPCS differently.

2.5 Potential Issues with Adding TPCS to Current Voice Communications

Using the call sign to talk about (rather than talking to) other aircraft on the same frequency introduces a potential for confusion for controllers, FPPs, and TPPs. Pilots and controllers will have to continue to be careful with call signs with the introduction of TPCS since problems exist today with similar call signs being confused, as noted previously (Monan, 1991; Grayson and Billings, 1981; Bürki-Cohen, 1995; Cardosi et al., 1999; Canadian Aviation Safety Board, 1990; Van Es, 2004).

First, flight crews and controllers should remain alert for the transposition of call signs (e.g., 561 versus 651). As with now, both flight crews and controllers will need to exercise caution and remain alert to similar flight identifications, especially during periods of fatigue. Actions suggested under current ops include attention and awareness of the issue, within cockpit coordination, as well as questioning transmissions that are out of the ordinary or unusual for the current conditions (Wright and Patten, 1996). UK Civil Aviation Authority (2000a) further recommends the following: if the flight crew is in doubt about an ATC communication, do not use the readback for confirmation (e.g., don't rely upon ATC to hear and confirm. Instead, question the initial communication). Other recommendations include: flight crews advising ATC if they believe another aircraft has misinterpreted an instruction, ATC advising flight crews if similar call signs are on the same frequency, and ATC listening to and confirming flight crew readbacks (also Bürki-Cohen, 1995; Cardosi et al., 1999; Van Es, 2004).

Call signs can be visually or aurally similar and can be confusing in either format (Cardosi et al., 2011; UK Civil Aviation Authority, 2000a). Visual confusion can occur for the controller when reading flight strips or surveillance displays. The flight crew can also have visual confusion when looking at a traffic display. Aural confusion can happen during pilot and controller voice communication exchanges. Aural confusion associated with TPCSs will be discussed first.

In a First Party Loop, a controller and FPP have a communications transaction that references a TPA. Since the communication is over voice on a common frequency, the TPPs can hear their call sign used in the communication. Since hearing their call sign is normally what has the flight crew tune into the communication from ATC, they may start listening to the remainder of the communication. The TPPs may not know whether their identification was being used as a TPCS or not. This could result in two issues:

1. If TPPs overhear their call sign used on the frequency, they may think the communication is for them. This could lead to them to querying ATC, which results in extra transmissions and use of valuable frequency time.
2. They could also possibly not ask and accept an instruction or clearance that was intended for another aircraft / the FPA.

While both are undesirable, the latter is clearly the more concerning one. For the FPP, the introduction of TPCS could cause confusion because there are two call signs within the same communication. It may also cause confusion for FPPs if the utilized TPCS does not intuitively match the airline designator on the CDTI traffic display (e.g., Speedbird Seven Two Three versus BAW 723).

Another consideration for the implementation of TPCS is the increase or reduction in the amount of information conveyed in the communication. Preferably, TPCS use could reduce the number of information elements in the communication (e.g., reduce the elements in a TA). As mentioned, numerous reports have indicated that the more information that is included in a transmission, the more likely there is to be a communication problem (e.g., Cardosi, 1993; Morrow et al., 1993). Recent exercises exploring the voice breakpoint issue, including a simulation, indicate that the IM clearances can get too complex and point to two areas of concern: reference aircraft TPCS and reference aircraft intended flight path information (Bone, Peterson, and Penhallegon, 2013; Peterson, Bone, and Long, 2013). The TPCS can be an issue when the airline name (e.g., “Brickyard”) doesn’t closely match the airline three letter designator on the CDTI traffic display (e.g., “RPA”). Flight crews reported difficulties trying to decode the flight identification and still pay attention / write down the remainder of the clearance (Bone et al., 2013). In the US, the issue of which method to use for identifying the reference aircraft is being examined in an independent body of work (FAA, 2011) and this simulation report is part of that effort.

If TPCS is used at the end of a communication, ATC may need to consider using “break” between back–to-back transmissions to FPP or should refrain from issuing such strings of instructions since it can confuse different message sets and discourage pilot readbacks (Cardosi et al., 1999).

Prinzo (2001) noted an issue that will need to be avoided with TPCS. She reported a situation where a pilot makes the following transmission, “U P S one eleven, in sight.” ATC may have difficulty determining whether UPS 111 is replying and reporting something in sight or whether another aircraft is reporting UPS 111 in sight but not using their FPCS. Structure can be confusing if not predictable and unambiguous (Anderson, 1990). It may be necessary to continue to enforce the guidance to always use the ownship call sign (per FAA, 2012a, section 4-2-1b) and to train the controllers about this issue.

Another issue to consider in line operations is the improper entry of the FPCS by the FPP in the CDTI. ICAO (2001) states that pilot entry or ACARS / FMS update is required for the broadcast of FPCS. Any errors will be broadcast to other aircraft causing identification issues. Until it becomes routine to enter such information and to use it in ASAs, pilots should be trained on the importance of proper entry of their FPCS.

A summary of possible TPP, FPP, and ATC TPCS identification and execution errors with regard to TPCS use are summarized in Appendix A. These tables summarize the overall operational error, source, type, and contributing factors. Explanations and examples are also provided. Not all errors are applicable to both Telephonic and Letters-based formats. The final column specifies which formats may be most prone to the various error types.

The majority of these TPCS issues are for voice communications. When CPDLC is available and utilized, there is no Third Party Loop so the TPPs do not hear the TPCSs, which eliminates the potential confusion. Additionally, for the FPPs, the TPCS format that will be transmitted over CPDLC is expected to be the same as that shown on CDTI so there should be very little confusion for FPPs. Hébraud and Cloërec (2007) reported that controllers found CPDLC acceptable and important for this TPA identification process.

2.6 TPCS Experience

While numerous simulations and some field activities have used some form of TPCS in ASAs, only a few specifically addressed it as a specific area of interest. The following sections review both. In activities that utilized TPCS in the work but did not treat it as a specific topic of interest, an overview is provided with details on the specific phraseology. In activities that specifically looked at and documented the use of TPCS, more detail is provided. Field tests are reviewed first, then simulations, then a survey of the international ADS-B community, and finally a summary is provided.

2.6.1 Field Operations Utilizing TPCS

As part of the joint government/industry initiative between the Cargo Airline Association (CAA) and the FAA, ADS-B operational applications were demonstrated and evaluated in a series of operational evaluations (Op Evals). TPCS was examined in each of the Op Evals. A short overview of the events is provided below while specifics related to TPCS for each event follow.

Op Eval 1 was hosted by Airborne Express and took place at its Wilmington, Ohio hub in 1999 (Operational Evaluation Coordination Group, 2000). The applications demonstrated included Enhanced Visual Acquisition, Enhanced Visual Approaches (aka ATSA-VSA), ASSA (aka ATSA-SURF), Departure Spacing, Station Keeping, and In-Trail or Lead Climbs and Descents. It was a one day event with three flight periods. Twenty-four aircraft and one ground vehicle were equipped with avionics.

Op Eval 2 was conducted at the UPS hub at Louisville, Kentucky in 2000 (Operational Evaluation Coordination Group, 2001). The applications that were examined at Op Eval 2 included Approach Spacing (an implementation of IM), Departure Spacing, and ASSA / FAROA / ATSA-SURF (Joseph et al., 2003 and Olmos, Bone, and Domino, 2001). It was a four day event with six three-hour flight periods, including day and night operations. Seventeen aircraft and one ground vehicle were equipped with avionics. A third major operational evaluation was planned but was not conducted to the scale originally planned.

The two Op Evals included ATC and pilots as well as aircraft and ground vehicles. Op Eval participants included aircraft from avionics manufacturers, cargo airlines, pilot associations, the US military, as well as private aircraft. All aircraft were equipped with a CDTI and the associated processing systems that were required to demonstrate the applications under study.

Op Eval 3 was a reduced greatly in scope from the previous Op Eval and from what was originally planned. However, simulations preparing for the event examined the same type of applications as the previous two events.

The resulting data from these events included technical data link performance, human factors data for flight crews and ATC, and FAA certification flight reports. Some of the results provided validation of previous simulation research and other outcomes provided questions / issues for further examination.

2.6.1.1 Operational Evaluation 1

At Op Eval 1, flight crews initiated use of telephonic / conventional TPCS (it should be noted that some aircraft were from UPS where the call sign is the same for a letters-based format and telephonic / conventional), while ATC did not use TPCS. Flight crew phraseology used was "[Ownship call sign] [TPCS] in sight." The exact procedures for the flight crews were as follows.

- "Responses to traffic callouts must be based on looking out window. DO NOT CALL TRAFFIC IN SIGHT BASED SOLELY ON CDTI.
- Begin all radio responses with your own callsign.
- Traffic not sighted out window: "(your callsign) roger, traffic not in sight".
- Traffic sighted out window, but not on CDTI: "(your callsign) roger, traffic in sight". If directed to follow traffic: "(your callsign) roger, follow (traffic)".
- Traffic sighted out window and on CDTI: "(your callsign) roger, (traffic callsign) in sight". If directed to follow traffic: "(your callsign) roger, follow (traffic callsign)".
- If conflicting traffic is noted on CDTI, coordinate as appropriate with ATC: "(ATC facility), (your callsign), we show traffic (position, distance)"."

In her analysis of voice communications tapes from Op Eval 1, Prinzo (2001) and Prinzo (2003) found that CDTI traffic display use (with TPCS available) led to some unsolicited reports of traffic in sight. These unsolicited reports either led to a clearance or a request to repeat the unexpected message. CDTI traffic display use also led to reduced frequency congestion with more complex pilot messages and less complex ATC messages. When using the CDTI traffic display, pilots reported more traffic in sight (and less not in sight), but had longer onset times of reporting traffic in sight. These results indicate that pilots may be using the CDTI traffic display to continue looking for traffic when visible on the CDTI traffic display but not readily out-the-window. Although communication problem rates were low overall (4%), all involved use of the CDTI traffic display and most involved use of TPCS (which is not surprising since both were new to the flight crews). For example, TPCS use by flight crews, led to ATC issue with pilot reporting "UPS one eleven, in sight" since ATC was not sure if UPS 111 is reporting something in sight or another aircraft is reporting UPS 111 in sight.

Cieplak et al. (2000) also examined the use of TPCS at Op Eval 1 based on voice communications and human factors observer data. They found that neither flight crews nor controllers reported confusion over hearing TPCS repeated by another flight crew. Additionally, no flight crew whose call sign was used in a traffic reference mistakenly responded. The data did show that approximately three to four times the use of TPCS by the flight crew alerted ATC to the fact that the wrong aircraft had been identified by the flight crew. This detection of mis-identification would not have been possible until later (if ever) without the use of TPCS.

2.6.1.2 Operational Evaluation 2

At Op Eval 2, both flight crews and ATC used TPCS during day (with poor visibility) and night (with good visibility) approach operations in a mixed aircraft equipage environment (i.e., not all aircraft were on the same ADS-B link and could see all aircraft on their CDTI traffic display). For the examination of the Op Eval 2 call sign procedure, the controllers were encouraged to append their TA with the TPCS if the TPA could be displayed on the ownship's CDTI. The type of ADS-B equipage was denoted on flight strips that were provided to the controllers. To distinguish between an aircraft being spoken to in a TA, TPCS was spoken by ATC using (conventionally spoken) alphabet letters (e.g., “U-A-L one twenty three”) (it should be noted that some aircraft were from UPS where the call sign is the same for letters and telephonic / conventional). In traffic related messages, ATC used TPCS in 89% of their transmissions, and pilots used TPCS in 53% of their transmissions.

About equal numbers of pilots thought use of TPCS was either effective or confusing. Most agreed that the use of TPCS made it easier to correlate called traffic with a visual target, but it was still an open question as to whether experience would overcome the possibility of confusion when ownship call sign is heard as part of a traffic call to another aircraft (Olmos, Bone, and Domino, 2001). As for ATC, controllers thought it would be more beneficial to use current procedures and for the pilots to use TPCS to confirm they had the correct aircraft in sight, if that traffic was displayed on the CDTI traffic display. ATC also had issues with mixed equipage and determining when they could or could not use TPCS (Olmos et al., 2001). They reported that these procedures were cumbersome and difficult to apply consistently, especially when superimposed over the task of determining whether an aircraft was ADS-B equipped in those scenarios demonstrating a mixed equipage environment.

As also seen in Op Eval 1, Prinzo and Hendrix (2003) noted three incidents where ATC used TPCS to confirm the flight crew was following the correct aircraft during approach. They also noted that use of the CDTI traffic display and ADS-B did not cause a notable increase in workload of either ATC or the flight crews.

2.6.1.3 Preparation for Operational Evaluation 3

A limited number of flight crews and controllers provided feedback on the use of TPCS during three simulations conducted to prepare for Op Eval 3 (Bone, Helleberg, and Domino, 2003). During the Approach Spacing for Instrument Approach (ASIA) application (an implementation of IM), ATC and flight crews used the telephonic / conventional TPCS during TAs when controllers determined it was appropriate to do so.

Overall, the pilots indicated that TPCS use was beneficial and had few problems. However, pilots from simulation 3 provided mixed responses trending toward neutral, suggesting that it was confusing to hear their own call sign when their aircraft was being pointed out to another aircraft. Pilots from simulation 2 somewhat agreed that adding call sign to traffic call outs would be beneficial. Pilot responses from simulation 3 were mixed, trending toward neutral. Pilots expressed some concern over including the TPCS at the end of a TA. Pilots suggested that the TPCS should be embedded within the TA to reduce the likelihood of confusion.

The controllers somewhat agreed that the TPCS procedure improved the standard TA. They somewhat disagreed that it created too much congestion on the radio frequency. They also responded neutrally to positively as to the benefits from using TPCS during a TA. During the debriefings, controllers indicated that the TPCS procedure was awkward, but also suggested that this could be due to inexperience. They preferred to add the TPCS onto the end of their normal TA, rather than embed the TPCS within the advisory. They also suggested that it might be possible to replace the standard TA with an advisory utilizing only the TPCS. They indicated that, within the current environment, confusion about which traffic aircraft was advised occurred fairly often.

The controllers expressed some concern that pilots could become “desensitized” to their own call sign. They also suggested that frequency congestion could increase as a result of pilots “keying up” due to being confused about to whom a particular radio transmission was directed. They indicated that the TPCS procedure alone would be unlikely to increase frequency congestion, but they felt that confusion resulting from its use could increase frequency congestion. Overall, the TPCS procedure received mixed reviews overall from both pilots and controllers.

2.6.2 HITL Simulations Examining ASA Concepts with TPCS

The following sections will describe research conducted that explored the development of ASAs that used TPCS. The material is broken into three types of ASA applications: Situation Awareness (SA), CAVS, and IM.

2.6.2.1 SA ASAs

In a preliminary examination of the ATC benefits of conducting the ATSA-VSA (RTCA, 2003), Olmos and Mundra (1999) recruited three active TRACON controllers to provide feedback on the concept. The controllers could use the telephonic / conventional TPCS in the TA to CDTI-equipped aircraft conducting visual separation and visual approach operations. The TA was abbreviated based on use of the TPCS (e.g., “Northwest 930, traffic you’re following is 12 o’clock, United 133”). Although the number of participants was limited, the controllers were enthusiastic about use of TPCS. They reported that having a convenient means to know which aircraft were equipped with CDTI would allow them to use TPCS in the TAs. They reported that their communication workload was reduced and that they were able to focus their attention to other tasks such as vectoring to final. They also found it beneficial to provide the TA whenever it worked into their other tasks with the pilots reporting the traffic on the CDTI and the plan to acknowledge when the aircraft is acquired out-the window.

In two simulations conducted by Airbus and reported in Raynaud et al. (2007), a phonetic format was used by pilots and controllers. The experiments examined ATSA-VSA and ATSA-SURF with pilot participants. Controllers issued traffic with the phonetic spelling of the three letter airline designator. Pilots could reply with the same format. The pilots reported that the use of phonetic TPCS helped in the identification of traffic especially with "unusual airlines," e.g., those there the airline name and airline three letter designator did not closely match. Pilots also reported that they were able to use the standard / telephonic format of TPCS (even if the phonetic TPCS was better) from controller communications on the common frequency not related to ATSA-VSA and ATSA-SURF when correlating traffic from those communications with the information on the CDTI traffic display. However, pilots also reported that the phonetic TPCS was not easy to use and had a negative impact on their workload. They also reported it was hard to memorize the entire TPCS. In ATSA-SURF, pilots reported that the use of TPCS helped correlate traffic out-the-window. The reports stated that TPCS should be examined further.

Raynaud et al. (2007) also summarized a simulation by DSNA. However, additional detail is available in Pianetti et al., (2007). The simulation examined the ATSA-AIRB concept with both pilots and controllers, including the use of TPCS. Controllers issued a TA with current phraseology and no TPCS. Pilots could reply to the TA with the phonetic spelling of the three letter TPCS (e.g., “Traffic *Bravo Alpha Whiskey 6 2 5* in sight, Air France 1 2 3 4”). The phraseology was tested at major and secondary airports as well as in the en route environment.

Pianetti et al. (2007) encouraged the pilots to use the phonetic TPCS and then reported how often the pilots used it. In 34% of the cases, they did not use any form of TPCS. In 26% of the cases, the phonetic TPCS was used. In 3% of the cases, no reply was made for the TA. Pilots never identified the wrong aircraft. However, in 34% of the cases, a TPCS was used but not the proper, phonetic TPCS for the identified aircraft. Mistakes in TPCS format included using the telephonic TPCS and saying the letters (but not phonetically). Other cases included transposing letters and saying a letter or number incorrectly.

Most of the pilots and controllers found the phonetic TPCS operationally acceptable. Pilots indicated that the phonetic TPCS communications were lengthy and the identifiers were complex, adding to workload and frequency loading. However, pilots and controllers reported that TPCS helped confirm the identification of correct traffic and could help detect errors. In fact, errors occurred in the simulation with pseudopilot readbacks of TPCS, and all four were detected by the controller who then clarified the traffic of interest. Pilots also reported listening to the communications between ATC and other aircraft that used the standard / telephonic format of TPCS and using that information to monitor traffic on the CDTI traffic display. However, they did report some difficulties correlating the telephonic format used by ATC and the three letters shown on the CDTI traffic display.

Pilots also reported difficulty memorizing the phonetic TPCS and difficulty with mismatch between the ATC spoken telephonic format and the phonetic format. They also reported additional workload searching for the traffic on the CDTI traffic display. Results were generally mixed on the need for TPCS in TAs during ATSA-AIRB operations. However, participants proposed only using the aircraft identifier in cases where it is believed to be relevant.

2.6.2.2 CAVS

After the SA ASA concepts (e.g., ATSA-VSA) had been developed, another ASA called CAVS (formerly known as CDTI Enhanced Flight Rules [CEFR]) underwent simulation activities as an application that took the next logical operational step forward. CAVS moved beyond simulation and has been fielded by UPS, and is under development in Minimum Operational Performance Standards (MOPS) activities.

The operational concept for CAVS is to use the information available from the CDTI for traffic identification and separation monitoring during visual approaches. CAVS makes the transition from pilots using the CDTI to assist with spacing judgments during visual approaches when the aircraft remains continuously in sight out-the-window (like that done for ATSA-VSA), to using information from the CDTI to monitor and maintain visual separation even when that aircraft is not in view out-the-window. In effect, the operational definition of “visual separation” is expanded to include the use of the CDTI to substitute for out-the-window visual contact when maintaining pilot-determined separation. Requirements for the conduct of the visual approach are unchanged except for pilot use of the CDTI for visual separation. However, the flight crew will be required to correlate the aircraft seen out-the-window with its symbol on the CDTI traffic display prior to using the CDTI for visual separation.

A series of four HITL simulations, with pilots and controllers, were conducted to refine the application description and the associated procedures previously developed within the Safe Flight-21 Program (Bone, Domino, Helleberg, and Oswald, 2003; Bone, Helleberg, Domino, and Johnson, 2003a, b, & c). The simulations examined numerous variables: power control (auto-throttle or the higher workload method of manual speed control), approach types (parallel visual and single stream instrument), weather conditions (day, night, haze, and cloud layers), aircraft types (large, 757, and heavy), CDTI locations (primary field of view and throttle quadrant forward console), different periods using only the CDTI traffic display for separation, spacing instructions and alerts, two crew member operations, as well as reference aircraft failure conditions. Forty-five pilots from various airlines participated in the simulations.

The phraseology used for TAs under the CAVS application was the same as with current visual separation except that advisories and crew responses involved the use of TPCS by controllers and the flight crew, at their discretion. It should be noted that the use of TPCS is not required for CAVS but could be optional for any TA.

In the first simulation (Bone, Domino, Helleberg, and Oswald, 2003), TPCS in the telephonic / conventional format was appended to the end of the standard TA phraseology to permit pilots to correlate the aircraft seen visually out-the-window with its symbol on the CDTI traffic display. Controllers acted as confederates but were asked to use TPCS during each advisory to allow for a sufficient number of events from which to form opinions. Flight crews could also use TPCS in their response to the advisory. TPCS could also be used in the controller instruction to follow the reference aircraft (e.g., “United 235, follow Delta 112, maintain own separation”). Pilots generally agreed that the use of the TPCS was acceptable, not difficult, aided in the positive identification of the reference aircraft, and was beneficial. However, pilot opinions were mixed when asked whether it was confusing to hear their ownship call sign in a TA to another aircraft.

In the second simulation (Bone et al., 2003a), TPCS in the telephonic / conventional format use was an option for the confederate air traffic controllers but they were encouraged to use it. It could be appended to the end of the standard TA phraseology to permit pilots to correlate the aircraft seen visually out-the-window with its symbol on the CDTI traffic display. Flight crews could also use call sign in their response to the advisory. TPCS could also be used in the controller instruction to follow the reference aircraft (e.g., “United 235, follow Delta 112, maintain visual separation.”). Pilots again generally agreed that the use of the TPCS aided in the positive identification of the reference aircraft and that it was beneficial. However, pilot opinions were mixed when asked whether it was confusing to hear their own call sign in a TA to another aircraft and whether it was acceptable to use TPCS in a reply to ATC.

In the third simulation (Bone et al., 2003c), both controllers and pilots acted as subjects. TPCS in the telephonic / conventional format use was an option for air traffic controllers. It could be appended to the standard TA phraseology to permit pilots to correlate the aircraft seen visually out-the-window with its symbol on the CDTI traffic display. Flight crews could also use the TPCS in their response to the advisory. TPCS could also be used in the controller instruction to follow the reference aircraft (e.g., “United 235, follow Delta 112, maintain visual separation.”). Pilots again generally agreed that the use of the TPCS aided in the positive identification of the reference aircraft and that it was beneficial. However, pilot opinions were mixed when asked whether it was acceptable to use TPCS in a reply to ATC and whether the addition of TPCS made communications difficult. Although concerns were expressed, pilots agree that the TPCS procedure could be operationally acceptable with the appropriate modifications to phraseology and with additional experience and practice.

In the fourth and final simulation (Bone et al., 2003b), TPCS use by confederate controllers in TAs and by pilots in the reply to TAs was optional at all times. TPCS could also be used in the controller instruction to follow the reference aircraft (e.g., “United 235, follow Delta 112, maintain visual separation.”). Only twenty-five percent (25%) of the flight crew communications involved use of TPCS in response to the TA from ATC. TPCS use by ATC was minimal. Therefore, some of the pilots never heard TPCS used in a TA or never used TPCS in a reply. Those pilots did not reply to some or all of these questions. Pilots generally agreed that the use of the TPCS use was acceptable, worthwhile, aided in the positive identification of the reference aircraft, and was beneficial. They also generally agreed that it was acceptable to use TPCS in a reply to ATC. However, pilot opinions were again mixed when asked whether the addition of TPCS made communications difficult. Although concerns were expressed, pilots again agree that the TPCS procedure could be operationally acceptable with the appropriate modifications to phraseology and with additional experience and practice. These pilot responses towards the TPCS procedure were the most favorable yet in the CAVS simulations. This indicates that the most acceptable initial implementation to both ATC and pilots may be pilot use of TPCS in the reply to the ATC issued TA without TPCS.

For CAVS simulations, TPCS use during TAs was not required. It was examined since it could be used for any application using a CDTI traffic display with TPCSs, and it was expected to help with the initial visual acquisition. Controllers and pilots used the telephonic / conventional format. The simulations indicated that pilots thought TPCS could have benefits in reference identification but that it had the potential to cause confusion. Overall, pilots generally agreed that the TPCS procedure could be operationally acceptable with the appropriate modifications to phraseology and with additional experience and practice. The feedback from the simulations also showed that any use of TPCS during TAs must be optional for both pilots and air traffic controllers and should never be required. The final simulation was the least “controlled” from a laboratory perspective and applied lessons learned from TPCS use in previous simulations. It appeared to have a procedure that ATC was comfortable with in the near term, which was ATC TAs with little if any use of TPCS but with flight crew use of TPCS in the reply.

2.6.2.3 IM

IM is intended to create operational benefits through management of intervals between aircraft in various environments (e.g., arrival, departure, en route). IM is comprised of both ground (GIM) and flight deck (FIM) components. GIM supports the controller in determining which aircraft are capable of acting as participants and, depending on the operation, the sequence of aircraft, the status of IM, and a desired interval. The FIM component has the displays necessary for the flight crew to enter the IM clearance information, perform IM, and monitor conformance with the IM clearance.

IM has been explored internationally in simulations (e.g., Hebraud, Hoffman, Papin, et al., 2004; Barmore et al. 2005; Mercer, Callatin, Lee, Prevot, and Palmer, 2005; Bone et al., 2008), has initial standards developed (e.g., RTCA, 2011), has been field tested (e.g., Operational Evaluation Coordination Group, 2001; Lohr, Oseguera-Lohr, Abbott, Capron, and Howell, 2005) and has been fielded (e.g., Penhallegon and Bone, 2013). The US and Europe are also currently funding development of international MOPS for IM and the US is developing plans for fielding the concept around the 2020 timeframe. As IM is a significant aspect of the simulation that is the subject of this paper, a concept overview is first provided before past simulation results are reviewed. While it describes IM in the context of an arrival operation, the conduct of IM in other environments is very similar.

IM Arrivals Concept Overview

An IM Arrival operation typically starts in the en route airspace. At the appropriate point, the en route GIM automation displays to the controller an aircraft pair that is capable of conducting IM, as well as the desired spacing goal. The controller then decides whether or not to initiate IM on a capable aircraft (termed the “IM aircraft”) based on sector traffic, arrival flow sequence, and the spacing requirement for a given IM pair.

The IM aircraft is intended to be initially set up to follow the reference aircraft in the arrival sequence at the time of initiation, although the assigned spacing goal may be large enough to allow another aircraft to be merged between the two further downstream. The controller provides the initiation information to the flight crew in a clearance with elements such as the assigned spacing goal and the point to achieve the assigned spacing goal (called the achieve-by point).

Once the IM clearance is provided to the flight crew, it is entered into the FIM equipment which then checks that the information is appropriate for the operation and that the reference aircraft is in ADS-B surveillance range. If the reference aircraft is not in ADS-B surveillance range, the system cannot arm or engage. Once the reference aircraft is in range, is on the expected trajectory, and meets the necessary performance requirements, IM is initiated and the FIM equipment provides an IM Speed for the flight crew to fly. Situation awareness information is available to assist the flight crew in monitoring the progression of the spacing operation. IM information is expected to typically be provided on a CDTI traffic display, although information could be provided on other displays as well.

With the presentation of each new IM Speed, the flight crew ensures it is feasible for the aircraft's current configuration and environmental conditions. The crew is expected to follow the IM Speeds in a timely manner consistent with other cockpit duties unless conditions prevent it (e.g., safety, operational, FIM equipment, or regulatory issues). If unable, the flight crew stops following the IM Speeds and contacts the controller to announce that they are unable to conduct IM. The controller then terminates the IM operation. Similarly, if the controller becomes aware of any conditions that prevent continued IM such as safety, operational, or regulatory issues, the controller will contact the flight crew to terminate IM. If no issues arise for either ATC or the flight crew causing a suspension or termination, the flight crew continues following the IM speeds and the controller continues monitoring the operation until the aircraft reaches the planned termination point. At this point, the flight crew discontinues flying IM Speeds and terminates IM.

When IM operations are in effect, not all aircraft are required to conduct IM. Aircraft that are not capable of conducting IM can receive speed advisories from the controller.

TPCS Use in IM Simulations

Several previous experiments used a form of TPCS in an IM simulation but did not report out on the use of TPCS specifically, i.e., advantages or disadvantages of the specific TPCS use were not reported. The following bulleted items are some key bodies of work. Other activities used a form of TPCS in an IM simulation and reported out on the use and feedback in more detail. Several of those activities are described after the bullets.

- The body of CoSpace work examined implementations of IM with pilots and controllers (e.g., Grimaud, Hoffman, Rognin, Zeghal, and Deransy, 2001; Aligne, Grimaud, Hoffman, Rognin, and Zeghal, 2003; Hebraud, Hoffman, Papin, et al., 2004; Hebraud, Hoffman, Pene, et al., 2004; Boursier et al., 2006) used the transponder code in the reference aircraft identification. The reference aircraft identification process seemed to change very little over the course of the simulations.
    - Reference aircraft identification.
        - Controller: "Lufthansa 534, select target 4522."
        - Pilot: "Lufthansa 534, target 4522 identified, 8 o'clock, 30 miles."
- Barmore et al. (2005) conducted a simulation of IM operations with pilots and controllers. Controllers used the telephonic / conventional TPCS in the spacing instruction and the pilot read back the instruction with the same TPCS.
    - IM clearance.
        - Controller: "American 123, cleared Precision Spacing, maintain one two zero seconds spacing, reference Continental 321."
        - Pilot: "Cleared Precision Spacing, maintain one two zero seconds spacing, reference Continental 321, American 123."

- Nyberg (2006) tested an implementation of IM and had pilots and controllers using phonetic spelling of the airline three letter designator of the TPA.
    - Expectation and reference aircraft identification.
        - Controller: "Scandinavian 123, expect spacing, leader Sierra Alpha Sierra 456."
        - Pilot: "Expect spacing, leader Sierra Alpha Sierra 456, Scandinavian 123."
    - IM clearance.
        - Controller: "Scandinavian 123, ASAS spacing leader Sierra Alpha Sierra 456, 60 seconds at <waypoint>."
        - Pilot: "ASAS spacing leader Sierra Alpha Sierra 456, 60 seconds at <waypoint>, Scandinavian 123."

Fusai, Schaefer, and Ruigrok (2004) used the TPCS for both pilots and controllers in a manner very similar to some of the other European work where the transponder code was used in the traffic identification communication but not in the spacing instruction. Subsequent communications used the term "target" and not the TPCS. Some pilots reported difficulties while other pilots reported it acceptable but recommended a short unique code. The authors recognized the difficulty in choosing a best option for TPCS and stated that even if the transponder code can help avoid confusion, that the topic of which TPCS to use requires further examination.

Hassa, Haugg, and Udovic (2005) examined an implementation of IM with controllers acting as participants. The authors reported developing simplified phraseology for the simulation and that phraseology was an area of emphasis for the evaluation. The simulation used a TPCS where the airline name and the numeric flight identification were reversed (e.g., Speedbird 3405 / BAW 3405 was 3405 Speedbird). That format was used because it was available on pilot and controller displays and the transponder code was not expected to be available in their timeframe. The format was used in the reference aircraft identification and the pilot readback and then repeated in the controller spacing instruction but not in the pilot readback. Sample communications are shown below.

- Reference aircraft identification.
    - Controller: "Lufthansa 672, for spacing, select target 456 Air France."
    - Pilot: "Air France identified, 030 degrees, 15 miles, Lufthansa 672."
- IM clearance.
    - Controller: "Lufthansa 672, remain 10 miles behind 456 Air France."
    - Pilot: "Wilco. 10 miles behind, Lufthansa 672."

Other communications related to the reference aircraft such as reports of distance from the reference aircraft included the term "target" and not the TPCS. If the flight crew did not know the airline name when being issued the spacing instruction and asked the controller for clarification, the controller was told to use the three letter phonetic spelling in the reply. The results indicated that the controllers thought the reversed TPCS was difficult to use and proposed another option such as the 24 bit address, the transponder code, or the telephonic / conventional TPCS. They recommended the use of the telephonic / conventional TPCS for the next simulation.

Finally, Mercer et al. (2005) conducted a simulation of an implementation of IM with controllers and pilots in TRACON airspace. The IM clearance included the telephonic / conventional TPCS (e.g., "Delta 620, merge behind then follow American 142, 100 seconds in trail." They reported that out of 323 clearances utilizing TPCS, neither controllers nor pilots ever misidentified an aircraft. The phraseology was found acceptable for both pilots and controllers.

2.6.2.4 Survey of International ADS-B Community

While ASA standards were under development in 2005, an activity was started to gain further insight into the effects of using TPCS in voice communications related to reference aircraft identification during ASAs. It was believed that the literature on TPCS (some of which has already been reviewed in previous sections) was limited based on TPCS being used in simulations but only to examine a specific application, i.e., TPCS was used but not evaluated. Also, there were reports that activities related to choosing a TPCS method had taken place but formal reports had not been released. Therefore, a decision was made to conduct a formal survey.

In 2005, a cover letter and an online survey were sent to the Requirements Focus Group (RFG) Application Description Subgroup within the standards community and the members were asked to either complete the survey themselves or distribute it to the appropriate researchers for completion. The general purpose was to reveal the different methods previously used (and possibly not sufficiently reviewed in the literature) and to make recommendations on the use of TPCS to both the RFG and ICAO. The ultimate objective was to shortlist the most suitable TPCS method for further evaluation and final selection of the best method by operational experts (Bone, 2005).

The on-line survey asked 29 questions and some had sub-questions. The first set of questions dealt with the environment that TPCS was examined in and who participated. The next set of questions dealt with who used the TPCS, how it was used, and the format used. The final set of questions dealt with the acceptability of and any recommended improvements for the chosen format.

Eleven replies were received from US and European researchers. The survey was believed to represent the majority of the research conducted to that point. The feedback was based on TPCS use in committee evaluations, simulations, and in-flight evaluations. It included basic and advanced ASAs as well as operations en route, in the terminal, and on the airport surface. Eighty-two percent of the replies stated that TPCS was not primary variable in the activity and some did not specifically examine TPCS. Most activities reported asking questions about TPCS but few results were actually reported. The TPCS used was determined primarily through operator consultation or previous simulation use.

The US activities mostly used a TPCS that was the same as that used today (i.e., telephonic), while most European activities used a modified version (e.g., reversed company name and flight number, transponder code, ICAO 24-bit address). None of the evaluations compared different uses of traffic identification.

Results indicated that pilots generally agreed that they would use the TPCS as tested / proposed in the activity, including current or modified versions. However, only about half of the controllers were willing to use the TPCS as tested / proposed in the activity. The other half said they would not or did not provide a clear stance.

The researchers reported that the activity participants proposed recommendations such as the following:

- TPCS used in communications should be that on CDTI traffic display.
- Preference for the telephonic / conventional format of TPCS when it was not used.
- Data link should be used.
- TPCS should be optional, but available for use when operationally advantageous.
- Add something before TPCS such as “Target is…”

2.6.2.5 Summary

Several forms of TPCS have been tested in previous activities. Table 2-5 provides a summary across the set of work summarized in this report.

Table 2-5. Summary of Previous Activities Utilizing TPCS

ASA Concept	Activity	Speaker	Format	Communication Type where TPCS Used	Select Reference
Several	Op Eval 1 field test	Pilot only	Telephonic / Conventional	Traffic Advisory	Operational Evaluation Coordination Group (2000)
Several	Op Eval 2 field test	ATC and pilots	Letters	Traffic Advisory	Operational Evaluation Coordination Group (2001)
Several	Op Eval 3 field test prep	ATC and pilots	Telephonic / Conventional	Traffic Advisory	Bone et al. (2003)
SA	Enhanced Visual Approach / ATSA-VSA simulation	ATC only	Telephonic / Conventional	Traffic Advisory	Olmos and Mundra (1999)
SA	ATSA-VSA and ATSA SURF simulations	ATC and pilots	Phonetic	Traffic Advisory	Raynaud et al. (2007)
SA	ATSA-AIRB simulation	ATC only	Phonetic	Traffic Advisory	Pianetti et al (2007)
CAVS	CAVS activities	ATC and pilots	Telephonic / Conventional	Traffic Advisory and CAVS Clearance	Bone et al. (2003b)
IM	Co-Space activities	ATC and pilots	Transponder code	Traffic Identification	Hebraud, Hoffman, Pene, et al. (2004)
IM	Airborne Precision Spacing	ATC and pilots	Telephonic / Conventional	IM Clearance	Barmore et al. (2005)
IM	IM Simulation	ATC and pilots	Phonetic	Traffic Identification and IM Clearance	Nyberg (2006)
IM	IM Simulation	ATC and pilots	Transponder code	Traffic Identification	Fusai et al. (2004)
IM	IM Simulation	ATC and confederate pilots	Reversed	Traffic Identification and IM Clearance	Hassa et al. (2005)
IM	IM Simulation	ATC and confederate pilots	Telephonic / Conventional	IM Clearance	Mercer et al. (2005)

Based on the results of previous activities, there does not appear to be a clear, optimal choice that works for all situations. It also appeared that while there were concerns about the potential for confusion when using current phraseology (i.e., telephonic / conventional), few to no actual occurrences were clearly realized in the reported activities. Recommendations were then made to conduct a simulation or set of simulations that specifically examined TPCS options and to treat TPCS as the main variable with the application being secondary and only there so that TPCS can be examined within the proper context.

2.7 HITL Simulations Directly Examining Alternate TPCSs

After the results of the international community were released, a preliminary set of simulations were started to specifically examine TPCS in a systematic way. The first full study to do so was reported in Kerns, Benson, and Penhallegon (2009). The authors examined three methods for utilizing TPCS in TAs during normal and highly similar call sign scenarios with controller participants.

- Pilot use of phonetic TPCS in a reply to an ATC TA. No controller use.
- Controller use of telephonic / conventional TPCS in a TA. No pilot use.
- Controller and pilot use of the term "flight" in place of the airline company name in the TA exchanges (e.g., "Flight one twenty three" for "United one twenty three").

The specific phraseology is shown in Table 2-6.

Table 2-6. Sample communications from Kerns, Benson, and Penhallegon (2009)

Example Controller Advisory	Example Pilot Readback
Traffic to follow for Big East RNAV Arrival, 10 o'clock, 5 miles, Flight level 240	Traffic Uniform Alfa Lime Five Twenty, identified
Traffic to follow for Big East RNAV Arrival, 10 o'clock, UNITED Five Twenty	Traffic 10 o'clock, identified
Traffic to follow for Big East RNAV Arrival, FLIGHT Five Twenty	Traffic 10 o'clock, FLIGHT Five Twenty identified

Controllers were generally positive regarding the use of TPCS. Overall, the authors found that the use of "flight" by the pilots and controllers did not convey the necessary information for mutual understanding and agreement on the TPA. They also found that the pilot reply with phonetic TPCS was less effective. The most effective method appeared to be controller use of telephonic / conventional TPCS in a TA (without a pilot reply, since that was not tested). This format also had the fewest incorrect traffic identification errors. However, controllers showed a general preference for the format where both pilots and controllers used the term "flight" in place of the company name. There was no evidence that any of the tested conditions were different for TPPs responding incorrectly to the controller TA. Overall, the results of the simulation appear inconclusive based on differences in subjective and objective results. The authors recommended examining the issues further and examining the controller use of "flight" and pilot replies with TPCS.

In a follow-on study specifically examining TPCS, Kerns, Penhallegon, and Benson (2009) examined three methods for utilizing TPCS in TAs and a spacing operation during normal and highly similar call sign scenarios and scenarios with call signs that were difficult to decode into the airline three letter designator, (e.g., Cactus as A W E) with multiple pilot participants flying in terminal airspace.

The three formats used were:

- Pilot use of phonetic letters TPCS in a reply to an ATC. No controller use.
- Controller and pilot use of telephonic / conventional TPCS.
- Controller and pilot use of the term "flight" in place of the airline company name (e.g., "Flight one twenty three" for "United one twenty three").

The specific phraseology is shown in Table 2-7.

Table 2-7. Sample communications from Kerns, Penhallegon, and Benson, (2009)

Format	Application	Phraseology
1	Approach	**Controller**: Traffic to follow for CSIGN3 Arrival, *10 o'clock, 10 miles, FL340* **Pilot**: Traffic *BRAVO TANGO ALPHA Ninety Four Eleven* identified **Controller**: Follow at least [3/4/5] miles behind traffic, proceed direct PTINO **Pilot**: Direct PTINO, following traffic
	Arrival	**Controller**: Traffic, *10 o'clock, 5 miles, Boeing 737* **Pilot**: Traffic *BRAVO TANGO ALPHA Ninety Four Eleven* identified **Controller**: Cleared for visual approach, follow that traffic, CONTACT Tower **Pilot**: Cleared for the visual, contacting Tower
2	Approach	**Controller**: Traffic to follow for CSIGN3 Arrival, *DELTA Thirty Five Thirty Three* **Pilot**: Traffic *DELTA Thirty Five Thirty Three* identified **Controller**: Follow at least [3/4/5] miles behind traffic, proceed direct PTINO **Pilot**: Direct PTINO, following traffic
	Arrival	**Controller**: Traffic, *DELTA Thirty Five Thirty Three* **Pilot**: Traffic *DELTA Thirty Five Thirty Three* identified **Controller**: Cleared for visual approach, follow that traffic, contact Tower **Pilot**: Cleared for the visual, contacting Tower
3	Approach	**Controller**: Traffic to follow for CSIGN3 Arrival, *10 o'clock, FLIGHT Five Twenty* **Pilot**: Traffic *FLIGHT Five Twenty* identified **Controller**: Follow at least [3/4/5] miles behind traffic, proceed direct PTINO **Pilot**: Direct PTINO, following traffic
	Arrival	**Controller**: Traffic, *10 o'clock, FLIGHT Five Twenty* **Pilot**: Traffic *FLIGHT Five Twenty* identified **Controller**: Cleared for visual approach, follow that Traffic, contact Tower **Pilot**: Cleared for the visual, contacting Tower

Pilots were generally positive regarding the use of TPCS. The use of a form of TPCS (either telephonic / conventional TPCS or "flight" in place of the airline company name) by the controller in the transaction identifying traffic reduced the frequency congestion over controllers not using a form of TPCS (but the pilot replying with the phonetic letters TPCS). None of the studied communication methods were affected by the presence of highly similar call signs or call signs that were difficult to decode into the airline three letter designator. Pilots also preferred when controllers used a form of TPCS when identifying traffic because it supported mutual understanding and agreement on the TPA. Potentially surprisingly, when choosing between the two forms of TPCS used by the controller, pilots reported a slight preference for the use of “flight” in place of the airline company name over the use of telephonic / conventional TPCS. However, the use of “flight” resulted in fewer errors being corrected, as compared to the other two communication methods. Table 2-8 provides a summary of the TPCS methods used in the simulations.

Table 2-8. Summary of Two Preliminary Simulations Specifically Examining TPCS

Activity	Alternative	Speaker	Format	Communication Type where TPCS Used	Reference
TPCS Simulation 1	1	Confederate pilot only	Phonetic	Traffic Advisory	Kerns, Benson, and Penhallegon, 2009
	2	ATC only	Telephonic / Conventional	Traffic Advisory	
	3	ATC and confederate pilots	Delimiter Replacement	Traffic Advisory	
TPCS Simulation 2	1	Pilot only	Phonetic	Traffic Advisory	Kerns, Penhallegon, and Benson, 2009
	2	Pilots and confederate ATC	Telephonic / Conventional	Traffic Advisory and Traffic Identification	
	3	Pilots and confederate ATC	Delimiter Replacement	Traffic Advisory and Traffic Identification	

Based on the two simulations, the authors suggested examining a combination of the two forms of TPCS used by the controller (e.g., using an external delimiter such as “Flight United six twenty) to balance subjective preferences of pilots and controllers against error trapping and objective performance.

2.8 SBS approach to addressing TPCS

Based on the results from past work, the international survey, and data from the preliminary TPCS simulations, FAA SBS decided to start an activity to specifically examine TPCS. SBS also identified a risk associated with TPCS in 2007 to ensure the topic was appropriately addressed and tracked so that TPCS could be used when needed for ASAs. In 2011, the ADS-B In ARC recommended that the FAA, “should identify phraseology requirements, challenges, and risks associated with [TPCS]…the FAA should form an appropriately supported Action Team to develop actual phraseology that can be validated through various Human-in-the-loop analyses.” (ADS-B In ARC, 2011, p. I-1)

In 2011, the FAA developed a TFID Human Factors Analysis Master Test Plan to specify the plan to finalize phraseology and terminology for TPCS so the appropriate guidance material can be updated to enable TPCS use in the national airspace (FAA, 2011). Operational workshops and HITL simulations are described. The Test Plan specifies three phases:

- 1 – Identification of ATC Phraseology and Terminology Alternatives.
    - Subject matter experts from the FAA, unions, research organizations, and industry discussing and debating TPCS alternatives so that candidate options could be tested in a Phase 2 simulation.
    - Status: Completed prior to the start of Phase 2. The report is available in FAA, 2012c.
- 2 – Determine the Best Solution.
    - Taking the recommendations from Phase 1 and testing them in a HITL environment. The goal of this phase is to come up with a recommendation for TPCS.
    - Status: Results are the subject of this report.
- 3 – Validation of Phase 2 solution.
    - Taking the recommendations from Phase 2 and validating the proposed solution to support the updating of FAA guidance material.
    - Status: At the time of the writing this report, Phase 3 coordination was underway.

2.9 Phase 2 / Current Study Development Effort

This simulation was designed to be the activity to satisfy Phase 2 of the SBS plan (FAA, 2011). The research goal was to evaluate TPCS voice communications alternative candidates proposed by TFID OFG in the Phase 1 report (FAA, 2012c).

The Phase 1 effort consisted of several activities. The first main activity of the group was to understand the topic, issues, and alternatives and then to recommend TPCS solutions. When considering potential solutions, the members were told the following:

- "Mandating the transmission of the aircraft identification using the phonetic alphabet (Alpha, Bravo, Charlie, etc.) as 'the' solution was unacceptable to the operational community.
- Use of the word 'Target' as a delimiter in voice transmissions could imply a threatening situation that was unacceptable to the operational community.
- Placement of any reference to the aircraft being talked 'about' at the end of the transmission could be problematic" (FAA, 2012c, p. 13).

Considering these points, nine recommendations were submitted by the members. After discussions, the recommendations were consolidated to seven options:

1. Letter then number: "eh eh el five thirty seven" (A-A-L 537).

2. ICAO phonetic then number: “Alpha - Alpha - Lima five thirty seven” (A-A-L 537).
3. Telephony (company name) then number: “American five thirty seven.”
4. Invert the flight number and "Five thirty seven, Alpha - Alpha - Lima" (537 A-A-L) then the ICAO phonetic character.
5. Invert the number and then the “Five thirty seven, American” (537 A-A-L) registered Telephony name.
6. Distinct leading delimiter: “CDTI Traffic, [Telephony-number],” or “Flight, [Telephony-number],” or “Target is [Telephony-number].”
7. Bracketing delimiter(s): “Target, [Telephony-number], Target.

Members were then asked to rank these seven recommendations from highest (1) to lowest (7). The results of that survey are shown in Table 2-9.

Table 2-9. Survey Results from Ranking the Seven Phase 1 TPCS Recommendations (from FAA, 2012c)

	State each individual letter and number digit	State the 3-Letter telephony call signs with reference material available to the flight crew	Inverting the registered telephony aircraft identification and the numberical digits	Inverting the phonetic alphabet characters and the number digits	Inserting the aircraft identification with a "Distinct" leading delimiter	State each letter and digit using the ICAO phonetic alphabet characters	Bracketing the aircraft identification with a "Distinct" delimiter
Scorer 1	7	2	4	5	3	6	1
Scorer 2	4	1	7	6	2	3	4
Scorer 3	2	7	2	4	7	1	7
Scorer 4	2	4	5	6	1	3	7
Scorer 5	2	1	6	7	3	4	5
Scorer 6	5	2	6	7	1	4	3
Scorer 7	1	5	4	2	7	3	6
Scorer 8	4	2	1	3	4	7	7
Scorer 9	4	2	7	7	2	7	3
Scorer 10	5	2	1	4	6	3	7
Scorer 11	3	1	7	6	4	5	4
Scorer 12	2	1	5	7	3	6	4
Scorer 13	2	4	3	5	6	1	7
Scorer 14	1	6	5	7	5	2	4
Totals	**44**	**40**	**63**	**76**	**54**	**55**	**69**

After the ranking process, the team met to reach consensus on the top recommendations to be tested in Phase 2. A survey conducted by NASA was also considered at that time. Three options got the best rankings, but a fourth was only one point away from the third (even though members were discouraged from using that option when considering the potential solutions). It was determined by the group that the fourth option “was so closely aligned with [the third] that it could be eliminated as a candidate for the Phase 2 HITL” (FAA, 2012c, p. 14). Therefore, the Phase 1 report made the following recommendations for three candidate solutions:

- “State each individual letter and number digit.
    - o Using the existing ATC traffic phraseology as a baseline and then adding the identifier (as it appears on the ATC display and the CDTI) of the traffic being talked “about”. This relieves ambiguity between the controller and the pilot who must discern or correlate the three-letter identifier (AAL) with the appropriate call sign (American).
- State the 3-Letter telephony call signs with reference material available to the pilot.
    - o Using the existing ATC traffic phraseology and then adding the call sign of the traffic being referred to or talked “about”. The pilot will have access to 3-letter telephony call signs via electronic means or written reference.
- Inserting the aircraft identification with a “Distinct” leading delimiter.
    - o Using the existing ATC traffic phraseology and then adding the call sign of the traffic being referred to or talked “about” is inserted with ‘Target is [TFID identifier]’, ‘Flight [TFID identifier],’ ‘CDTI Traffic is [TFID Identifier].’” (FAA, 2012c, p. 5)

Table 2-10 shows these three options with names and examples.

Table 2-10. Phase 1 Proposed TPCS Candidates Defined

Name	Telephonic / Conventional	Telephonic with Delimiter	Letters
TPCS Example	“United 123”	“Flight United 123”	“U A L 123”

The three candidate solutions were used for the start of the definition of the Phase 2 simulation. During the initial simulation development, it was determined that additional decisions were necessary prior to defining the communications with the recommended candidates. The following topics needed resolution prior to finalizing the simulation plan.

- The location of TPCS, relative to surrounding phraseology, needed to be defined. As noted earlier, it could potentially be earlier or later in the message.
- The TPCS delimiter term had to be decided. Several possibilities existed and there did not appear to be a single choice was most optimal.
- The TPCS delimiter location needed to be decided. As noted earlier, the delimiter could be placed externally or internally relative to the airline designator and numeric flight identification.

With regard to the location of the TPCS, there may be a logical location for the TPCS within the context of an individual communication necessary for an operation. However, the location can have an impact on the acceptability and the error rate of that TPCS based on a particular location. It was noted previously that the TPCS cannot be the first element in the ATC transmission since that slot is reserved for FPCS. However, the TPCS could be after the FPCS and still be earlier in the communication. Additionally, the TPCS can be later in the ATC transmission or be the final element in some communications. Discussions were had on the location of the

TPCS and were based on the expected operations to be examined: TAs and IM (the IM implementation and communications are discussed in Section 2.6.2.3). The location for the TPCS in the IM communication was based on messages defined for CPDLC that are also expected to be applicable to voice communications (RTCA and European Organisation for Civil Aviation Equipment (EUROCAE), 2013). The TPCS needed to be placed within the context of those messages. TPCS was able to be placed both earlier and later, including at the very end, in the IM clearance. TPCS could also be placed both earlier and later in the standard TA. Earlier and later positions were chosen to be examined for both operations so that the impact of the position of the TPCS could be evaluated.

For the delimiter, terms such as “flight” and “target” had been proposed in past activities. In discussions during the Phase 2 simulation development, concerns were raised that the term “target” implied a threatening situation, as noted in FAA (2012c). So that option was ultimately discarded. In author (Bone and Penhallegon) telephone discussions with Kim Cardosi and Tracy Lennertz of the Department of Transportation (DOT) Volpe Center, it was determined that the term “flight” may be too close to terms used currently and may not include enough syllables to be noticed by a TPA as a differentiator. Therefore, “flight” was also discarded. The term “reference” was also debated. It was determined that “reference” was different enough from currently used phraseology and had enough syllables to act as an effective delimiter. The term was then proposed to the TFID OFG, who accepted it as the delimiter to use for the Phase 2 simulation.

The delimiter location also needed to be decided. The location of the delimiter could be located inside (e.g., United **Reference** 123) or outside (e.g., **Reference** United 123) of the telephonic / conventional TPCS. The authors had discussions with the TFID OFG about these two options. Use of the delimiter outside the call sign caused the authors concern about whether it would be heard by the TPA and whether it would be effective as a differentiator between FPCSs and TPCSs. However, insertion of a delimiter inside the call sign could be more difficult to say for both the controller and pilot. Ultimately, it was decided that the best method to test was the internal delimiter as it best served the intended purpose.

Four communication alternatives were ultimately chosen based on the proposed TPCS format options and locations, as well as the delimiter term and location options. (For the rest of this report, the term alternative refers to a TPCS format in a specific location, relative to its surrounding phraseology.) These four alternatives allowed for the examination of the different formats (telephonic / conventional, telephonic with delimiter, and letter) and the positions (earlier and later) for TPCS. This document defines the combination of the TPCS format and TPCS position as the TPSC alternative. Samples of each of those communications ultimately chosen are shown in Table 2-11. Note that the pilot readback phraseology was the same for both the Telephonic Earlier and Later TA alternatives.

Table 2-11. Four Alternatives Chosen for Phase 2 Simulation

Name	Telephonic / Conventional - Earlier	Telephonic / Conventional - Later	Telephonic with Delimiter - Earlier	Letters - Earlier
Sample ATC IM Clearance	**“**United 123, for interval spacing, traffic is **American 456**. Cross PECHY 120 seconds behind that traffic”	“United 123, for interval spacing, cross PECHY 120 seconds behind **American 456**”	“United 123, for interval spacing, traffic is **American Reference 456**. Cross PECHY 120 seconds behind that traffic”	“United 123, for interval spacing, traffic is **A-A-L 456**. Cross PECHY 120 seconds behind that traffic”
Sample Pilot IM Clearance Readback	“Traffic is **American 456**. Cross PECHY 120 seconds behind that traffic. United 123”	“Cross PECHY 120 seconds behind **American 456**. United 123”	“Traffic is **American Reference 456**. Cross PECHY 120 seconds behind that traffic. United 123”	“Traffic is **A-A-L 456**. Cross PECHY 120 seconds behind that traffic. United 123.”
Sample ATC Traffic Advisory	**“**United 123, traffic is **American 456**, one o’clock, four miles, eastbound, MD80, flight level 210. Report identified”	“United 123, traffic is one o’clock, four miles, eastbound, MD80, flight level 210, **American 456**. Report identified”	“United 123, traffic is **American Reference 456**, one o’clock, four miles, eastbound, MD80, flight level 210. Report identified”	“United 123, traffic is **A-A-L 456**, one o’clock, four miles, eastbound, MD80, flight level 210. Report identified”
Sample Pilot Traffic Advisory Readback	**“American 456** identified. United 123”	“**American 456** identified. United 123”	“**American Reference 456** identified. United 123”	“**A-A-L 456** identified. United 123”

The following section reviews the research questions and hypotheses with regard to these four alternatives.

3 Research Questions and Hypotheses

In order to provide research results that establish a basis for down-selecting a final TPCS alternative, a HITL simulation was developed to evaluate the selected alternatives in an operational context in higher-fidelity communications environment. The simulation was designed to evaluate TPCS alternative candidates proposed by the OFG during an arrival and approach operation in order to determine the acceptability of each alternative to both flight crews and controllers and evaluate any potential performance tradeoffs among the candidate alternatives.

As discussed in previous sections, using a method other than current day phraseology to refer to a TPA on the voice frequency may reduce the potential for confusion. The solution should minimize the potential for TPPs on a common frequency to become confused about transmissions referring to them, as well as allow pilots and controllers to establish a clear awareness of the aircraft they are referencing. The three formats and two position options were developed into four options to examine:

1. Telephonic – Earlier (T-E).
2. Telephonic – Later (T-L).
3. Telephonic with Delimiter – Earlier (TD-E).
4. Letters – Earlier (L-E).

As a result, the TPCS alternatives were evaluated with regard to two conditions:

1. Performance in conveying TPCS information between controllers and FPPs (First Party Loop).
2. How alternatives vary with respect to TPP confusion in mistakenly believing messages are for them (Third Party Loop).

Based on these conditions, the set of selected alternatives, and the desired operations from which to examine the alternative described in Section 2, a series of research questions were developed to help make these determinations. First, three overall research questions were identified to provide an overall framework for the study:

1. Is deviating from the use of the Telephonic format necessary to reference a TPA?
2. If so, are there user acceptability and performance trade-offs between the chosen TPCS alternatives (i.e., Letters and Telephonic Delimiter)?
3. Are there user acceptability and performance trade-offs between placing the TPCS Earlier versus Later in a message?

Using these general research questions as the overall study framework, seven specific research questions and associated hypotheses were developed for the study. These specific research questions were generally organized by communication party loop and are described in the following sections.

3.1 First Party Loop Research Questions and Hypotheses

RQ1: Will deviations from Telephonic (Earlier or Later) affect acceptability and performance of TPCS conveyance between controllers and FPPs?

Wickens et al. (2004) describe how expectations based on past experiences help pilots and controllers process information more quickly and more accurately. In addition, Hassa et al. (2005) noted that controllers in their IM study recommended the use of a telephonic / conventional format for TPCS in future studies. As such, it is likely that current call sign phraseology (Telephonic) will demonstrate the lowest workload and most favorable subjective ratings from controllers as compared to Letters and Telephonic Delimiter. Since the Telephonic format requires no extra work on the controller's part to say FPCSs and TPCSs differently, and also probably requires the fewest overall syllables in the message as compared to Letters and Telephonic Delimiter, it will likely result in the lowest workload, fewest errors, and thus be most favorably rated by controllers. As such, the first hypothesis is:

- <u>Hypothesis #1A</u>: Controllers will subjectively prefer current call sign phraseology to convey TPCS and will make fewer clearance phraseology errors.

Controllers may get confused if they receive a message with two call signs said the same way. For example, Cardosi (1994) and Cardosi et al. (1996) reported that similar call signs were the most common coincident factor in miscommunications in the local / tower and TRACON environments. Since the Telephonic format makes no additional differentiation, outside of position in the readback communication structure between FPCS and TPCS conveyance, more occurrences of controller confusion (FPA versus TPA identification errors) during pilot readbacks are likely to be observed as there is no additional call sign coding to suggest whether it is the FPP or a TPP reading back the clearance. As such, Telephonic will demonstrate more occurrences of controller confusion with regard to TPPs as compared to Letters and Telephonic Delimiter - Earlier.

- <u>Hypothesis #1B</u>: Readbacks with two call signs in the same format are more likely to be confusing to controllers than readbacks that use a different format for FPCS versus TPCS.

Pianetti et al. (2007) noted that pilots did report some difficulties correlating the airline telephony designator used by ATC and the airline three letter designator shown on the CDTI traffic display. As such, the Letters format should show better FPP performance as compared to Telephonic. Since no translation between the airline letter designator and airline telephony designator is required with Letters, less workload should be required from the pilot to acquire the target on the CDTI traffic display. This should reduce FPP workload and reply lag times and facilitate more accurate target identification by the FPP. This reduced workload should also result in fewer FPP readback errors.

- <u>Hypothesis #1C</u>: FPPs will report lower workload and make fewer identification errors with the Letters format than with the Telephonic format.
- <u>Hypothesis #1D</u>: FPPs will make fewer readback errors with the Letters format than with the Telephonic format.

The purpose of adding a delimiter is to differentiate a TPA from the FPA in a message. Adding a delimiter will also require the FPP to filter it out prior to correlation with the CDTI traffic display. However, if the position and conveyance method of call sign is kept the same (i.e., Telephonic), it is not anticipated that filtering out the delimiter word alone will have a measurable impact on the FPPs ability to identify the reference aircraft. As such, no FPP performance differences in the conveyance of TPCS are expected to be observed between the Delimiter and Telephonic formats.

- Hypothesis #1E: Adding a delimiter to current call sign phraseology will not affect the FPP reference aircraft identification error rate.

RQ2: Will acceptability and performance differences between the Letters and Telephonic Delimiter formats be observed between controllers and FPPs?

Hassa et al. (2005) noted that controllers in their IM study recommended the use of a telephonic / conventional format for TPCS in future studies. The Telephonic format maintains consistency between FPCS and TPCS conveyance and with how controllers currently convey call sign. This means that controllers will only have to remember to add a single term (the delimiter) to differentiate the TPCS. However, the Letters format is a completely new way of conveying call sign. Although it is possible that reading the letters off a display may be easier than having to remember to insert a new term into current phraseology, it may be less than that required to remember to say the airline three letter designator differently between FPCSs and TPCSs. As such, it is postulated that Letters will require additional workload to use as compared to Telephonic Delimiter, and thus be less favorably rated by controllers.

- Hypothesis #2A: Controllers will report less workload and prefer the Telephonic Delimiter format than Letters.

The Letters and Telephonic Delimiter formats will demonstrate similar levels of effectiveness with regard to controller confusion with TPA identification. Both alternatives use methods to differentiate FPCSs and TPCSs. Since controllers are likely to listen to the entire readback messages, as opposed to keying in only when the airline three letter designator is noted, both methods are expected to be effective in reducing controller confusion with regard to TPA. No background research has yet been identified that suggests one method may be more effective than the other in reducing controller confusion with TPA.

- Hypothesis #2B: During FPP readback, no difference in controller confusion will be observed between the Letters or Telephonic Delimiter formats.

Pianetti et al. (2007) noted that pilots did report some difficulties correlating the airline telephony designator used by ATC and the airline three letter designator shown on the CDTI traffic display. As such, the Letters format should show better FPP performance as compared to Telephonic Delimiter. Since no translation between the airline three letter designator and airline telephony designator is required with Letters, less workload should be required from the pilot to acquire the target on the CDTI traffic display. This should reduce FPP workload and reply lag times and facilitate more accurate reference aircraft identification by the pilot.

- Hypothesis #2C: FPPs will show reduced workload and make fewer identification errors with the Letters format than the Telephonic Delimiter format.

RQ3: Will Earlier versus Later position affect the acceptability and performance of TPCS conveyance between controllers and FPPs?

Elements included in TA communications are standard and are conveyed in a standard format. Adding TPCS to the end of a message may allow controllers to maintain their natural rhythm in providing advisories, as nothing changes until the last element. This seems to be supported by controllers in Op Eval 3, who reported a preference for adding TPCS onto the end of their normal TA, rather than embed the TPCS within the advisory (Bone et al., 2003). As such, controllers are expected to prefer and show fewer errors and less workload with TPCS in the Later position.

- Hypothesis #3A: The Later position of TPCS in the TA messages will show reduced controller workload, phraseology errors, and increased acceptability.

For the IM clearance, controllers may exhibit a subjective preference and report lower workload for having TPCS later in the overall message as placing TPCS later in the IM clearances can result in a slightly more natural sounding message and fewer overall words. Controllers are likely to notice and prefer this. Controllers are also likely to report that having a shorter message results in less workload and fewer clearance phraseology errors are thus also expected.

- Hypothesis #3B: The Later position of TPCS in the IM clearance will show reduced controller workload, phraseology errors, and increased acceptability.

Though Bone et al. (2003) report that Op Eval 3 pilots expressed some concern over including the TPCS at the end of a TA, pilots in CAVS simulations reported that appending TPCS to the end of a standard TA aided in the positive identification of the reference aircraft and that it was beneficial (Bone, Domino, Helleberg, and Oswald, 2003; Bone et al., 2003a). Olmos et al. (2001) report that most Op Eval 2 pilots agreed that the use of TPCS made it easier to correlate called traffic with a visual target. Extending this, it is possible that providing clock position and distance first will help the pilot determine where to locate a reference aircraft on the CDTI traffic display. Though the benefit is less likely to be observed when the reference aircraft is expected to be in a consistent, known position a high percentage of the time, it is still possible that for TA communications, the Later position will likely be more effective in conveying TPCS to FPPs as compared to the Earlier position.

- Hypothesis #3C: With current day formats, placing TPCS in the Later position in a TA will help the FPP find the reference aircraft more quickly and will result in fewer identification errors.

In a recent pilot / controller workshop examining IM clearance complexity, flight crews reported difficulties trying to decode the Telephonic TPA call sign and still pay attention / write down the remainder of the clearance (Bone et al., 2013). As such, it is expected that, the Later position will be slightly more effective in conveying the overall message to FPPs as compared to the Earlier position for IM clearances. The TPCS element may assume an airline three letter designator that is not immediately intuitive to FPPs. They may have trouble interpreting the TPCS information and if presented Earlier, they may miss some of the clearance information that follows. Putting TPCS in the Later position in the message should make it easier for them to grasp the other elements and avoid getting caught up in TPCS decoding to the neglect of the other clearance elements.

- Hypothesis #3D: With current day formats, placing TPCS in the Later position in an IM clearance will make it easier for the FPP to grasp the entire initiation message.

RQ4: Is the performance of some alternatives diminished by the increased presence of non-intuitive call signs?

It is likely that some call signs (e.g., "Citrus" for TRS) will not be intuitively recognizable to pilots. When the Telephonic format is in use, pilots in these cases may require a tool in the cockpit to help them identify the airline three letter designator such that they can select the appropriate reference aircraft on their CDTI traffic display. Without such a tool, or if they elect not to use it, pilots may require additional transmissions to verify the intended traffic or they may also attempt to determine the airline three letter designator based on the numeric flight identification or the airline designator. This is likely to lead to time delays and errors. Since the Letters format establishes the airline three letter designator without requiring translation, it is likely that it will demonstrate higher FPP performance in cases of non-intuitive call signs.

- Hypothesis #4: The Letters format will result in fewer FPP identification errors than the Telephonic format in situations with non-intuitive call signs.

3.2 Third Party Loop Research Questions and Hypotheses

RQ5: Will deviations from the Telephonic format affect the level of TPP confusion?

Past studies have noted that similar call signs are a common contributing factor in wrong aircraft accepting clearances intended for other aircraft (e.g., Cardosi et al., 1999; Van Es, 2004). The Telephonic format results in the most similarity between how a TPP would expect their call sign to be spoken versus how it is actually spoken on the frequency. As such, the Telephonic format is expected to demonstrate more occurrences of TPP confusion as compared to the Letters and Telephonic Delimiter formats. Since the Telephonic format makes no differentiation between FPCS and TPCS conveyance, unlike Letters and Telephonic Delimiter, more occurrences of TPP confusion (identification errors) are likely to be observed.

- Hypothesis #5: Instances of TPP confusion will be higher with the Telephonic format as compared to the Letters and Telephonic Delimiter formats.

RQ6: Will differences in the level of TPP confusion be observed between the Letters and Telephonic Delimiter formats?

It is likely that TPPs will begin specifically listening to the transmission when they hear their airline telephony designator. However, TPPs may miss information placed between the airline designator and the numeric flight identification. Although this may be more likely for shorter delimiter word choices, longer delimiters may still have questionable effectiveness in reducing TPP confusion. Since the Letters format uses a completely different method to convey call sign than what is used for a FPA, it is more likely to be effective in differentiating a TPA on the frequency. As such, instances of TPP confusion are expected to be less with the Letters format than with the Telephonic Delimiter format.

- Hypothesis #6: The Letters format will be more effective in reducing TPP confusion than the Telephonic Delimiter format.

RQ7: Will Earlier versus Later position affect occurrences of TPP confusion?

TPP confusion may be affected by how TPCS is used in an overall communication. If the Telephonic format is the final element in the communication, it may be confusing as the TPCS is in the same format as FPCS and is left “dangling.” If the TPCS is anywhere else earlier or later, there is the potential to “steal” an instruction or clearance if that information follows the TPCS. It is unclear which of these effects may be stronger and so no difference with regard to TPP confusion is expected to be observed between the two positions for both IM and TA messages.

- Hypothesis #7: TPP confusion will be the same regardless of whether the Telephonic format is in the Earlier or Later position.

4 Methods

4.1 Simulation Environment

The study was conducted in the MITRE Aviation Integration Demonstration and Experimentation for Aeronautics (IDEA) Laboratory, using its flight deck, pseudopilot, en route ATC, and terminal ATC simulation capabilities.

To address the TPCS research questions, it was necessary to create a rich, high-fidelity voice communications environment. To create such an environment, it was necessary to include as many possible different voices on the communication frequency (as would be experienced in field operations). This environment was created through the use of the participant controllers, several participant pilots and pseudopilots, and recorded voice tracks for other aircraft. The following sections provide an overview of the capabilities and associated workstations used in the simulation.

4.1.1 Air Traffic Controller Workstations

The medium-fidelity controller workstations consisted of a Display System Integration (DSI) workstation for the en route controller and a Standard Terminal Automation Replacement System (STARS) workstation for the terminal controller.

4.1.1.1 En route

The en route workstation had a representative 2K display with a DSI interface. The workstation had a Cortron Display System Replacement (DSR) keyboard, trackball, and standard Display Interface Keypad (DIK) (Figure 4-1). The DSI was an upgrade from the current DSR and consisted of an en route NextGen mid-term display containing ERAM-like functionality and capabilities. These included problem notification, customizable toolbars, tear-off functionality for buttons and sub-lists, and improved data interaction areas. The DSI interface is shown in Figure 4-2.

MITRE

Figure 4-1. DSI Workstation for En Route Controller

Figure 4-2. DSI Interface

MITRE

Additional automation capabilities were not added to support the IM operations as they were not believed to be necessary for the TPCS simulation.

4.1.1.2 Terminal

The terminal workstation had a representative 2K display that displayed the STARS interface. The STARS workstation was very similar to the currently fielded STARS system. The workstation had a (non-STARS) QWERTY keyboard and mouse (Figure 4-3). Some keys were programmed to serve as special function keys for use in terminal operations. The STARS workstation software consisted of a Terminal Controller Workstation display (Figure 4-4), and contained the STARS functionality necessary for the simulation, including preview areas and a Display Control Bar (DCB). The necessary functionality was defined and validated as sufficient by a controller supporting the simulation.

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Figure 4-3. STARS Workstation for Terminal Controller

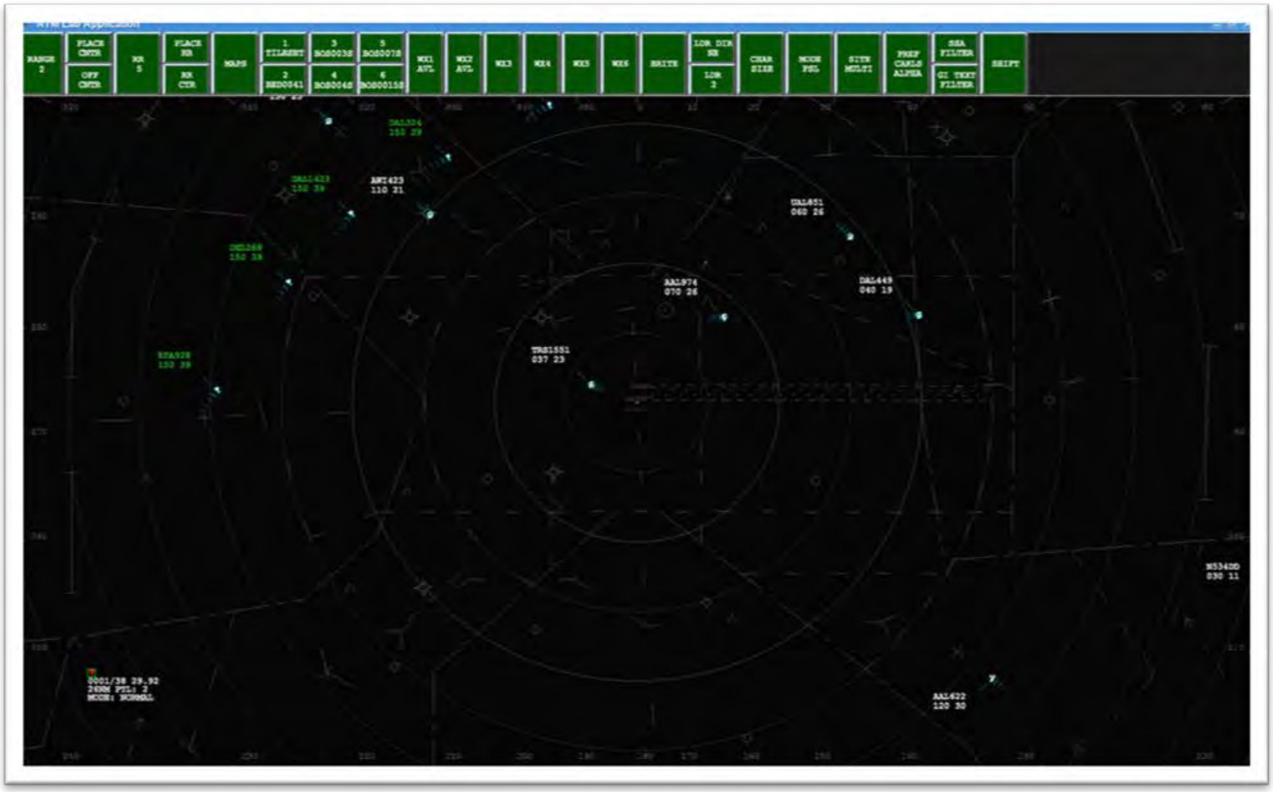

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Figure 4-4. STARS Interface

4.1.2 Flight Crew Workstations

The flight crew workstations used for this study consisted of four lower fidelity cockpit workstation sand one medium-fidelity Boeing (B)777-like cockpit simulator workstation. The panel and display configurations of the cockpit workstations were very similar. However, the medium-fidelity cockpit was enclosed in a shell and had other hardware control capabilities such as yokes, an overhead panel, and a throttle quadrant.

4.1.2.1 Lower Fidelity Cockpit Workstations

Each lower fidelity cockpit workstation (Figure 4-5) was designed for two-person crew usage and had three flat-panel PC displays that hosted the Navigation Displays (NDs) with the CDTI traffic display, an ADS-B Guidance Display (AGD), the Primary Flight Displays (PFDs), and the Engine-Indicating and Crew-Alerting System (EICAS) (Figure 4-6, Figure 4-7, Figure 4-8). The workstations were built with both hardware and software Mode Control Panels (MCPs) interfaces; however, issues with the MCP hardware panels resulted in the use of the software MCP for the majority of the simulation runs.

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Figure 4-5. Lower Fidelity Cockpit Workstation

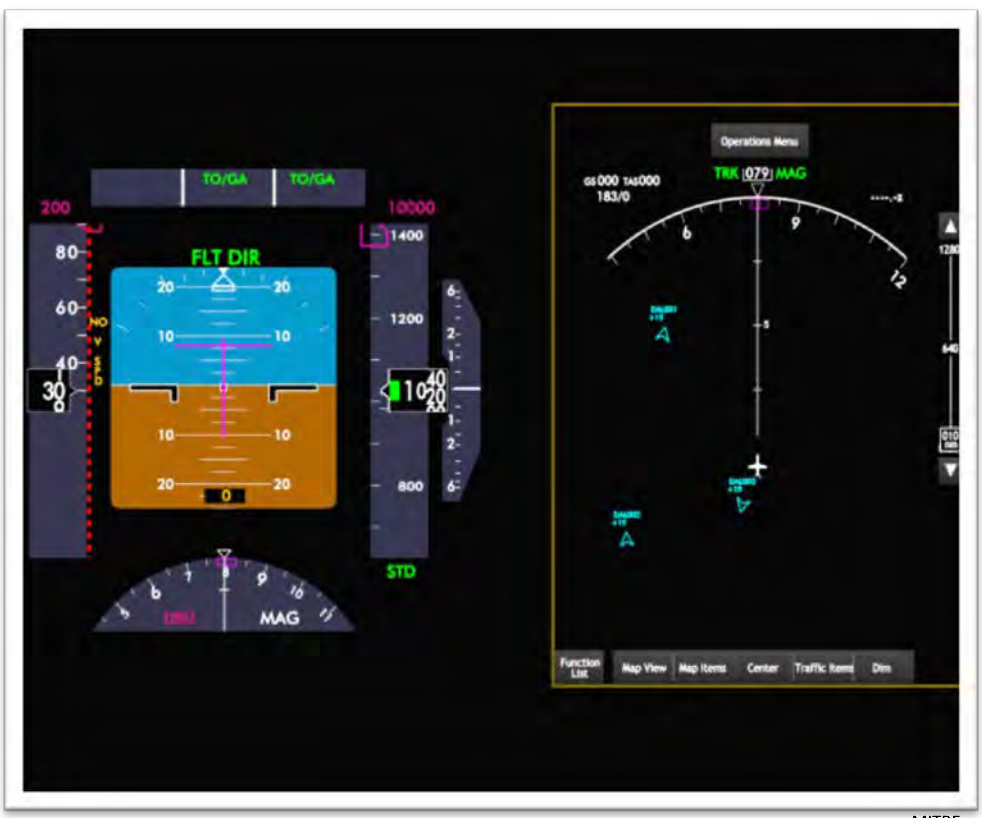

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Figure 4-6. Left Lower Fidelity Cockpit PFD/ND/CDTI Display

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Figure 4-7. Center Lower Fidelity Cockpit Display

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Figure 4-8. Right Lower Fidelity Cockpit PFD/ND/CDTI Display

The workstations also had physical hardware for two Radio Management Panels (RMPs), a Control and Display Unit (CDU), a mouse or touchpad controller, three toggle switches for gear, flaps, and speed brake control, as well as a new, simulation-only button (to push when ownship call sign was heard in a communication). There were no visual out-the-window displays provided, as the simulation scenarios took place in Instrument Meteorological Conditions (IMC).

4.1.2.2 B777-like Cockpit Simulator Workstation

This cockpit simulator consisted of a standard B777 cockpit layout (Figure 4-9). It included elements such as an MCP, two RMPs, dual CDUs, dual PFDs and NDs, EICAS, AGD, and dual touchscreen Electronic Flight Bags (EFBs) hosting the CDTI traffic displays. One EFB was located at the captain's eleven o'clock position and the other was located at the first officer's one o'clock position. The 180-degree out-the-window visual scene was set to IMC with a cloud floor of 600 feet Above Ground Level (AGL). As with the lower fidelity cockpits, a button was available to push when ownship call sign was heard in a communication.

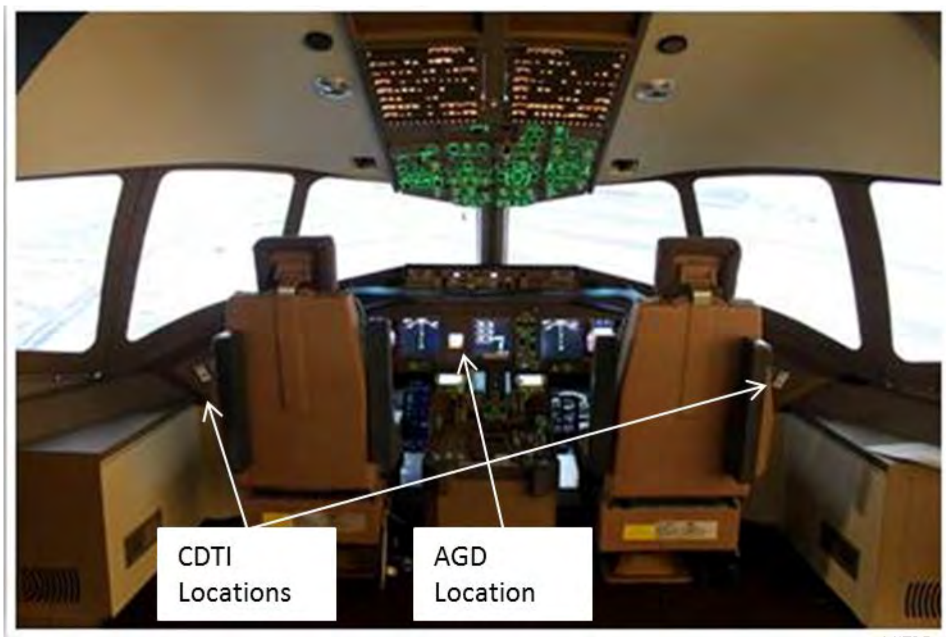

Figure 4-9. B777 Cockpit Simulator Workstation

4.1.2.3 CDTI

All cockpit simulators were equipped with the CDTI traffic display shown in Figure 4-10. The CDTI provides basic traffic information to the cockpit and is used to set up and monitor IM operations. The CDTI used in this simulation was designed to allow for the integration, control, and operation of multiple ASAs in a seamless manner. The overall CDTI design philosophy is described in Stassen, Penhallegon, & Weitz (2010) and Estes, Penhallegon, & Stassen (2010).

After the appropriate information had been entered into the FIM equipment and the initiation requirements were met, the FIM equipment provided an IM Speed for the flight crew to fly. The FIM equipment utilized an algorithm to provide the IM Speeds so the flight crew could achieve the assigned spacing goal at the Achieve-By Point. The algorithm was based on the EUROCONTROL CoSpace algorithm (Hoffman, Ivanescu, Shaw, and Zeghal, 2003).

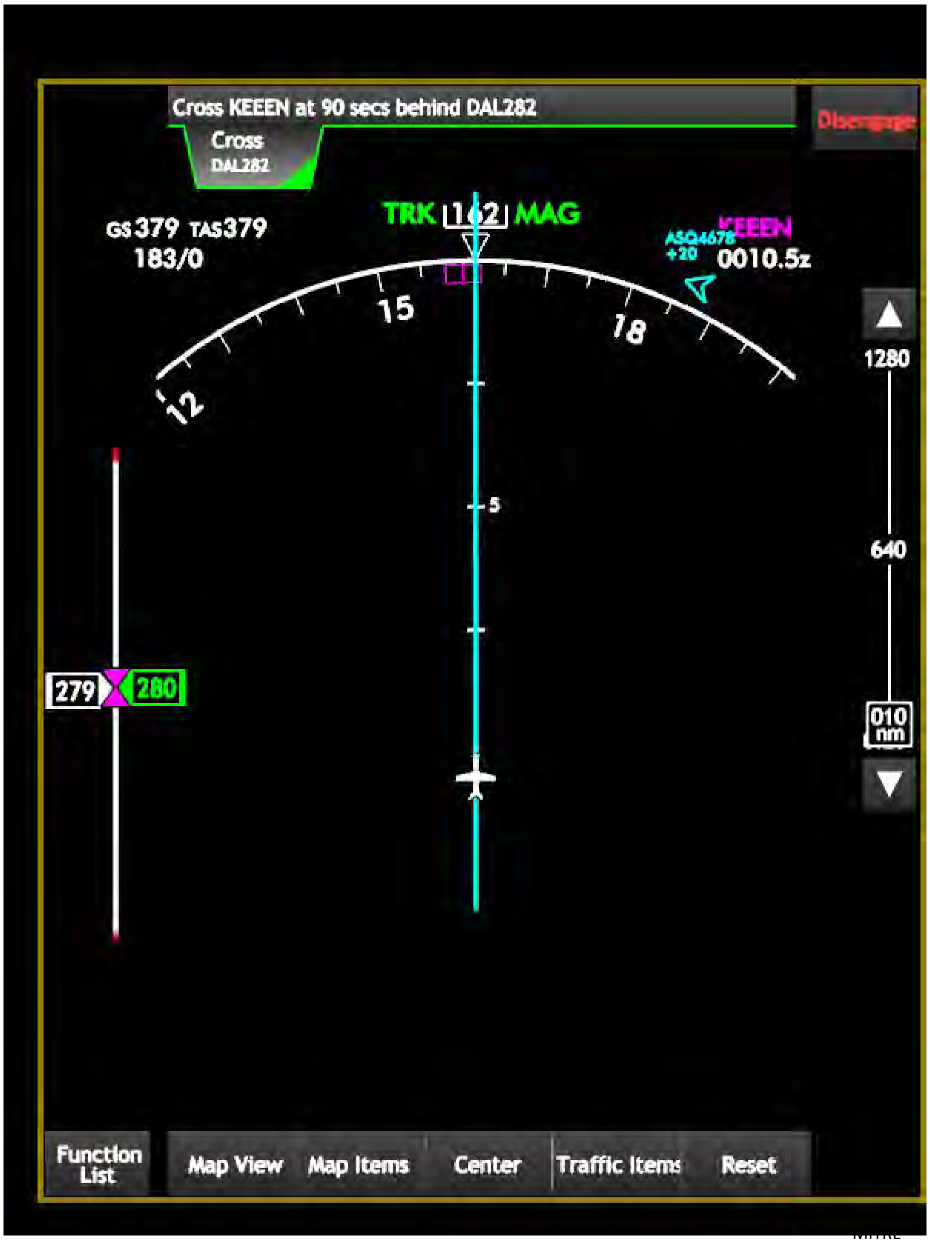

Figure 4-10. CDTI

4.1.2.4 AGD

The AGD provided a forward field of view display of key IM information. The AGD was located between the left ND and the EICAS display in the B777 cockpit. It was located on the center display in the lower fidelity cockpits. Four pieces of information were provided to the crew via the AGD: reference aircraft call sign, IM Speed, the current in-trail time, and the assigned spacing goal. The AGD and the associated information are shown in Figure 4-11.

Figure 4-11. AGD

4.1.3 Pseudopilot Workstations

The pseudopilot interface is termed Simpilot (Figure 4-12). It allowed pseudopilots to control multiple simulated aircraft in a designated sector of airspace. It provided information (i.e., call sign and type) about the aircraft under pseudopilot control and allowed the user to control the aircraft by adjusting heading, airspeed, altitude, and the navigation route. Those changes are reflected on controller displays and CDTI traffic displays. The radio frequency of the aircraft can also be changed. The system has a map display, Vertical Navigation (VNAV), Lateral Navigation (LNAV), and auto throttle controls, a command entry window, a command history window, a notes area, and programmable quick-keys. The programmable quick-keys were used to execute complex commands (such as the IM clearance and landing clearance) with only a single button press. The system also had an automated audio capability, which pseudopilots used to initiate pre-recorded voice messages for specific aircraft (Figure 4-13). This capability is discussed in Section 4.1.5.

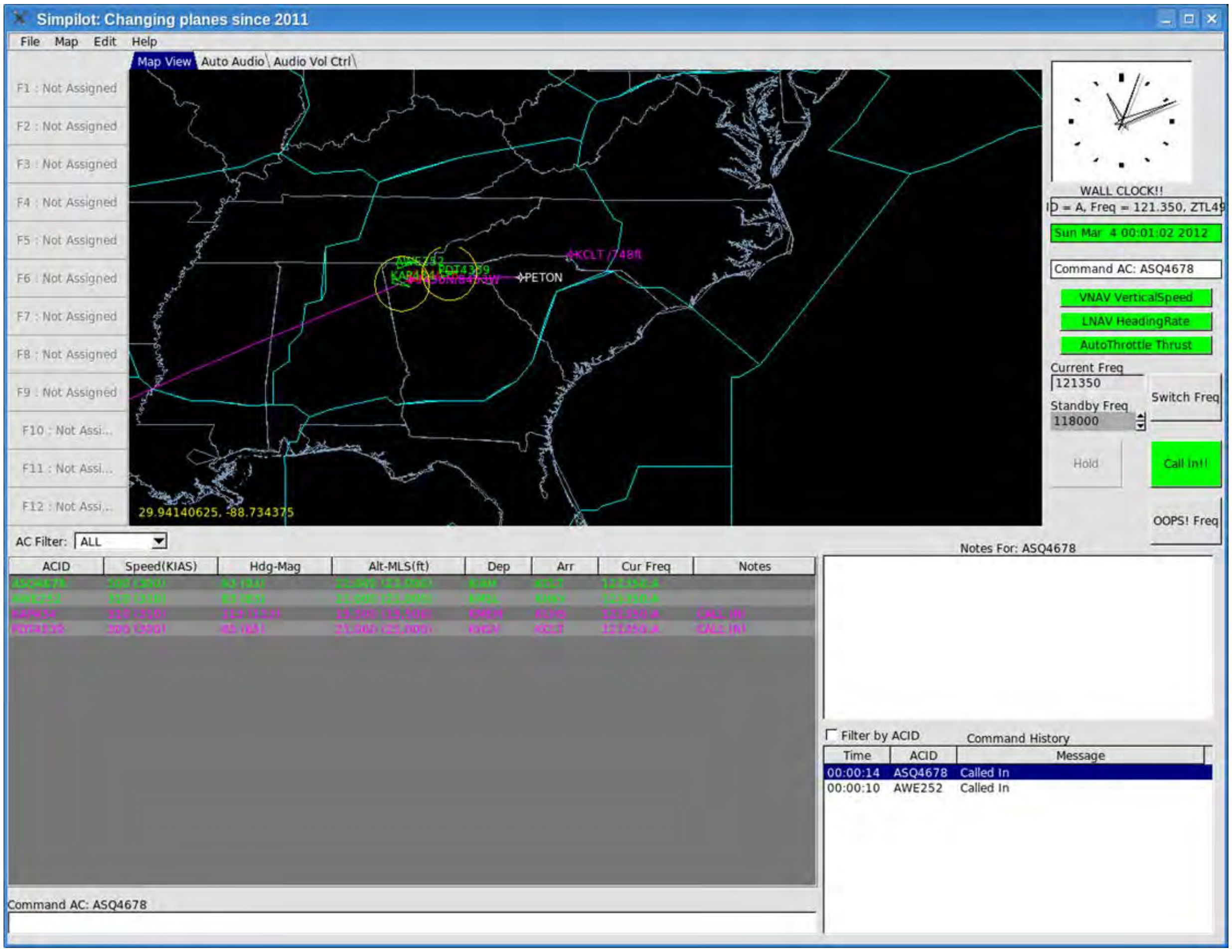

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Figure 4-12. Pseudopilot Interface (i.e., Simpilot)

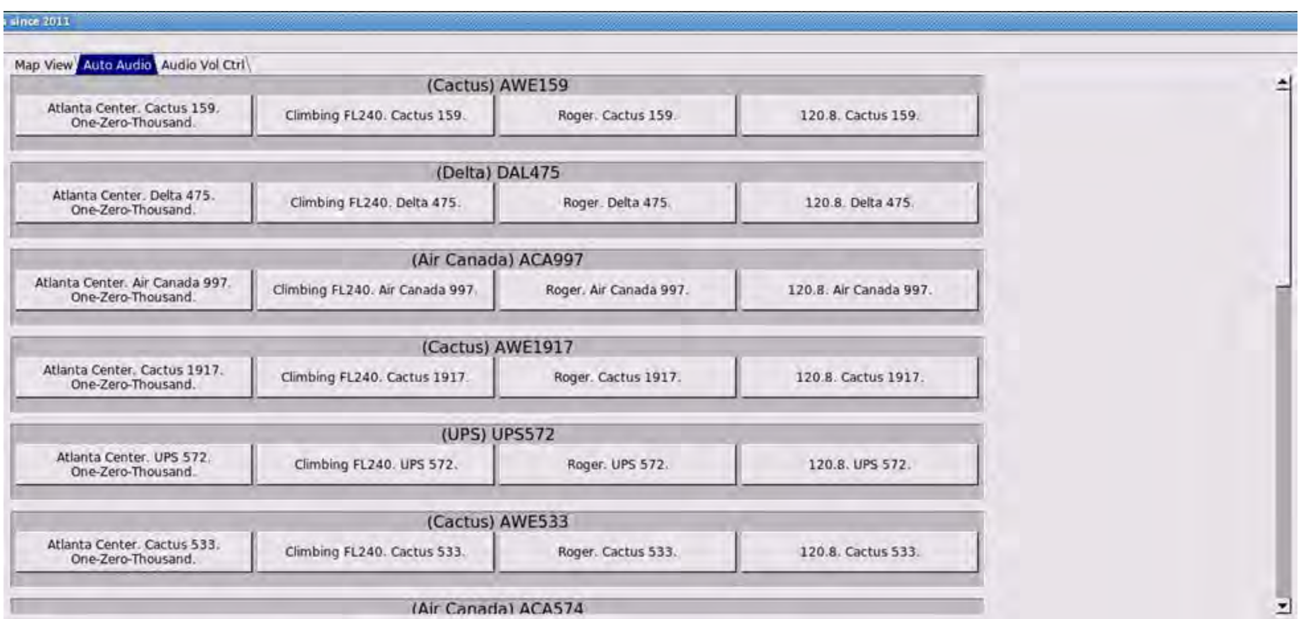

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Figure 4-13. Pseudopilot Voice Recording Interface

4.1.4 Workstation Physical Arrangement

The en route and terminal controller workstations were placed next to each other in order to facilitate any coordination that might be necessary. The controller workstations were remotely located relative to the cockpit simulators. The B777 cockpit simulator was enclosed by a curtain to prevent noise pollution and any distractions. The four lower fidelity simulators were placed next to each other, but dividers were placed between each workstation in order to prevent participants from viewing the other workstations and to block noise. White noise was also introduced in each workstation to simulate cockpit noise and to further block background noise (e.g., intra-cockpit communications from other workstations).

4.1.5 Voice Environment

A key element of the rich, high-fidelity voice communications environment was the inclusion of multiple voices for the flight crew of the aircraft in the simulation. While it would have been desirable to have a unique voice for each aircraft, the amount of participants required to achieve this would have been prohibitive. However, a rich voice communication environment was still achieved with numerous voices over two frequencies (one en route and one terminal).

Across the two frequencies were:

- Three two-person participant flight crews in the lower fidelity simulators.
- One two-person participant flight crew in the B777 simulator.
- One en route participant controller.
- One terminal participant controller.
- One single-aircraft pseudopilot.
- Two en route pseudopilots.
- Two terminal pseudopilots.
- Voice recordings engaged by the terminal pseudopilot stations for 10 aircraft.
- Voice recordings engaged by the en route pseudopilot stations for 16 aircraft.

The voice recordings were different voices for each aircraft. Several volunteers provided the voices for the recordings. The recordings were only done for routine communications that could be predicted, recorded a priori, and triggered without modification. If the pseudopilot did not have a recording available for those aircraft based on an unexpected communication, the pseudopilot could answer for that aircraft. While the voice changed for the aircraft, it was believed that it could be representative of a situation where the PF needed to handle a call when the PM was busy.

A third frequency was available that broadcast the ATIS. A schematic of the voice environment is provided in Figure 4-14.

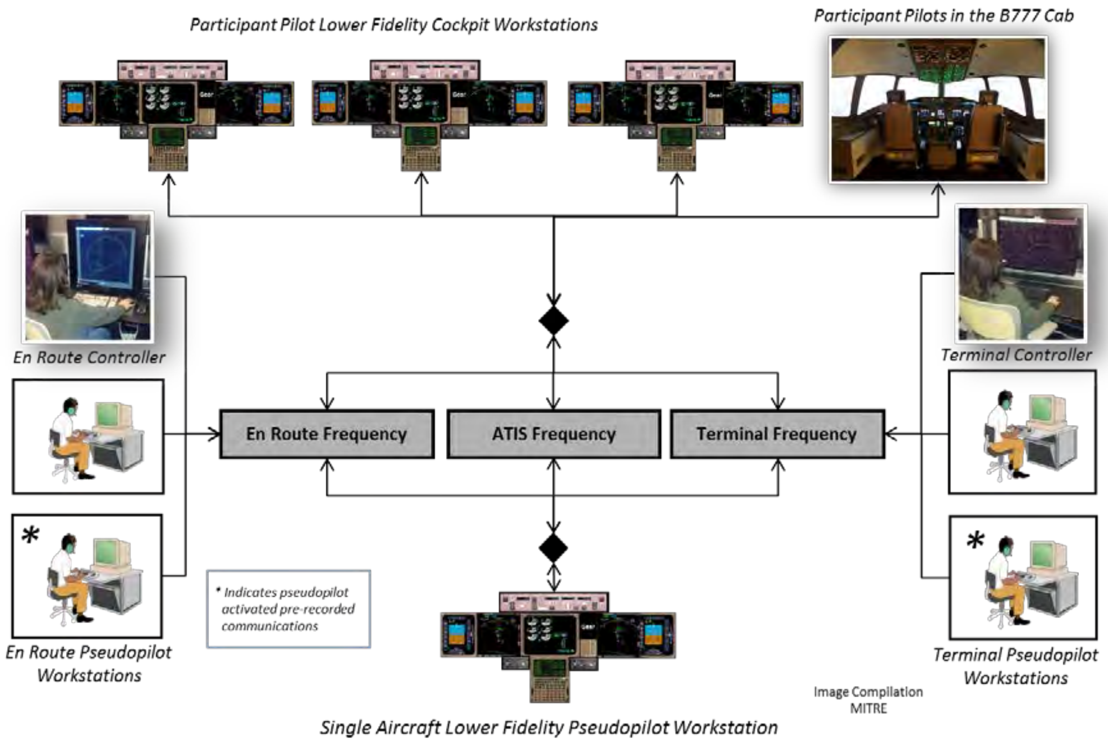

Figure 4-14. Communications Environment

4.2 Participants

Two controllers and eight pilots were scheduled for each single day session. Participants were compensated for their involvement. Five pseudopilots per day acted as pilots for all non-participant piloted aircraft.

4.2.1 Air Traffic Controllers

Controller participant recruiting was coordinated through the FAA SBS Program Office. For en route, controller participants were required to have Radar (R)-side experience and have actively controlled traffic, real or simulated, within the preceding five years. Experience in arrival sectors was preferred, but not required. For terminal, controller participants were required to have Common Automated Radar Terminal System (CARTS) or STARS experience and have actively controlled terminal traffic, either real or simulated, within the preceding five years.

On one occasion, an active en-route controller was not available from a facility. A retired controller supporting the SBS program office volunteered to fill in. This participant was not experienced working the simulation scenarios, so his performance and error data is included in the en route results pool. However, since he was familiar with the purpose of the study, his subjective data is not. In total, seven active en route controllers, one fill-in en route controller, and eight active terminal controllers participated in the study. This results in a total sample size of 15 controllers for the subjective data and 16 controllers for the objective data. Participants came from a variety of TRACONS and ARTCCs. En route controller experience ranged from 2 to 29 years with a mean of 15 years. Terminal controller experience ranged from 3 to 30 years with a mean of 18 years.

4.2.2 Pilots

The experimenters decided to implement two-person flight crews in order to make the pilot experience as realistic as practical. This would allow crews to distribute workload, coordinate on and confirm the ATC assigned reference aircraft on the CDTI traffic display, and provide additional stimulation such that they would not necessarily focus on listening to the frequency as they might as a single pilot.

When planning for the simulation, the researchers had discussions about what pilot participants were needed for the simulation. It was determined that since it was a simulation directly addressing call sign, it was necessary to have the pilot participants using the call sign of their current airline. If the pilots had to use a generic call sign, or that of another airline, they may have difficulties remembering the new call sign and may miss calls. Therefore, specific airlines were selected to be represented in the study and pilot crews would need to be from the same airline. After some discussion, Southwest, American, United, and US Airways were selected mainly on the probability of being able to supply enough participants for the study.

Once the airlines were determined, participants were recruited from the selected airlines. The pilots were required to have a current Airline Transport Pilot (ATP) certificate as well as at least 100 hours experience of Federal Aviation Regulation (FAR) 121 glass cockpit experience on any type aircraft. Recently furloughed or medically disqualified pilots who had flown within the previous twelve months were still eligible.

Ultimately, sixty-four pilots participated in the simulation. For each day, the pilots were assigned to act as either the Pilot Flying (PF) or Pilot Monitoring (PM), based on whether they were current Captains or First Officers. Captains were assigned to the PF position. First Officers were assigned to the PM role. If a crew consisted of two captains or two First Officers, the role assignment was random. Once assigned, they did not alternate roles. Experience ranged from 4,500 to 27,000 total flight hours with a mean of 14,127 hours. Three of the four selected airlines (American, United, and US Airways) provided 16 pilots each while Southwest Airlines was able to provide 13 pilots. Therefore, three pilots from other carriers (Cathay Pacific, World, and Mesa) who met the experience criteria had to be recruited to fill the openings with the individual Southwest pilots. While this was not ideal, it was necessary to maintain data and scenario continuity. The non-Southwest pilots were placed in the PF role so they would not be in the role normally intended to talk on the radio frequency. This was hoped to minimize the impact.

4.2.3 Pseudopilots

Five individuals served as pseudopilots to fly and communicate as the non-participant aircraft. Two pseudopilots were in the en route environment, and two other pseudopilots were in the terminal environment. A fifth pseudopilot operated one of the lower fidelity cockpits. Most pseudopilots participated across multiple days.

4.3 Scenario Design

Five traffic files with unique call signs were developed: one for the training scenarios and four for the data collection scenarios. The training scenario was used prior to each data collection scenario so the participants could become familiar with the use of the specific TPCS format for that data collection scenario. Each of the four data collection scenarios examined a different TPCS alternative. The airspace and communication protocols remained the same across the scenarios. However, the scenarios were varied through changes in call signs of aircraft and participant aircraft starting and sequence position within the scenario. The following sections will review the design of the scenarios.

4.3.1 Airspace

The airspace modeled for this simulation included two sectors, one en route and one terminal. The en route sector comprised an area approximately 100 miles by 100 miles, spanning altitudes of 10,001 feet to 23,999 feet. It was modeled after an Atlanta Center sector. Arriving aircraft entered the sector flying the PECHY7 Standard Terminal Arrival Route (STAR) on the north side at either FL220 or FL230 and transitioned through the sector to PECHY and then to KEEEN waypoints, where they were handed off to the terminal sector. The handoffs occurred at around 10,000 Mean Sea Level (MSL) and 250 knots. The simulated en route sector along with major traffic flows is shown in Figure 4-15.

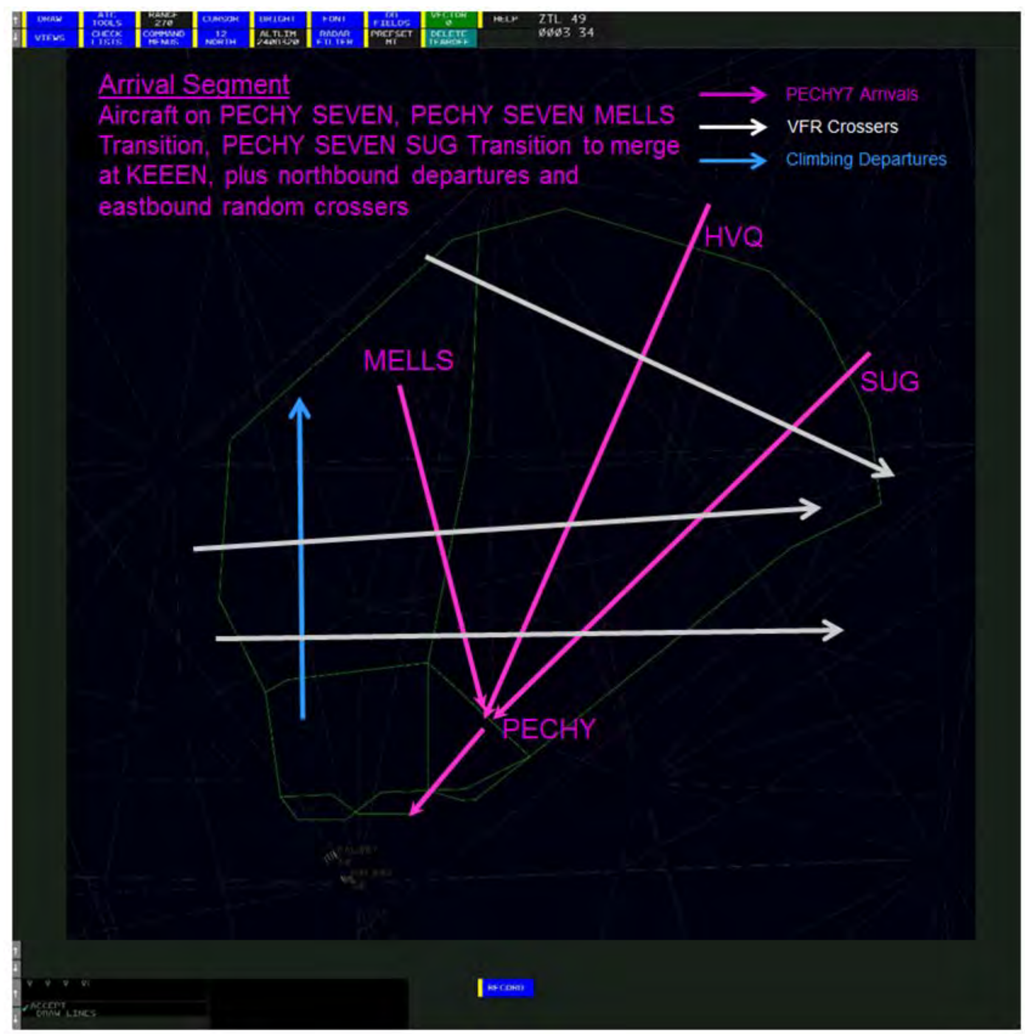

Figure 4-15. Simulated En Route/Arrival Sector

The terminal sector comprised an area approximately 40 miles by 45 miles, from the surface to 10,000 feet. Arriving aircraft entered the sector on the north side near the KEEEN fix on the PECHY7 STAR at approximately 10,000 feet and were vectored to downwind, base, and final for runway 26R on the north complex of Atlanta-Hartsfield International Airport (KATL). This flow was merged with traffic flying the ERLIN arrival on downwind in the traffic pattern. Additional parallel traffic entered the sector from the east side at 7,000 feet and transitioned directly onto final for runway 27L. The simulated terminal sector along with major traffic flows is shown in Figure 4-16.

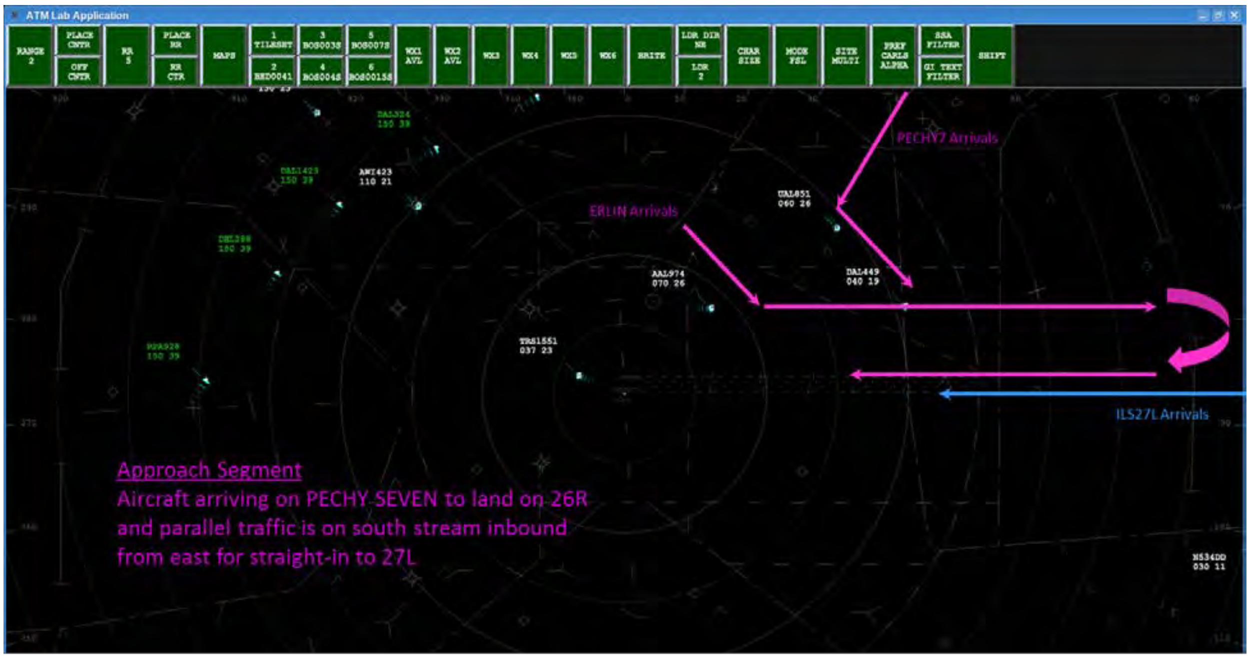

Figure 4-16. Simulated Terminal/Approach Sector

4.3.2 Traffic

Traffic was generated using actual traffic data for KATL from March 2012. The traffic data included departing (en route only) and arriving traffic. It also included a mix of aircraft performance capabilities. The data was manipulated to meet simulation requirements, including:

- Increasing traffic levels to represent desired density.
- Adding additional arrival streams onto the PECHY 7 STAR to keep the data collection scenarios below 30 minutes and to allow for the participant pilots to start the scenarios from several different initial positions.
- Increasing or decreasing the altitude of aircraft arriving at KATL using the PECHY 7 STAR to avoid traffic conflicts with the new arrival streams.
- Increasing or decreasing the altitude of crossing traffic in order to deconflict the arrival stream with any crossing aircraft.
- Modifying aircraft call signs (see the following section).

Participant pilots acted as one of the aircraft per scenario in the traffic set. There were four positions that the participant pilots could occupy. Each position was experienced once for the practice and data collection scenarios. Participant pilots never conducted IM off of the same reference aircraft when flying the different scenarios.

En route controller participants were told that aircraft on the PECHY 7 STAR could conduct IM and that crossing traffic could not. Each aircraft that flew the arrival flew an optimized profile descent with variable top-of-descent points.

En route controller participants were instructed to hand-off traffic to adjacent sectors as per normal operations. They were given a generic sector code for all handoffs not going to the terminal controller participant in order to reduce workload associated with remembering adjacent sectors. The en route controllers were also asked to issue a crossing restriction of 10,000 feet and 250 knots at KEEEN.

4.3.3 Call Sign Selection

For the participant pilot aircraft, the call signs remained the same throughout the simulation: Southwest 521 (SWA 521), United 428 (UAL 428), American 883 (AAL 883), and Cactus 934 (AWE 934) (for US Airways). Unique sets of call signs were designated for each of the four data collection scenarios (and the practice scenario). These call signs were varied to make the scenarios different enough from each other so that participants did not become too familiar with the scenarios.

Non-intuitive call signs were also implemented in the simulation for the purpose of examining impacts of the TPCS formats on communications that involve call signs that are not intuitively matched between the airline telephony designator and airline three letter designator. The simulation non-intuitive call signs were created, as opposed to using existing non-intuitive call signs, in order to eliminate any potential for participant's familiarity. These non-intuitive call signs were only used in the en route TAs and are shown in Table 4-1.

Table 4-1. Fictitious, Non-intuitive Call Signs used in Data Collection Scenarios

Data Collection Scenario	Airline Telephony Designator	Airline Three Letter Designator
1	Rugby	SLY
	Birddog	JKW
	Calypso	XRS
	Redhawk	BJB
2	Dogfish	RBI
	Rhino	HAM
	Snapple	WEN
	Nugget	TRG
3	Caribou	KPA
	Quickjet	CYA
	Boardwalk	ILT
	Westpoint	BKN
4	Broomstick	RZO
	Sandpiper	WIA
	Crawdad	BEU
	Bigbird	WXZ

Generating these fictitious, non-intuitive call signs necessitated that participants would have to use reference materials to look up the airline telephony designator and airline telephony designator. As mentioned previously, this type of reference material was also recommended by the TFID OFG to help pilots decode unfamiliar airline names and the three letter designators.

TPCS reference books were developed that allowed pilots to look up the TPCS format either by three letter designator or the airline name. The paper reference books may not be necessary or the ultimate implementation for pilots (an electronic version was also considered), but their use allowed for the collection of subjective feedback. Call sign reference cards were also provided to the controllers.

The tables in Appendix A were developed to understand all the ways that call signs could be confusing. Taking these into account, no specific effort was made to deliberately include call signs with confusing numeric flight identifications in any of the scenarios.

4.4 Communications and Experimental Phraseology

Communications during the simulation included standard instructions and clearances as well as the new communications for TPCS. Controllers and pilots were requested to specifically use the phraseology provided by the experimenters (including readbacks), and reminder phraseology templates were provided to them at their workstations. As mentioned previously, the four TPCS alternatives were placed into either an IM clearance or TA. Those communications are discussed next.

4.4.1 IM Clearances

To conduct IM operations, several different communication transactions can occur. The following are expected transactions between the air traffic controller and flight crew.

- Initiating IM (also known as the IM clearance)
    - The IM clearance may or may not include information related to selecting a Reference Aircraft.
- Querying / providing status of IM
- Reporting of key IM parameters
- Suspending and resuming IM
- Terminating IM

Of the set of expected transactions, the IM clearance is expected to be the most complex message. The IM clearance could include the following elements (RTCA, 2011):

- IM clearance type
- Assigned spacing goal
- Special points (e.g., Achieve-by point, planned termination point)
- Reference aircraft call sign
- Reference aircraft intended flight path information

Thus in general, an IM Clearance could have the following format:

> "For interval spacing, cross [Achieve-by Point] [IM Clearance Type and Assigned Spacing Goal] behind [Reference Aircraft TPCS] on [Reference Aircraft intended flight path information]. Terminate at [Planned Termination Point]."

IM was only conducted in the en route environment. Both participant and pseudopilot aircraft received IM clearances. The en route controller was provided a paper list with the IM aircraft pairings and assigned spacing goals. The controller then provided the IM aircraft an IM clearance including the TPCS (always different per participant per scenario), an assigned spacing goal (ranging from approximately 90 to 335 seconds), and an achieve-by point (which was always the fix PECHY). As mentioned previously, the IM messages were constructed based on the IM CPDLC message set established for CPDLC standards activities in RTCA SC-186 and EUROCAE WG-51 and RTCA SC-214 and EUROCAE WG-78 (RTCA and EUROCAE, 2013).

Once received, the flight crew entered the IM clearance information into the CDTI and flew IM speeds until the achieve-by and coincident planned termination point (PECHY), which was prior to the terminal boundary.

The following IM clearance phraseologies and readbacks were briefed to the pilots and controllers to use in the simulation. Based on the work of Cardosi (e.g., 1993), it was determined that each of the IM clearances had five elements. The five elements were the phrase "for interval spacing," the reference aircraft call sign (e.g., American 456), the achieve-by point (e.g., PECHY), and the numeric value of the assigned spacing goal (e.g., 120), and the term “seconds” (because distance is also an option in IM operations. In these examples, the FPCS is United 123 and the TPCS is American 456 (underlined in the examples for clarity).

T-E:

Atlanta Center: “United 123, for interval spacing, traffic is American 456. Cross PECHY 120 seconds behind that traffic.”

UAL123 Readback: “Traffic is American 456. Cross PECHY 120 seconds behind that traffic. United 123.”

T-L:

Atlanta Center: “United 123, for interval spacing, cross PECHY 120 seconds behind American 456.”

UAL123 Readback: “Cross PECHY 120 seconds behind American 456. United 123.”

TD-E:

Atlanta Center: “United 123, for interval spacing, traffic is American Reference 456. Cross PECHY 120 seconds behind that traffic.”

UAL123 Readback: “Traffic is American Reference 456. Cross PECHY 120 seconds behind that traffic. United 123.”

L-E:

Atlanta Center: “United 123, for interval spacing, traffic is A-A-L 456. Cross PECHY 120 seconds behind that traffic.”

UAL123 Readback: “Traffic is A-A-L 456. Cross PECHY 120 seconds behind that traffic. United 123.”

4.4.2 Traffic Advisories

En route and terminal controllers were told to issue the TA as defined by standard operating procedures (FAA, 2012b), with the addition of TPCS and a request for reference aircraft identification confirmation. The en route controller issued TAs for crossing traffic, while the terminal controller issued TAs for aircraft on a parallel runway. Only the en route controllers issued TAs that included the fictitious, non-intuitive call signs.

En route and terminal controllers were instructed to provide at least one TA to each participant aircraft. They were also instructed to provide at least one TA where the participant aircraft was the TPA. They were also asked to issue as many TAs as they could, even if they would not necessarily do that operationally.

Following issuance of the advisory, the flight crew searched for the TPA on the CDTI traffic display. Once the TPA was located, the flight crew reported the TPA “identified” using the TPCS. This task was similar to the reporting of “CDTI contact” in past literature (e.g., Raynaud et al., 2007 in Section 2.3.1). Participants were briefed that “identified” specifically indicated that the traffic was identified on the CDTI traffic display, versus “in-sight” which would indicate that the traffic was acquired visually out-the-window.

The following TA phraseologies and readbacks were briefed to the pilots and en route and terminal controllers to use in the simulation. Based on the work of Cardosi (e.g., 1993), it was determined that each of the TAs had seven elements. The seven elements were the reference aircraft call sign (e.g., American 456), the clock position (e.g., one), the distance (e.g., four), the direction of travel (e.g., eastbound), the aircraft type (e.g., MD80), the flight level (e.g., 210), and the phrase “report identified.” In these examples, the FPCS is United 123 and the TPCS is American 456 (underlined for clarity). It should be noted that the TPCS was always placed first in the pilot readback since they only readback the TPCS and “identified.”

T-E:

Atlanta Center / Atlanta Approach: “United 123, traffic is American 456, one o’clock, four miles, eastbound, MD80, flight level 210. Report identified.”

UAL123 Readback: “American 456 identified. United 123.”

T-L:

Atlanta Center / Atlanta Approach: “United 123, traffic is one o’clock, four miles, eastbound, MD80, flight level 210, American 456. Report identified.”

UAL123 Readback: “American 456 identified. United 123.”

TD-E:

Atlanta Center / Atlanta Approach: “United 123, traffic is American Reference 456, one o’clock, four miles, eastbound, MD80, flight level 210. Report identified.”

UAL123 Readback: “American Reference 456 identified. United 123.”

L-E:

Atlanta Center / Atlanta Approach: “United 123, traffic is A-A-L 456, one o’clock, four miles, eastbound, MD80, flight level 210. Report identified.”

UAL123 Readback: “A-A-L 456 identified. United 123.”

4.5 Simulation Conduct

Upon arrival, pilot and controller participants were brought to separate rooms. Each group was given consent forms and demographics questionnaires to complete and both groups were given a custom introductory briefing. Participants were briefed on the use of TPCS, IM operations, the purpose of the study, their own simulator interfaces, and their responsibilities. While the briefings were similar, they did not include details that were only relevant to the other participants.

With regard to responsibilities, controllers were advised that their primary task was to follow normal ATC procedures. Their secondary task was to use the specified TPCS format in IM clearances and TAs. Controllers were given a paper list of aircraft to pair for IM and the assigned spacing goals for the pair. Controllers were asked to use the specific TPCS alternative for the scenario in their initial communications, but were told they could change to another alternative (or use the phonetic alphabet) should the flight crew request clarification. Finally, controllers were reminded that they were responsible for monitoring and maintaining separation for all aircraft in their sector, and could intervene at any time if necessary.

Flight crews were instructed to follow normal PF and PM roles. Pilots were also advised of their responsibilities specific to TPCS and interactions with the CDTI. For IM, the PM had the task of entering the IM clearance information into the CDTI and confirming aircraft selections with the PF. After confirmation and once IM went engaged, the PF had the task of entering the IM speeds into the MCP.

For TAs, the PM had the task of selecting the reference aircraft on the CDTI traffic display. The PM was also asked to press a button on their workstation indicating that they had heard their own call sign in a communication (whether the communication was intended for them or not), but they were told that this was not a priority of the simulation and to only do it if they thought of it. The general idea with this vague guidance was to not make them concentrate any more than usual on call signs on the voice frequency.

Flight crews were also asked to use the specified TPCS alternative for any initial communications and readbacks, but were told they could request clarification from ATC in any format that they deemed necessary.

After the briefing, pilots were provided with a startup checklist and controllers were provided a sector briefing. They were also introduced to the electronic questionnaire data collection procedures.

Participants were then taken to the laboratory and given approximately 30 minutes to familiarize themselves with their workstation, procedures, airspace, and to ask any questions. Once initial training was completed, participants were given a short break, and then instructed to prepare for the first practice scenario. A practice scenario was conducted prior to each data collection scenario so the participants could become familiar with the use of the TPCS format for that scenario. Each practice scenario lasted approximately 15 minutes.

Each practice scenario was followed by the data collection scenario for the specific TPCS alternative. Each of the four data collection scenarios lasted approximately 30 minutes. Each participant experienced the same set of data collection scenarios (in a repeated measures design). The order of the scenarios was randomized across days, so that each set of participants experienced the same four scenarios with the TPCS alternative, but not in the same order. Table 4-2 shows the scenario presentation order for each of the eight run days.

Table 4-2. Scenario Presentation Order by Date

	Run Date							
Alternative	**11/6**	**11/7**	**11/8**	**11/14**	**11/15**	**11/27**	**11/28**	**11/29**
T-E	3rd	2nd	1st	4th	3rd	2nd	1st	4th
T-L	4th	1st	3rd	2nd	4th	1st	4th	2nd
TD-E	2nd	3rd	4th	1st	2nd	3rd	3rd	1st
L-E	1st	4th	2nd	3rd	1st	4th	2nd	3rd

After each data collection scenario, participants were given a post-scenario questionnaire. After finishing the last data collection scenario, participants were provided with a post-simulation questionnaire. Once they completed the final questionnaire, pilots and controllers came together for the first time to participate in a structured debrief. The debrief was the final event of the simulation. Data collection details are provided in the following section.

4.6 Data Collection

Three methods of data collection were used for this simulation: questionnaires, system recorded data, and observations.

4.6.1 Questionnaires

Four questionnaires were used. All questionnaires were very similar across the three groups of participants. Questions specific to one participant group were only included in the appropriate questionnaires.

- **Demographic:** A questionnaire to gather participants' background and experience (Appendix B). It was issued prior to the start of the simulation. Two separate demographics questionnaires were developed: one for pilots and one for controllers.
- **Post- Scenario:** A questionnaire to gather feedback on the scenario just experienced (Appendix C). It was issued after each data collection scenario. Three separate post-scenario questionnaires were developed: one for pilots, one for en route controllers, and one for terminal controllers.
- **Post-Simulation:** A questionnaire to gather feedback on the full set of scenarios experienced over the course of the simulation (Appendix D). It was issued after completion of all the data collection scenarios. Three separate post-simulation questionnaires were developed: one for pilots, one for en route controllers, and one for terminal controllers.
- **Debrief:** A list of questions to gather general and open discussion feedback on the overall simulation. Separate pilot and controller questions were developed, though they were asked in a group setting.

The post-scenario and post-simulation questionnaires asked questions related to communications, workload, situation awareness, and simulation realism. The questionnaires included the Bedford Workload Rating Scale, end-anchored scales, as well as yes / no, multiple choice, and open-ended questions. Each question had an optional comment field. A seven-point agreement scale was used for most scale questions. Data from these questionnaires was normally gathered electronically (though paper copies were available as back-ups). The apparatus used to capture the data was a 7-inch Asus Nexus touchscreen tablet computer with a wireless keyboard.

4.6.2 System Recorded Data

Data for objective metrics was automatically recorded by the simulation environment and included:

- Aircraft state data, including speed changes, vectors, and altitude changes.
- Aircraft system inputs, including CDTI interactions such as aircraft selections, button pushing for hearing ownship call sign, as well as other actions and keystroke inputs.
- Audio frequency loading.
- Individual channel recordings were made and included push-to-talk logs. Open microphone voice recordings were also collected to capture any intra-cockpit communications between the PF and PM.

4.6.3 Observations

Simulation observers circulated among the participants during each data collection run. Observers took general notes and, when able, captured unusual communications and other occurrences when a participant engaged in a communication involving TPCS.

5 Results

The following sections present the results of the simulation. First the subjective results are summarized, followed by the objective results / audio transcript analysis.

5.1 Subjective Results

5.1.1 Subjective Results Analysis Methodology

The subjective results are based on the responses to the questionnaires and debrief. As mentioned previously, a seven-point agreement scale was used for most scale questions. Some of the questions, where it was determined appropriate, had options for "Don't Know" or "Not Applicable" (Figure 5-1).

1	2	3	4	5	6	7	O Don't know
Strongly Disagree						Strongly Agree	

Figure 5-1. Sample Seven-Point Anchored Scale with Don't Know Option

It should be noted that the term "format" was used in the questionnaires, but it was equivalent to the term "alternative" used in the majority of this paper. After the questionnaires were developed, it was decided to use the term "format" to refer to the specific method for saying TPCS. "Format" and "location" together equal the alternative, as described in Section 2.9.

Subjective results are from the post-simulation questionnaire unless otherwise specified. When summary statistics are provided, "*M*" indicates mean and "*SD*" indicates standard deviation. When "*n*" values or delta values are provided, the analyzed frequencies are less than total possible (en route controllers [n=7], terminal controllers [n=8], and pilots [n=64]) due to issues such as participants not answering a question. Any questions that were only asked of one group are noted as such. Otherwise, results represent all three participant groups.

Statistical tests were conducted for the seven point scale questions and the one TPCS ranking question. Whenever statistics are not reported for the seven point scale questions or the one TPCS ranking question, it is because significant results were not found for that question. The tests consisted of two-way, within subjects repeated measures MANOVAs, unless noted otherwise. The within subjects factors were TPCS alternative with four levels (T-E, T-L, TD-E, and L-E) and operation with two levels (IM and TA). The TPCS alternative main, operation main, and TPCS alternative x operation effects were tested using the multivariate criterion of Wilks' lambda (Λ). If the operation factor was not part of the question, it could not be tested (leaving only the TPCS alternative main effect to be tested). If significance was found, paired t-tests were conducted, controlling for family-wise error rate using Holm's sequential Bonferroni approach. It should be noted that due to low numbers of both en route and terminal controllers, and high variability in responses, only one test for controllers (en route) showed significance. All other reported statistical tests were for pilots.

When reporting results from the scale, questions may be summarized as "all participants agreed" if there was an occurrence in which all participant responses were on the 'agree' side of the scale, i.e., a rating of 5 to 7. When available, some or all of the comments may also be provided to highlight areas of strong agreement or to highlight important issues or new ideas. In addition, relevant comments from the debrief may be included.

5.1.2 Subjective Results

5.1.2.1 Acceptability and Use of TPCS

TPCS Alternative Preference

Participants were asked to indicate their level of agreement with the following statement: "The third party call sign format would be acceptable overall in line operations" (Figure 5-2).

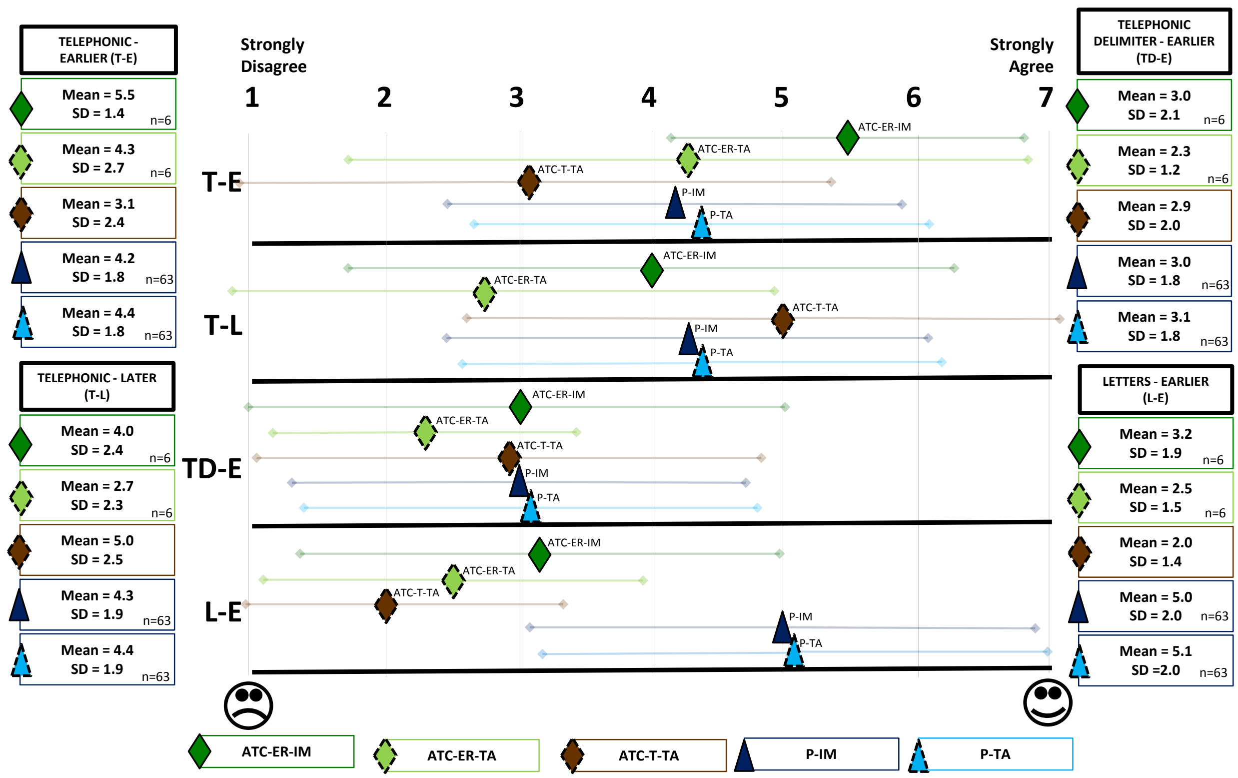

Figure 5-2. Participant replies to "The third party call sign format would be acceptable overall in line operations."

As can be seen from the figure, there is a large amount of variability and results might suggest that none of the other alternatives appeared to show an advantage across all the groups. However, all participants appeared to disfavor the TD-E alternative. En route controllers (ATC-ER) appear to exhibit a response difference between IM and TA contexts (with TA being less acceptable). Terminal controllers (ATC-T) appeared to exhibit an operational acceptability advantage for T-L.

For pilots, the repeated measures MANVOA found a significant main effect for TPCS alternative [$\Lambda = 0.59$, $F(3,60) = 14.12$, $p < 0.001$] (Figure 5-3). The pairwise comparisons revealed that pilots found L-E significantly more acceptable than T-E [$t(62) = 2.50$, $p = 0.015$] and T-L [$t(62) = 2.16$, $p = 0.035$]. It also revealed that pilots found TD-E significantly less acceptable than T-E [t (62) = -

4.01, p < 0.001], T-L [t (62) = -4.44, p < 0.001], and L-E [t (62) = -6.42, p < 0.001]. No significant difference in acceptability was found for T-E as compared to T-L.

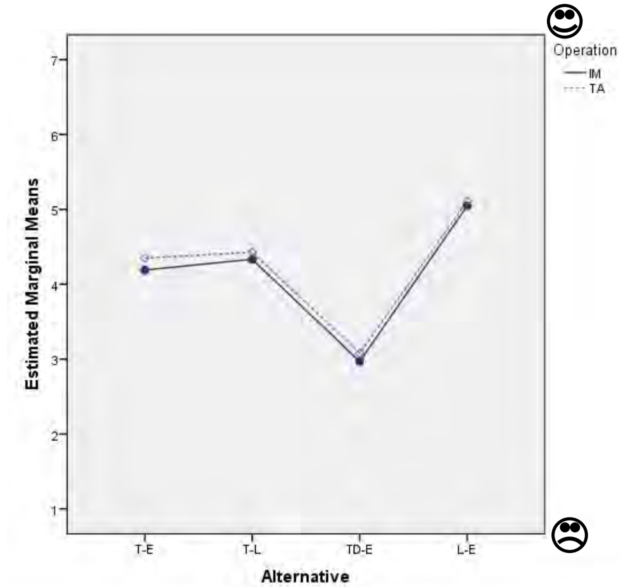

Figure 5-3. Pilot estimated marginal means for "The third party call sign format would be acceptable overall in line operations."

Participants were asked to "Rank each format, in order of preference, for communicating third party call sign." Percentage of first position rankings by participants are shown in Figure 5-4 (see also Table 5-1).

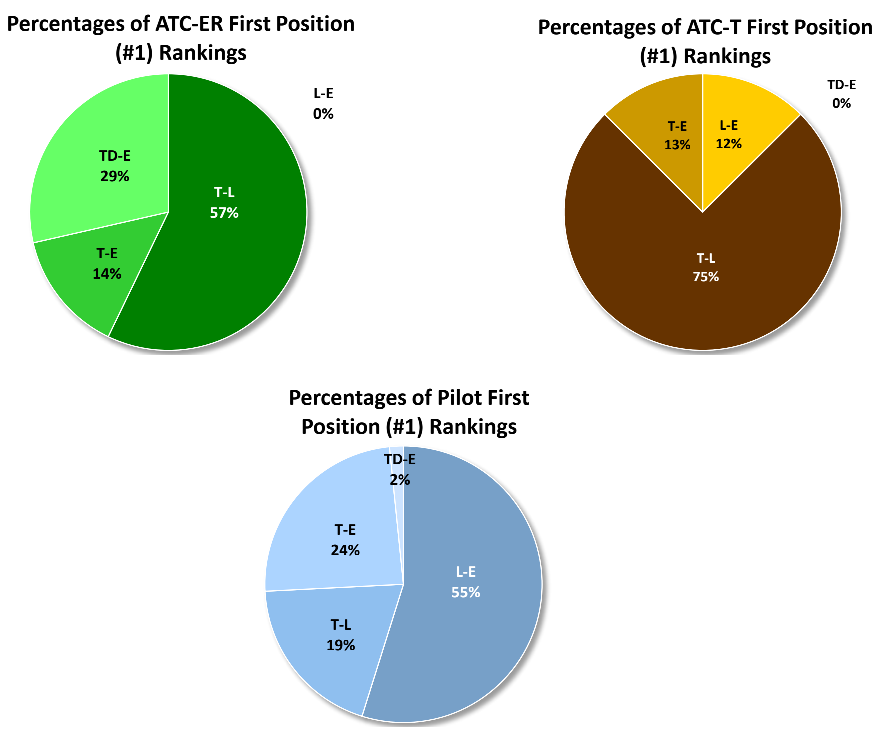

Figure 5-4. Percentage of first position rankings by participants in reply to "Rank each format, in order of preference, for communicating third party call sign."

Table 5-1. Means and Standard Deviations for "Rank each format, in order of preference, for communicating third party call sign."

Alternative	Participant	Mean (SD)	Missing
T-E	ATC-ER	2.7 (1.1)	0
	ATC-T	2.4 (0.9)	0
	Pilot	2.4 (1.0)	2
T-L	ATC-ER	1.7 (1.1)	0
	ATC-T	1.6 (1.2)	0
	Pilot	2.3 (0.9)	2
TD-E	ATC-ER	2.4 (1.3)	0
	ATC-T	3.3 (0.9)	0
	Pilot	3.5 (0.8)	2
L-E	ATC-ER	3.1 (0.7)	0
	ATC-T	2.8 (1.0)	0
	Pilot	1.8 (1.1)	2

For the en route controllers, over half ranked T-L as their most preferred alternative. The mean values also indicate a trend toward this being the first preference. The L-E option was never cited as the first choice and the means show a trend for it being least favorable. For the terminal controllers, seventy-five percent of the terminal controllers ranked T-L as their most preferred alternative. The TD-E alternative was never cited as the first choice and the means show a trend for it being least favorable. Unlike en route controllers, terminal controllers did rank L-E first 12% of the time. As can be seen, the controllers generally prefer T-L as their first choice and prefer the telephonic format in general.

For the pilots, over half (55%) ranked L-E as their most preferred alternative. TD-E was rarely chosen as the first preference. The repeated measures MANVOA found a significant main effect for TPCS Alternative [$\Lambda = 0.35$, $F(3,59) = 36.50$, $p < 0.001$] (Figure 5-5). The pairwise comparisons revealed that pilots ranked L-E significantly better than T-E [$t(61) = -2.49$, $p = 0.015$] and T-L [$t(61) = -2.44$, $p = 0.018$]. It also revealed that pilots ranked TD-E significantly worse than T-E [$t(61) = 5.73$, $p < 0.001$], T-L [$t(61) = 6.81$, $p < 0.001$], and L-E [$t(61) = 9.44$, $p < 0.001$]. No significant difference in ranking was found for T-E as compared to T-L.

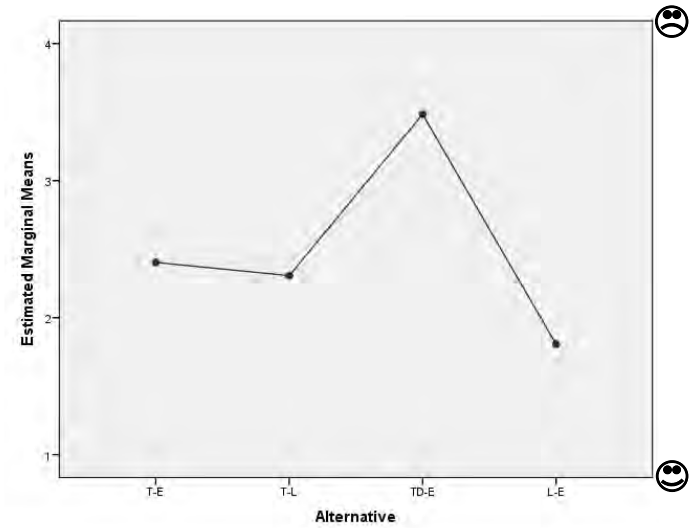

Figure 5-5. Pilot estimated marginal means for "Rank each format, in order of preference, for communicating third party call sign."

TPCS Use in Communications

Participants were asked to indicate their level of agreement with the following statement: "I was able to sufficiently communicate the third party call sign using the format" (Figure 5-6).

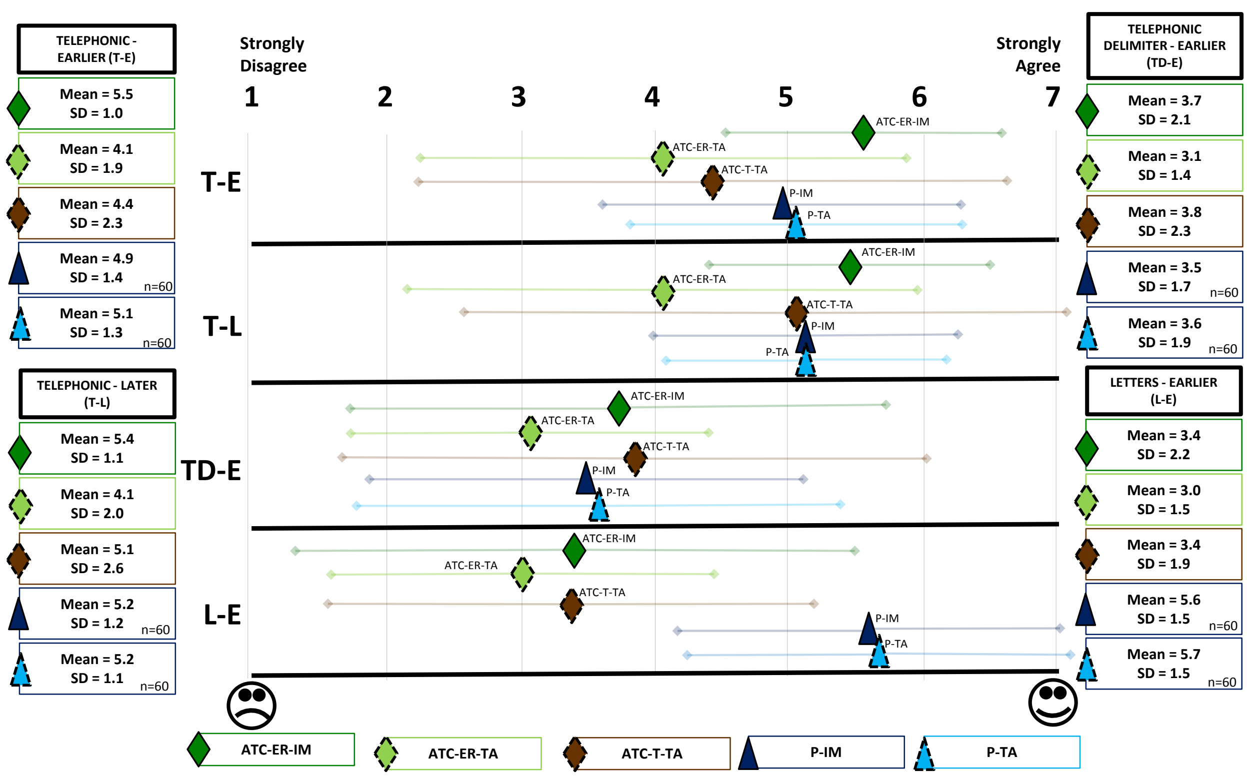

Figure 5-6. Participant replies to "I was able to sufficiently communicate the third party call sign using the format."

Overall, TD-E appeared to be the most challenging to use in communications. Both en route and terminal controllers appear to have a preference for the telephonic alternatives. En route controllers again appear to exhibit a response difference between the IM and TA contexts (with TA being less acceptable).

For pilots, the repeated measures MANVOA found a significant main effect for TPCS Alternative [$\Lambda = 0.45$, $F(3,57) = 23.38$, $p < 0.001$] (Figure 5-7). The pairwise comparisons revealed that pilots found L-E significantly better to communicate with ATC than T-E [$t(59) = 2.66$, $p = 0.010$] and T-L [$t(59) = 2.02$, $p = 0.048$]. It also revealed that pilots found TD-E significantly worse to communicate with ATC than T-E [$t(59) = -5.49$, $p < 0.001$], T-L [$t(59) = -6.97$, $p < 0.001$], and L-E [$t(59) = -7.96$, $p < 0.001$]. No significant difference in ability communicate with ATC was found for T-E as compared to T-L.

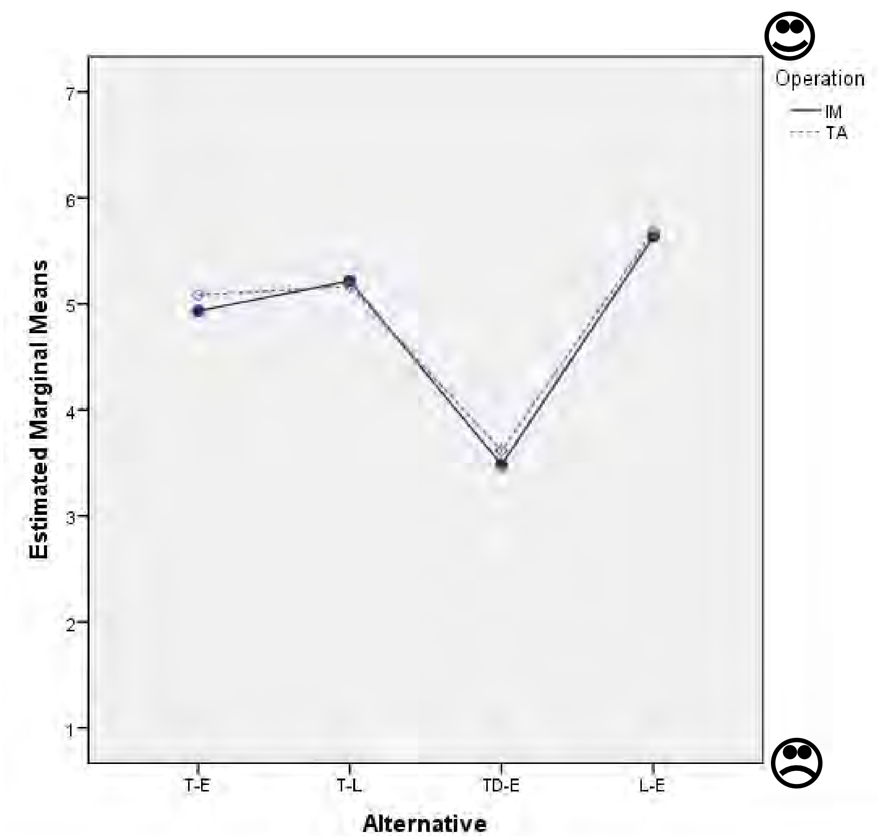

Figure 5-7. Pilot estimated marginal means for "I was able to sufficiently communicate the third party call sign using the format."

Though Bedford workload data was collected, the post-simulation workload acceptability data is more illustrative for the purpose of this report. Therefore, the Bedford results are not included. In the post-scenario questionnaire, participants were asked to indicate their level of agreement with the following statement: "My overall workload was acceptable" (Table 5-2).

Table 5-2. Means and Standard Deviations for "My overall workload was acceptable."

Alternative	Participant	Mean (SD)
T-E	ATC-ER	6.1 (0.7)
	ATC-T	6.1 (1.5)
	Pilot	5.5 (1.3)
T-L	ATC-ER	6.0 (0.8)
	ATC-T	6.6 (0.5)
	Pilot	5.6 (1.0)
TD-E	ATC-ER	5.6 (1.1)
	ATC-T	6.4 (0.7)
	Pilot	5.2 (1.2)
L-E	ATC-ER	6.1 (0.9)
	ATC-T	5.8 (1.3)
	Pilot	5.8 (1.3)

Under all conditions, all en route controllers agreed that their workload was acceptable. Under all conditions, all but two terminal controllers agreed that their workload was acceptable. One controller disagreed for the T-E alternative and anther controller disagreed for the L-E alternative. Under all conditions, the majority of pilots agreed that their workload was acceptable. The distribution is shown in Figure 5-8.

For pilots, the repeated measures MANVOA found a significant main effect for TPCS Alternative [$\Lambda = 0.83$, $F(3,61) = 4.18$, $p = 0.009$] (Figure 5-9). The pairwise comparisons revealed that pilots found the TD-E position significantly less acceptable for workload than T-L [$t(63) = -2.17$, $p = 0.034$], and L-E [$t(63) = -3.59$, $p = 0.001$]. No significant difference in acceptability was found for T-E as compared to T-L, L-E as compared to T-E, L-E as compared to T-L, or TD-E as compared to T-E.

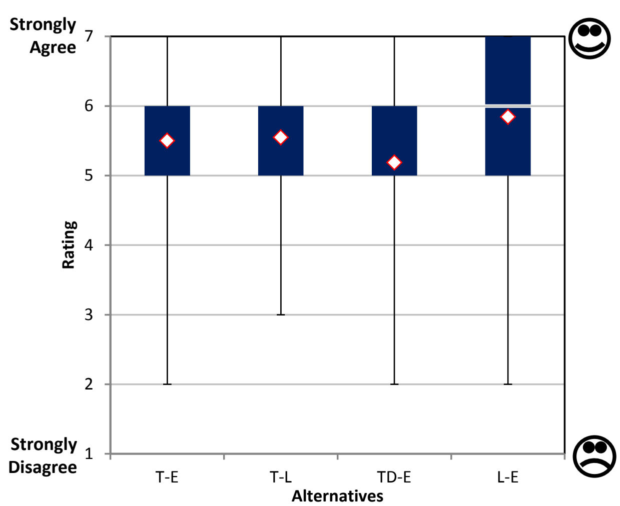

Figure 5-8. Pilot participant responses to "My overall workload was acceptable."

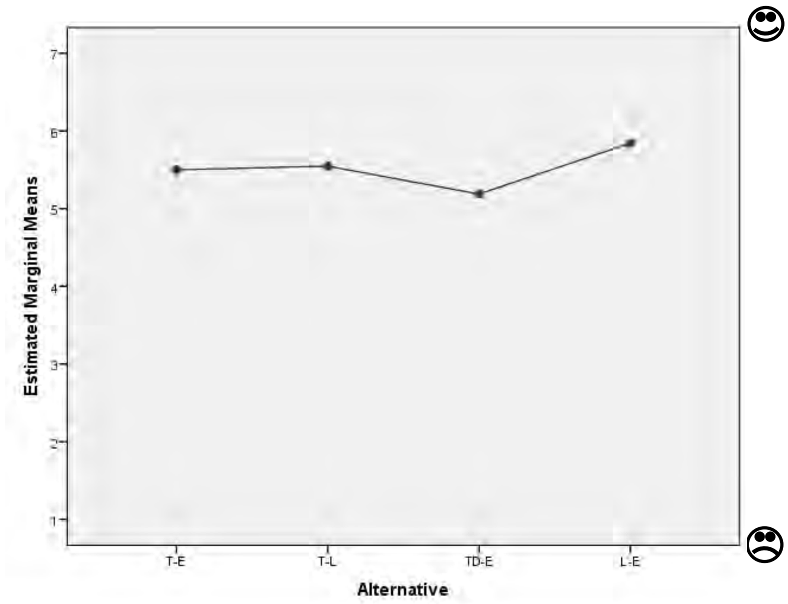

Figure 5-9. Pilot estimated marginal means for "My overall workload was acceptable."

In the post-scenario questionnaire, controllers were asked to indicate their level of agreement with the following statement: "I was able to understand pilot readbacks of third party call sign." Similarly, pilots were asked to indicate their level of agreement with the following statement "I was able to understand ATC communications involving third party call sign" Responses are shown in Figure 5-10.

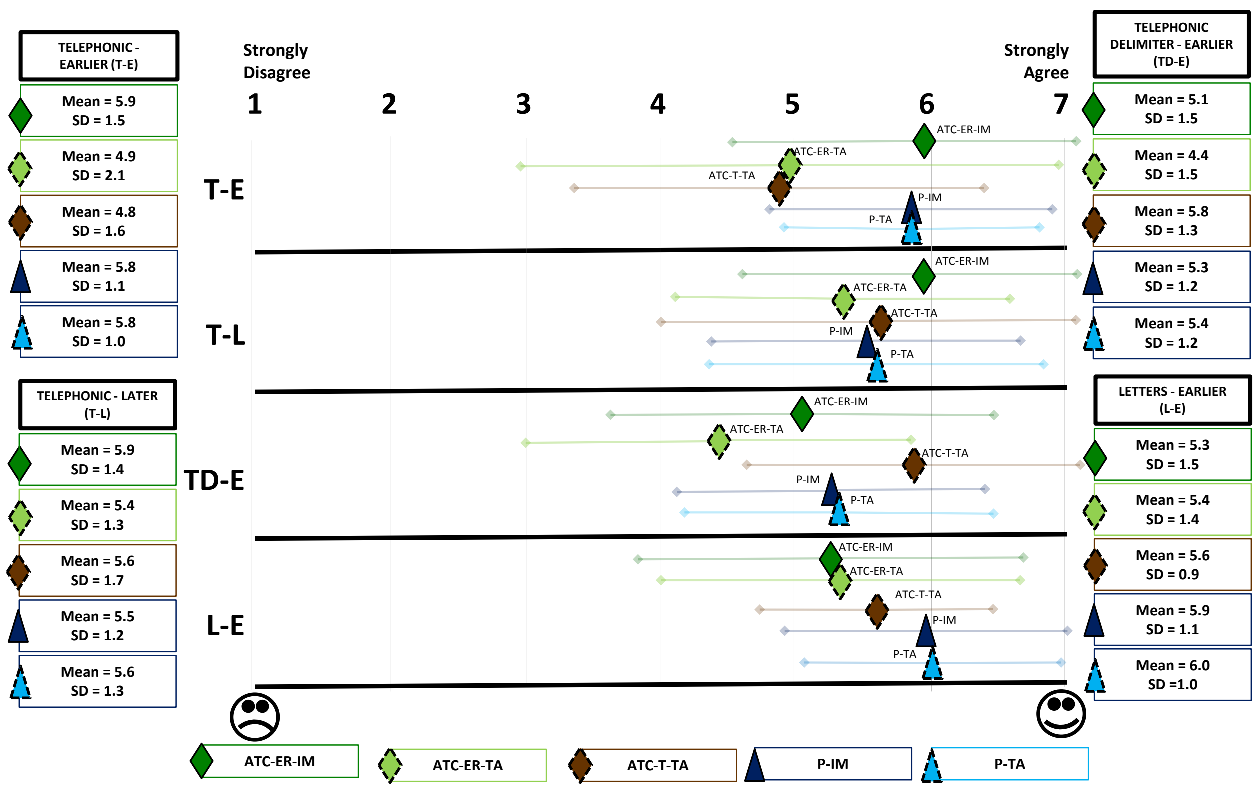

Figure 5-10. Participant replies to whether they were "able to understand [the other parties communications] of third party call sign."

Overall, most means appear to be on the agree side of the scale. It appears all participants felt they understood all of the alternatives during both operations. For pilots, the repeated measures MANVOA found a significant main effect for TPCS Alternative [$\Lambda = 0.76$, $F(3,61) = 6.55$, $p = 0.001$] (Figure 5-11). The pairwise comparisons revealed that pilots found L-E significantly better for understanding ATC than T-L [$t(63) = 2.57$, $p = 0.013$]. It also revealed that pilots found TD-E significantly worse for understanding ATC than T-E [$t(63) = -3.02$, $p = 0.004$], and L-E [$t(63) = -4.12$, $p < 0.001$]. No significant difference in acceptability was found for T-E as compared to T-L, L-E to T-E, or TD-E to T-L.

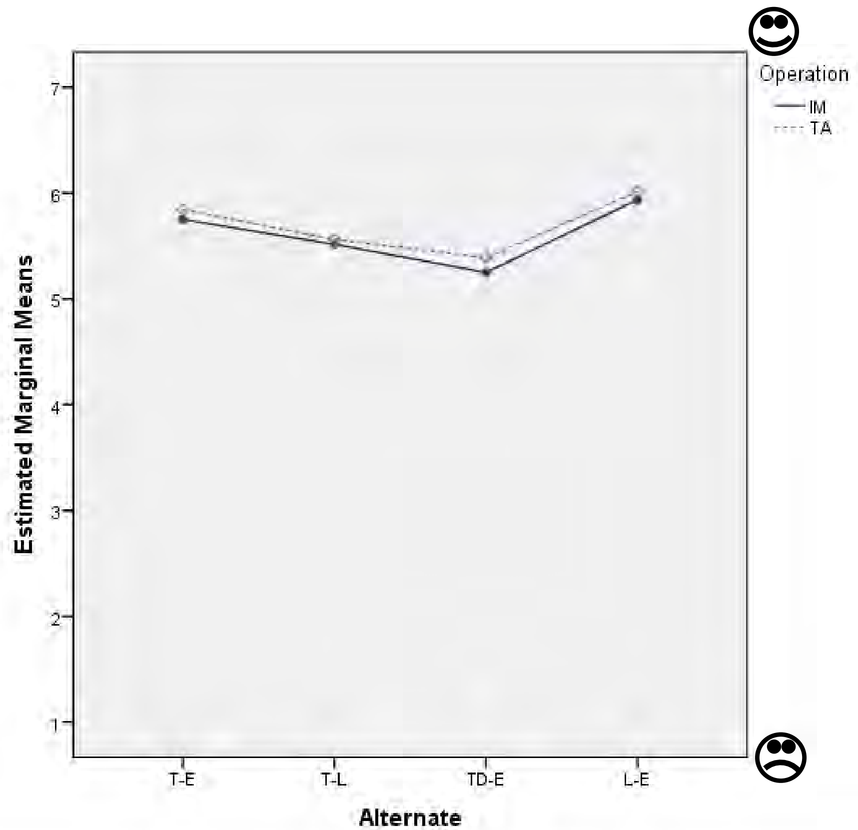

Figure 5-11. Pilot estimated marginal means for "I was able to understand ATC communications involving third party call sign."

In the post-scenario questionnaire, pilots were asked "Did you ever hear your call sign being used where you were being talked about (i.e., being addressed as a third party aircraft)?" (Figure 5-12). As can be seen, pilots almost always heard their call sign when being referred to as a TPA.

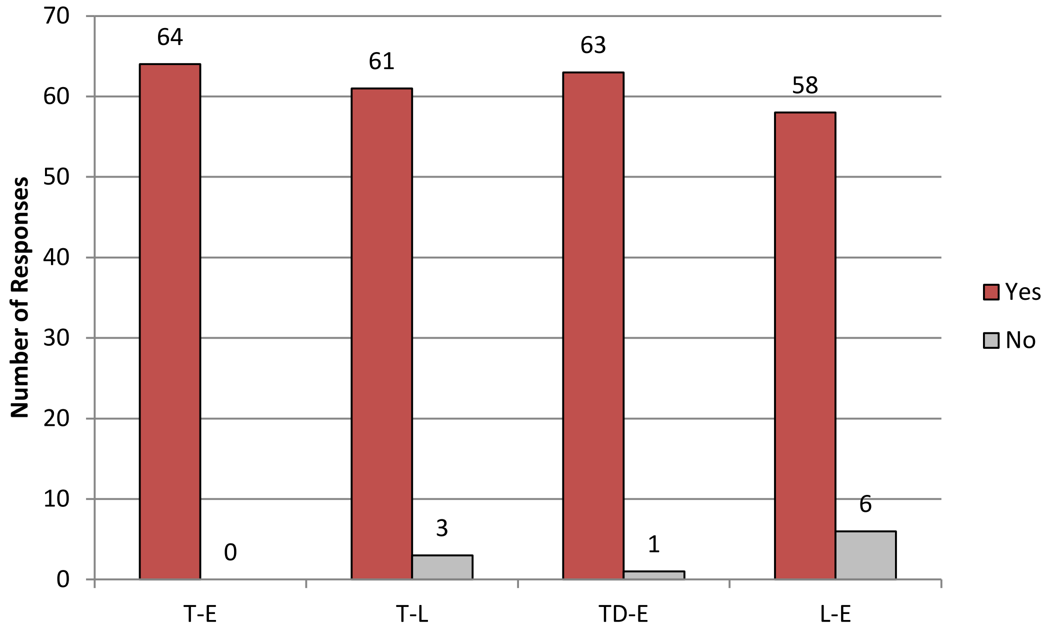

Figure 5-12. Pilot responses to when asked "Did you ever hear your call sign being used where you were being talked about (i.e., being addressed as a third party aircraft)?"

Pilots were asked a follow-on question about whether it was ATC or the TPP they heard say their call sign. Pilots could select one or both options. Responses are shown in Figure 5-13. As can be seen, most often pilots heard their call sign from the controller but also heard their call signs very often from the TPP. It is interesting to note that the frequency of hearing their call sign from ATC appears consistent across alternatives, while the frequencies may trend toward hearing it less from pilots in general and possibly even less with the L-E alternative (assuming the pilots and controllers used it equally frequently).

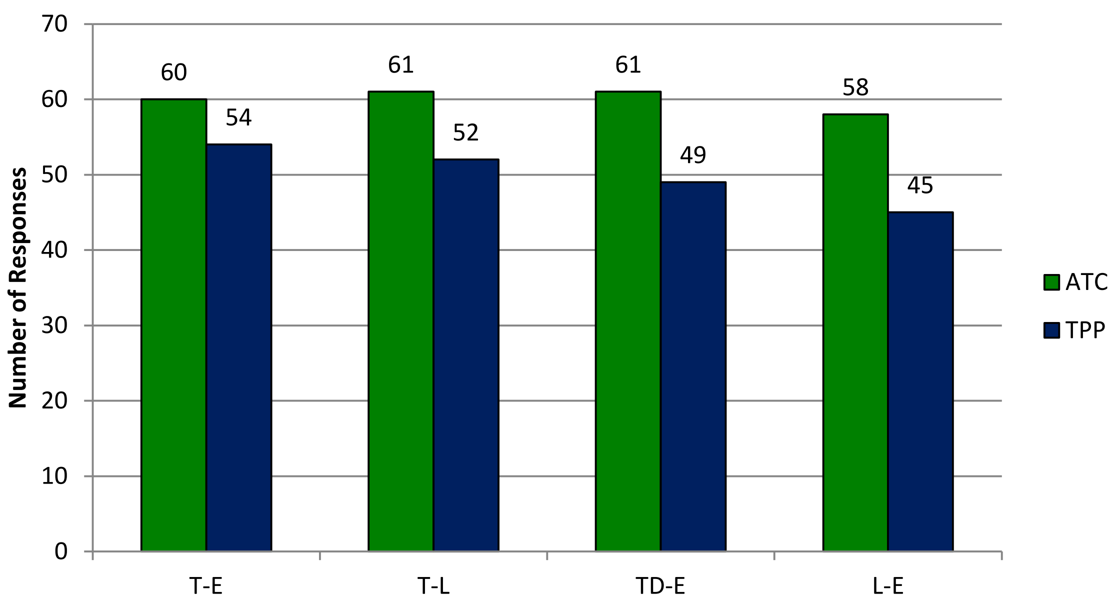

Figure 5-13. Pilot responses when asked about who they heard say their call sign.

TPCS Use with CDTI

Pilots were asked to indicate their level of agreement with the following statement: “The third party call sign format helped me find the aircraft on the CDTI” (Figure 5-14 and Table 5-3).

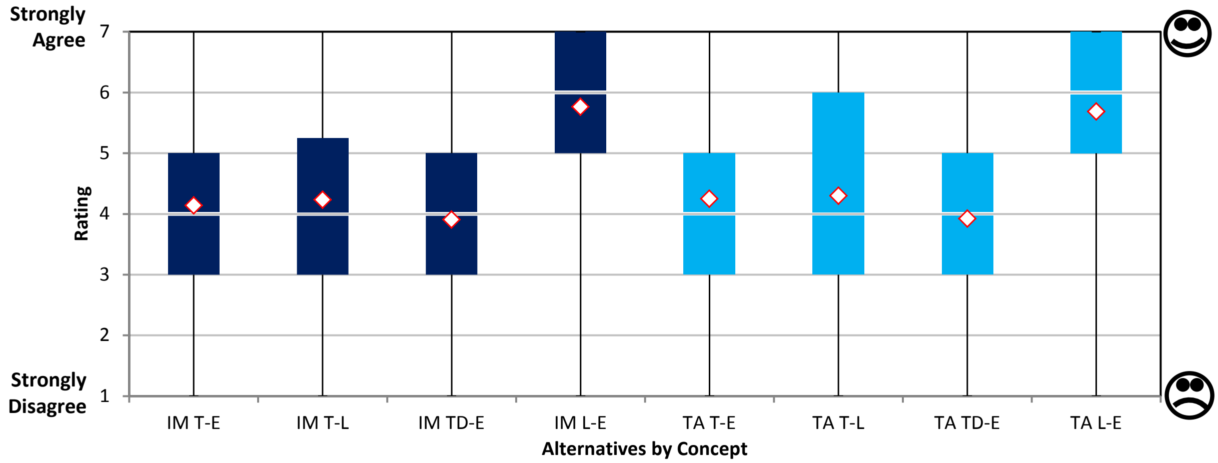

Figure 5-14. Pilot responses to “The third party call sign format helped me find the aircraft on the CDTI.”

Table 5-3. Means and Standard Deviations for “The third party call sign format helped me find the aircraft on the CDTI.”

Alternative	Operation	Mean (SD)
T-E	**IM**	4.1 (1.5)
	TA	4.3 (1.6)
T-L	**IM**	4.2 (1.6)
	TA	4.3 (1.6)
TD-E	**IM**	3.9 (1.7)
	TA	3.9 (1.7)
L-E	**IM**	5.8 (1.6)
	TA	5.7 (1.6)

The repeated measures MANVOA found a significant main effect for TPCS Alternative [$\Lambda = 0.58$, $F(3,61) = 14.56$, $p < 0.001$] (Figure 5-15). The pairwise comparisons revealed that pilots found L-E significantly more helpful in finding the aircraft on the CDTI than T-E [$t(63) = 6.11$, $p < 0.001$] and T-L [$t(63) = 5.62$, $p < 0.001$]. It also revealed that pilots found TD-E significantly less helpful in finding the aircraft on the CDTI than T-L [$t(63) = -2.05$, $p = 0.045$], and L-E [$t(63) = -6.19$, $p < 0.001$]. No significant difference for helpful in finding the aircraft on the CDTI was found for T-E as compared to T-L or TD-E as compared to T-E. Two pilots (3%) reported that for the non-Letters alternatives, they simply used the numeric flight identification.

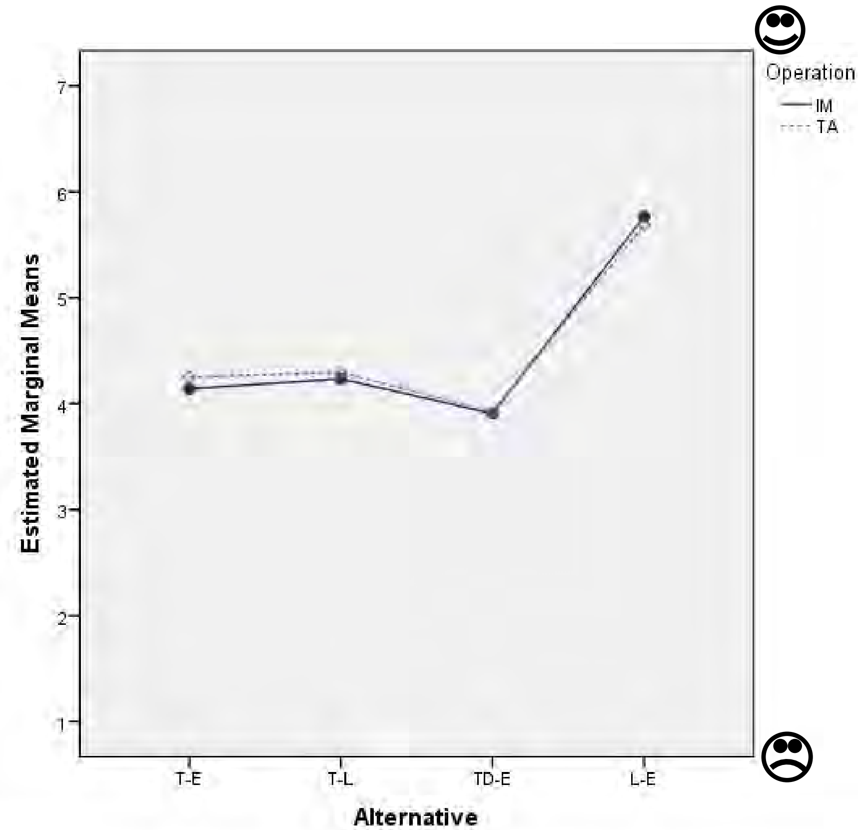

Figure 5-15. Pilot estimated marginal means for "The third party call sign format helped me find the aircraft on the CDTI."

Benefits of TPCS use in Current Environment

Participants were asked "Do you think that the use of third party call sign can solve any current day problems?" (Figure 5-16 and Table 5-4). En route controllers had fewer "yes" replies as compared to terminal controllers and had very limited comments. However, terminal controllers reported more favorably and reported more uses. A majority (75%) reported it would help with visual separation and TAs. They reported it would help when there are multiple aircraft and to avoid multiple traffic calls. One terminal controller (13%) also mentioned using TPCS during ground movements and being able to tell one aircraft to follow another. The last terminal controller reported "don't know" and did not comment. Finally, thirty six percent (23/64) of the pilots replied "don't know." Thirty nine percent (25/64) reported "yes." Of the pilots that reported "yes," forty percent mentioned it would help with situation awareness and positive identification of the TPA.

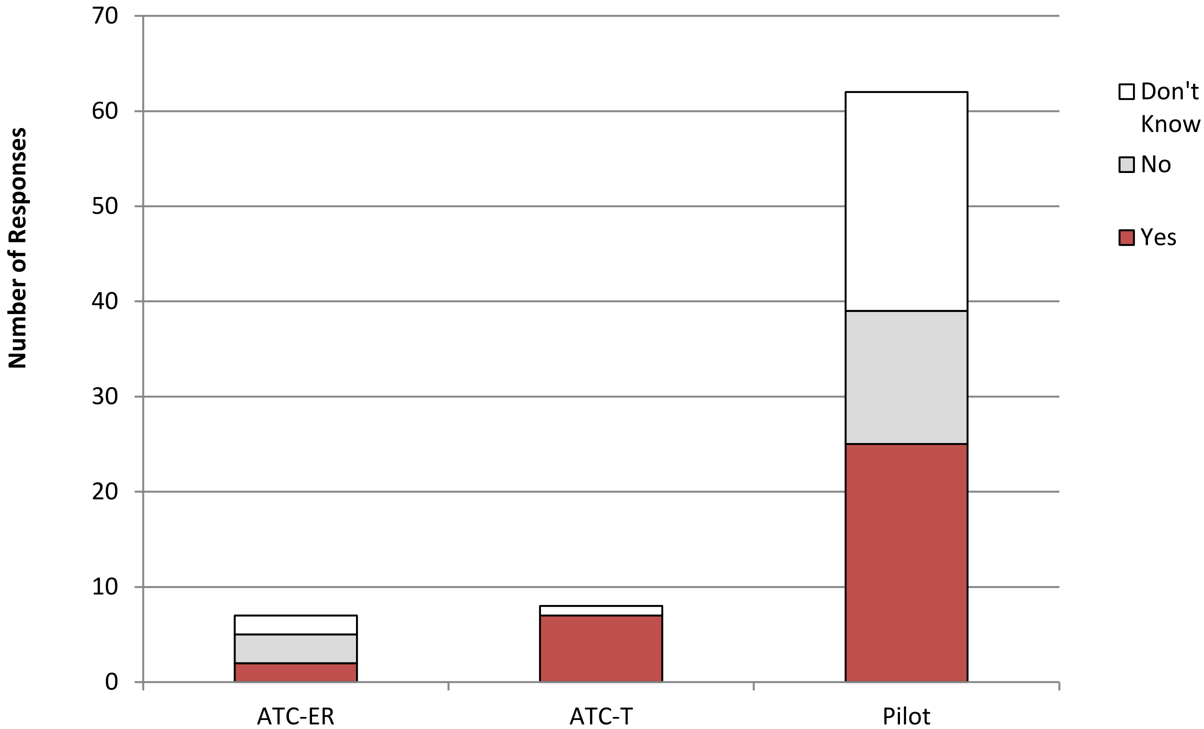

Figure 5-16. Participant replies to "Do you think that the use of third party call sign can solve any current day problems?"

Table 5-4. Response Counts for "Do you think that the use of third party call sign can solve any current day problems?"

Participant	Yes	No	Don't Know	Missing
ATC-ER	2	3	2	0
ATC-T	7	0	1	0
Pilot	25	14	23	2

5.1.2.2 Issues with the Use of TPCS

In the post-scenario questionnaires, participants were asked "Did you have any specific issues with the third party call sign format?" (Figure 5-17 and Table 5-5). Both controller groups again showed a slight trend to prefer the Telephonic options and more concerns about the TD-E and L-E alternatives. For pilots, the trends indicate they have more concerns about the TD-E alternative than the other options and that L-E may have the fewest issues (followed closely by the T-L alternative).

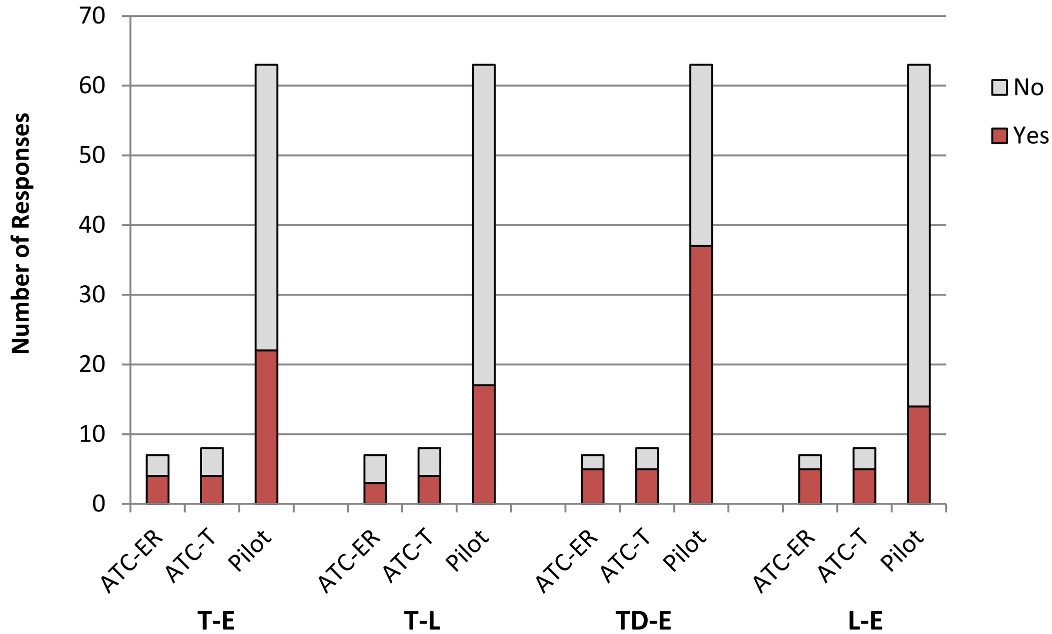

Figure 5-17. Participant replies to "Did you have any specific issues with the third party call sign format?"

Table 5-5. Response Counts for "Did you have any specific issues with the third party call sign format?"

Alternative	Participant	Yes	No	Don't Know	Missing
T-E	ATC-ER	4	3	0	0
	ATC-T	4	4	0	0
	Pilot	22	41	0	1
T-L	ATC-ER	3	4	0	0
	ATC-T	4	4	0	0
	Pilot	17	46	0	1
TD-E	ATC-ER	5	2	0	0
	ATC-T	5	3	0	0
	Pilot	37	26	0	1
L-E	ATC-ER	5	2	0	0
	ATC-T	5	3	0	0
	Pilot	14	49	0	1

Message Length as Related to TPCS

In the post scenario questionnaires, participants were asked whether “The length of the communication that included third party call sign affected the acceptability of the third party call sign format” (Figure 5-18 and Table 5-6). Across the participants, length of the communications appeared to have an impact on acceptability of TPCS overall, but did not appear to act as a differentiator between alternatives. The most noteworthy point may be that 88% (7/8) of the terminal controllers noted that the length of the communication affected the acceptability of the L-E option, whereas the majority of the en route controllers (5/7; 71%) reported the opposite.

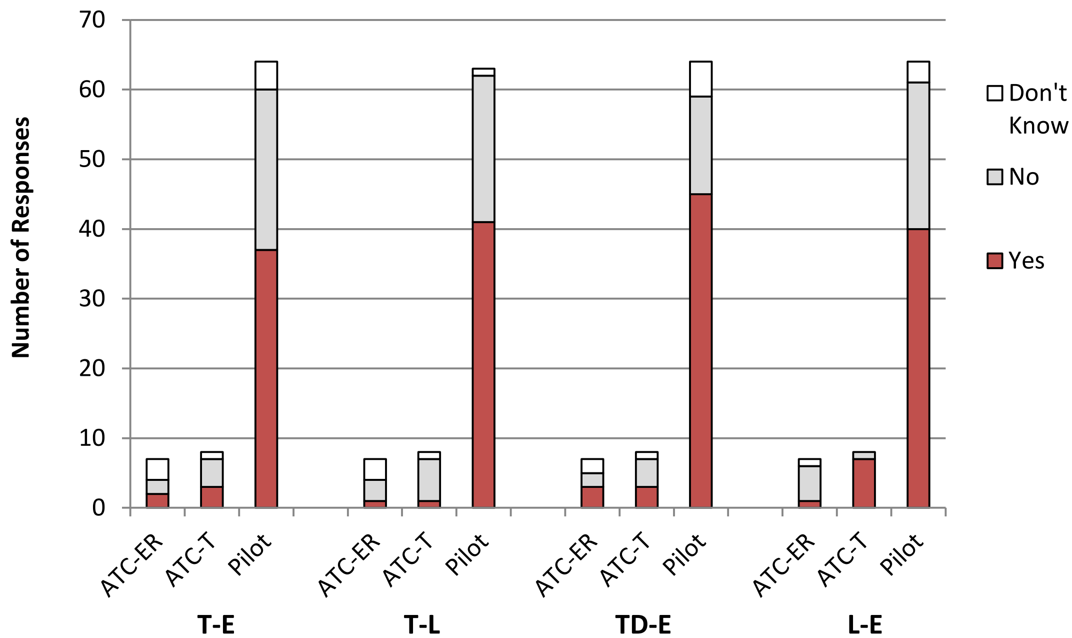

Figure 5-18. Participant replies to “The length of the communication that included third party call sign affected the acceptability of the third party call sign format.”

Table 5-6. Response Counts for "The length of the communication that included third party call sign affected the acceptability of the third party call sign format."

Alternative	Participant	Yes	No	Don't Know	Missing
T-E	ATC-ER	2	2	3	0
	ATC-T	3	4	1	0
	Pilot	37	23	4	0
T-L	ATC-ER	1	3	3	0
	ATC-T	1	6	1	0
	Pilot	41	21	1	1
TD-E	ATC-ER	3	2	2	0
	ATC-T	3	4	1	0
	Pilot	45	14	5	0
L-E	ATC-ER	1	5	1	0
	ATC-T	7	1	0	0
	Pilot	40	21	3	0

In the post scenario questionnaires, participants were asked whether "The length of the communication that included third party call sign was acceptable" (Figure 5-19).

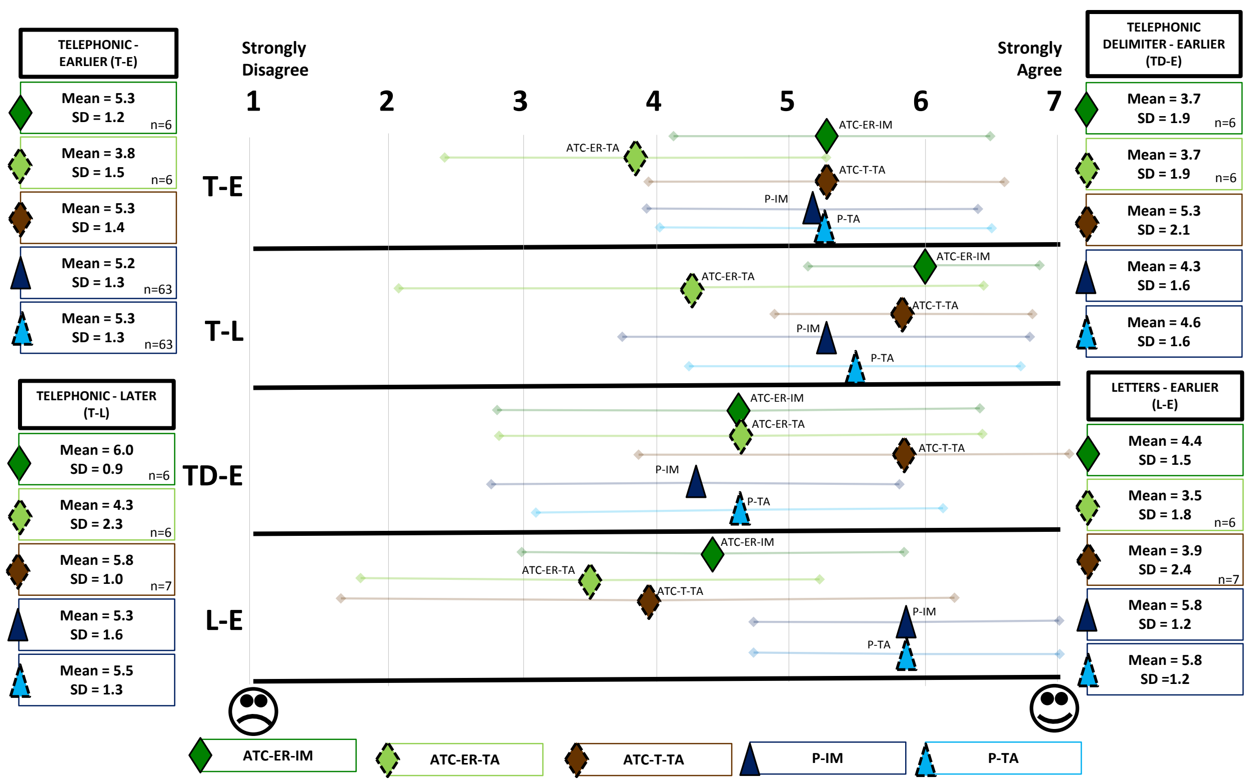

Figure 5-19. Participant replies to "The length of the communication that included third party call sign was acceptable."

Several of the answers showed large variability making it difficult to predict trends, though there appears to be slightly greater overall controller acceptability with regard to length of the T-L alternative and slightly less overall controller acceptability with regard to length of the TD-E alternative. For terminal controllers, it may be worth noting the large degree of variability on the L-E alternative. As before, en route controllers appeared to exhibit a response difference between IM and TA operations (with TA being less acceptable) for all but the TD-E format. This was shown in the repeated measures MANVOA that found a significant main effect for Operation [$\Lambda = 0.22$, $F(1,3) = 10.67$, $p = 0.047$] (Figure 5-20). The pairwise comparison for Operation revealed that controllers found the IM length to be significantly more acceptable for length than TA [$t(6) = 2.80$, $p < 0.031$].

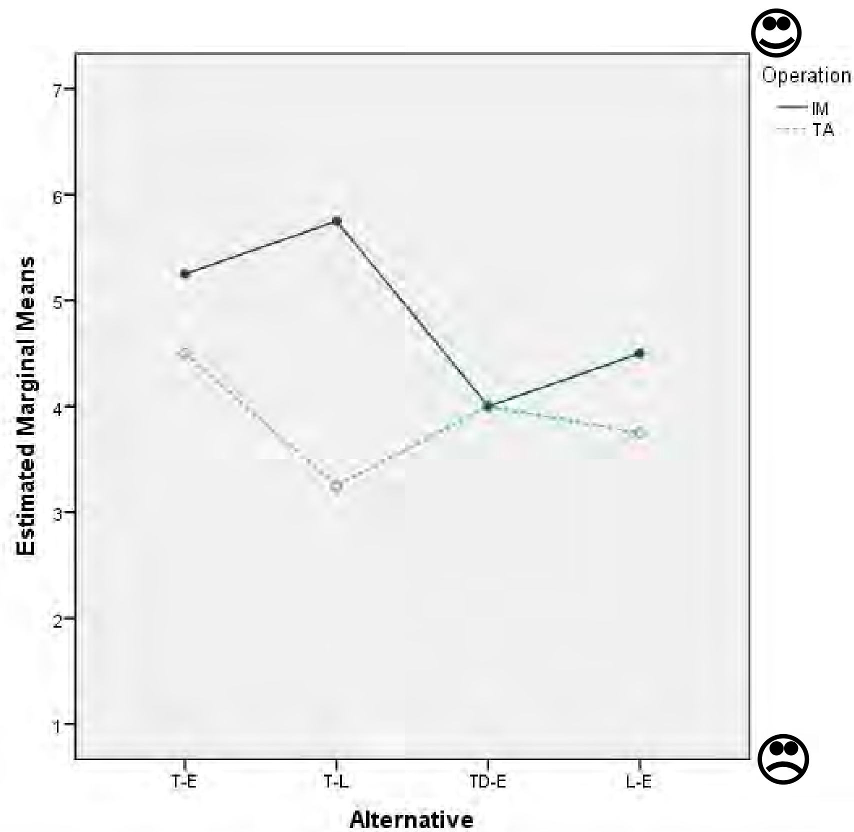

Figure 5-20. En route controller estimated marginal means for "The length of the communication that included third party call sign was acceptable."

For pilots, the repeated measures MANVOA found a significant main effect for TPCS Alternative [$\Lambda = 0.66$, $F(3,60) = 10.22$, $p < 0.001$] and Operation [$\Lambda = 0.82$, $F(1,62) = 13.80$, $p < 0.001$] (Figure 5-21). The pairwise comparisons revealed that pilots found the TD-E length significantly less acceptable than T-E [$t(62) = -4.33$, $p < 0.001$], T-L [$t(63) = -4.57$, $p < 0.001$], and L-E [$t(63) = -5.42$, $p < 0.001$]. No significant difference in acceptability of length was found for T-E as compared to T-L, L-E as compared to T-E, or L-E as compared to T-L. The pairwise comparison for Operation revealed that pilots found IM to be significantly less acceptable for length than TA [$t(63) = -3.71$, $p < 0.001$], which was the opposite of the en route controller replies.

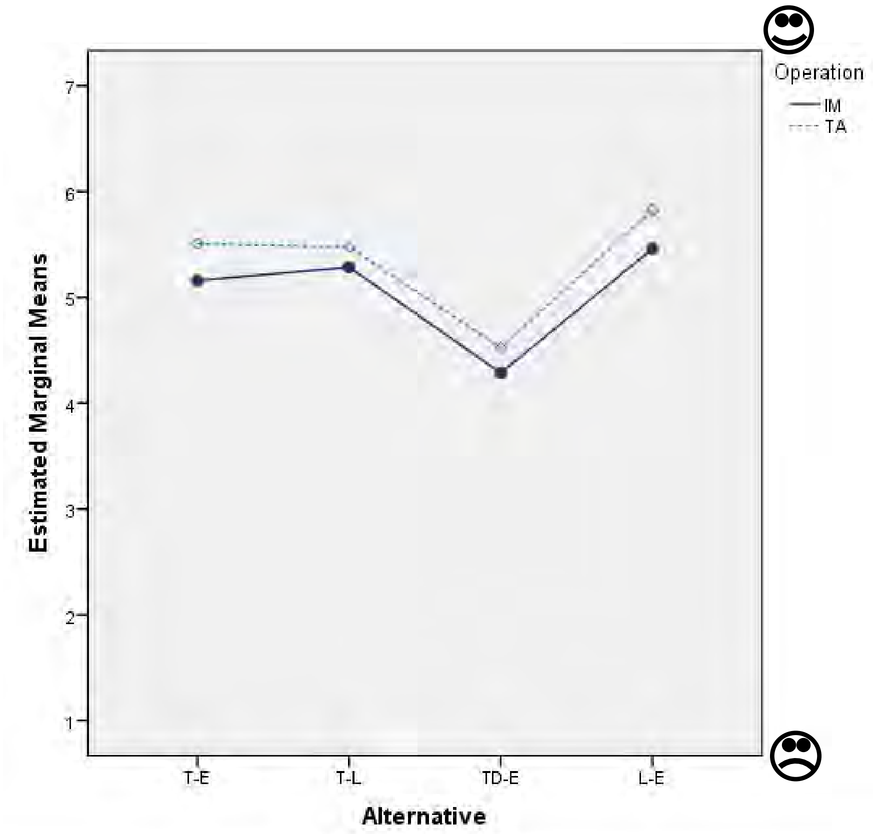

Figure 5-21. Pilot estimated marginal means for "The length of the communication that included third party call sign was acceptable."

TPCS Position in Communication

In the post scenario questionnaires, participants were asked to indicate their level of agreement with the following statement: “The third party call sign position within the communication was acceptable” (Figure 5-22).

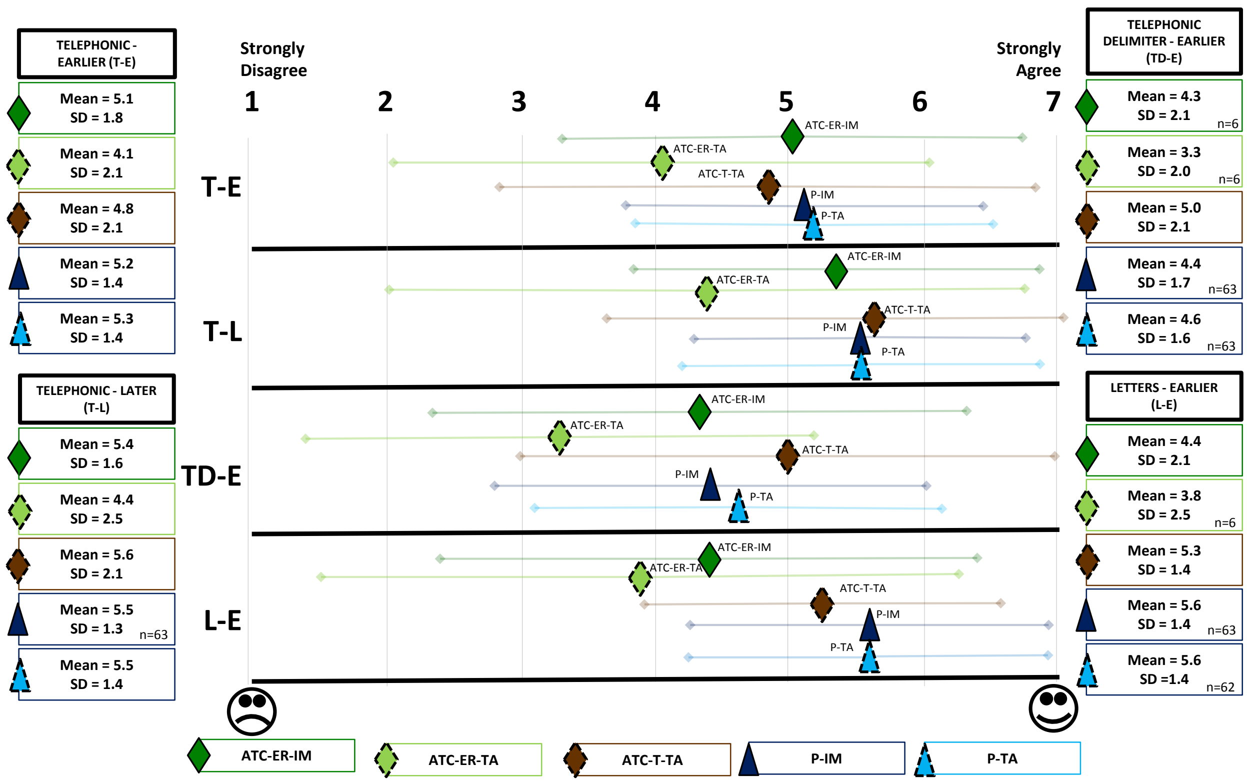

Figure 5-22. Participant replies to “The third party call sign position within the communication was acceptable.”

The subjective response data does not appear to show a clear answer for whether the Later (T-L) or Early (T-E, TD-E, and L-E) option is best. Therefore, the TPCS format may have an influence on the acceptability of the TPCS position. En route controllers again appear to exhibit a response difference between the IM and TA contexts (with TA being less acceptable). For IM, en route controllers appeared to prefer the positions of the T-L and T-E alternatives more than those of TD-E and L-E. Terminal controller responses may again show a general preference for the T-L alternative as compared to the other three.

For pilots, the repeated measures MANVOA found a significant main effect for TPCS Alternative [$\Lambda = 0.76$, $F(3,57) = 5.92$, $p = 0.001$] (Figure 5-23). The pairwise comparisons revealed that pilots found the TD-E position significantly less acceptable than T-E [$t(62) = -2.72$, $p = 0.008$], T-L [$t(61) = -3.82$, $p < 0.001$], and L-E [$t(60) = -4.16$, $p < 0.001$]. No significant difference in acceptability was found for T-E as compared to T-L, L-E as compared to T-E, or L-E as compared to T-L. Based on these results, it appears that format has an influence on the acceptability of the TPCS position.

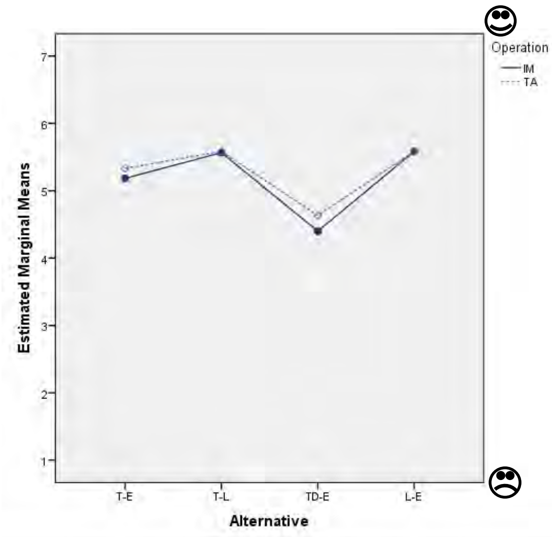

Figure 5-23. Pilot estimated marginal means for "The third party call sign position within the communication was acceptable."

In the post scenario questionnaires, participants were also asked to indicate their level of agreement with the following statement: "The third party call sign acceptability is affected by its position in the communication" (Figure 5-24). Most replies had a tendency to be from neutral to agree. The L-E replies tended to have a lot of variability, especially for the terminal controllers and pilots. Again, it can be seen that pilots did not appear to exhibit strong response differences between IM and TA contexts.

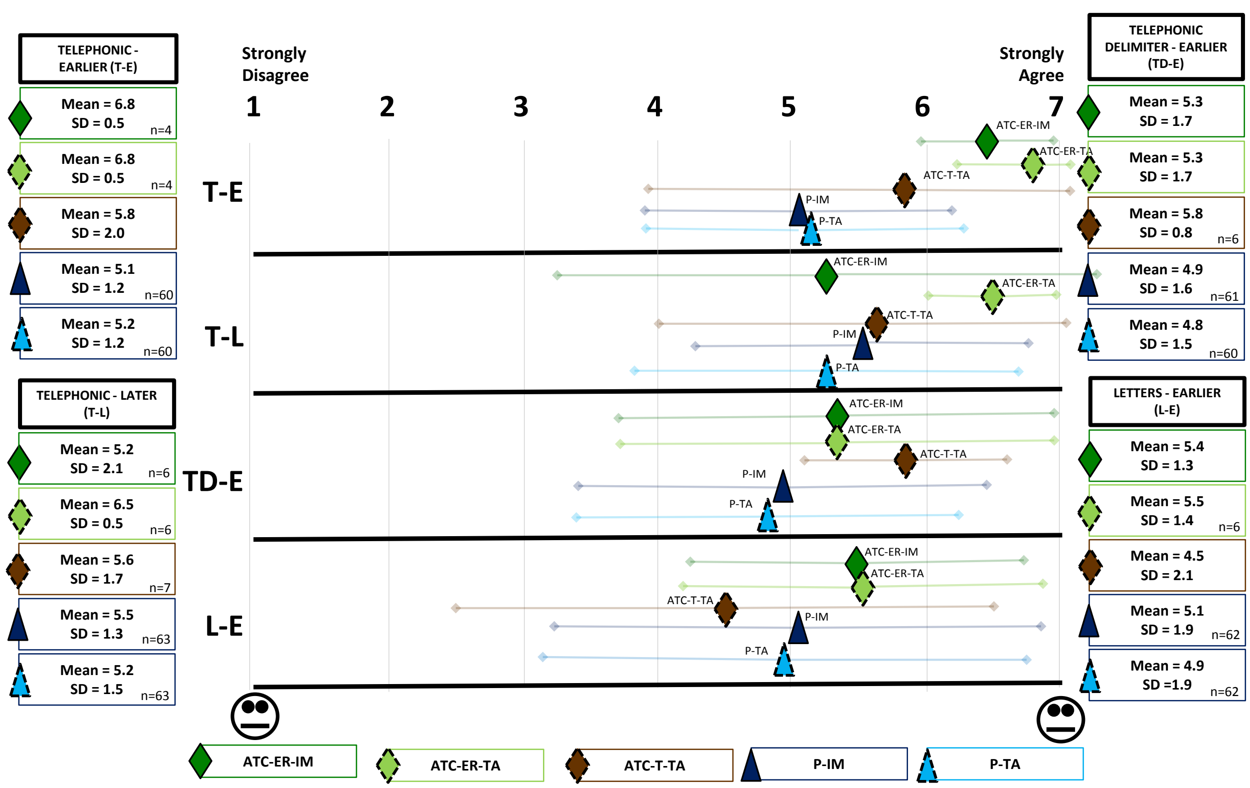

Figure 5-24. Participant replies to "The third party call sign acceptability is affected by its position in the communication."

Potential Errors Related to TPCS

In the post scenario questionnaires, participants were asked “Did use of the third party call sign cause you to make any errors?” (Figure 5-25 and Table 5-7). En route controllers appeared to have the least issues with the T-L alternative. Terminal controllers appeared to have the least issues with the T-E alternative. Pilots seemed to have the most issues with the TD-E alternative, with little difference between the others.

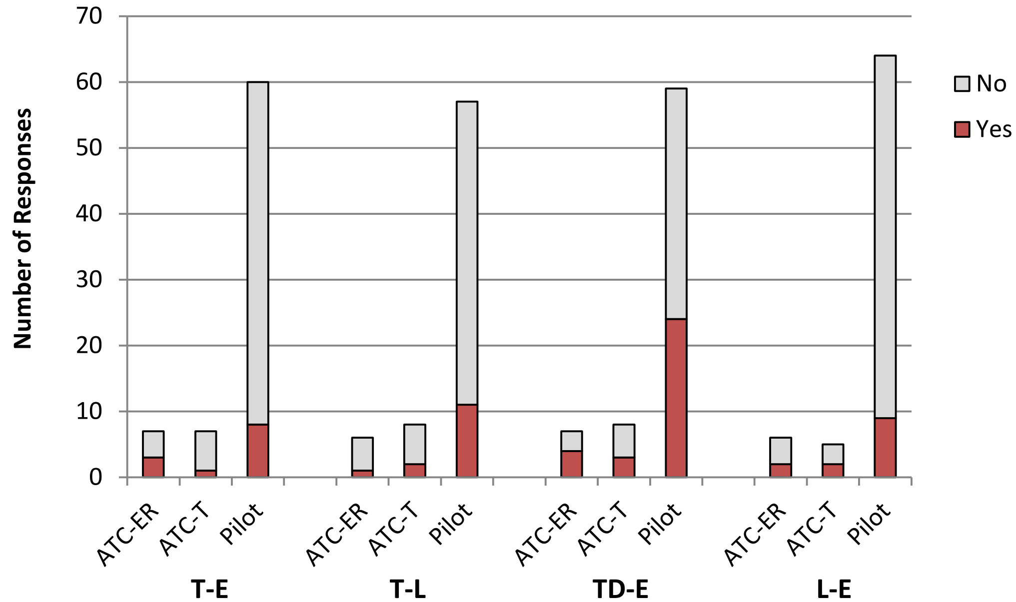

Figure 5-25. Participant replies to “Did use of the third party call sign cause you to make any errors?”

Table 5-7. Response Counts for “Did use of the third party call sign cause you to make any errors?”

Alternative	Participant	Yes	No	Don’t Know
T-E	ATC-ER	3	4	0
	ATC-T	1	6	1
	Pilot	8	52	0
T-L	ATC-ER	1	5	1
	ATC-T	2	6	0
	Pilot	11	46	0
TD-E	ATC-ER	4	3	0
	ATC-T	3	5	0
	Pilot	24	35	0
L-E	ATC-ER	2	4	1
	ATC-T	2	3	3
	Pilot	9	55	0

Participants were asked to indicate their level of agreement with the following statement: "I think the third party call sign format has the potential for pilot errors" (Figure 5-26).

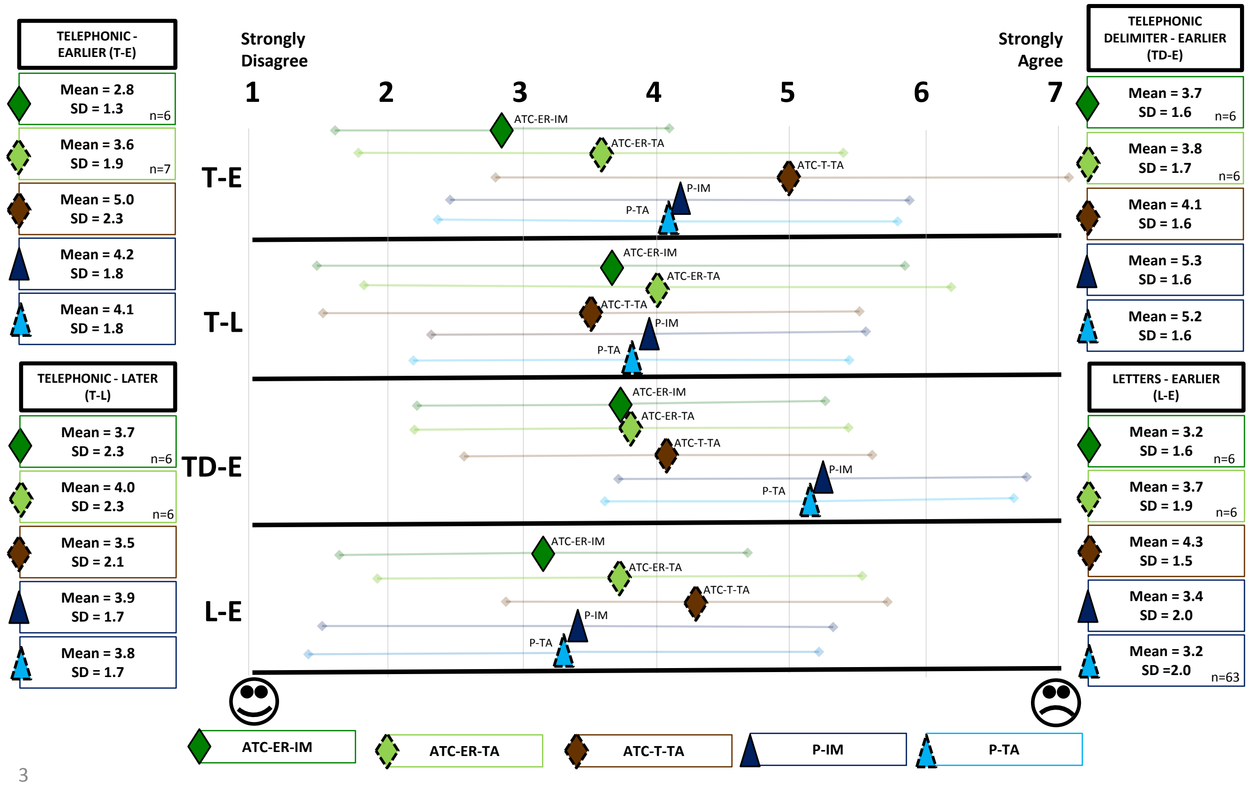

Figure 5-26. Participant replies to "I think the third party call sign format has the potential for pilot errors."

Most replies tended to be around the neutral point. The en route controller responses show minimal differences. Terminal controller replies seem to indicate that there may be more pilot errors with the T-E alternative but less with the T-L alternatives, suggesting that they may believe there is an inherent benefit of the Later position to pilots.

For pilots, the repeated measures MANVOA found a significant main effect for TPCS Alternative [$\Lambda = 0.55$, $F(3,60) = 16.36$, $p < 0.001$] (Figure 5-27). The pairwise comparisons revealed that pilots found L-E significantly less likely to have pilot errors than T-E [$t(63) = -2.95$, $p = 0.004$] and T-L [$t(63) = -2.06$, $p = 0.043$]. It also revealed that pilots found TD-E significantly more likely to have pilot errors than T-E [$t(63) = 3.45$, $p = 0.001$], T-L [$t(63) = 4.60$, $p < 0.001$], and L-E [$t(63) = 7.03$, $p < 0.001$]. No significant difference in the potential for pilot errors was found for T-E as compared to T-L.

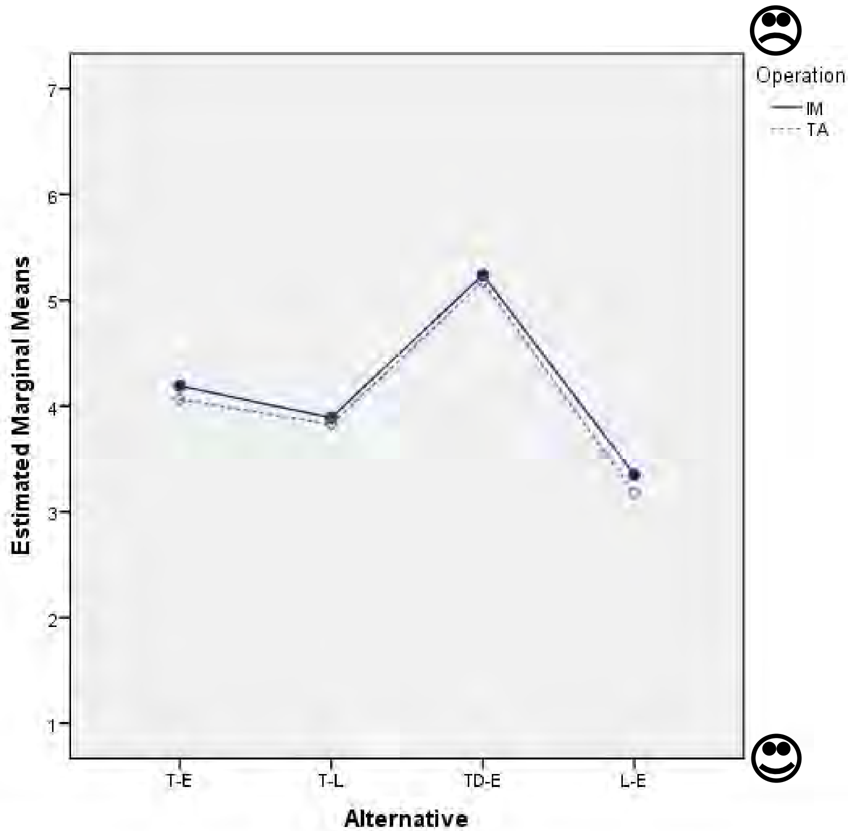

Figure 5-27. Pilot estimated marginal means for "I think the third party call sign format has the potential for pilot errors."

Pilots were asked "Do you believe you would get used to being talked about (i.e., being addressed as a third party aircraft) and not just to (i.e., receiving an ATC communication)?" (Figure 5-28). The vast majority of pilots (52/64; 81%) said that they would. Pilots were asked a follow-on question: "Would…experience reduce any concerns?" (Figure 5-29). One pilot did not reply. The majority (41/63; 65%) reported that experience would reduce concerns.

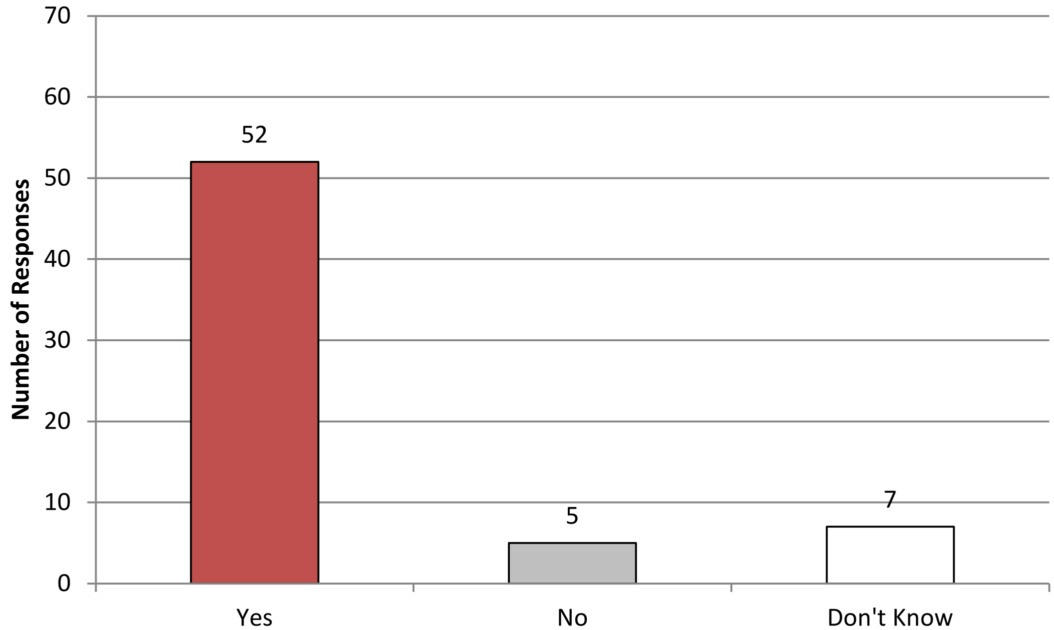

Figure 5-28. Pilot Participant replies to "Do you believe you would get used to being talked about (i.e., being addressed as a third party aircraft) and not just to (i.e., receiving an ATC communication)?"

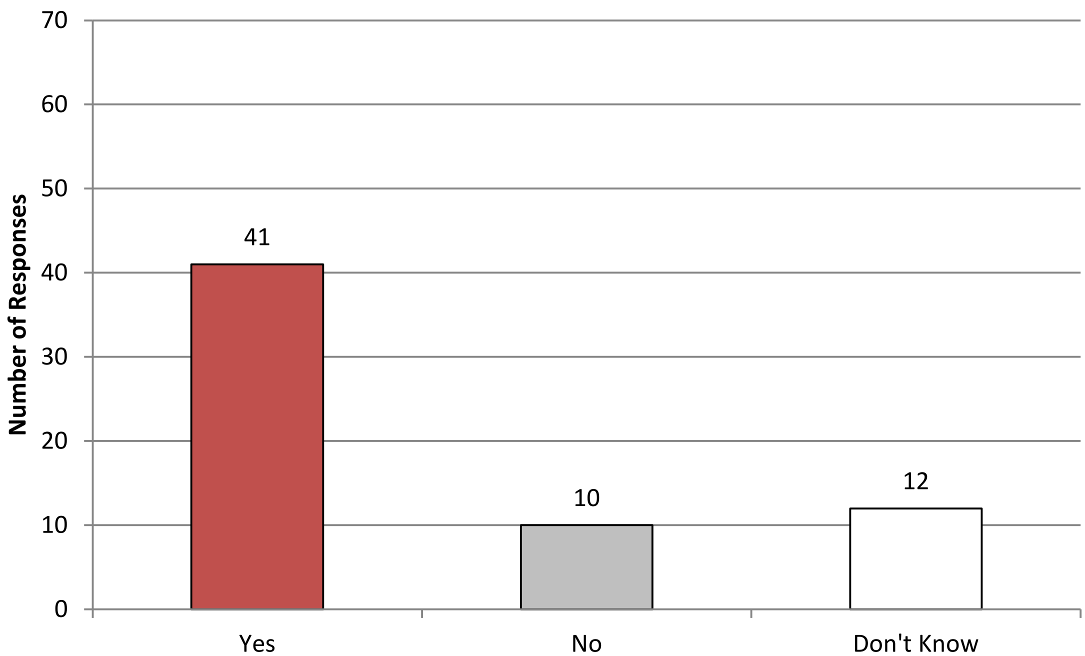

Figure 5-29. Pilot Participant replies to "Would that experience reduce any concerns?"

In the post scenario questionnaires, participants were asked whether they observed errors made by "flight crews related to call signs?" As shown in Figure 5-30 and Table 5-8, many participants reported hearing errors related to call signs by flight crews. Pilots and controllers reported several issues such as using the wrong format, pilots reporting the wrong TPCS, stumbling on the proper TPCS alternative, and missed calls. Terminal controllers reported approximately the same number of issues across the alternatives. En route controllers and pilots reported the least issues with the L-E alternative and the most with the TD-E format. Of the pilots that answered "yes" for the TD-E alternative, thirty six percent (16/45) reported hearing pilot errors related to the use and insertion of the delimiter term "reference." Deviations and error occurrences are analyzed further in Section 5.2.

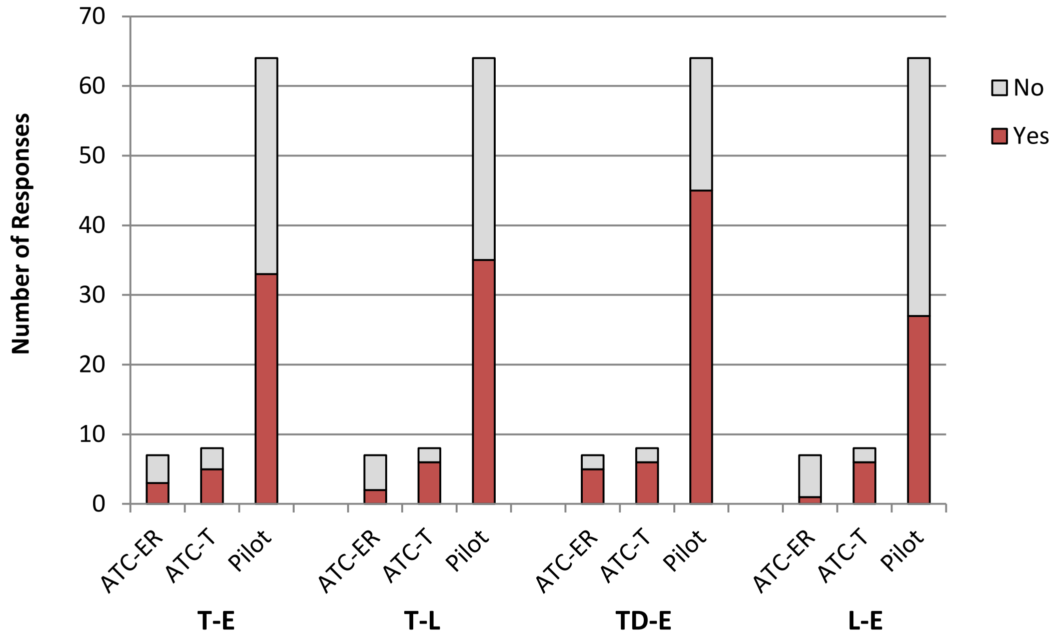

Figure 5-30. Participant replies to whether they observed errors made by "flight crews related to call signs."

Table 5-8. Response Counts for whether participants observed errors made by "flight crews related to call signs."

Alternative	Participant	Yes	No
T-E	**ATC-ER**	3	4
	ATC-T	5	3
	Pilot	33	31
T-L	**ATC-ER**	2	5
	ATC-T	6	2
	Pilot	35	29
TD-E	**ATC-ER**	5	2
	ATC-T	6	2
	Pilot	45	19
L-E	**ATC-ER**	1	6
	ATC-T	6	2
	Pilot	27	37

Participants were asked to indicate their level of agreement with the following statement: “I think the third party call sign format has the potential for controller errors” (Figure 5-31).

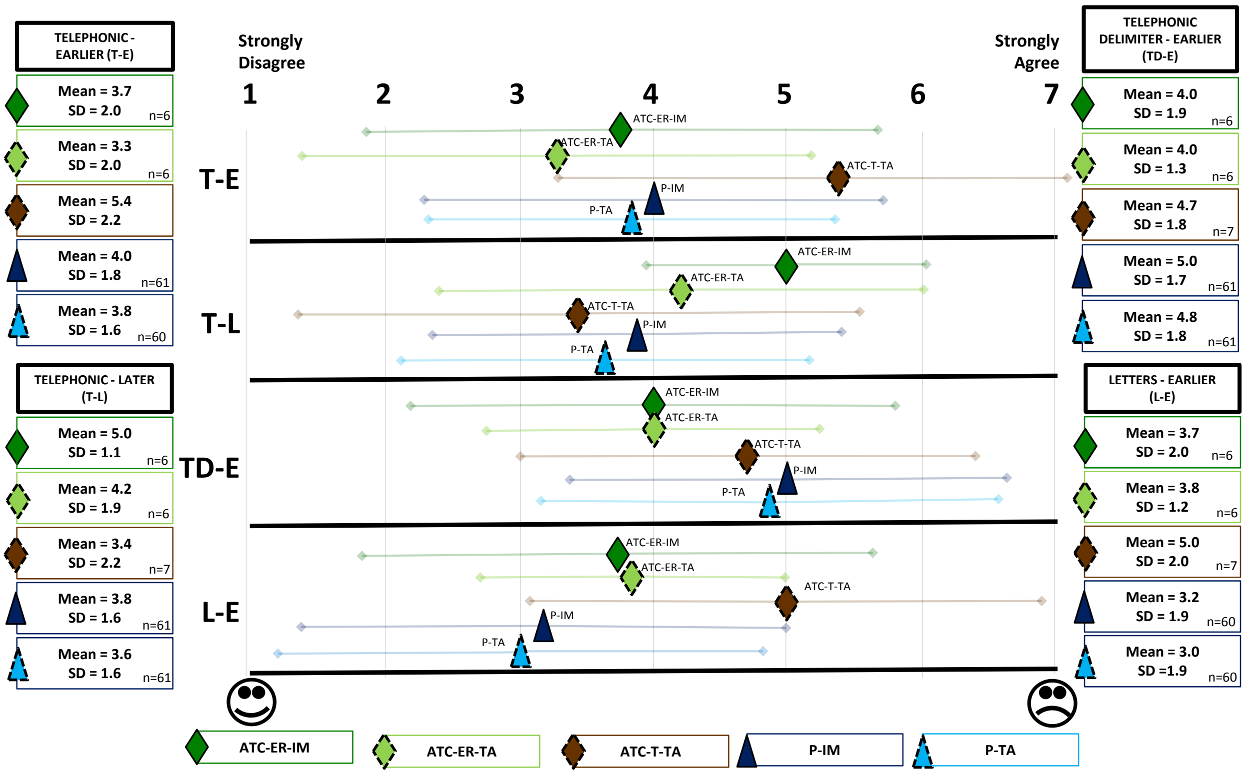

Figure 5-31. Participant replies to “I think the third party call sign format has the potential for controller errors.”

For IM, en route controller replies are all around the neutral point but may suggest that the T-L alternative will have more errors. Terminal controller replies indicate they may expect less errors from controllers using the T-L alternative, but more errors from the controller using the T-E alternative.

For pilots, the repeated measures MANVOA found a significant main effect for TPCS Alternative [$\Lambda = 0.54$, $F(3,56) = 16.00$, $p < 0.001$] and Operation [$\Lambda = 0.90$, $F(1,58) = 6.57$, $p = 0.013$] (Figure 5-32). The pairwise comparisons for TPCS Alternatives revealed that pilots found L-E significantly less likely to have controller errors than T-E [$t(59) = -3.19$, $p = 0.002$] and T-L [$t(59) = -2.67$, $p = 0.010$]. It also revealed that pilots found TD-E significantly more likely to have controller errors than T-E [$t(59) = 3.36$, $p = 0.001$], T-L [$t(59) = 4.57$, $p < 0.001$], and L-E [$t(59) = 6.99$, $p < 0.001$]. No significant difference in the potential for pilot errors was found for T-E as compared to T-L. The pairwise comparison for Operation revealed that pilots found IM to be significantly more likely to have controller errors than TA [$t(61) = 2.69$, $p = 0.009$].

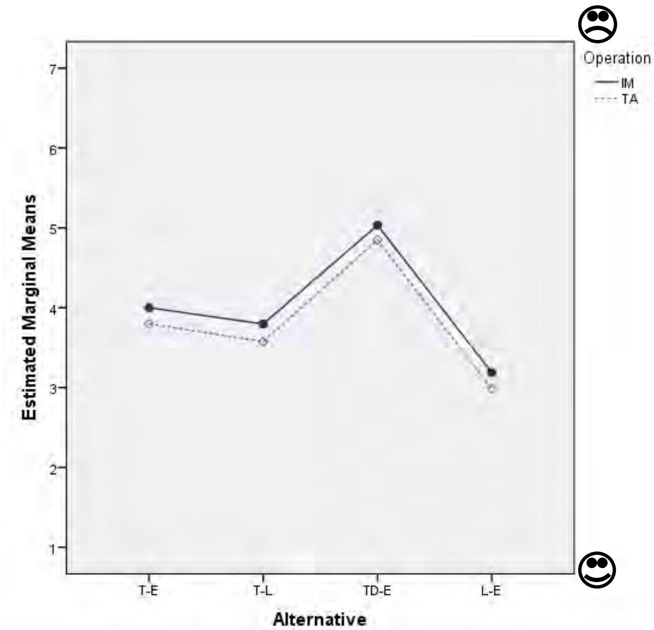

Figure 5-32. Pilot estimated marginal means for "I think the third party call sign format has the potential for controller errors."

In the post scenario questionnaires, pilots were asked "Did you observe any errors made by ATC related to call signs?" As shown in Figure 5-33, several pilots reported hearing errors. Pilots reported issues such as using the wrong format, use of the wrong TPCS (e.g., wrong TPA, transposing numbers, wrong airline), and stumbling on the proper TPCS alternative. The T-L alternative appears to be where pilots observed the fewest ATC errors related to TPCS. Several (7/31; 23%) pilots who reported "yes" for TD-E noted that, as with pilot errors, the use and insertion of the delimiter term "reference" was an issue for controllers. Some pilots reported that while there were some errors, they were corrected.

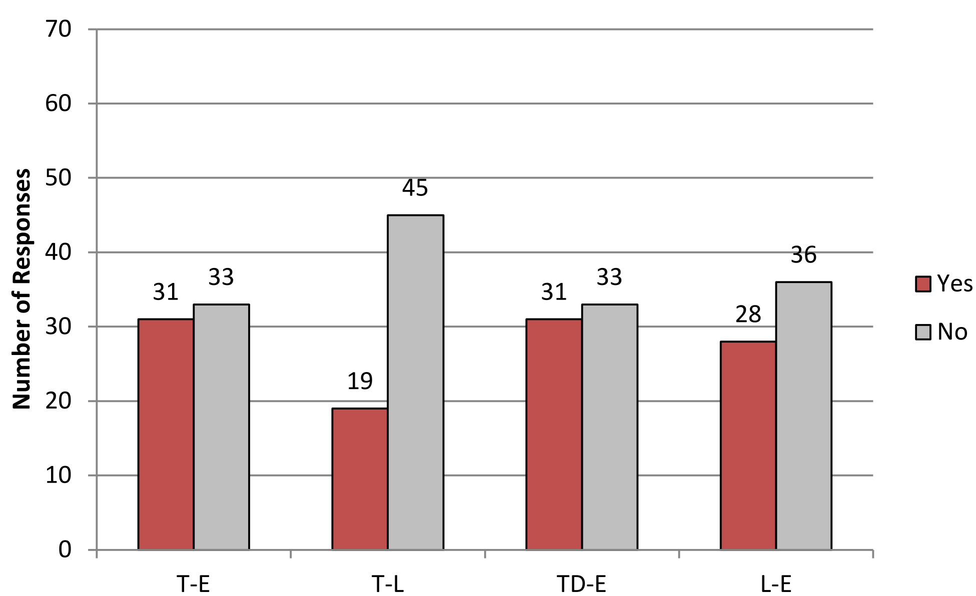

Figure 5-33. Pilot participant replies to "Did you observe any errors made by ATC related to call signs?"

In the post-scenario questionnaire, controllers were asked: "Did you ever experience confusion about who you were talking to vs. who you were talking about?" Similarly, pilots were asked "Did you ever experience confusion about whether your aircraft was being talked to (i.e., receiving an ATC communication) vs. talked about (i.e., being addressed as a third party aircraft)?" (Figure 5-34 and Table 5-9). The results suggest that controllers seemed to have reported more issues on this confusion than pilots as a proportion of responses. Trends indicate that for en route controllers, the T-E alternatives may have caused more self-reported confusion than T-L and TD-E. Terminal controllers reported the most confusion with T-E and the least with TD-E. Across all alternatives, the vast majority of pilots did not report being confused. The summary data in Table 5-9 may indicate that the L-E alternative caused the least confusion for pilots. When combining responses from all participants, the T-E alternative had about twice the reports of confusion as compared to the L-E alternative.

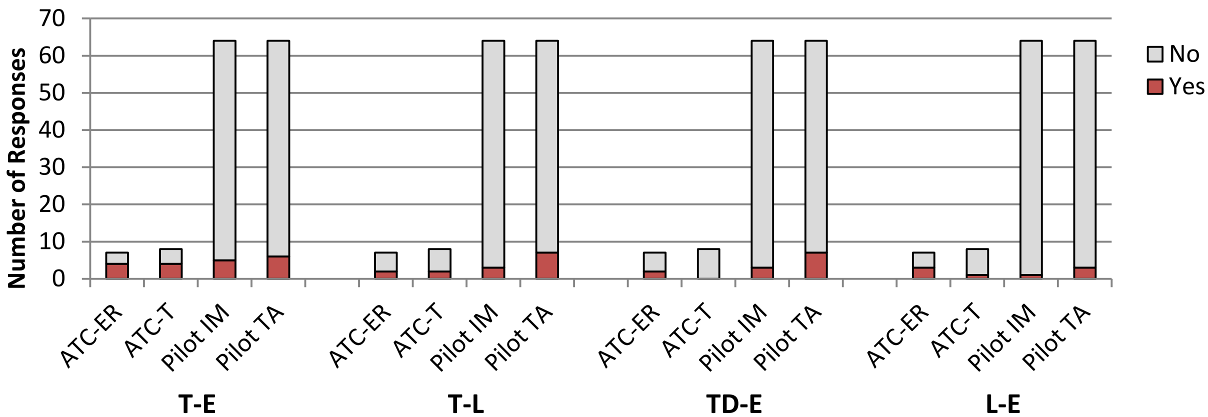

Figure 5-34. Participant replies to whether they experienced confusion about who was being talked to versus talked about

Table 5-9. Response Counts for whether participants experienced confusion about who was being talked to versus talked about

Alternative	Participant	Yes	No
T-E	ATC-ER	4	3
	ATC-T	4	4
	Pilot IM	5	59
	Pilot TA	6	58
T-L	ATC-ER	2	5
	ATC-T	2	6
	Pilot IM	3	61
	Pilot TA	7	57
TD-E	ATC-ER	2	5
	ATC-T	0	8
	Pilot IM	3	61
	Pilot TA	7	57
L-E	ATC-ER	3	4
	ATC-T	1	7
	Pilot IM	1	63
	Pilot TA	3	61

Pilots were asked to indicate their level of agreement with the following statement: "The third party call sign format caused confusion when trying to find the aircraft on the CDTI" (Figure 5-35 and Table 5-10).

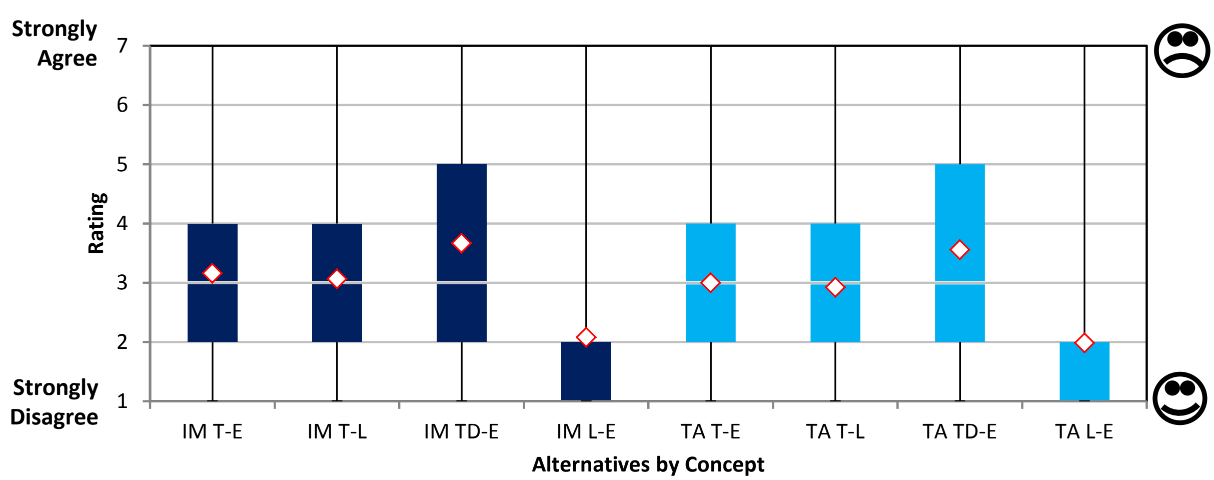

Figure 5-35. Pilot responses to "The third party call sign format caused confusion when trying to find the aircraft on the CDTI."

Table 5-10. Means and Standard Deviations for "The third party call sign format caused confusion when trying to find the aircraft on the CDTI."

Alternative	Operation	Mean (SD)	Missing
T-E	IM	3.2 (1.6)	1
	TA	3.0 (1.5)	1
T-L	IM	3.1 (1.6)	1
	TA	2.9 (1.6)	1
TD-E	IM	3.7 (1.8)	1
	TA	3.6 (1.8)	1
L-E	IM	2.1 (1.4)	1
	TA	2.0 (1.4)	1

For pilots, the repeated measures MANVOA found a significant main effect for TPCS Alternative [$\Lambda = 0.61$, $F(3,60) = 12.61$, $p < 0.001$] (Figure 5-36). The pairwise comparisons revealed that pilots found L-E significantly less confusing than T-E [$t(62) = -4.42$, $p < 0.001$] and T-L [$t(62) = -4.29$, $p < 0.001$]. It also revealed that pilots found TD-E significantly more confusing than T-E [$t(62) = 2.61$, $p = 0.011$], T-L [$t(62) = 3.47$, $p = 0.001$], and L-E [$t(62) = 6.18$, $p < 0.001$]. No significant difference in confusion was found for T-E as compared to T-L.

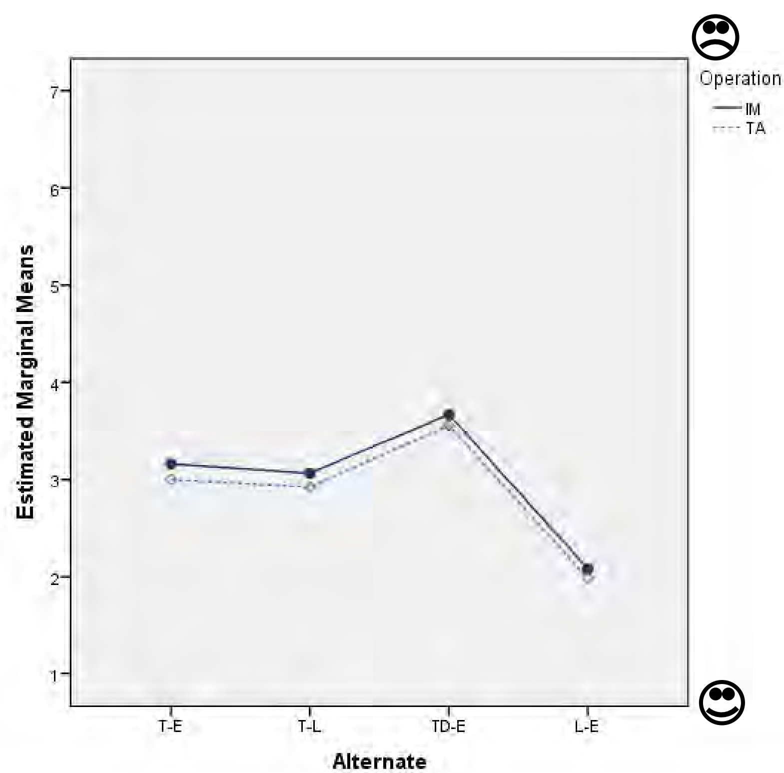

Figure 5-36. Pilot estimated marginal means for "The third party call sign format caused confusion when trying to find the aircraft on the CDTI."

Participants were asked “Are there call sign problems that exist in today’s environment that would be exacerbated by one of the third party call sign formats?” (Figure 5-37 and Table 5-11). Across all participants there were mentions of issues with non-native English speakers potentially having difficulties and also issues with similar sounding call signs.

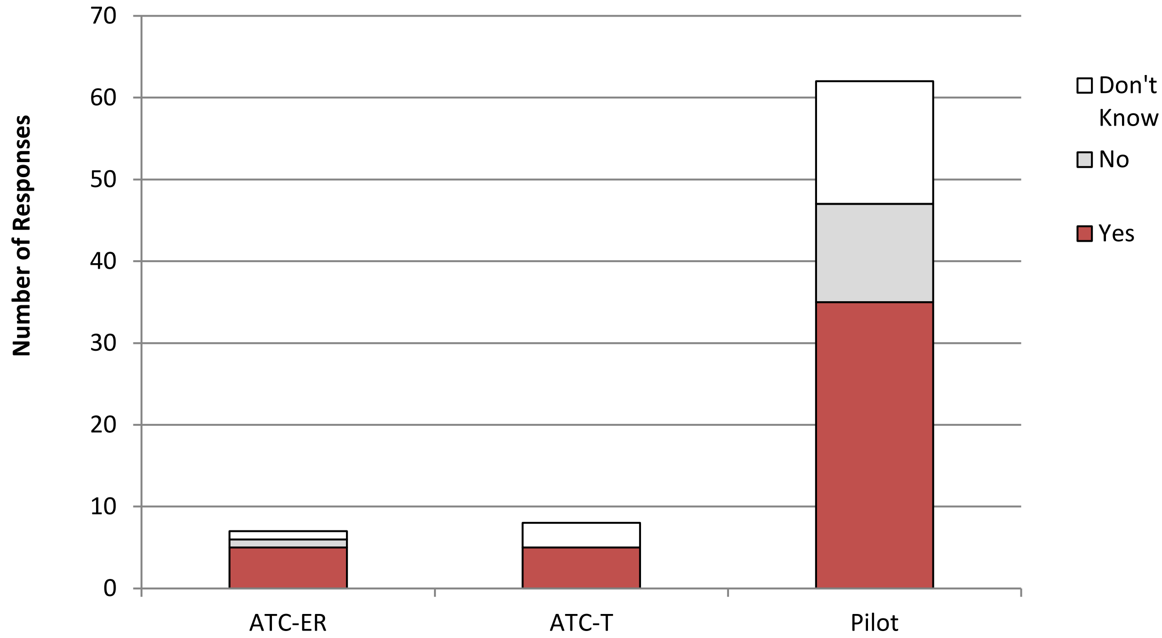

Figure 5-37. Participant replies to “Are there call sign problems that exist in today’s environment that would be exacerbated by one of the third party call sign formats?”

Table 5-11. Response Counts for “Are there call sign problems that exist in today’s environment that would be exacerbated by one of the third party call sign formats?”

Participant	Yes	No	Don’t Know	Missing
ATC-ER	5	1	1	0
ATC-T	5	0	3	0
Pilot	35	12	15	2

Participants were asked a follow-on question: “Which format, if any, exacerbates the problem?” Participants were allowed to choose more than one option (Figure 5-38). Controller opinions were varied; however, no terminal controllers reported that the T-L alternative would exacerbate the current day problem. Pilots had the most responses for the TD-E alternative, indicating that it is the alternative that will most exacerbate any current day problems.

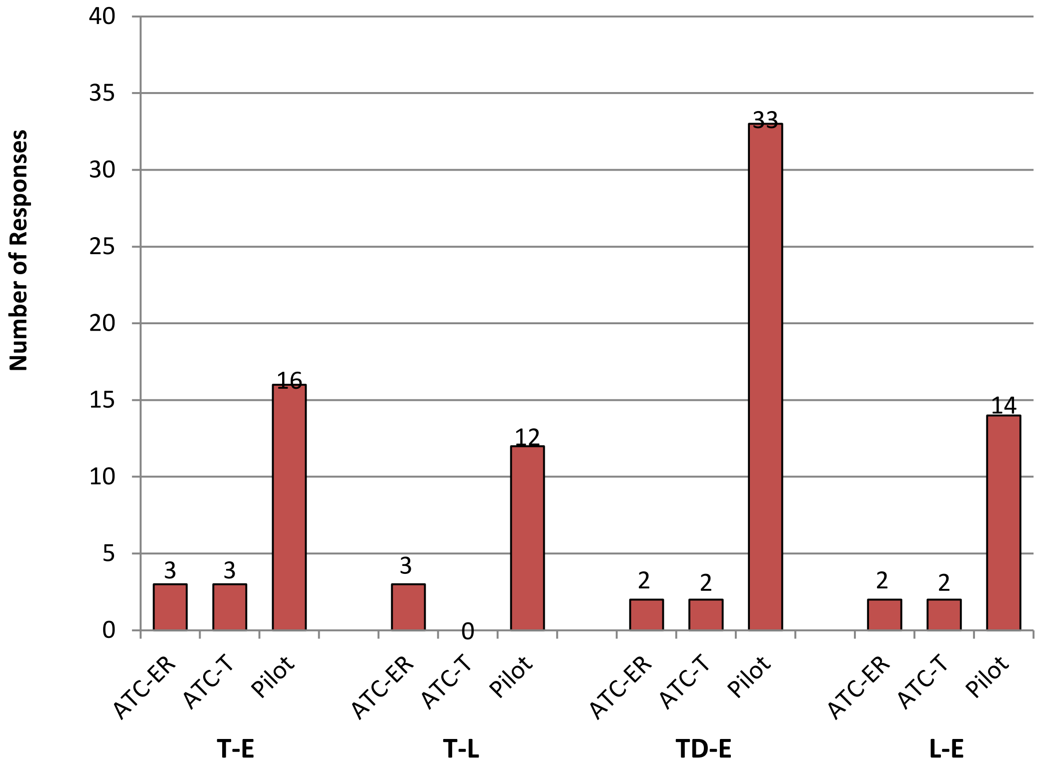

Figure 5-38. Participant replies to "Which format, if any, exacerbates the problem?"

Other TPCS Topics

Controller participants were asked "Does traffic density affect your acceptability of the third party call sign format?" (Figure 5-39). As can be seen, all en route (6/6 [1 controller did not answer]; 86%) and terminal (7/7 [1 controller did not answer]; 88%) controllers that answered reported that density affected the acceptability of the TPCS alternative. As would be expected, most comments said that as traffic density increases, the available frequency time decreases.

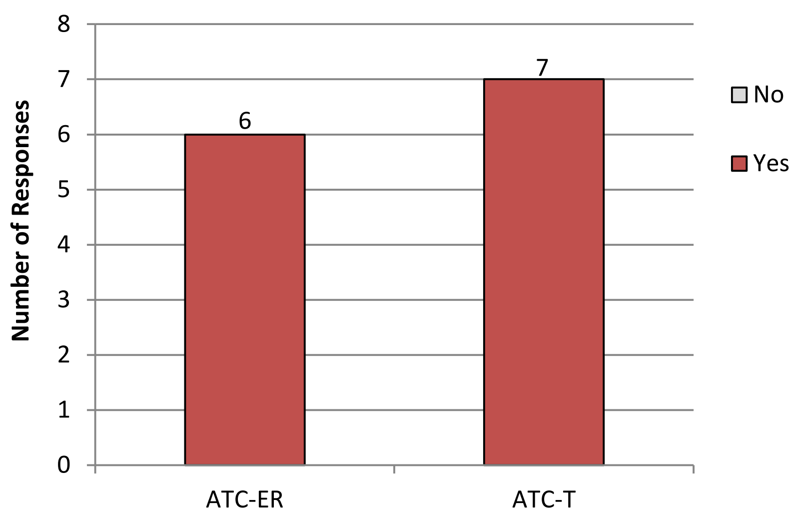

Figure 5-39. Controller participant replies to "Does traffic density affect your acceptability of the third party call sign format?"

In the post scenario questionnaires, pilots were asked “Did your crew ever have to reference your call sign reference document?” (Figure 5-40 and Table 5-12). As can be seen, the call sign reference was used more often than not for all the alternatives except L-E. It is interesting to note that some pilots continued to use the document for the L-E alternative.

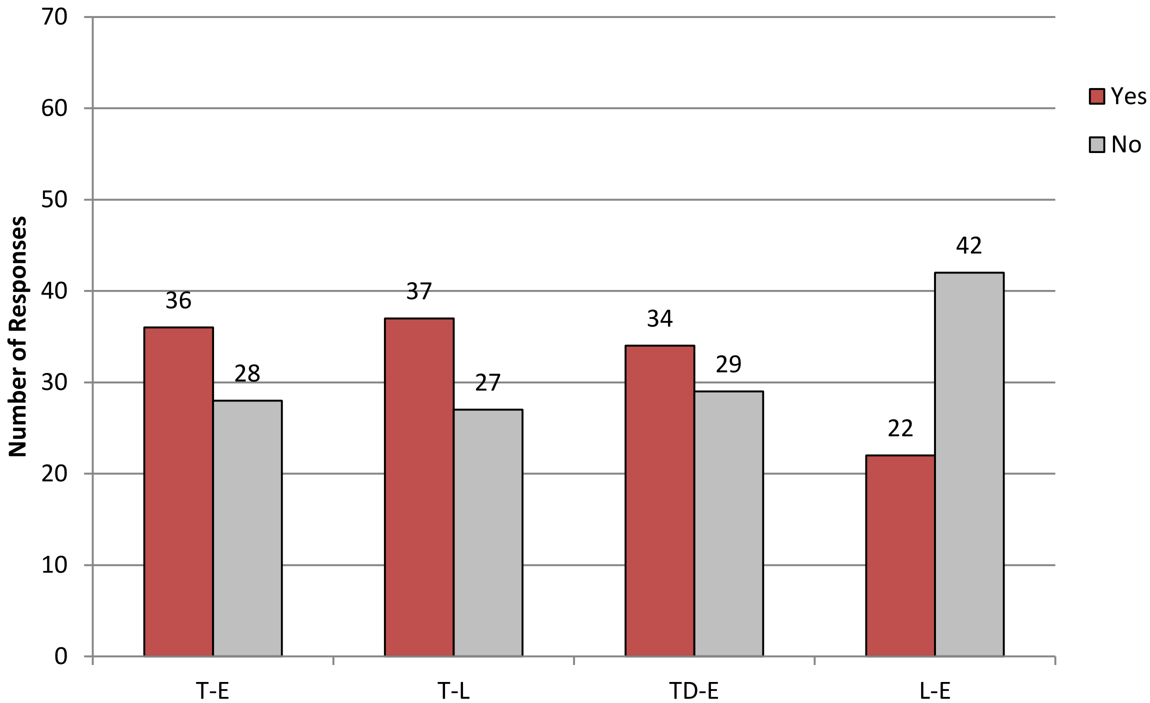

Figure 5-40. Pilot responses to “Did your crew ever have to reference your call sign reference document?”

Table 5-12. Response Counts for “Did your crew ever have to reference your call sign reference document?”

Alternative	Yes	No	Missing
T-E	36	28	0
T-L	37	27	1
TD-E	34	29	0
L-E	22	42	1

Pilots were asked a follow-on question: “Was that acceptable?” (Figure 5-41). For T-E, T-L, and TD-E, there is a mix of responses but all have mostly “yes” replies followed by missing replies, “no” replies, and finally “don’t know.” The L-E option where less use of the call sign reference document would be expected has more missing replies followed by “yes” replies. As can be seen overall, the use of a call sign reference document, under the various conditions, appears to be unacceptable to the minority of pilots across all alternatives (38/256; 15%). While it generally appears acceptable, pilots did report some concerns about having to look at the document. Some pilots comments noted that those concerns appeared to lessen (and become more acceptable because of less references) as the pilots got more familiar with the call signs.

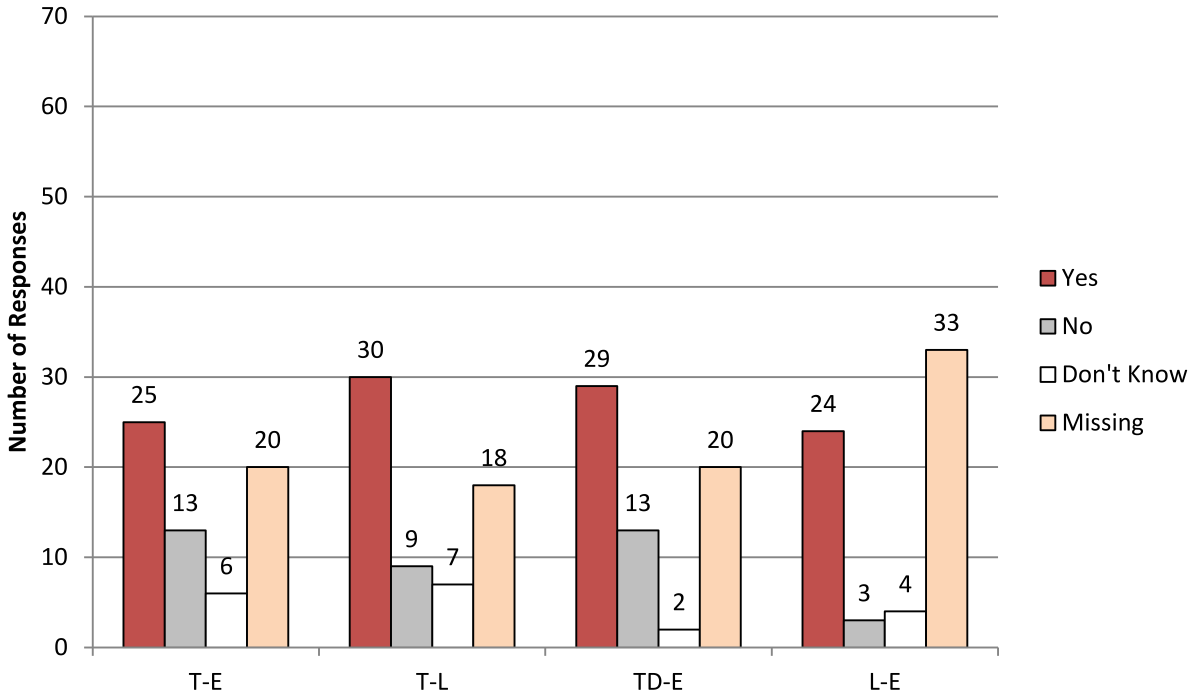

Figure 5-41. Pilot responses to whether it was acceptable to reference the third party call sign document.

5.1.2.3 Recommendations for TPCS

Participants were asked "If you found any of the third party call sign formats unacceptable, do you think that some changes could make them acceptable?" (Figure 5-42 and Table 5-13). En route controller replies were mixed but the T-L format seemed to be favored most. A majority (4/7; 57%) reported that the T-L alternative would be acceptable with changes, and 29% (2/7) reported it was acceptable as tested. but no specific recommendations were made. Terminal controller replies seem to indicate that the T-L was acceptable as tested. The majority (5/8; 63%) reported that the TD-E and L-E alternatives would not be acceptable with any changes. Pilot replies indicate that the L-E alternative was favored most with 84% (52/62) either saying it was acceptable as tested or would be acceptable with changes. It should be noted that while the T-E, T-L, and L-E options all had more "yes" and "acceptable as tested" replies, there were still several "no" replies. The most problematic could be the number of "no" replies from the terminal controller for the L-E option based on the number of positive pilot replies. The TD-E seemed to be the least favored with the majority (34/62; 55%) of pilot replies indicating that it could not be acceptable even with changes.

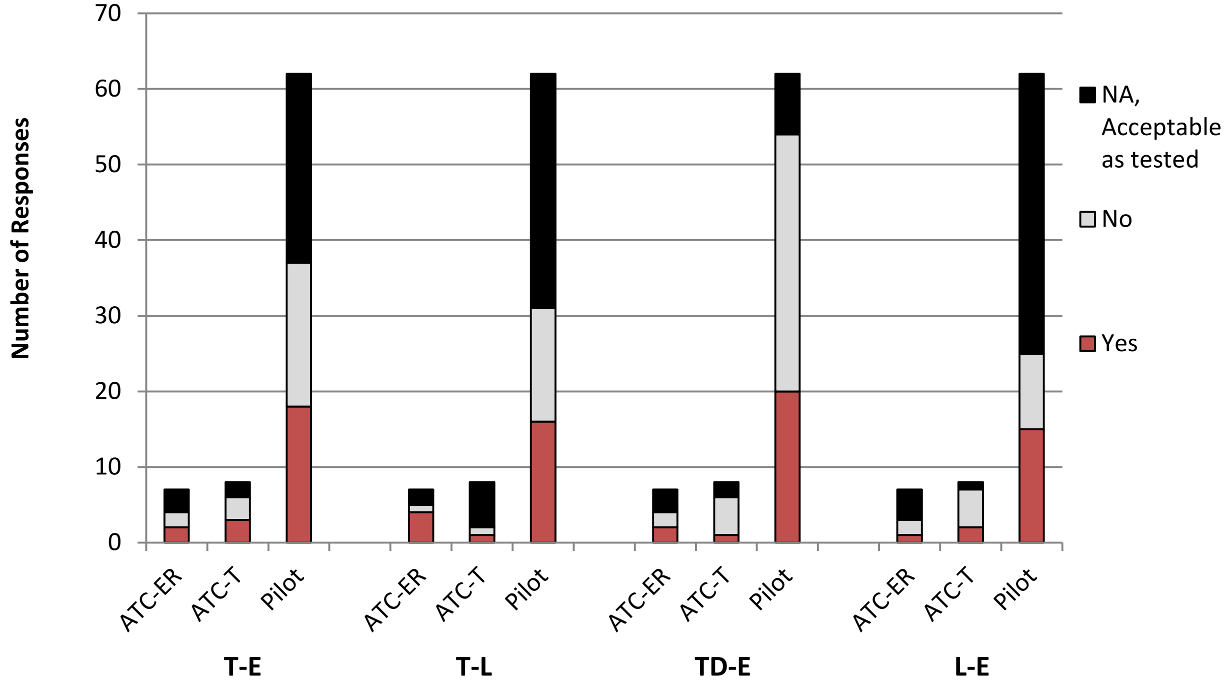

Figure 5-42. Participant replies to "If you found any of the third party call sign formats unacceptable, do you think that some changes could make them acceptable?"

Table 5-13. Response Counts for "If you found any of the third party call sign formats unacceptable, do you think that some changes could make them acceptable?"

Alternative	Participant	Yes	No	NA, Acceptable as tested	Missing
T-E	ATC-ER	2	2	3	0
	ATC-T	3	3	2	0
	Pilot	18	19	25	2
T-L	ATC-ER	4	1	2	0
	ATC-T	1	1	6	0
	Pilot	16	15	31	2
TD-E	ATC-ER	2	2	3	0
	ATC-T	1	5	2	0
	Pilot	20	34	8	2
L-E	ATC-ER	1	2	4	0
	ATC-T	2	5	1	0
	Pilot	15	10	37	2

Participants were asked “Would you recommend against using any of the formats in the real world?” (Figure 5-43 and Table 5-14). As can be seen, the majority of participants recommended against using one of the alternatives.

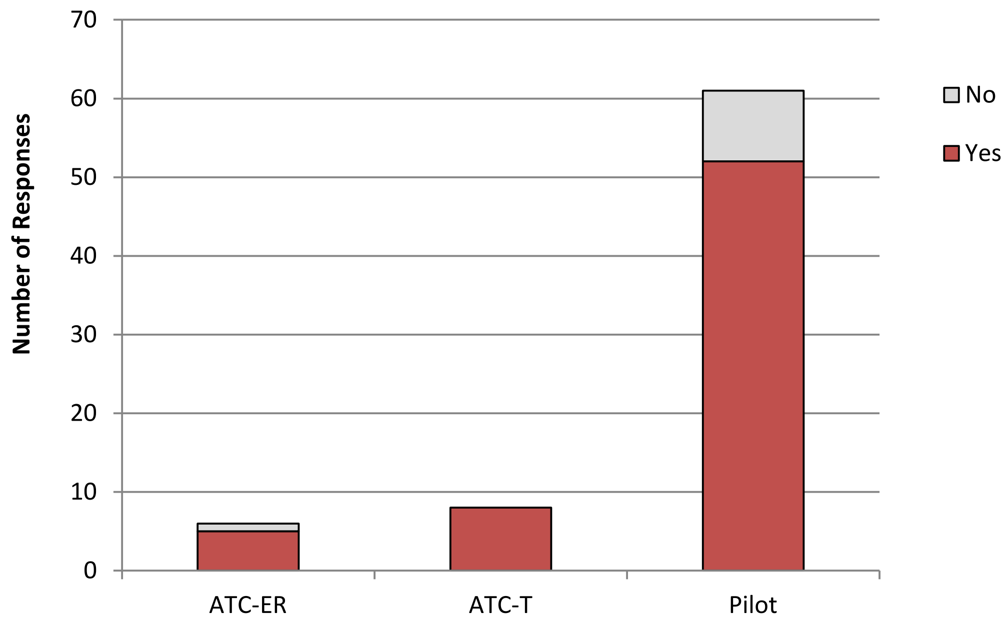

Figure 5-43. Participant replies to “Would you recommend against using any of the formats in the real world? If yes, please choose a format you recommend against using?”

Table 5-14. Response Counts for “Would you recommend against using any of the formats in the real world?”

Participant	Yes	No	Don’t Know	Missing
ATC-ER	5	1	1	0
ATC-T	8	0	0	0
Pilot	52	9	1	2

Participants were then asked to “choose a format you recommend against using.” Participants were allowed to choose more than one option (Figure 5-44). As can be seen, the most (44/90; 49%) responses were seen in recommendations against the TD-E alternative. The TD-E alternative was also reflected most in both controller replies (although it was equal to the T-E alternative for the en route controllers). The fewest (10/90; 11%) responses from all participants were seen for the T-L alternative indicating a preference for that alternative.

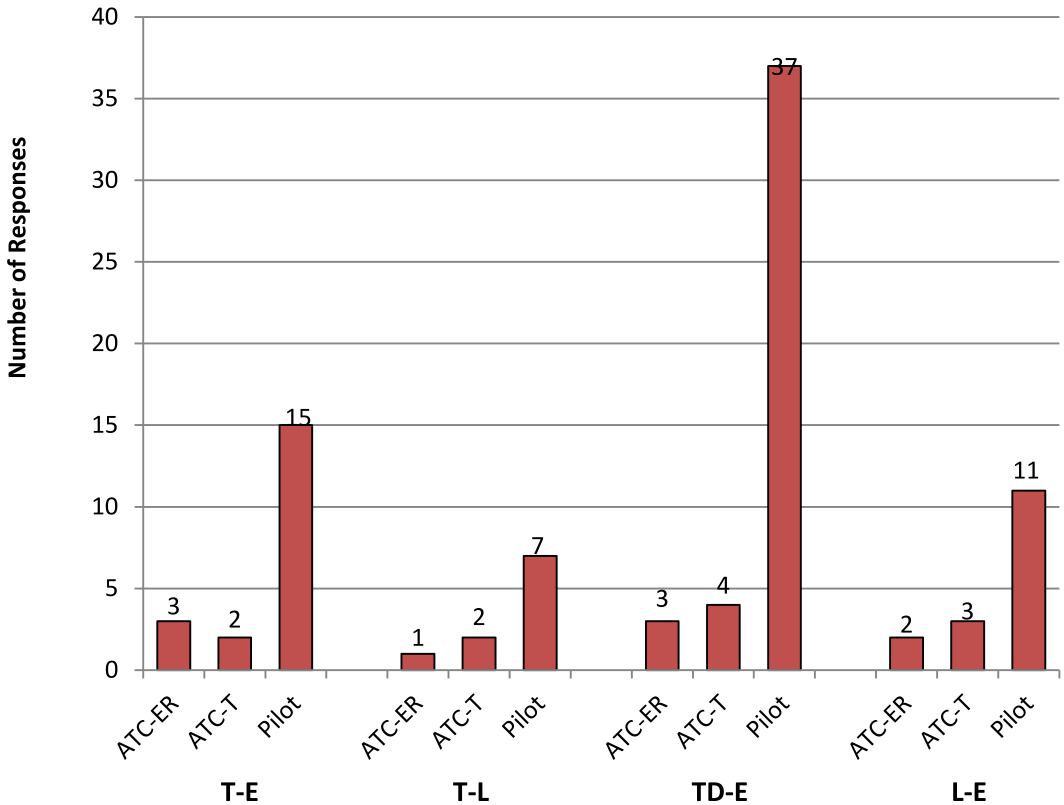

Figure 5-44. Participant replies to "choose a format you recommend against using"

Participants were asked "Do you believe there is a logical location within a communication for the third party call sign?" (Figure 5-45 and Table 5-15). Three of the four (75%) en route controllers that replied "yes" said later. Six of the seven (86%) terminal controllers that replied "yes" said later (one said earlier or later). Only one (14%) said earlier. Some pilots did not reply and some gave unclear answers. Of the pilot replies that had a clear comment for the location (25/44), the majority (14/25; 56%) preferred it being late in the communication, while 36% (9/25) preferred early and 8% (2/25) preferred in the middle. Therefore, as seen with the question on TPCS position acceptability within the communication, position of TPCS within the communication may depend on other factors such as format.

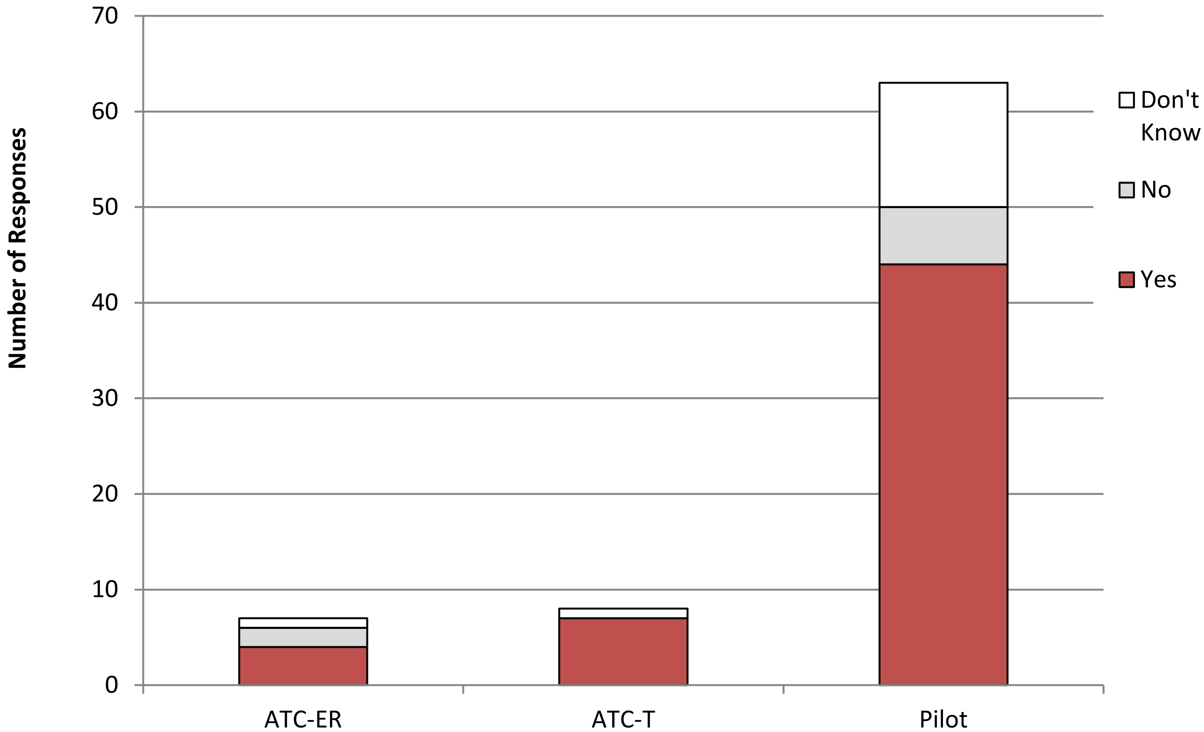

Figure 5-45. Participant replies to "Do you believe there is a logical location within a communication for the third party call sign?"

Table 5-15. Response Counts for "Do you believe there is a logical location within a communication for the third party call sign?"

Participant	Yes	No	Don't Know	Missing
ATC-ER	4	2	1	0
ATC-T	7	0	1	0
Pilot	44	6	13	1

Participants were asked "If delimiters were used to convey third party call signs, would you recommend keeping 'Reference' as the delimiter term? If no, do you have another recommendation?" Responses are shown in Figure 5-46 and Table 5-16. The majority (45/77 [2 responses were missing]; 58%) of participants did not recommend keeping the term "reference" for the delimiter term, if delimiters were used. Of the controllers (8/15; 53%) that chose "no" to keeping "reference," three commented and suggested "traffic." Pilots had limited recommendations but "flight" was mentioned twice and "traffic," "target," and "ID" were each mentioned once. Some of the pilots that chose "no" simply said do not use delimiters at all.

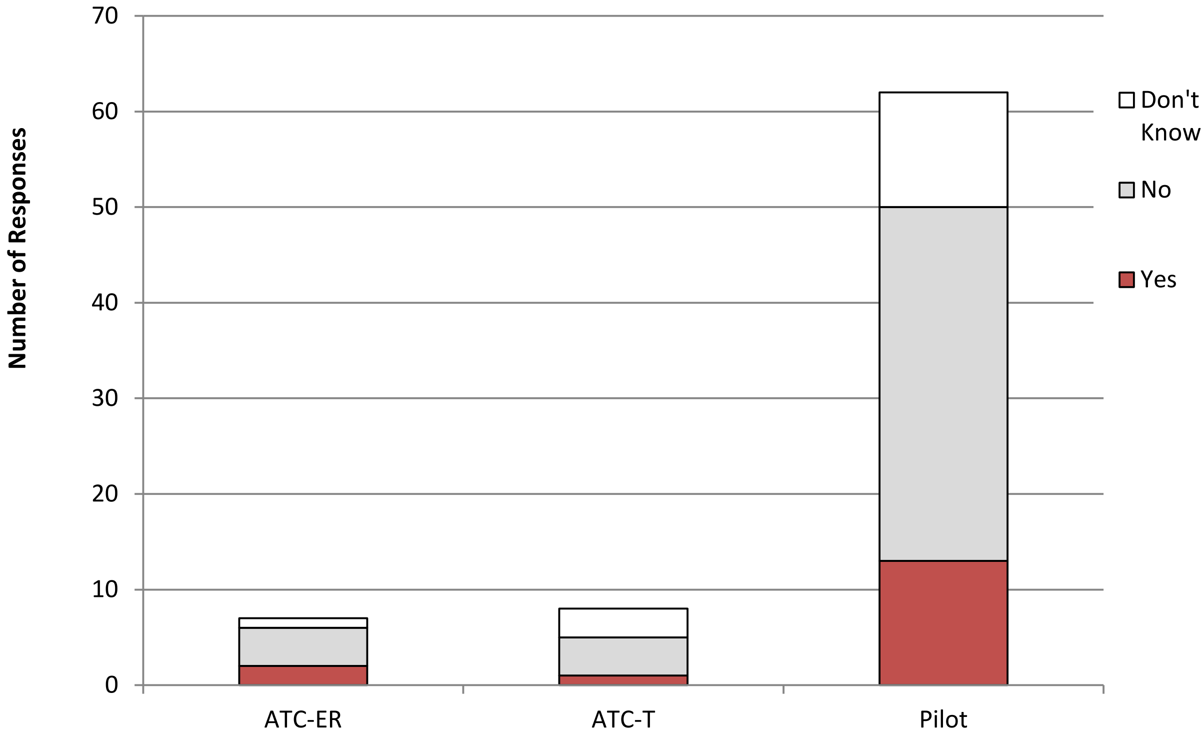

Figure 5-46. Participant replies to "If delimiters were used to convey third party call signs, would you recommend keeping 'Reference' as the delimiter term?"

Table 5-16. Response Counts for "If delimiters were used to convey third party call signs, would you recommend keeping 'Reference' as the delimiter term?"

Participant	Yes	No	Don't Know	Missing
ATC-ER	2	4	1	0
ATC-T	1	4	3	0
Pilot	13	37	12	2

Participants were asked "With the introduction of third party call sign into the traffic advisory and the ability of pilots to see the third party call sign on the traffic display, do you believe other elements of the traffic advisory could be removed?" Responses are shown in Figure 5-47 and Table 5-17. It appears that most controllers (13/15; 87%) and most pilots (39/61 [3 responses were missing]; 64%) are receptive to some reduction in traffic advisory information. "Aircraft type" had the most replies.

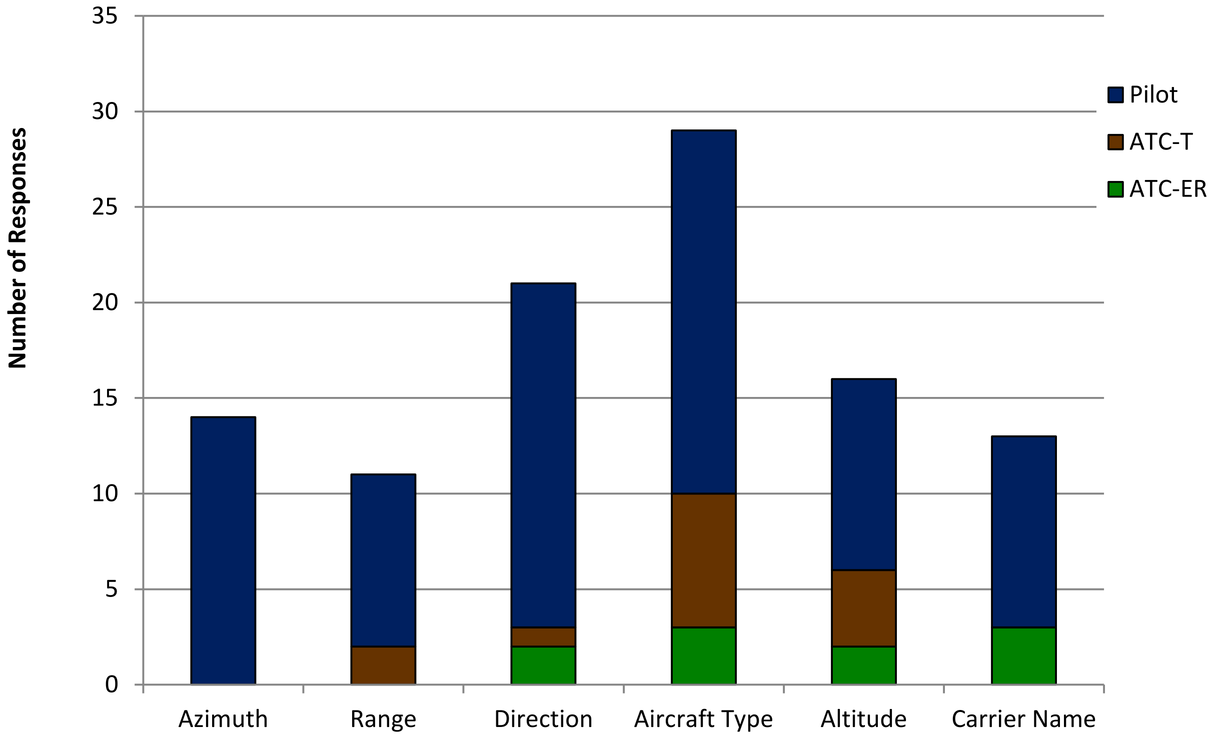

Figure 5-47. Participant replies to "With the introduction of third party call sign into the traffic advisory and the ability of pilots to see the third party call sign on the traffic display, do you believe other elements of the traffic advisory could be removed?"

Table 5-17. Frequencies for "With the introduction of third party call sign into the traffic advisory and the ability of pilots to see the third party call sign on the traffic display, do you believe other elements of the traffic advisory could be removed?"

Participant	Azimuth	Range	Direction	Aircraft type	Altitude	Carrier Name
ATC-ER	0	0	2	3	2	3
ATC-T	0	2	1	7	4	0
Pilot	14	9	18	19	10	10

5.1.2.4 Subjective Results Trends

Table 5-18 shows a summary of the statistical test outcomes for all the participants. Most results are related to TPCS alternative, with a limited number for IM versus TA operations. As has been noted previously, significant results from controller participants were only seen in one test. However, many pilot results demonstrated statistical significance. Across the set of subjective results, it can be seen that pilots generally preferred the L-E alternative more, preferred the TD-E alternative less, and were generally indifferent when comparing between T-E and T-L.

Table 5-18. Summary of Statistical Test Results across Subjective Data

	Alternative																		Operation		
	Pilot						ATC - ER						ATC - T						Pilot	ATC - ER	ATC - T
	T-E to T-L	L-E to T-E	L-E to T-L	TD-E to T-E	TD-E to T-L	TD-E to L-E	T-E to T-L	L-E to T-E	L-E to T-L	TD-E to T-E	TD-E to T-L	TD-E to L-E	T-E to T-L	L-E to T-E	L-E to T-L	TD-E to T-E	TD-E to T-L	TD-E to L-E	IM to TA	IM to TA	IM to TA
My overall workload was acceptable					First worse	First worse															
I was able to understand pilot readbacks (ATC comms) of third party call sign.			First better	First worse		First worse															
The third party call sign position within the communication was acceptable.				First worse	First worse	First worse															
The third party call sign acceptability is affected by its position																			First better	First better	
The length of the communication that included third party call sign was acceptable.				First worse	First worse	First worse															
I was able to sufficiently communicate the third party call sign using the format.		First better	First better	First worse	First worse	First worse															
I think the third party call sign format has the potential for pilot errors.		First better	First better	First worse	First worse	First worse													First better		
I think the third party call sign format has the potential for controller errors.		First better	First better	First worse	First worse	First worse															
The third party call sign format helped me find the aircraft on the CDTI.		First better	First better		First worse	First worse															
The third party call sign format caused confusion when trying to find aircraft on the CDTI.		First better	First better	First worse	First worse	First worse															
The third party call sign format would be acceptable overall in line operations.		First better	First better	First worse	First worse	First worse															
If you found any of the third party call sign formats unacceptable, do you think that some changes could make them acceptable?																					
Rank each format, in order of preference, for communicating third party call sign.		First better	First better	First worse	First worse	First worse															

Significant result- First better

Significant result - First worse

No significance

For controllers, slight trends on an individual question basis can be more revealing when looked at across the full set of questions. When looking at trends reported in the results across the 15 questions where participants compared and contrasted the TPCS alternatives, larger trends are revealed. Figure 5-48 and Table 5-19 show the number of times that a TPCS alternative was noted to be relatively better or worse than one or more alternatives. Across controllers, the TD-E alternative was noted most often as being the less favorable alternative. The T-L alternative was noted most often as being more favorable.

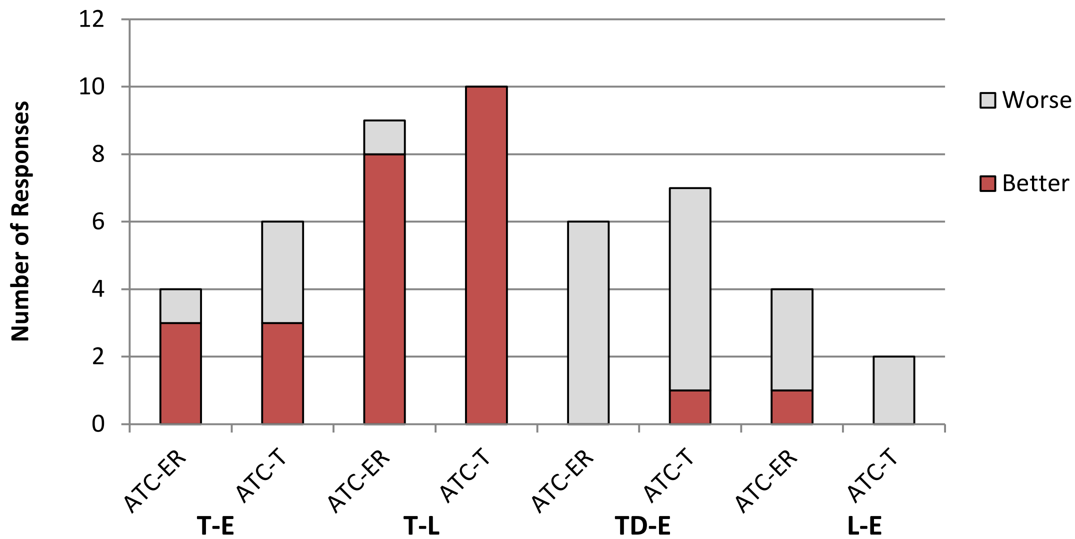

Figure 5-48. TPCS Alternative Participant Response Trends across Reported Questions

Table 5-19. Response Counts for TPCS Alternative Participant Response Trends across Reported Questions

Alternative	Participant	Better	Worse
T-E	ATC-ER	3	1
	ATC-T	3	3
	All	6	4
T-L	ATC-ER	8	1
	ATC-T	10	0
	All	18	1
TD-E	ATC-ER	0	6
	ATC-T	1	6
	All	1	12
L-E	ATC-ER	1	3
	ATC-T	0	2
	All	1	5

5.1.2.5 Simulation

Participants were asked to indicate their level of agreement with the following statement: "The overall simulation was effective as a context for evaluating different ways to convey third party call sign." En route (m = 6.3; SD = 0.8) and terminal (m = 6.6; SD = 0.5) controllers all agreed. Pilots generally agreed (m = 5.9; SD = 1.2; n = 62). Of the only four pilots (6%) who disagreed, two commented about the limitations of the lower fidelity cockpit simulator. Sharing the mouse was stated as a concern here and in the question about whether anything artificially affected the simulation for the evaluation.

5.2 Voice Communication Transcript Analysis

In order to examine the objective performance of each of the alternatives, all of the frequency audio was recorded and analyzed for notable events and errors. The following sections describe the data reduction process and error analysis results.

5.2.1 Voice Transcript Data Reduction

During data collection, individual channel recordings were made with push-to-talk logs. An individual voice communication file, in .wav format, was stored for each scenario (1-4), for each frequency (en route and terminal), for each day, totaling 8 recordings per day, 64 recordings in total. At the completion of data collection, these recordings were sent to an external vendor for transcription through a secure file transfer procedure. A letter of agreement was put in place with this vendor for procedures to maintain data security and privacy. The specific reduction instructions to the vendor are included in Appendix E.

Once the transcribed text files were received back from the vendor, the files were imported into an Excel worksheet. The data was formatted in the spreadsheet to accommodate formulas that calculated message duration, message lag, notable event and error types, counts specific to aircraft/participant, and attribute columns.

After the initial transcription data was placed into the spreadsheet and formatted, and formulas were updated, a search for negative lag values and for exceptionally large values was initiated. Negative lag values indicated possible areas of blocked or simultaneous transmissions, while exceptionally large lag values (values over 40 seconds) could sometimes indicate potential areas of missed transcription. The roles and call signs, based upon the transcribed text, were then manually entered into the appropriate columns.

Once the initial data was organized, each audio file was listened to in its entirety. The transcribed text was compared to the original audio file, as were attributes such as aircraft IDs and participant numbers. Additional message attributes, specific to the study (whether the message was an IM clearance or a TA) were also entered.

Following the audio file review, transaction numbers, transmission counts, and other attributes were entered. Transaction codes were then added to identify if the message was a first party or third party transaction.

The transcribed text of each IM and TA message was then reviewed. If an event was identified, an event code was entered, along with any transmission attributes. The number of message elements was then counted and added to the sheet.

After each worksheet was completely reviewed and all attributes were entered, any notes specific to that scenario and group of participants were also captured. These included interesting or unusual errors and possible explanations. Any exceptional cases of communications were also identified and captured for possible further case study. Following this, an automated script was developed that produced output tables of event occurrences based on desired transaction and transmission attributes. These attributes, as well as Communication Event Classifications, are defined in the next section.

5.2.2 Transaction and Transmission Attributes

The transcripts were reviewed for IM and TA communications. Individual messages were identified as transmissions. Sets of transmissions between participants on a specific operation or event were grouped into transactions. Each transaction was analyzed and manually coded with pre-defined attributes as shown in Table 5-20. Attribute details follow the table.

Table 5-20. Transaction Attributes

Transaction Attributes	Possible Values
Transaction Type	• IM • TA
Call Sign Type	• Intuitive (INT) • Non-Intuitive (NI)
Intended Recipient (from ATC)	• Participant Pilot • Pseudopilot
Pseudopilot Interference	• Yes • No
Combined Clearance	• Yes • No

Transaction Type

When a communications transaction was related to an IM operation (occurred in the en route environment only), it was coded as IM. When a communications transaction was related to a TA message (occurred in both en route and terminal), it was coded as TA.

Non-Intuitive

As described in Section 4.3.3, a set of non-intuitive call signs were generated and used for en route TAs in order to examine the impacts of the TPCS formats on communications that involve call signs that are not known to the pilots. When a communications transaction involved an aircraft with a non-intuitive call sign, it was coded “NI”. All other call signs were relatively common, and it was assumed that participants could reasonably infer them from their airline three letter designator (e.g., UAL = United) or infer the designator from the spoken call sign.

Intended Recipient

For all ATC communications transactions that involved a TA or IM operation, an intended pilot recipient for the ATC communication was assigned (either “Pseudo” or “Participant”).

Pseudopilot Interference

An attribute code of "Interference" was assigned to any instances where the intended recipient of the original ATC TA or IM communication was a participant pilot, but a pseudopilot intercepted the communication by mistake. The purpose of this attribute was to note instances where failure to reply (by the participant) or confusion from the initial (incorrect) readback by the pseudopilot may have influenced follow-on communications.

Combined Clearances

An attribute of "Combined" was assigned for communications transactions where ATC paired additional clearances or information, not related to the original TA or IM, with an original TA message or IM clearance. This typically occurred in the terminal environment, where the terminal controller would sometimes include a vector or altitude instruction with a TA message.

Attributes for items related to each transmission, such as communication type, events (non-standard phraseology, questions, or TPCS format problems), or alternative TPCS formats used were also captured for each transmission. These transmission attributes are summarized in Table 5-21. Attribute details follow the table.

Table 5-21. Transmission and Event Attributes

Transmission / Event Attributes	Possible Values
Event Classification	• A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P
Transmission Type	• Initial Clearance / Initial Advisory (ATC) • Readback (Pilot / Pseudo) • Readback 2, 3, etc. (Pilot / Pseudo) • Readback Response (ATC) • Readback Response 2, 3, etc. (ATC) • Other Pilot Communication (Pilot / Pseudo) • Other ATC Communication (ATC)
Event Corrected By	• Immediately Self-corrected • Later Self-corrected • FPP or TPP Corrected • Pseudo Corrected • ATC corrected
Portion of Message Involving Event	• FPCS • TPCS • Non-Call Sign • Fix • Interval • Interval Spacing • Report Identified
Event Source	• ATC • FPP Participant • TPP Participant • FPP Pseudo • TPP Pseudo • Recording
Format Used (if different from alternative being tested)	• None • Telephonic • Delimiter • Delimiter Outside • Delimiter Letters • Delimiter Outside Letters • Letters • Letters (modified) • Phonetic

Event Classifications

As described in Section 4.4, controllers and pilots were asked to use specific sets of phraseology that varied slightly between scenarios, depending on the alternative being tested. Occurrences of errors and deviations from the prescribed phraseology were tracked and assigned a letter code indicating the nature of the event. Event codes and examples of each type are below. The portion of the transaction that illustrates the event is italicized.

A. **Reply Failure**: A speaker fails to respond to a TPCS-related message, such as when a flight crew fails to provide a readback for an ATC clearance or message. For example:

> **ATC:** American Eight Ninety Two, traffic one o'clock, three zero miles, eastbound, Dash eight, flight level two one zero, uh, Cactus Eighteen Fifty Six, report identified.
> **AAL892:** *(No response)*

B. **Full Repeat Request**: The listener requests a repeat of the entire message, or just requests a general repeat, without specifying which specific item they need (e.g., "say again, please?"). For example:

> **ATC:** Delta Three Thirty Seven, for interval spacing, traffic is Southwest Four Thirteen, cross PECHY one hundred and forty five seconds behind that traffic.
> **DAL337:** *Delta Three Thirty Seven, please repeat.*
> **ATC:** Delta Three Thirty Seven, for interval spacing, traffic is Southwest Four Thirteen, cross PECHY one hundred and forty five seconds behind that traffic.
> **DAL337:** Traffic is Southwest Four Thirteen, cross PECHY one hundred and forty five seconds behind that traffic, Delta Three Thirty Seven.

C. **Partial Repeat Request**: The listener requests that the speaker repeat a specific portion of the message. For example:

> **ATC:** Delta Two Twenty One, traffic is Air Canada Six Ninety Seven, they'll be at two o'clock, one zero miles, southbound, six thousand, it's a 737, descending, er, excuse me, an MD-80, and, uh, ((unintelligible)).
> **DAL221:** Uh, *repeat the aircraft again*.
> **ATC:** Delta Two Twenty One, traffic is, is Air Canada Six Ninety Seven, at two o'clock, one zero miles, converging, MD-80, report identified.
> **DAL221:** Air Canada Six Thirty Seven identified, Delta Two Twenty One.

D. **Format Utilization**: The speaker uses the wrong format (e.g., uses Telephonic instead of Letters or fails to include the Delimiter term in the TPCS element). Also includes cases format deviations such as putting the delimiter outside of the call sign, the use of a delimiter term other than "reference", the use of the phonetic alphabet to indicate letters, or the failure to use TPCS at all. This event type does *not* include right format / wrong position errors, such as Letters / Later (these are covered under event type "E"). This could also include deviations from current call sign phraseology for FPCS elements.

Examples:

Example 1 (Delimiter Outside):
ATC: Southwest Five Twenty One, for interval spacing, traffic is Delta Two Eighty Two, cross PECHY one two five seconds behind that traffic.
SWA521: *Delta Two Eighty Two reference is identified, cross PECHY one two five seconds behind*.

Example 2 (TPCS failure):
ATC: Southwest Five Twenty One, *<no TPCS>* traffic one o'clock, three zero miles, eastbound, RJ one, one five thousand five hundred, VFR, report identified.
SWA521: Alright, we're looking for traffic, Southwest Five Twenty One.

E. **Element Order Change**: These events include cases where the speaker changes the order of message elements in the communication as compared to standard operating procedures (FAA, 2012b) and the prescribed experimental phraseology. This could be a minor event (such as switching the order of aircraft type and altitude in a TA message), or a more significant event that could directly impact the communication of TPCS. These include right format / wrong position cases.

Example:

(Provided the prescribed alternative is Telephonic Later, this would be a TPCS event, because Cactus Forty Seven Forty One should come before "report identified." Note that SWA521 would also receive an "E" event for their readback communication as they start their message with their FPCS, versus placing it at the end of their message.)
ATC: Southwest Five Twenty One, traffic two o'clock, one five miles, eastbound, Dash eight, flight level two one zero, report identified, uh, it's *Cactus Forty Seven Forty One*.
SWA521: Alright, *Southwest Five Twenty One*, we've got Cactus Forty Seven Forty One identified.

Note: If, in an IM clearance, a response of "[TPCS] identified" was given (which is appropriate for a TA message) instead of "traffic [TPCS]", an event code of "E" was assigned for TPCS, unless an incorrect format for TPCS was used, in which case an event code of "D" was assigned.

F. **Aircraft Display Selection Error:** As noted in Section 4.5, participants were requested to select the aircraft on the CDTI traffic display that they believed they heard identified as the TPA from ATC. These selections were recorded and compared against the ATC voice communications and this event includes occasions where the aircraft selected on the CDTI traffic display by the FPP did not match the TPCS assigned by ATC. This also describes events where the FPP fails to select an aircraft on the CDTI traffic display at all, even though they report the TPCS aircraft as "identified." An example of this type of error could be when ATC uses "UPS One Twenty Three" in a TA, but the flight crew selects UPS 1223 on their CDTI traffic display.

G. **<u>Aircraft Verbal Selection Error:</u>** These events include cases where the call sign used by the speaker appeared to be intentional (based on what could be inferred about the situation from the rest of the transaction), but it was for the incorrect aircraft. This event also covers cases where the wrong carrier code is paired with a correct flight number. For example:

> **ATC:** American Eight Eighty Three, traffic is *Bird Dog, correction*, Rugby Seven Eight Seven, two o'clock, two zero miles, southeastbound, Cessna one-, Cessna four twenty one, one five thousand five hundred, VFR, report identified.
> **AAL883:** American, uh, I'm sorry, Rugby Seven Eight Seven identified, American Eight Eighty Three.

Note: This event covers cases where the wrong carrier name was used (e.g., American instead of Delta). However, if the airline designator was correct but an incorrect numeric flight identification was given, an event code of "H" was assigned.

H. **<u>Execution Error:</u>** Includes general transmission errors. Call sign related events are when controllers or pilots had an error anywhere in the call sign element of the message, including transposing or substituting numbers in the flight number identification, etc. Execution errors with other elements of the message may include, for example, wrong assigned spacing goal for an IM clearance or wrong altitude for a TA. It also includes "stumbles" in the communication, whether immediately self-corrected or not. For example:

> **ATC:** *Cactus Nine Forty Three*, traffic one o'clock, seven miles, eastbound, Cheyenne, uh one five thousand five hundred.
> **AWE934:** Okay, Cactus Nine Four Three, er, Nine Three Four, we are looking for traffic.

Note: If the wrong carrier name was used (e.g., American instead of Delta), an event code of "G" was assigned. (If the airline designator was correct, but an incorrect numeric flight identification was given, an event code of "H" was assigned.)

I. **<u>Incomplete Call Sign:</u>** This includes occasions where the speaker only includes a portion of the call sign element in their message (e.g., airline designator with no numeric flight identifier or numeric flight identifier with no airline designator). For example:

> **ATC:** Citrus Nine Forty Nine, traffic is S-W-A Two Ninety Three, three o'clock, four miles, eastbound, level five thousand, Boeing 737, report identified.
> **TRS949:** *Two Ninety Three* is identified for Citrus Nine Forty Nine.

J. **<u>Incomplete Message:</u>** This includes events when call sign is appropriately present, but other elements of the message are missing (e.g., fix or "for interval spacing" for the IM clearance, or the "report identified" for the TA). It also includes cases where pilots fail to include prescribed element(s) in their readback.

Example 1 (Report Identified):
ATC: Southwest Five Twenty One, traffic American One Twenty Three, one o'clock, three zero miles, eastbound, RJ one, one five thousand five hundred, VFR. *<no "report identified">*
SWA521: Alright, we're looking for traffic, Southwest Five Twenty One.

Example 2 (Fix):
ATC: American Eight Eighty Three, for interval spacing, traffic is Delta Thirteen Twenty One, cross *<no fix given>* one zero zero seconds behind that traffic.
AAL883: Delta One Three Two One identified, American Eight Eighty Three, and, uh, say the fix you want us to cross one zero zero seconds behind that traffic?

Note: If a TPCS element was not included, it was identified as an event type "D" (TPCS Format Utilization).

K. **Verification Request:** This includes events where ATC uses the correct FPCS, and either the FPP *or* TPP asks ATC if the clearance was intended for them (e.g., "was that for UAL428?"). For example:

ATC: United Four Twenty Eight, traffic is, uh, Citrus Fifty Nine Oh Three, they'll be eleven o'clock, seven miles, westbound, six thousand, on the parallel runway, report identified.
UAL428: *And, I'm sorry, was that for United Four Twenty Eight?*
ATC: United Four Twenty Eight, yes sir, traffic is, uh, Citrus Fifty Nine Oh Three, at eleven, twelve o'clock, six miles, westbound on final for the parallel, six thousand, report identified.
UAL428: Citrus Fifty Nine Oh Three identified, United Four Twenty Eight.

L. **Intercepted Communication:** This event includes cases where the pilot of a TPA aircraft responds to (reads back) and / or executes a clearance intended for another aircraft. For example:

ATC: Cactus Nine Forty Two, for interval spacing, traffic is Southwest reference Two Forty Seven, cross PECHY one for five seconds behind that traffic.
DAL966: *Cross PECHY one for five seconds behind Southwest reference Two Four Seven, Delta Nine Sixty Six.*
ATC: And that was for Cactus Nine Forty Two.
AWE942: Cross PECHY one four five seconds behind Southwest reference Two Four Seven, Cactus Nine Forty Two.

M. **"Not Identified" TPA Identification Failure:** This covers cases where the FPP receives TPCS, but is not able to identify the TPA on their CDTI and responds with "not identified." This event type was not observed in the simulation.

N. **Open-Loop TPA Identification Failure:** When the FPP receives a TPCS, provides a read back of "looking for traffic" but then never follows up with an "identified" as originally instructed, the communication was coded as an open-loop failure. For example:

ATC: Dogfish Three Twenty Two, traffic nine o'clock, one five miles, southbound, MD eighty, descending two, descending through, uh, flight level two zero zero to one zero thousands, it's American Four Forty Seven, report identified.
RBI322: *Looking for traffic, Dogfish Three Twenty Two. <No further follow-up indicating that the traffic was identified.>*

Note: These events were not assigned in cases where ATC failed to state "report identified" in their initial clearance or message.

O. <u>Words Added:</u> Includes cases where communications involve additional words or repeats of message words or elements.. For example:

ATC: Air Canada Six Ninety Seven, for interval spacing, traffic is American Eight Eight Three, *cross three three*, cross PECHY three three five seconds behind that traffic.
ACA697: *Okay,* cross PECHY three three five seconds behind American Eight Eight Three, Air Canada Six Ninety Seven.

P. <u>Utterances:</u> Additional sounds added to messages, such as "um", "uh", or "er". For example:

ATC: Delta Two Twenty One, traffic is Air Canada Six Ninety Seven, they'll be at two o'clock, one zero miles, southbound, six thousand, it's a 737, descending, er, excuse me, an MD-80, and, *uh,* ((unintelligible)).
DAL221: *Uh*, repeat the aircraft again.

Notes:

- For a "P" event (utterance) to be associated with the TPCS or FPCS elements of the communication, the utterance ("uh," "er," "oh") must have been located WITHIN the TPCS or FPCS (e.g., "United, er, One Twenty three"). If the utterance was made before or after the call sign (or outside of the call sign), it was associated with a Non-Call Sign element.
- In cases where multiple utterances were identified in the transcript text, the audio files were reviewed to determine if multiple instances of "P" events occurred or if they should be counted as a single event.

Transmission Type

Each ATC transmission within an IM or TA transaction was coded as one of the following:

- An Initial Clearance (IC) for the first IM clearance issued by the controller in an IM transaction.
- An Initial Advisory (IA) for the initial TA information provided by the controller in a TA transaction, an ATC communication (for general responses to pilot questions, for questions directed to the pilot, or for general individual pieces of information).

- A readback response (for direct responses to pilot readbacks, including corrections or repeats).

For pilot transmissions in an IM or TA transaction, the transmission type was coded as one of the following:

- A readback if the response contained a repeat of one or more elements from the original Initial clearance
- A Pilot Communication for questions or communications that did not contain any elements from the IC or IA.

Some transactions involved multiple pilot readback and ATC readback response steps to confirm all of the information in the IC or IA. The first occasion where a pilot included an element of the IC or IA is considered the “official” or “first order” readback (RB) and the controller’s response was classified as the “first order” readback response (RR). Subsequent readbacks and readback responses were coded as RB2, RR2, RB3, RR3, etc. To avoid confounding the results with error effects compounding through multiple communications, most of the analyses involving pilot transmissions only include events in the first order readback and direct ATC readback response.

Corrections

Any corrections to transmission events were identified and coded. If the correction occurred within the same transmission, it was identified as an Immediately Self-corrected item. If the correction was made by the original source of the event, but in a later transmission (within the same transaction), it was labeled as a Later Self-corrected item. If the correction was made by someone other than the original source of the event, the correction was identified as either: FPP Corrected, TPP Corrected, Pseudopilot Corrected, or ATC Corrected, as appropriate.

Portion of Message Involving Event

When an event was present in a communication, the specific message element related to that event was identified. For each event, possible elements included one of the following:

- **FPCS**
- **TPCS**
- **Fix:** The achieve-by point for IM.
- **Interval:** The time-based assigned spacing goal, in seconds, provided to the FPA for IM operations.
- **Interval Spacing:** The phrase “for interval spacing”, as prescribed to be included in the IM clearance. ATC participants were instructed to use this phrase after the FPCS, but before providing the TPCS, so that FPPs were aware that they were about to receive an IM clearance.
- **Report Identified:** The phrase “report identified”, used in the TA messages. (Note: when this portion is identified for a flight crew communication, it means that there was an event related to the flight crew’s use of the response “identified” as part of the TA.)

- **Non-Call Sign:** Any other communication elements besides an aircraft call sign, such as clock position or distance, if it was related to an event.

Source of Event

When an event was present in a communication, the source of the event was also identified. For each event, possible sources included one of the following:

- **ATC Participant:** The controller participant, in either terminal or en route.
- **FPP Participant:** A participant flight crew member, communicating as a FPP.
- **TPP Participant**: A participant flight crew member, communicating as a TPP.
- **FPP Pseudo:** A MITRE confederate pseudopilot, communicating as a FPP.
- **TPP Pseudo:** A MITRE confederate pseudopilot, communicating as a TPP.
- **Recording:** A pre-recorded voice message, played by the MITRE confederate pseudopilot.

Format Used

In cases where a speaker incorrectly applied the TPCS format being tested, the deviation was recorded. For each Format Utilization event, possible formats and deviations included one of the following:

- **None:** The speaker did not use a TPCS in the communication.
- **Telephonic:** The speaker used a Telephonic format.
- **Telephonic Delimiter:** The speaker used a Telephonic format with a Delimiter term between the airline designator and the numeric flight identification (e.g., "United Reference One Twenty Three").
- **Telephonic Delimiter Outside:** The speaker used a Telephonic format with a Delimiter term, but the Delimiter term was not between the airline designator and the numeric flight identification, and was instead placed either in front of the airline three letter designator or after the numeric flight identification (e.g., "Reference United One Twenty three," or "Cactus Seven Sixty two reference").
- **Telephonic Delimiter Letters:** The speaker used a Letters format with a Delimiter term between the airline designator and the numeric flight identification (e.g., "U-A-L Reference One Twenty three," "A-W-E Reference Seven Sixty two," "A-A-L Reference Eight Eighty three").
- **Telephonic Delimiter Outside Letters:** The speaker used a Letters format with a Delimiter term, but the Delimiter term was not between the airline designator and the numeric flight identification, but was instead placed in front of the airline designator and or after the numeric flight identification (e.g., "Reference U-A-L One Twenty three," "A-W-E Seven Sixty two Reference").
- **Letters:** The speaker used a Letters format.

- **Letters (modified):** The speaker used a Letters, but the letters used were not the standard airline three letter designator (e.g., "U-A One Twenty three," or "A-A Eight Eighty three").
- **Phonetic:** The speaker used a Phonetics format for the airline designator (e.g., "Uniform Alpha Lima One Twenty three," "Alpha Whiskey Echo Seven Sixty two").

5.2.3 Transmission Usability Classifications

Events counts associated with dependent communications, such as pilot RBs and ATC RRs, could be inflated if the preceding transmissions (such as the IC or IA) deviated in certain ways from the prescribed phraseology. In order to fairly compare event occurrences with pilot RB and ATC RRs, it was necessary to code the preceding transmission as either "Usable" or "Not Usable" to suggest whether it may have had a confounding effect on the downstream communications. As such, for pilot RB and ATC RRs, only event occurrences associated with a "Usable" preceding transmission are counted and compared.

When summing the observed events for each transmission type, the Usable versus Not-Usable classification is not necessary. For example, the usability ATC ICs or IAs was determined to establish a data pool of transactions in which pilot RBs are unlikely to be confounded by ATC deviations or errors. In other words, only the events associated with RBs that were in response to Usable ICs or IAs were counted and reported. Pilot RBs that were in response to Not Usable ATC ICs or IAs were filtered from the counts. However, the deviations and errors occurring in that set of pilot RBs were summed and counted, whether those events made the pilot RBs usable or not. For the purpose of analyzing ATC RRs, only transmissions associated with Usable pilot RBs were summed and counted.

It should be noted that a Not Usable classification does not necessarily mean that the communication would have been problematic in an operational context. This is especially the case with pilot readbacks, where there is some latitude in how pilots can respond to an instruction or clearance. Instead, this classification was performed for data analysis purposes in order to eliminate the potential for upstream events to confound and artificially inflate the counts of downstream events. The classification guidelines for Usable versus Not Usable transmissions are included in Appendix F.

An overall summary of observed not usable transmissions as a proportion of total transmissions is provided in Table 5-22 and Figure 5-49. ATC ICs and TAs include transmissions to both pilots and pseudopilots. Pseudopilot RBs are not included in the pilot RBs. Also, only RBs that are in response to usable ATC ICs and IAs are included. Counts for ATC RRs are only those in response to usable pilot (not pseudo) RBs.

Table 5-22. Not Usable Transmissions as a Proportion of Total Transmissions

Alternative	Transmission Type	Observed Occurrences Not Usable	Observed Occurrences Usable	Total % Not Usable
T-E	ATC-ER-IM	13	66	21%
	Pilot IM RBs	16	11	
	ATC-ER-TA	15	86	
	ATC-T-TA	21	138	
	Pilot TA RBs	24	41	
T-L	ATC-ER-IM	4	79	15%
	Pilot IM RBs	7	22	
	ATC-ER-TA	8	101	
	ATC-T-TA	22	115	
	Pilot TA RBs	21	44	
TD-E	ATC-ER-IM	8	73	33%
	Pilot IM RBs	27	5	
	ATC-ER-TA	39	55	
	ATC-T-TA	22	132	
	Pilot TA RBs	39	14	
L-E	ATC-ER-IM	5	74	26%
	Pilot IM RBs	28	3	
	ATC-ER-TA	30	66	
	ATC-T-TA	18	135	
	Pilot TA RBs	27	35	

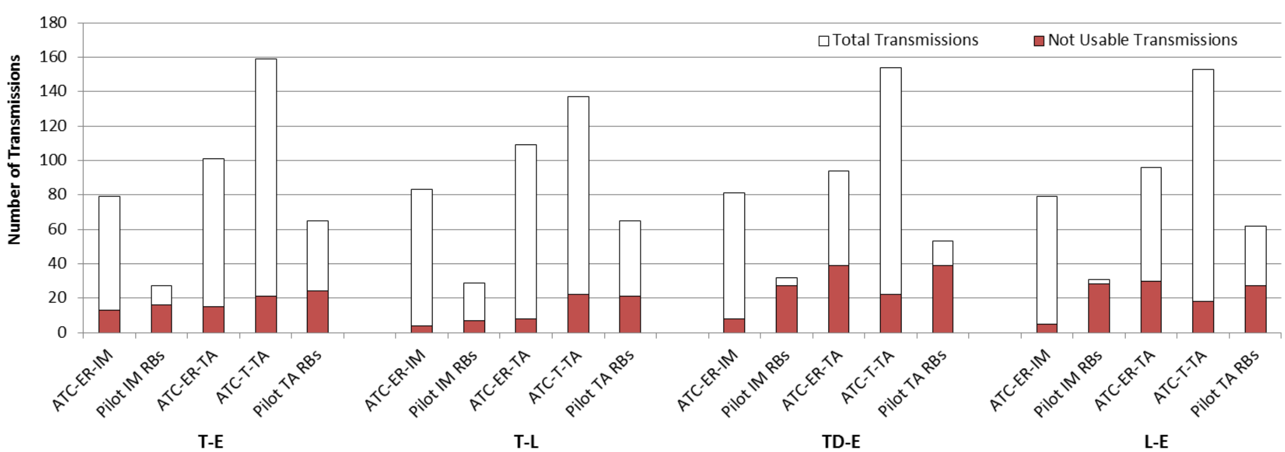

Figure 5-49. Not Usable Transmissions as a Proportion of Total Transmissions

The results show that overall, pilots and controllers appeared to have the fewest number of issues with the T-L format (15% not usable), and the greatest number with the TD-E and L-E formats (33% and 26% not usable, respectively). Large proportions of pilot readbacks were classified as not usable. Many of these cases were due to TPCS format errors and element order changes involving call sign, which are analyzed in more detail in the following sections.

5.2.4 Event Occurrence Results

The data tables in Appendix G summarize the overall counts for each observed event type by transmission type. A separate table is presented for each alternative. These tables only include IM and TA transactions and ATC dependent transmissions, such as pilot RBs and ATC RRs, only include counts that are in response to a usable immediate preceding transmission. The other "comms" rows summarize any events observed with pilot clarifying questions back to the controller and any additional attempts to read back information to the controller. Additionally, the Total Transmissions column indicated how many individual transmissions were included for the event counts. It is possible for an individual transmission to have more than one event type, or more than one of the same event type, associated with it. The event type counts are summed in the Total Event Counts column and the breakdown of each observed event type for those transmissions are included in the subsequent columns.

To further analyze the occurrences of each event type as related to the hypotheses, related events were grouped into sets. The events that comprise each set are mapped in Table 5-23. The event analyses in the follow-on sections are organized per set.

Table 5-23. Event Sets

Set	Included Events
1. ATC Confusion Events	• Full repeat request (B) • Partial repeat request (C)
2. ATC Phraseology Events	• Format Utilization (D) • Element Order Change (E) • Execution Error (H) • Incomplete Call Sign (I) • Incomplete Message (J)
3. First Party Pilot (FPP) Reference Aircraft Identification Events	• Full Repeat Requests (B) • Partial Repeat Requests (C) • Aircraft Display Selection Error (F) • Aircraft Verbal Selection Error (G) • Verification Request (K) • "Not Identified" TPA Identification Failure (M) • Open-Loop TPA Identification Failure (N)
4. First Party Pilot (FPP) Readback Events	• Format Utilization (D) • Element Order Change (E) • Execution Error (H) • Incomplete Call Sign (I) • Incomplete Message (J)
5. Third Party Pilot (TPP) Confusion Events	• Verification Request (K) • Intercepted Communication (L)

The figures in the following sections are intended to demonstrate the occurrences of certain events proportional to the number of times that they could have occurred. Each figure is preceded by explanatory text explaining it, but Figure 5-50 provides a general example for how the figures in this section should be interpreted:

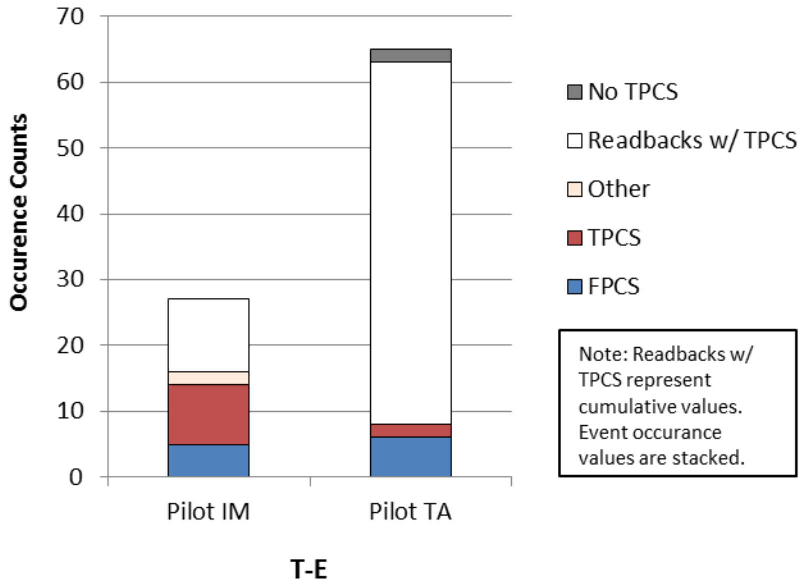

Figure 5-50. Example Event Occurrences for Figure Explanation

Figure 5-50 shows the number of occurrences of a particular event in Pilot RBs in response to usable ATC IM clearances and TAs for the T-E alternative. IM was conducted in en route airspace only, but the TA combines pilot RBs in both the en route and terminal domains. The height of the columns represents the total number of possibilities for this event to have occurred. Depending on the event type, this is usually either the number of usable ICs and IAs provided to participant pilots or the total number of participant pilot readbacks in response. In this example, the total occurrences are the number of pilot readbacks in response to each operation type.

The figure also includes a shaded region at the top that shows the proportion of clearances that did or did not include the TPCS element. Since this event can only manifest TPCS errors if the TPCS element was present, the proportion of TPCS occurrences (shown stacked in the column) should be viewed as a proportion of the column height up to but not including the No TPCS shaded region. However, event occurrences related to FPCS or Other could have occurred any time, so these should be viewed as a proportion of the entire column height. The figure note is intended to remind the reader that the number of Readbacks with TPCS should be viewed as the height of the column. However, the other shaded areas are “stacked”, and the number of occurrences for each should be viewed as the shaded area only and not only where the height of the area happens to fall.

Specifically, this means that figure results should be interpreted as:

- All IM RBs included the TPCS element. However, only 63 of 65 TA RBs included the TPCS element.

- For IM RBs, there were 5 events involving FPCS, 9 involving TPCS, and 2 involving other. This means a total of 16 events were observed for this transmission type, out of a total of 27 possible occurrences. Since the TPCS element was included in all Readbacks, they can all be viewed as a proportion of the total column height.
- For TA RBs, there were 6 events involving FPCS, 2 involving TPCS, and none involving Other. Since there were no cases in which a RB did not include their FPCS (ownship call sign), the following result is suggested: for the T-E alternative for pilot IM RBs, 6 out of 65 possible occurrences (9%) of this event type involved FPCS.
- Since there were two occasions in which TPCS was not included in a TA RB, the following result is suggested: for the T-E alternative in pilot TA RBs, 2 out of 63 possible occurrences of this event type involved TPCS.

The majority of the figures in this section should be interpreted per the above.

Results trends are suggested by simple proportional percentage comparisons across the alternatives. The authors considered performing statistical analyses on the event data; however, the data reduction for these analyses would be problematic because the sample sizes vary widely and there were numerous interactions and dependencies between the events. In particular, participants across the alternatives had different numbers of opportunities to make errors as controllers varied with regard to how often they made calls to pilots and how often pilot participants were referred to as TPAs. Also, how problematic those calls were would have to be considered in terms of the kinds of errors made. In addition, some events cannot occur without another element or event type also being present (such as requiring the TPCS element to be present in a transmission when examining TPCS format utilization errors), which must be accounted for in the final data set. These issues and the potential for event errors were accounted for in a gross way in the proportional representations, but the data reduction necessary for further statistical analysis is beyond the scope of this report.

5.2.4.1 All Events

Before analyzing individual event sets, Table 5-24 shows the total number of deviation and error events observed for each group and alternative. ATC events are counted for ICs and IAs provided to both pilot participants and pseudopilots. Only pilot participant events in response to usable ATC ICs and IAs are counted. Since individual messages could contain multiple “Other” element events for Element Order Change, Execution Error, and Incomplete Messages, the counts for Other consist of the number of transmissions that contain one or more of the event type. This allows these events to be included in the proportionality representations as otherwise, it is difficult to determine how many possible times these events could have occurred. All other events and types could only occur once per transmission.

Table 5-24. Total Event Counts

Alternative	Transmission Type	Observed Events (B-N)	Total Events
T-E	ATC-ER-IM	21	303
	Pilot IM	45	
	ATC-ER-TA	72	
	ATC-T-TA	111	
	Pilot TA	54	
T-L	ATC-ER-IM	9	209
	Pilot IM	22	
	ATC-ER-TA	41	
	ATC-T-TA	96	
	Pilot TA	41	
TD-E	ATC-ER-IM	12	373
	Pilot IM	60	
	ATC-ER-TA	112	
	ATC-T-TA	111	
	Pilot TA	78	
L-E	ATC-ER-IM	6	343
	Pilot IM	54	
	ATC-ER-TA	110	
	ATC-T-TA	110	
	Pilot TA	63	

Figure 5-51 illustrates the total number of events observed by alternative for each of the participants and operations. ATC events are shown as a proportion of total ICs and IAs provided to pilot participants and pseudopilots. Only pilot events in response to usable ATC ICs and IAs are counted. It was not possible to provide a proportional representation for pilot events as the possible occurrences varied depending on event type. However, proportional representations are provided for pilot transmissions in the following event set analysis sections. Additionally, since some individual transmissions contained more than one event type, it is possible for the total number of events to exceed the total number of transmissions. This occurred for this data set in TD-E and L-E, ATC-ER-TA. In these cases, the event count areas were adjusted to span the entire height of the column.

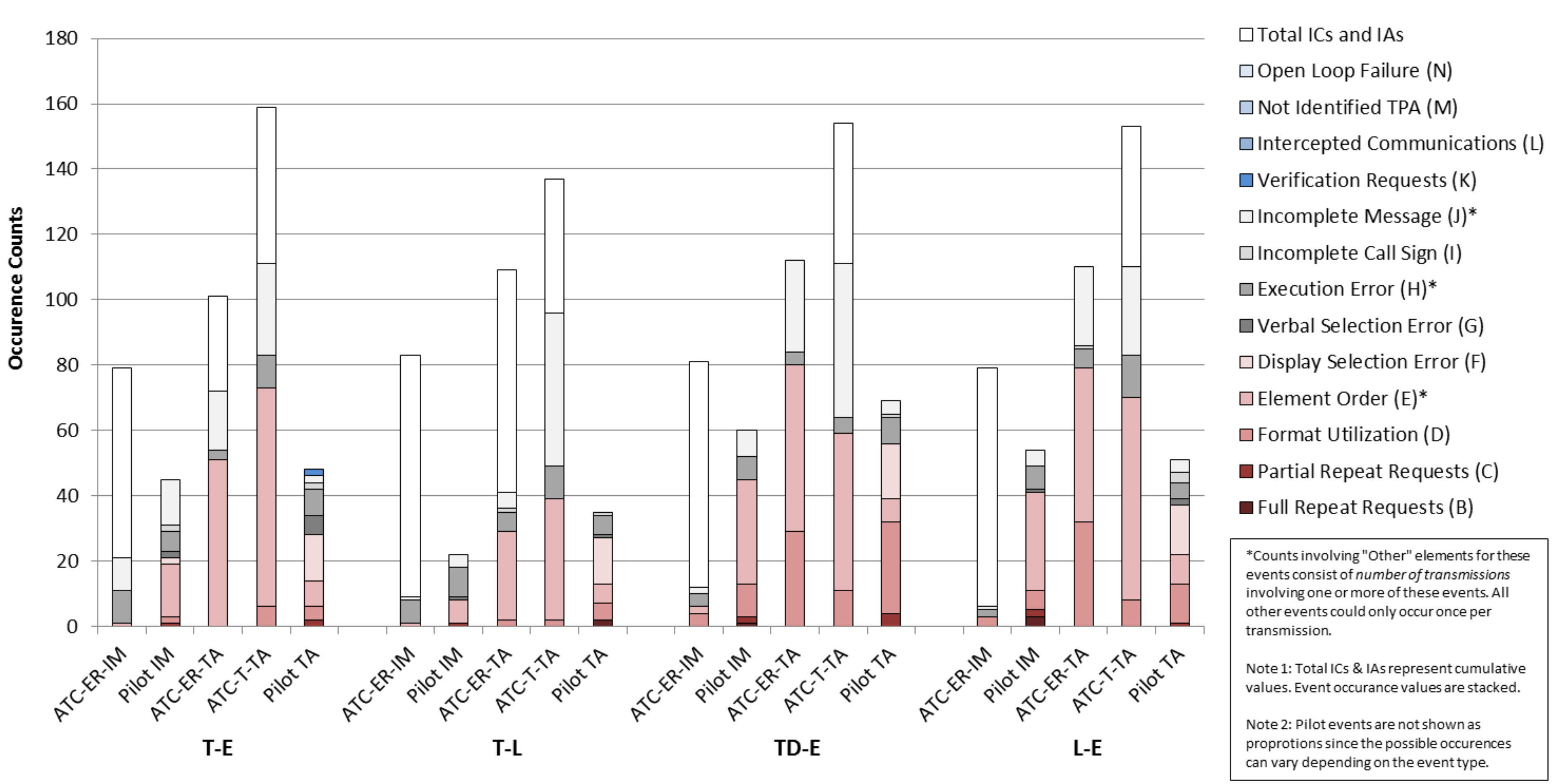

Figure 5-51. Total Events Observed by Participant Group

The overall results show that in general, most deviations and errors occurred with the TAs and not the IM clearances. Element Order Changes and Incomplete Messages accounted for the majority of the observed events. The alternative with the fewest number of total events across the participants was T-L. TD-E showed the most and T-E and L-E were nearly tied. The following sections provide more detailed analyses of the event occurrences and proportions.

5.2.4.2 ATC Confusion Events

There were zero Full Repeat Request (B) events or Partial Repeat Request (C) events from both en route and terminal ATC after usable pilot RBs. As such, there is no evidence to suggest that there was any difference between any of the alternatives with regard to controller confusion resulting from FPP use of TPCS.

5.2.4.3 ATC Phraseology Events

The ATC Phraseology Events were intended to capture events related to the controller's verbal communication of the IC or IA. They included items such as using the wrong TPCS format (or not including a TPCS at all), transposing order for elements in the transmission, other execution errors such as transposing or substituting numbers in the numeric flight identification of the FPCS or TPCS, or failing to include prescribed message elements.

Table 5-25 shows the total number ATC Phraseology events observed for each alternative. ATC events are counted for ICs and IAs provided to both pilot participants and pseudopilots. Since individual messages could contain multiple "Other" element events for Element Order Change, Execution Error, and Incomplete Messages, the counts for Other consist of the number of transmissions that contain one or more of the event type. This allows these events to be included in the proportionality representations as otherwise, it is difficult to determine how many possible times these events could have occurred. All other events and types could only occur once per transmission.

Table 5-25. ATC Phraseology Event Counts

Alternative	Transmission Type	Occurrences (D, E, H, I, J)		Event % of Total Possible
		Observed	Possible	
T-E	ATC-ER-IM	21	79	59%
	ATC-ER-TA	72	101	
	ATC-T-TA	108	159	
T-L	ATC-ER-IM	9	83	44%
	ATC-ER-TA	40	109	
	ATC-T-TA	95	137	
TD-E	ATC-ER-IM	12	81	67%
	ATC-ER-TA	99	94	
	ATC-T-TA	110	154	
L-E	ATC-ER-IM	6	79	64%
	ATC-ER-TA	95	96	
	ATC-T-TA	108	153	

Figure 5-52 summarizes the event occurrence counts of each event included in this set as a proportion of the approximate number of times that event count have occurred. The total height of each column represents the total number of ICs and IAs issued by controllers for each operation type. The shaded areas represent the event occurrence counts. Since some individual transmissions contained more than one event type, it is possible for the total number of events to exceed the total number of transmissions. This occurred for this data set in TD-E, ATC-ER-TA, in which there were five more events than TAs. To represent this, the event count areas were adjusted to span the entire column.

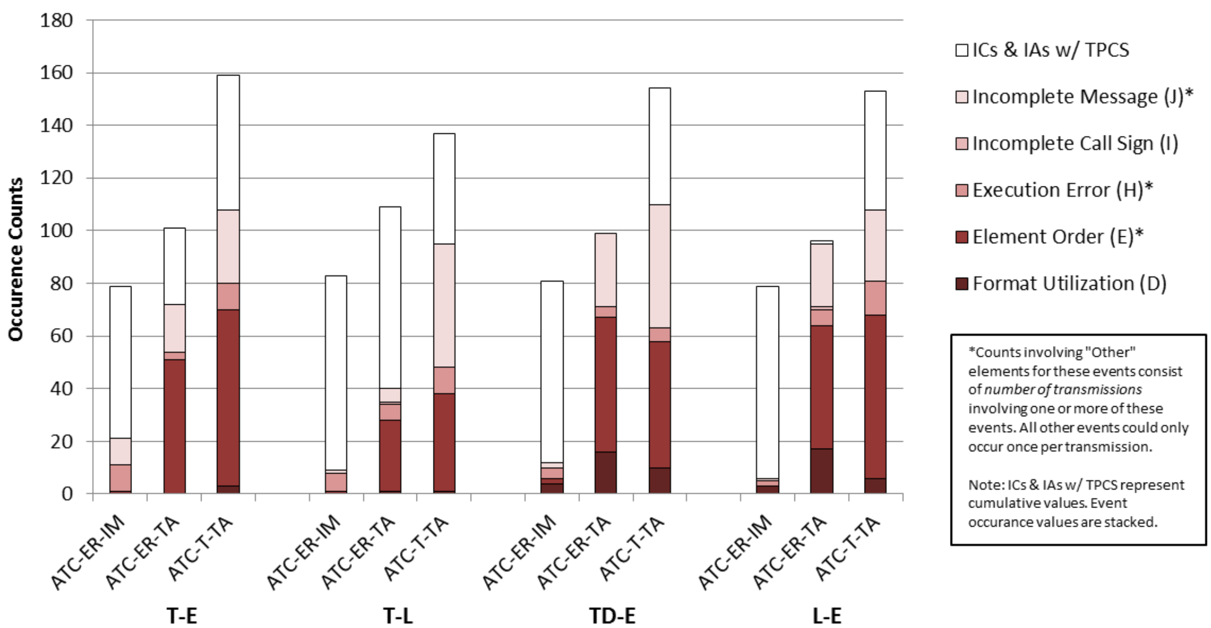

Figure 5-52. ATC Phraseology Event Occurrences

The results show overall that controllers were able to keep their deviations from the prescribed IM clearance phraseology relatively small across the alternatives, as compared to the Traffic Advisories. Overall the fewest proportional number of events occurred with the T-L alternative (44%) and the most with TD-E (67%). Many of the events resulted from Element Order change and Format Utilization events. In actual operations, these kinds of events might not have a major effect on the understandability of the communication. However, they are tracked here to help illustrate the relative difficulty for pilots to manage each of the formats.

To isolate the potential impact of unique communications required for the simulation, an additional analysis was performed to examine the number of ICs or IAs with either an Execution Error (H), Incomplete Call Sign (I), or Missing Element (J) events, or a combination. For example, a single transmission with 2 H's and 1 J would just be counted as "1 transmission." This allows the number of transmissions with these errors to be represented as proportional to the total number of ICs and IAs given, as otherwise it is difficult to determine how many possible times these events could have occurred. The occurrences were further filtered to remove errors related to TPCS and missing elements that involved "Report Identified." Execution Error events that involved a self-correction within the transmission were also not counted for this analysis, though they are counted in the later event analyses.

Table 5-26 shows the total number of IC or IA transmissions with one or more filtered H, I, or J events observed for each alternative. The possible occurrences are the total number of ICs and IAs, summed across the eight run days.

Table 5-26. ATC Filtered H, I, and J Phraseology Event Counts

Alternative	Transmission Type	Occurrences (H, I, J) Observed	Occurrences (H, I, J) Possible	Event % of Transmission Type	Event % of Total Possible
T-E	ATC-ER-IM	11	79	14%	10%
	ATC-ER-TA	11	101	11%	
	ATC-T-TA	13	159	8%	
T-L	ATC-ER-IM	3	83	4%	11%
	ATC-ER-TA	1	109	1%	
	ATC-T-TA	31	137	23%	
TD-E	ATC-ER-IM	3	81	4%	15%
	ATC-ER-TA	8	94	9%	
	ATC-T-TA	37	154	24%	
L-E	ATC-ER-IM	2	79	3%	8%
	ATC-ER-TA	4	96	4%	
	ATC-T-TA	19	153	12%	

Figure 5-53 summarizes the number of IC and IA transmissions with filtered H, I, or J events as a proportion of the approximate number of times that event count have occurred. The total height of each column represents the total number of ICs and IAs for each operation type. The shaded areas represent the number of transmissions with one or more events.

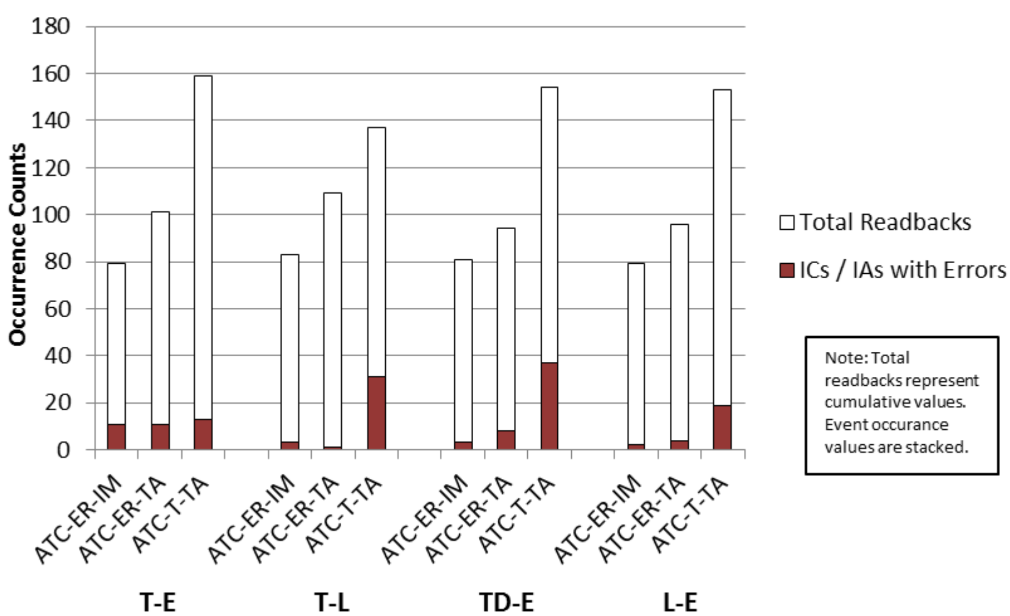

Figure 5-53. ATC Filtered H, I, and J Event Occurrences

With regard to IM clearances, the fewest transmissions with H, I, or J errors was observed with the L-E alternative (3%), and the most were observed with T-E (14%). T-L and TD-E had the same proportion, 4%. With TAs, ATC-ER showed the smallest proportion of transmissions with errors with T-L (1%) and the most with T-E (11%). Terminal controllers appeared to have the most number of transmissions with errors with TD-E (24%) and the fewest with T-E (8%). Across the alternatives L-E appeared to result in the fewest number of problematic IC and IA transmissions (8%) and TD-E appeared to have the most (15%). Additional differences are noted in the following detailed analyses.

ATC Format Utilization (D) Events

Table 5-27 shows the occurrences of ATC Format Utilization (D) events by kind, including FPCS, TPCS, and No TPCS in their ICs and IAs. The FPCS events are where controllers used anything other than current standard (telephonic) phraseology when communicating with a FPP. TPCS events are when controllers deviated from the prescribed TPCS format when referring a TPA to a FPP. No TPCS events are when the controller did not include a TPCS in the IC or IA to the FPP. The table also includes the number of opportunities for each event to occur (since controllers varied in the number of ICs and IAs they provided). In this case, the possible occurrences are the total numbers of ATC IM clearances and TAs provided to pilots and pseudopilots for each alternative, summed across the simulation. Possible TPCS occurrences are lower than Possible No TPCS occurrences as there was no opportunity for a controller to use a wrong TPCS format when they did not use TPCS at all in their IC or IA.

Table 5-27. Occurrence Counts for ATC Format Utilization (D) Events

Alternative	Transmission Type	Observed Occurrences			Possible Occurrences	Event % of Total Possible
		FPCS	TPCS	No TPCS	ICs and IAs	
T-E	ATC-ER-IM	0	0	0	79	< 1%
	ATC-ER-TA	0	0	0	101	
	ATC-T-TA	0	0	3	159	
T-L	ATC-ER-IM	0	0	0	83	< 1%
	ATC-ER-TA	0	0	1	109	
	ATC-T-TA	0	0	1	137	
TD-E	ATC-ER-IM	0	4	0	81	9%
	ATC-ER-TA	0	3	13	94	
	ATC-T-TA	0	9	1	154	
L-E	ATC-ER-IM	0	3	0	79	8%
	ATC-ER-TA	0	2	15	96	
	ATC-T-TA	0	4	2	153	

Figure 5-54 portrays the occurrences of ATC Format Utilization events for each alternative and transmission type. The total height of each column represents the total number of ICs and IAs issued by controllers for each operation type. The shaded No TPCS area at the top of the columns shows the number of ICs and IAs in which the controller did not include a TPCS in their transmission. The other shaded area, TPCS, represent the Format Utilization event occurrence counts. Since controllers needed to include TPCS in order for a TPCS format event to occur, these counts should be viewed as a proportion of the height of the column below the No TPCS shading.

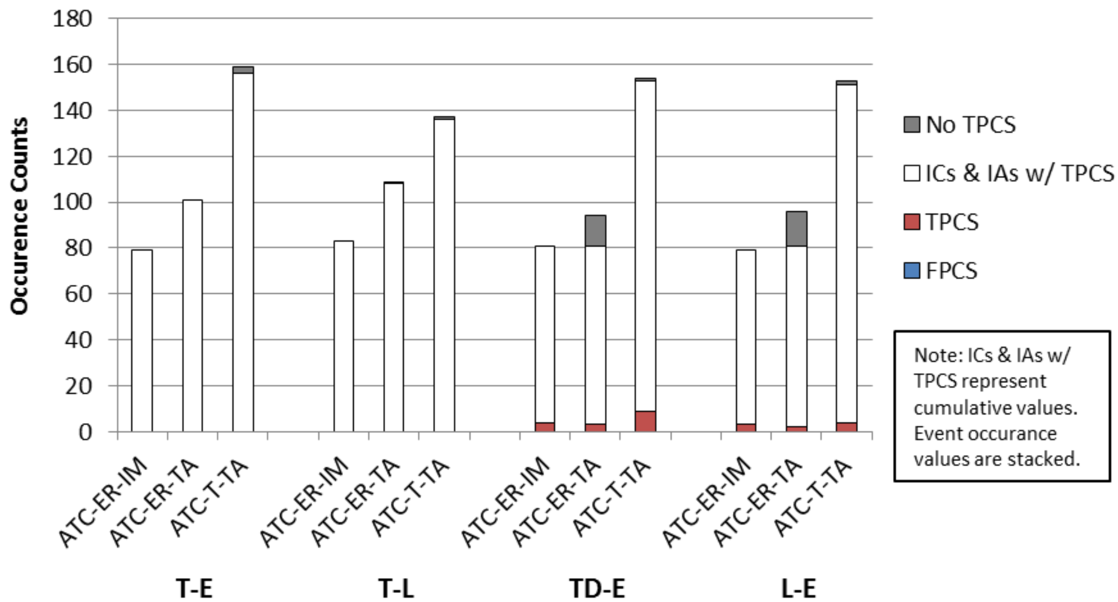

Figure 5-54. ATC Format Utilization (D) Occurrences

The results show that there were zero occurrences in which a controller had a format error with the FPCS. The results also show that controllers were easily able to remember to use the Telephonic formats without a delimiter term. However, some issues were observed with consistently including and applying the Delimiter (9%) and Letters (8%) TPCS formats.

When ATC TPCS Format Utilization events occurred with TPCS, Figure 5-55 summarizes the formats that controllers used instead. It includes events for IM and TA operations, for both en route and terminal. It also includes cases where TPCS was not included in the transmission.

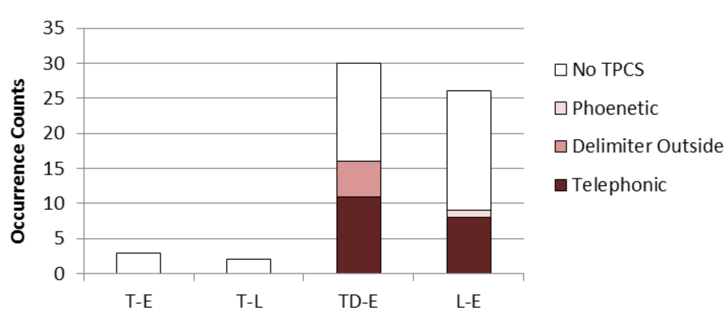

Figure 5-55. ATC TPCS Format Deviations

The results show that in most cases with the Delimiter and Letters formats, deviations mostly consisted of using the Telephonic format. For TD, this was usually just the controller not saying the delimiter term in the transmission. However, there were five observed occurrences in which the controller put the Delimiter term either before the airline designator or after the numeric flight identification, instead of between them. For the Letters format, there was one observed case where a controller used the phonetic alphabet instead of just pronouncing the letters.

ATC Element Order Change (E) Events

Table 5-28 shows the occurrences of ATC Element Order Change (E) events by kind, including FPCS, TPCS, and Other in their ICs and IAs. The FPCS events are where controllers spoke the FPCS anywhere other than at the beginning of the IC or IA. TPCS events are when controllers deviated from the prescribed TPCS location when referring a TPA to a FPP. These occurrences capture cases where controllers used the T-E alternative when they were asked to use T-L, or vice-versa. The table also includes counts for the number of transmissions with one or more transpositions of any of the other elements of the message. For IM, this could be, for example, transposing the assigned spacing goal and the Fix. For a TA, an example could be transposing the heading and altitude from the order prescribed in the (FAA, 2012b). The table also includes the number of opportunities for each event to occur (since controllers varied in the number of ICs and IAs they provided). In this case, the possible occurrences are the total numbers of ATC IM clearances and Traffic Advisories provided to pilots and pseudopilots for each alternative, summed across the eight run days.

Table 5-28. Occurrence Counts for ATC Element Order Change (E) Events

Alternative	Transmission Type	Observed Occurrences			Possible Occurrences	Event % of Total Possible
		FPCS	TPCS	Other	ICs and IAs	
T-E	ATC-ER-IM	0	1	0	79	35%
	ATC-ER-TA	0	7	44	101	
	ATC-T-TA	0	3	64	159	
T-L	ATC-ER-IM	0	0	1	83	20%
	ATC-ER-TA	0	3	24	109	
	ATC-T-TA	0	1	36	137	
TD-E	ATC-ER-IM	0	2	0	81	31%
	ATC-ER-TA	0	20	31	94	
	ATC-T-TA	0	2	46	154	
L-E	ATC-ER-IM	0	0	0	79	33%
	ATC-ER-TA	0	6	41	96	
	ATC-T-TA	0	2	60	153	

Figure 5-56 portrays the occurrences of ATC Element Order Change (E) events for each alternative and transmission type. The total height of each column represents the total number of ICs and IAs issued by controllers for each operation type. The shaded No TPCS area at the top of the columns shows the number of ICs and IAs in which the controller did not include a TPCS in their transmission. The other shaded areas represent the Element Order Change occurrence counts for TPCS and Other. Since an Element Order change “Other” event could have occurred with any IC or IA, it should be viewed as a proportion of the entire column. However, since controllers needed to include TPCS in order for a TPCS Element Order Change event to occur, these counts should be viewed as a proportion of the height of the column below the No TPCS shading.

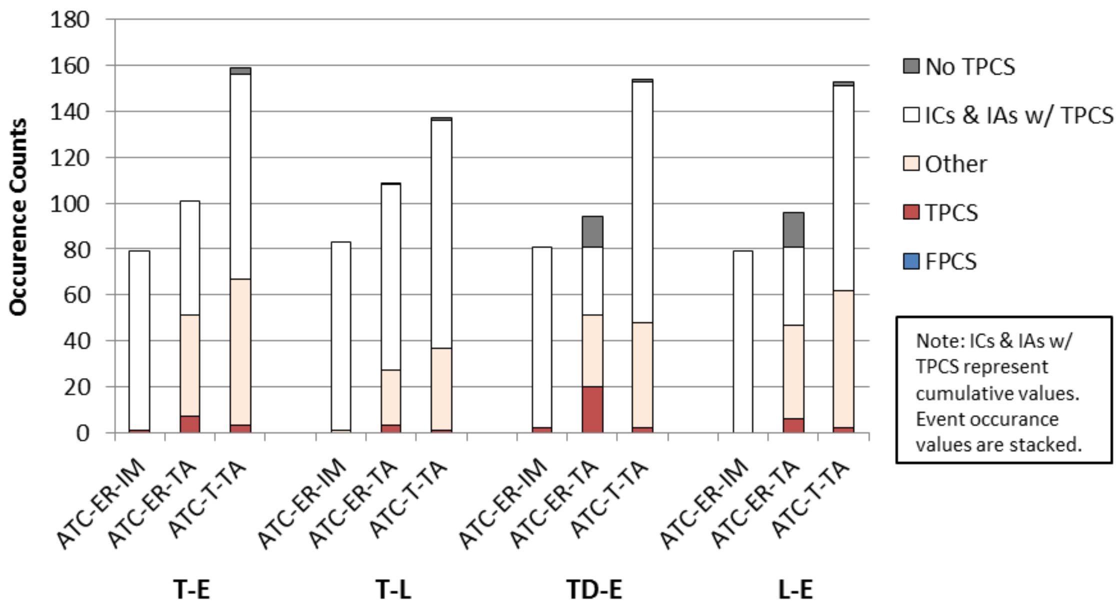

Figure 5-56. ATC Element Order Change (E) Occurrences

The results generally show that for the IM clearances, controllers exhibited very few to no occurrences of putting FPCS or TPCS in non-prescribed message locations. Twenty observed cases of TPCS Element Order Change events were noted for TD-E, ATC-ER-TA; however, 15 of them came from the same participant. Still, this suggests that controllers demonstrated higher message order variability for this alternative than the others. There were several noted occurrences of Element Order Changes for other elements, with the fewest for the T-L alternative for both en Route and terminal (20%) and the most for T-E (35%).

ATC Execution Error (H) Events

Table 5-29 shows the occurrences of ATC Execution Error (H) events by kind, including FPCS, TPCS, and Other in their ICs and IAs. The FPCS and TPCS events are where controllers had an error anywhere in the call sign element of the message, including transposing or substituting numbers in the flight identifier, etc. The table also includes counts for the number of transmissions with one or more errors with any of the other elements of the message, for example wrong assigned spacing goal for an IC or wrong altitude for an IA. The table also includes the number of opportunities for each event to occur (since controllers varied in the number of ICs and IAs they provided). In this case, the possible occurrences are the total numbers of ATC IM clearances and TAs provided to pilots and pseudopilots for each alternative, summed across the eight run days.

Table 5-29. Occurrence Counts for ATC Execution Error (H) Events

Alternative	Transmission Type	Observed Occurrences			Possible Occurrences	Event % of Total Possible
		FPCS	TPCS	Other	ICs and IAs	
T-E	ATC-ER-IM	0	4	6	79	7%
	ATC-ER-TA	0	1	2	101	
	ATC-T-TA	2	3	5	159	
T-L	ATC-ER-IM	0	2	5	83	7%
	ATC-ER-TA	0	2	4	109	
	ATC-T-TA	3	2	5	137	
TD-E	ATC-ER-IM	0	0	4	81	4%
	ATC-ER-TA	1	1	2	94	
	ATC-T-TA	1	2	2	154	
L-E	ATC-ER-IM	0	0	2	79	6%
	ATC-ER-TA	1	2	3	96	
	ATC-T-TA	4	3	6	153	

Figure 5-57 portrays the occurrences of ATC Execution Error (H) events for each alternative and transmission type. The total height of each column represents the total number of ICs and IAs issued by controllers for each operation type. The shaded No TPCS area at the top of the columns shows the number of ICs and IAs in which the controller did not include a TPCS in their transmission. The other shaded areas represent Execution Error occurrence counts for FPCS, TPCS, and Other. Since an Execution Error Event with FPCS or Other could have occurred with any IC or IA, they should be viewed as a proportion of the entire column. However, since controllers needed to include TPCS in order for an Execution Error Event with TPCS to occur, these counts should be viewed as a proportion of the height of the column below the No TPCS shading.

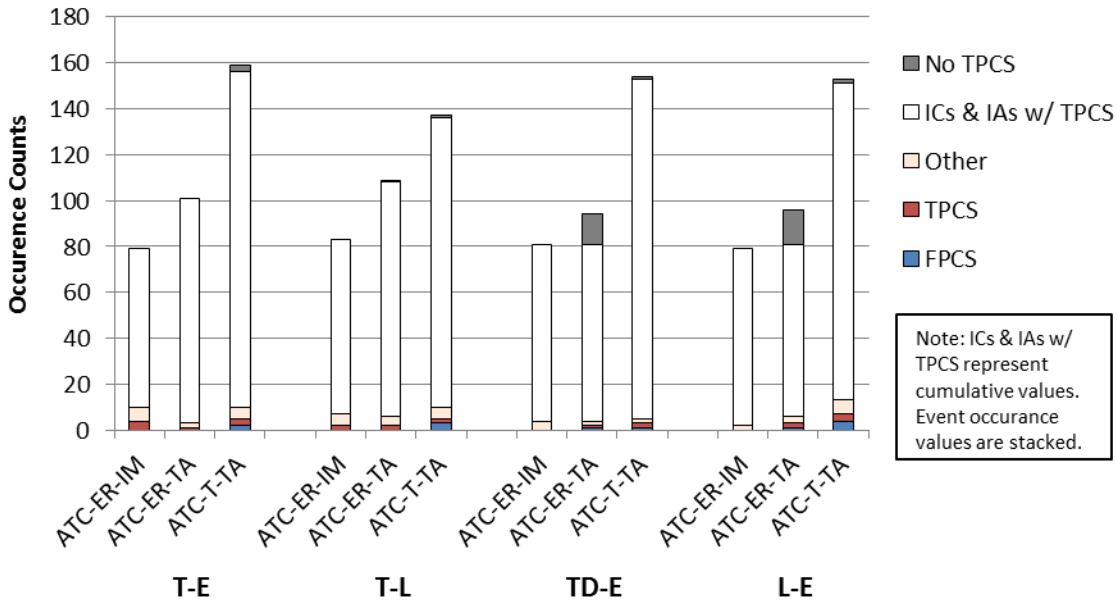

Figure 5-57. ATC Execution Error (H) Occurrences

The results show very few overall Execution Error occurrences for any element type. With only a 3% difference between the alternatives with the highest (T-E, T-L: 7%) and lowest (TD-E: 4%) percentages of Execution Error events, there does not appear to be a notable difference between any of the alternatives with regard to Execution Errors.

ATC Incomplete Call Sign (I) Events

Only two Incomplete Call Sign events were observed for ATC – both for TPCS by ATC-ER for a TA. One occurred with the T-L alternative and the other occurred for the L-E alternative. Since the numbers of observed occurrences are so few, there is no evidence to suggest a relationship between alternative and occurrences of this error event.

ATC Incomplete Message (J) Events

Table 5-30 shows the occurrences of ATC Incomplete Message (J) events by kind, including FPCS, “Report Identified,” and Other in their ICs and IAs. The FPCS events are where controllers did not include FPCS in their message. Report Identified is only applicable to IAs and were cases when controllers did not request pilots to confirm the identification of the TPA. “Other” indicates any time any of the other prescribed message elements were not included in the message. For example, these could be not including the fix in an IC or not including aircraft type in an IA. This event type does not include TPCS. If a controller did not include TPCS in their IC or IA, this was captured as a Wrong Format (D) No TPCS event. The table also includes the number of opportunities for each event to occur (since controllers varied in the number of ICs and IAs they provided). In this case, the possible occurrences are the total numbers of ATC IM clearances and Traffic Advisories provided to pilots and pseudopilots for each alternative, summed across the eight run days.

Table 5-30. Occurrence Counts for ATC Incomplete Message (J) Events

Alternative	Transmission Type	Observed Occurrences			Possible Occurrences	Event % of Total Possible
		FPCS	"Report Identified"	Other	ICs and IAs	
T-E	ATC-ER-IM	0	N/A	10	79	17%
	ATC-ER-TA	0	8	10	101	
	ATC-T-TA	0	18	10	159	
T-L	ATC-ER-IM	0	N/A	1	83	16%
	ATC-ER-TA	0	4	1	109	
	ATC-T-TA	0	19	28	137	
TD-E	ATC-ER-IM	0	N/A	2	81	23%
	ATC-ER-TA	0	23	5	94	
	ATC-T-TA	0	11	36	154	
L-E	ATC-ER-IM	0	N/A	1	79	16%
	ATC-ER-TA	0	22	2	96	
	ATC-T-TA	0	12	15	153	

Figure 5-58 portrays the occurrences of ATC Incomplete Message (J) events for each alternative and transmission type. The total height of each column represents the total number of ICs and IAs issued by controllers for each operation type. The shaded areas represent Incomplete Message occurrence counts for FPCS, "Report Identified," and Other. These counts should be viewed as a proportion of the height of the entire column.

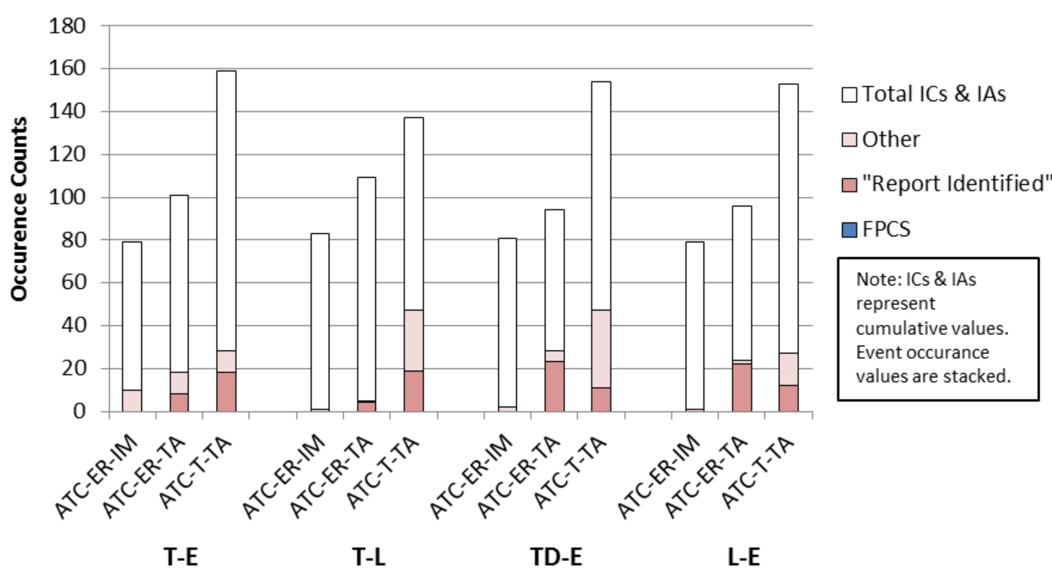

Figure 5-58. ATC Incomplete Message (J) Occurrences

There were no observed occurrences of a FPCS being left out of an IC or IA. However, the T-E alternative tended to have more message elements left out of the IM clearance than with the other alternatives. Overall, though, controllers rarely left elements out of the ICs. TAs showed higher occurrences of deviations from the 7110.65 prescribed phraseology. For en route, not including "Report Identified" in an IA comprised most instances of missing elements. For terminal controllers, however, missing elements were mostly split between "Report Identified" and other elements. The fewest overall message elements left out appeared to occur with En Route in the T-L alternative, though the terminal controllers showed one of the highest rates of missing elements for this alternative. Overall, the T-L and L-E alternatives showed the lowest overall percentage of Incomplete Messages (16%) and TD-E showed the highest (23%).

5.2.4.4 FPP Reference Aircraft Identification Events

The FPP Reference Aircraft Identification Events were intended to capture events related to how well the FPP was able to understand and identify the TPA included in the ATC IC or IA. It included event types such as whether the pilot asked the controller to repeat in full or any part of the IC or IA, whether the pilot identified the wrong aircraft on the CDTI traffic display or returned an incorrect call sign for the reference aircraft, or whether the pilot was unable to even identify any aircraft as the reference.

Table 5-25 shows the total number of FPP Reference Aircraft Identification events observed for each alternative. Only participant events from RBs in response to usable ATC ICs and IAs are included. Counts from TA-INT include both en route and terminal TAs. Deliberate non-intuitive call signs were only provided in en route.

Table 5-31. FPP Reference Aircraft Identification Event Counts

Alternative	Transmission Type	Occurrences (B, C, F, G, M, N)		Event % of Transmission Type	Event % of Total Possible
		Observed	Possible		
T-E	Pilot IM	5	28	18%	29%
	Pilot TA - INT	12	35	34%	
	Pilot TA - NI	10	30	33%	
T-L	Pilot IM	2	32	6%	19%
	Pilot TA - INT	11	36	31%	
	Pilot TA - NI	6	30	20%	
TD-E	Pilot IM	3	32	9%	27%
	Pilot TA - INT	14	32	44%	
	Pilot TA - NI	7	24	29%	
L-E	Pilot IM	6	32	19%	26%
	Pilot TA - INT	9	34	26%	
	Pilot TA - NI	9	26	35%	

Figure 5-59 summarizes the event occurrence counts of each event included in this set as a proportion of the approximate number of times that event count have occurred. The top of each column represents the total number of possible event occurrences summed for each of the event types to maintain the overall proportion relationship. The shaded areas represent the event occurrence counts.

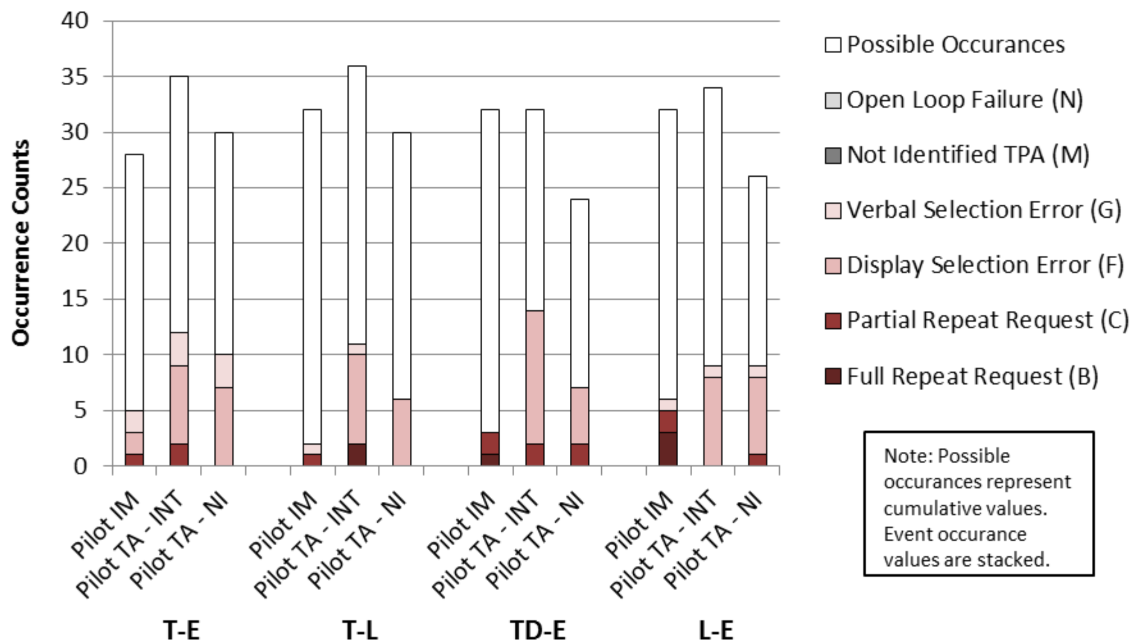

Figure 5-59. First Party Pilot Reference Aircraft Identification Occurrences

The results show overall that pilots were able to keep their deviations from the prescribed IM and TA readback phraseology relatively small with only 14 occurrences or less across the alternatives. Aircraft identification appeared to generally be more successful with IM operations than with TAs. Overall it appeared that the T-L alternative facilitated the fewest issues (19%) with reference aircraft identification and T-E had the most (29%).

When comparing IM across the alternatives, L-E showed the highest proportion of identification issues (19%, versus 18% and lower for the others). When comparing across the alternatives for TAs with NI call signs, L-E also showed the highest proportion of identification issues (35 %, versus 33% and lower for the others). However, L-E showed the lowest proportion of events for TAs with INT call signs (26%, versus > 31% and more for the others). Display Selection Errors were the main contributors. For most alternatives, aircraft identification issues with NI call signs were less than those with Intuitive call signs. However for the L-E alternative, aircraft identification issues, due primarily to Display Selection Error events, were greater with NI call signs (35%) than with INT (26%). This may suggest that L-E might not be as effective as expected in helping crews identify aircraft with unfamiliar or non-intuitive call signs. Additional differences are noted in the following detailed analyses.

Pilot Full Repeat Request (B) Events

Table 5-32 shows the occurrences of Pilot Full Repeat Request (B) events in response to Usable ATC ICs and IAs. Filtering out Not Usable ICs and TAs ensures that ATC deviations from the prescribed phraseology do not contribute to and confound the pilot's understanding of the clearance or advisory. The difference in event occurrences for TAs with INT and NI call signs are shown under Transmission Type. The table also includes the number of opportunities for each event to occur (since controllers varied in the number of ICs and IAs they provided). In this case, the possible occurrences are the total numbers of Usable ATC IM clearances and Traffic Advisories provided to pilot participants (not pseudopilots) for each alternative, summed across the eight run days.

Table 5-32. Occurrence Counts for Pilot Full Repeat Request (B) Events

Alternative	Transmission Type	Occurrences		% of Possible
		Observed	Possible	
T-E	Pilot IM	0	28	0%
	Pilot TA - INT	0	35	
	Pilot TA - NI	0	30	
T-L	Pilot IM	0	32	2%
	Pilot TA - INT	2	36	
	Pilot TA - NI	0	30	
TD-E	Pilot IM	1	32	1%
	Pilot TA - INT	0	32	
	Pilot TA - NI	0	24	
L-E	Pilot IM	3	32	3%
	Pilot TA - INT	0	34	
	Pilot TA - NI	0	26	

Figure 5-60 portrays the occurrences of Pilot Full Repeat Request (B) events for each alternative and transmission type. The total height of each column represents the total number of ICs and IAs issued by controllers for each operation type. The shaded areas represent Incomplete Message occurrence counts for FPCS and Other. These counts should be viewed as a proportion of the height of the entire column.

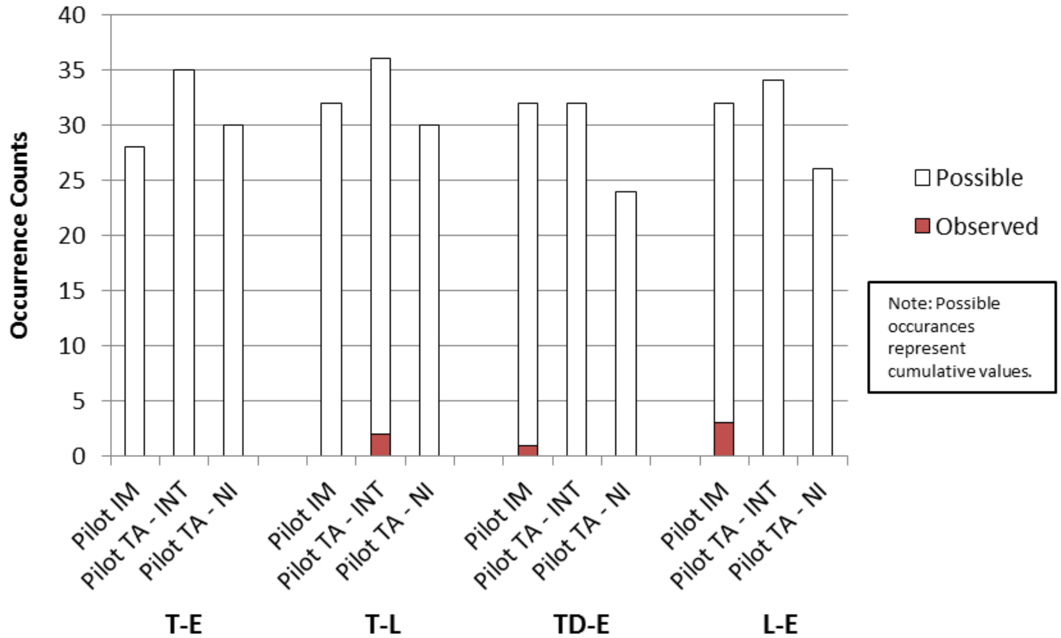

Figure 5-60. Pilot Full Repeat Request (B) Occurrences

The results show that there were only a very few cases where pilots asked for a full repeat of the IC or IA. The highest numbers observed were with IM clearances with the L-E alternative, but with so few observed occurrences, it is difficult to surmise a clear relationship between alternative and pilot full repeat requests.

Pilot Partial Repeat Request (C) Events

Table 5-33 shows the occurrences of Pilot Partial Repeat Request (C) events in response to Usable ATC ICs and IAs. Filtering out Not Usable ICs and TAs ensures that ATC deviations from the prescribed phraseology do not contribute to and confound the pilot's understanding of the clearance or advisory. The difference in event occurrences for Traffic Advisories with INT and NI call signs are shown under Transmission Type. This event type specifically tracks the number of times pilots requested a repeat of the reference aircraft versus any of the other elements. The table also includes the number of opportunities for each event to occur (since controllers varied in the number of ICs and IAs they provided). In this case, the possible occurrences are the total numbers of Usable ATC IM clearances and Traffic Advisories provided to pilot participants (not pseudopilots) for each alternative, summed across the eight run days.

Table 5-33. Occurrence Counts for Pilot Partial Repeat Request (C) Events

Alternative	Transmission Type	Observed Occurrences		Possible Occurrences	Event % of Transmission Type	Event % of Total Possible
		TPCS	Other	ICs and IAs		
T-E	Pilot IM	0	1	28	4%	3%
	Pilot TA - INT	2	0	35	6%	
	Pilot TA - NI	0	0	30	0%	
T-L	Pilot IM	1	0	32	3%	1%
	Pilot TA - INT	0	0	36	0%	
	Pilot TA - NI	0	0	30	0%	
TD-E	Pilot IM	1	1	32	6%	7%
	Pilot TA - INT	2	0	32	6%	
	Pilot TA - NI	2	0	24	8%	
L-E	Pilot IM	1	1	32	6%	3%
	Pilot TA - INT	0	0	34	0%	
	Pilot TA - NI	1	0	26	4%	

Figure 5-61 portrays the occurrences of Pilot Partial Repeat Request (C) events for each alternative and transmission type. The total height of each column represents the total number of ICs and IAs issued by controllers for each operation type. The shaded areas represent repeat requests for the TPCS and other elements. These counts should be viewed as a proportion of the height of the entire column.

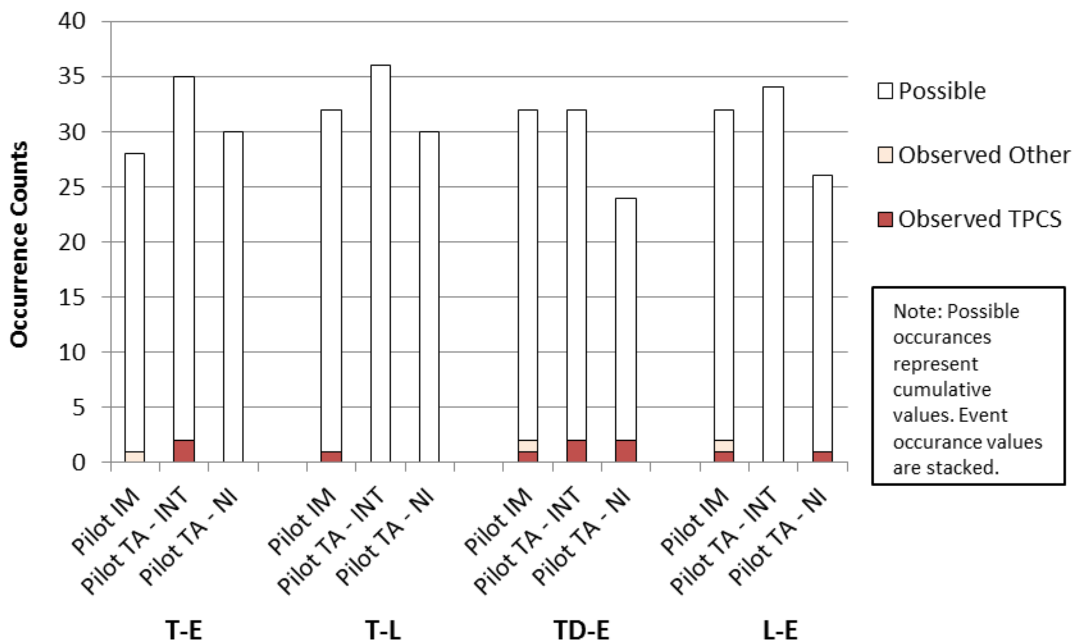

Figure 5-61. Pilot Partial Repeat Request (C) Occurrences

The results show that TPCS was the element that pilots requested most to be repeated in the ICs and IAs, though it did not often occur. It also appeared that the most Partial Repeat Requests occurred with the TD-E alternative (7%) and the fewest with T-L (1%). With so few observed occurrences, it is difficult to determine if L-E conveyed NI TPCS any more effectively than the other alternatives.

Pilot Aircraft Display Selection Error (F) Events

Table 5-34 shows the occurrences of Pilot Aircraft Display Selection Error (F) events in response to Usable ATC ICs and IAs. These are cases where the aircraft selected on the TD by the FPP did not match the TPCS assigned by ATC in an IC or IA. Filtering out Not Usable ICs and TAs ensures that ATC deviations from the prescribed phraseology do not contribute to and confound the pilot's understanding of the clearance or advisory. The difference in event occurrences for Traffic Advisories with INT and NI call signs are shown under Transmission Type. The table also includes the number of opportunities for each event to occur (since controllers varied in the number of ICs and IAs they provided). In this case, the possible occurrences are the total numbers of Usable ATC IM clearances and Traffic Advisories provided to pilot participants (not pseudopilots) for each alternative, summed across the eight run days.

Table 5-34. Occurrence Counts for Pilot Aircraft Display Selection Error (F) Events

Alternative	Transmission Type	Occurrences		Event % of Transmission Type	Event % of Total Possible
		Observed	Possible		
T-E	Pilot IM	2	28	7%	17%
	Pilot TA - INT	7	35	20%	
	Pilot TA - NI	7	30	23%	
T-L	Pilot IM	0	32	0%	14%
	Pilot TA - INT	8	36	22%	
	Pilot TA - NI	6	30	20%	
TD-E	Pilot IM	0	32	0%	19%
	Pilot TA - INT	12	32	38%	
	Pilot TA - NI	5	24	21%	
L-E	Pilot IM	0	32	0%	16%
	Pilot TA - INT	8	34	24%	
	Pilot TA - NI	7	26	27%	

Figure 5-62 portrays the occurrences of Pilot Aircraft Display Selection Error (F) events for each alternative and transmission type. The total height of each column represents the total number of ICs and IAs issued by controllers for each operation type. The shaded areas represent Incomplete Message occurrence counts for FPCS and Other. These counts should be viewed as a proportion of the height of the entire column.

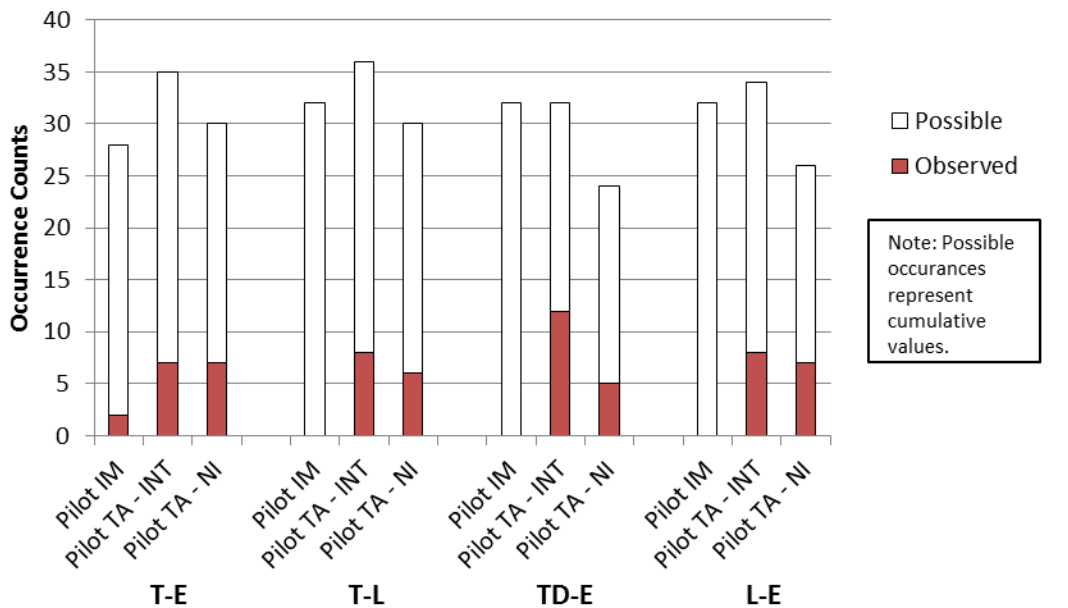

Figure 5-62. Pilot Aircraft Display Selection Error (F) Occurrences

The results show that the only times Aircraft Display Selection Errors were observed with an IM clearance was with the T-E alternative. Almost all of the Pilot Aircraft Display Selection Errors occurred with TAs. This is likely due to potentially more variability in the TPA position with a TA versus an IM operation. Though an attempt was made to vary the starting position of the reference aircraft relative to each participant, it still may have had fewer logical proximate locations than with the TAs. The most Aircraft Display Selection Errors occurred with the TD-E alternative (19%) and the fewest with T-L (14%). L-E continued to have a greater proportion of event with NI call signs (27%) than with INT (24%), which does not suggest that L-E had a benefit in helping to convey unfamiliar call signs. This was also true with T-E (NI - 23%; INT – 20%), though not with the T-L and TD-E alternatives.

Pilot Aircraft Verbal Selection Error (G) Events

Table 5-35 shows the occurrences of Pilot Aircraft Verbal Selection Error (G) events in response to Usable ATC ICs and IAs. These are cases where call sign used by the speaker was intentional, but was for an incorrect aircraft (as could best be inferred by the authors from the rest of the transaction). Filtering out Not Usable ICs and TAs ensures that ATC deviations from the prescribed phraseology do not contribute to and confound the pilot’s understanding of the clearance or advisory. The difference in event occurrences for Traffic Advisories with INT and NI call signs are shown under Transmission Type. The table also includes the number of opportunities for each event to occur (since controllers varied in the number of ICs and IAs they provided). In this case, the possible occurrences are the total numbers of (first order) pilot RBs that include TPCS in response to useable ICs and IAs.

Table 5-35. Occurrence Counts for Pilot Aircraft Verbal Selection Error (G) Events

Alternative	Transmission Type	Occurrences Observed	Occurrences Possible	Event % of Transmission Type	Event % of Total Possible
T-E	Pilot IM	2	28	7%	9%
	Pilot TA - INT	3	33	9%	
	Pilot TA - NI	3	31	10%	
T-L	Pilot IM	1	30	3%	2%
	Pilot TA - INT	1	36	3%	
	Pilot TA - NI	0	29	0%	
TD-E	Pilot IM	0	31	0%	0%
	Pilot TA - INT	0	31	0%	
	Pilot TA - NI	0	23	0%	
L-E	Pilot IM	1	31	3%	3%
	Pilot TA - INT	1	34	3%	
	Pilot TA - NI	1	25	4%	

Figure 5-63 portrays the occurrences of Pilot Aircraft Verbal Selection Error (G) events for each alternative and transmission type. The total height of each column represents the total numbers of (first) pilot RBs that include TPCS in response to useable ICs and IAs for each operation type. The shaded areas represent observed occurrences. These counts should be viewed as a proportion of the height of the entire column.

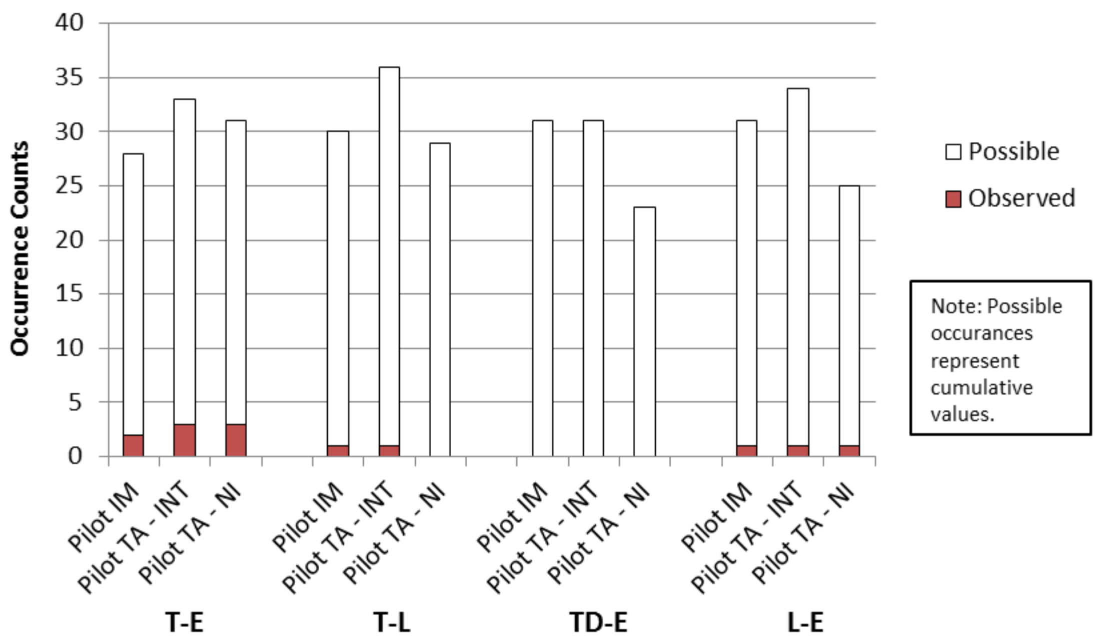

Figure 5-63. Pilot Aircraft Verbal Selection Error (G) Occurrences

The results show very few occurrences of Pilot Verbal Selection Errors. The most were observed for the T-E alternative (9%) and none were observed for TD-E. Occurrences were very low as well for T-L (2%) and L-E (3%).

Pilot Verification Request (K) Events

Table 5-36 shows the occurrences of First Party Pilot Verification Request (K) events in response to Usable ATC ICs and IAs. These are cases where the pilot of an aircraft ATC was intending to communicate with asked for verification that the message was for them. Filtering out Not Usable ICs and TAs ensures that ATC deviations from the prescribed phraseology do not contribute to and confound the pilot's understanding of the clearance or advisory. The table also includes the number of opportunities for each event to occur (since controllers varied in the number of ICs and IAs they provided). In this case, the possible occurrences are the total numbers of Usable ATC IM clearances and Traffic Advisories provided to pilot participants (not pseudopilots) for each alternative, summed across the eight run days.

Table 5-36. Occurrence Counts for Pilot Verification Request (K) Events

Alternative	Transmission Type	Observed Occurrences	Possible Occurrences
T-E	Pilot IM	0	28
	Pilot TA	2	65
T-L	Pilot IM	0	32
	Pilot TA	0	66
TD-E	Pilot IM	0	32
	Pilot TA	0	56
L-E	Pilot IM	0	32
	Pilot TA	0	60

Figure 5-64 portrays the occurrences of Pilot Verification Request (K) events for each alternative and transmission type. The total height of each column represents the total number of ICs and IAs issued by controllers for each operation type. The shaded areas represent observed occurrences. These counts should be viewed as a proportion of the height of the entire column.

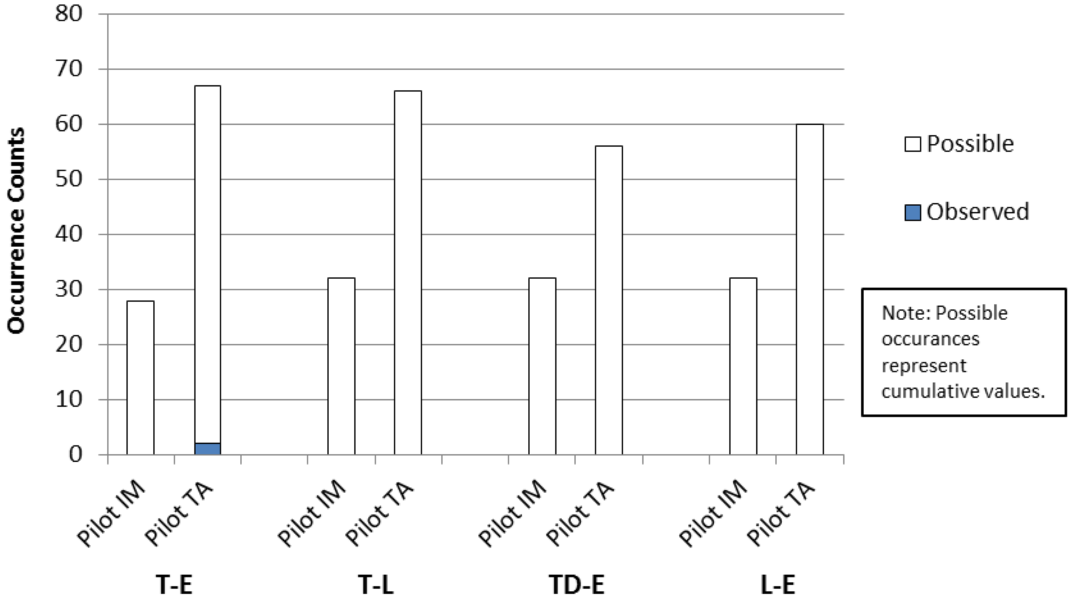

Figure 5-64. Pilot Verification Request (K) Occurrences

Only two FPP verification request events in response to Usable ICs and IAs were observed in the entire simulation. Though these were both with the Pilot response to T-E, this is not enough to infer a difference between the alternatives for this event.

Pilot "Not Identified" TPA Identification Failure (M) Events

There were zero "Not Identified" TPA Identification Failure (M) events observed for the pilot participants in the simulation in response to Usable ICs and IAs. This suggests that all pilots were equally successful in believing that they had identified their reference aircraft, across all of the alternatives.

Pilot Open-Loop TPA Identification Failure (N) Events

There were zero Open-Loop TPA Identification Failure (N) events observed for the pilot participants in the simulation in response to Usable ICs and IAs. This suggests that all pilots were equally successful in confirming their receipt of the reference aircraft identification, across all of the alternatives.

5.2.4.5 First Party Pilot Readback Events

The FPP Readback Events were intended to capture events related to the pilots' verbal communication of information provided in the ATC IC or IA. It included event types such as whether the pilot used the correct TPCS Format, whether they transposed the order of the elements in their RB transmission relative to the phraseology element order suggested by the experimenters, and whether they had any other kinds of errors such as not including portions of the FPCSs or TPCSs or other prescribed message elements.

Table 5-37 shows the total number FPP Readback events observed for each alternative. Only events from RBs in response to usable ATC ICs and IAs are included. TA counts include both en route and terminal. Since individual messages could contain multiple "Other" element events for Element Order Change, Execution Error, and Incomplete Messages, the counts for Other consist of the number of transmissions that contain one or more of the event type. This allows these events to be included in the proportionality representations as otherwise it is difficult to determine how many possible times these events could have occurred. All other events and types could only occur once per transmission.

Table 5-37. FPP Readback Event Counts

Alternative	Transmission Type	Occurrences (D, E, H, I, J)		Event % of Total Possible
		Observed	Possible	
T-E	Pilot IM	40	27	67%
	Pilot TA	22	65	
T-L	Pilot IM	20	29	38%
	Pilot TA	16	65	
TD-E	Pilot IM	57	32	120%
	Pilot TA	45	53	
L-E	Pilot IM	48	31	83%
	Pilot TA	29	62	

Figure 5-65 summarizes the event occurrence counts of each event included in this set as a proportion of the approximate number of times that event count have occurred. The total height of each column represents the total number of pilot RBs in response to usable ATC ICs and IAs for each operation type. The shaded areas represent the event occurrence counts. Since some individual transmissions contained more than one event type, it is possible for the total number of events to exceed the total number of transmissions. This occurred for this data set in Pilot IM for T-E, TD-E, and L-E. To represent this, the event count areas were adjusted to span the entire column.

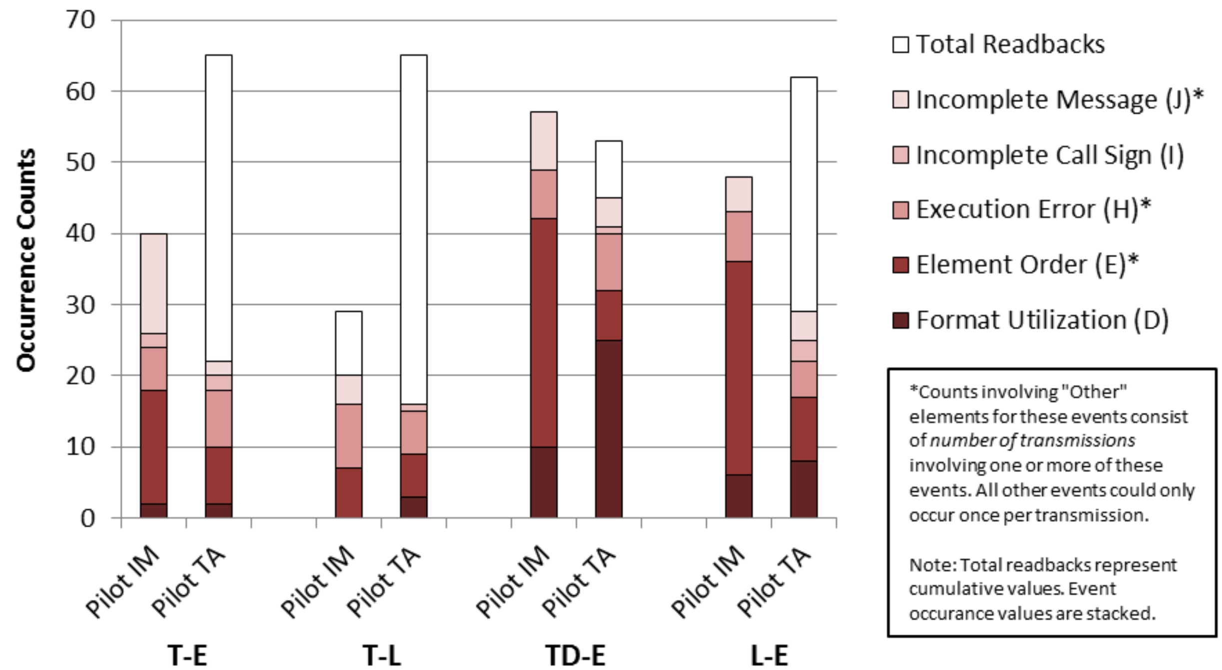

Figure 5-65. FPP Readback Event Occurrences

The results suggest that overall, pilots had the fewest RB issues with the T-L alternative (38%) and the most with TD-E (120%) for both IM and TA operations. The high number of issues for TD-E and L-E in particular appear to be driven by Element Order and Format Utilization events. It should be noted that in actual operations, these kinds of events are unlikely to have a major effect on the understandability of the communication. However, they are tracked here to help illustrate the relative difficulty for pilots to manage each of the formats. An analysis of the event types more likely to result in problems with the recipient understanding the message is below. There also appeared to be a greater proportion of issues with IM clearance readbacks than with TAs across all the alternatives, which was not unexpected as the IM clearance RBs required more elements than the TA RBs.

To isolate the potential impact of unique communications required for the simulation, an additional analysis was performed to examine the number of transmissions with either an Execution Error (H), Incomplete Call Sign (I), or Missing Element (J) events, or a combination. For example, a single transmission with 2 H's and 1 J would just be counted as "1 transmission." This allows the number of transmissions with these errors to be represented as proportional to the total number of readbacks, as otherwise it is difficult to determine how many possible times these events could have occurred. Then, the occurrences were further filtered to remove errors related to TPCS. Execution Error events that involved a self-correction within the transmission were also not counted for the following analysis, though they are counted in the later event analyses. Table 5-38 shows the total number of FPP filtered Readback H, I, and J events observed for each alternative. Only events from RBs in response to usable ATC ICs and IAs are included. TA counts include both en route and terminal. The possible occurrences are the total number of (first) pilot participant RBs, summed across the eight run days.

Table 5-38. FPP Filtered H, I, and J Readback Event Counts

Alternative	Transmission Type	Occurrences (H, I, J) Observed	Occurrences (H, I, J) Possible	Event % of Transmission Type	Event % of Total Possible
T-E	Pilot IM	8	27	30%	9%
	Pilot TA	0	65	0%	
T-L	Pilot IM	5	29	17%	6%
	Pilot TA	1	65	2%	
TD-E	Pilot IM	7	32	22%	12%
	Pilot TA	3	53	6%	
L-E	Pilot IM	8	31	26%	11%
	Pilot TA	2	62	3%	

Figure 5-66 summarizes the number of transmissions with filtered H, I, or J events as a proportion of the approximate number of times that event count have occurred. The total height of each column represents the total number of pilot RBs in response to usable ATC ICs and IAs for each operation type. The shaded areas represent the number of transmissions with one or more events.

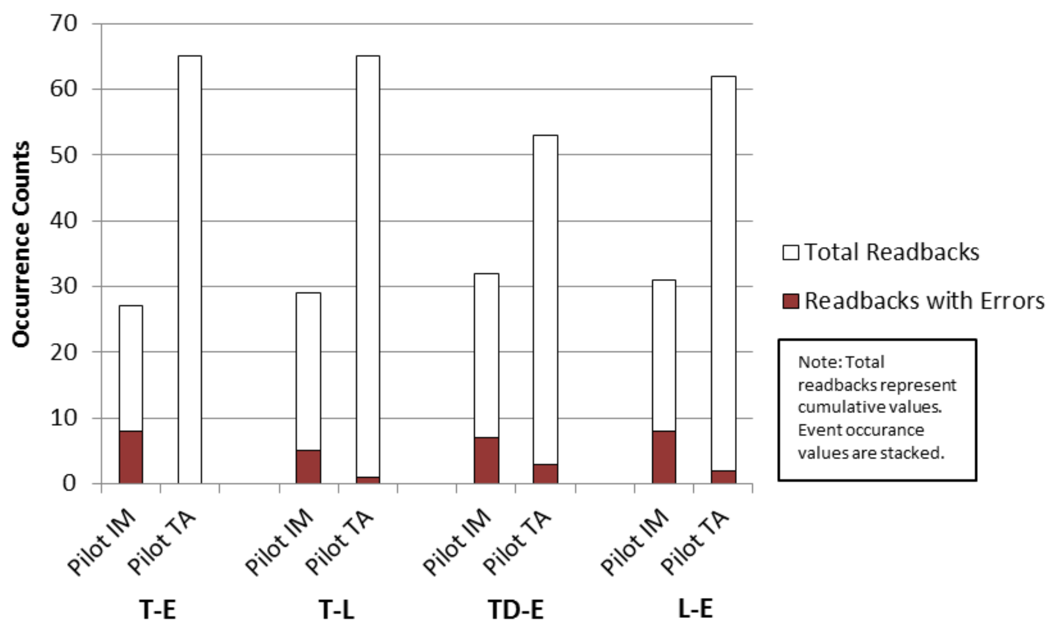

Figure 5-66. FPP Filtered H, I, and J Readback Event Occurrences

With the more operationally significant event types, most of the pilot RB transmissions with errors occurred in response to IM clearances. The fewest issues responding to ICs were seen with the T-L alternative (17%) and the most were observed with T-E (30%). Overall proportions for TAs were much lower. Zero events were observed with T-E and only 2% were observed for T-L. L-E showed only 3% and the greatest proportion was observed with TD-E, at 6%. The overall proportions were relatively similar across the alternatives, with T-L showing the fewest (6%) and TD-E showing the most (12%) but L-E and T-E were very close.

Finally, to provide a basis of comparison for the kinds of errors typically analyzed in past work (e.g. Cardosi, 1993), an analysis was run that examined the occurrences of transmissions with one or more pilot RB execution error (H) events as a percentage of (usable) ATC ICs given to pilot participants. Table 5-39 shows the total number of non-TCPS, FPP H Readback events observed for each alternative. H events that were immediately self-corrected are not included.

Table 5-39. Pilot IM Readback Filtered Execution Error Proportions

	T-E	T-L	TD-E	L-E
Number of Pilot IM RB Transmissions with One or More Execution (H) Errors	1	2	3	5
Number of Usable ICs to Pilots	28	32	32	32
Readbacks with Errors as % of Usable ICs	3.6%	6.3%	9.4%	15.6%

The results show that overall, pilots made the smallest proportion of IM RB execution errors with T-E, and the most with L-E. Additional differences are noted in the following detailed analyses.

Pilot Format Utilization (D) Events

Table 5-40 shows the occurrences of Pilot Format Utilization (D) events by kind, including FPCS, TPCS, and No TPCS in their (first) RBs resulting from usable ICs and IAs. Filtering out Not Usable ICs and TAs ensures that ATC deviations from the prescribed phraseology do not contribute to and confound the pilot's understanding of the clearance or advisory. The FPCS events are where pilots used anything other than current standard (telephonic) phraseology when communicating with ATC. TPCS events are when pilots deviated from the prescribed TPCS format when referring to a third party aircraft with ATC. No TPCS events are when the pilot did not include a TPCS in their first RB. The table also includes the number of opportunities for each event to occur (since controllers varied in the number of ICs and IAs they provided). In this case, the possible occurrences are the total number of pilot participant (first) RBs, summed across the eight run days.

Table 5-40. Occurrence Counts for Pilot Readback Format Utilization (D) Events

Alternative	Transmission Type	Observed Occurrences			Possible Occurrences	Event % of Total Possible
		FPCS	TPCS	No TPCS	First RBs	
T-E	Pilot IM	0	2	0	27	4%
	Pilot TA	0	0	2	65	
T-L	Pilot IM	0	0	0	29	3%
	Pilot TA	0	1	2	65	
TD-E	Pilot IM	0	10	0	32	41%
	Pilot TA	0	22	3	53	
L-E	Pilot IM	0	6	0	31	15%
	Pilot TA	0	4	4	62	

Figure 5-67 portrays the occurrences of Pilot Format Utilization events for each alternative and transmission type. The total height of each column represents the total number of (first) pilot RBs for each operation type. The shaded No TPCS area at the top of the columns shows the number of RBs in which the pilot did not include a TPCS in their transmission. The other shaded area, TPCS, represents the Format Utilization event occurrence counts. Since pilots needed to include TPCS in order for a TPCS format event to occur, these counts should be viewed as a proportion of the height of the column below the No TPCS shading.

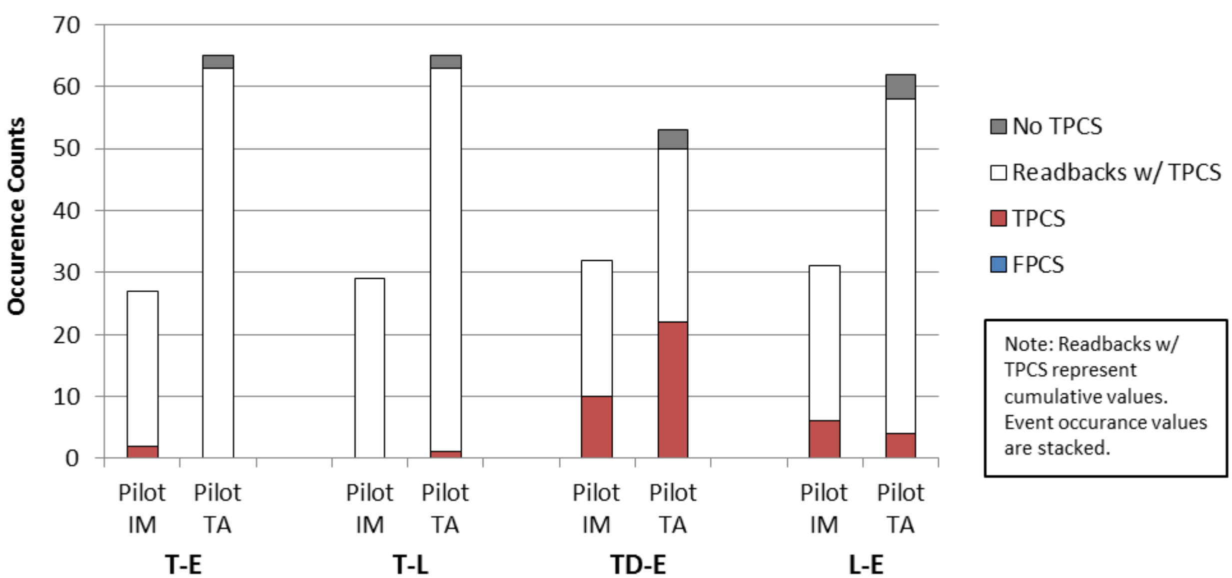

Figure 5-67. Pilot Readback Format Utilization (D) Occurrences

The results show that there were zero occurrences in which a pilot had a format error with the FPCS in their RBs. Few Format Utilization Events were observed with T-E and T-L (4% and 3%, respectively). More were observed with Letters (15%) and the most were observed with TD-E

(41%). Overall, pilots had were easily able to remember to use the Earlier and Later Telephonic alternatives, but had some issues consistently using the TD-E and L-E formats for TPCS.

When pilot (first) RB Format Utilization events occurred with TPCS, Figure 5-68 summarizes the formats that pilots used instead. It includes events for both IM and TA operations and also shows cases where TPCS was not included in the transmission.

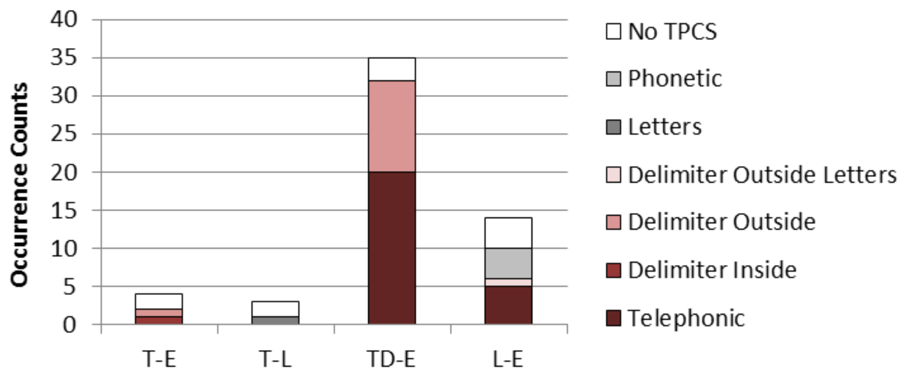

Figure 5-68. Pilot TPCS Format Deviations

The results show that in most cases with the Delimiter and Letters formats, deviations mostly consisted of using the Telephonic format. For the TD-E alternative, this was usually just the pilot not saying the delimiter term in the transmission. However, there were 12 observed occurrences in which the pilot put the Delimiter term either before the airline designator or after the numeric flight identifier, instead of between them. For the Letters format, there were five cases where the pilot just used telephonic instead of letters, and four observed cases where a pilot used the phonetic alphabet instead of just pronouncing the letters.

Pilot Element Order Change (E) Events

Table 5-41 shows the occurrences of Pilot Element Order Change (E) events by kind, including FPCS, TPCS, and Other in their (first) RBs resulting from usable ICs and IAs. Filtering out Not Usable ICs and TAs ensures that ATC deviations from the prescribed phraseology do not contribute to and confound the pilot’s understanding of the clearance or advisory. The FPCS events are where pilots include ownship call sign anywhere other than at the end of the RB, as prescribed by the phraseology suggested by the experimenters. TPCS events are when pilots deviated from the prescribed TPCS location in their RBs. The table also includes counts for the number of transmissions with one or more order transpositions of any of the other elements of the message. For IM, this could be, for example, transposing the assigned spacing goal and the Fix. Since the only TA elements pilots were expected to RB were FPCS, TPCS, and “identified,” these events would capture any deviation from the phraseology order prescribed by the experimenters. The table also includes the number of opportunities for each event to occur (since controllers varied in the number of ICs and IAs they provided). In this case, the possible occurrences are the total number of pilot participant (first) RBs, summed across the eight run days.

Table 5-41. Occurrence Counts for Pilot Readback Element Order Change (E) Events

Alternative	Transmission Type	Observed Occurrences			Possible Occurrences	Event % of Total Possible
		FPCS	TPCS	Other	First RBs	
T-E	Pilot IM	5	9	2	27	
	Pilot TA	6	2	0	65	26%
T-L	Pilot IM	5	1	1	29	
	Pilot TA	4	2	0	65	14%
TD-E	Pilot IM	7	23	2	32	
	Pilot TA	5	2	0	53	46%
L-E	Pilot IM	5	21	4	31	42%
	Pilot TA	5	4	0	62	

Figure 5-69 portrays the occurrences of pilot RB Element Order Change (E) events for each alternative and transmission type. The total height of each column represents the total number of pilot (first) RBs for each operation type. The shaded No TPCS area at the top of the columns shows the number of RBs in which the pilot did not include a TPCS in their transmission. The other shaded areas represent the Element Order Change occurrence counts for TPCS and Other. Since Element Order Change FPCS or Other events could have occurred with any RB, they should be viewed as a proportion of the entire column. However, since pilots needed to include TPCS in order for a TPCS Element Order Change event to occur, these counts should be viewed as a proportion of the height of the column below the No TPCS shading.

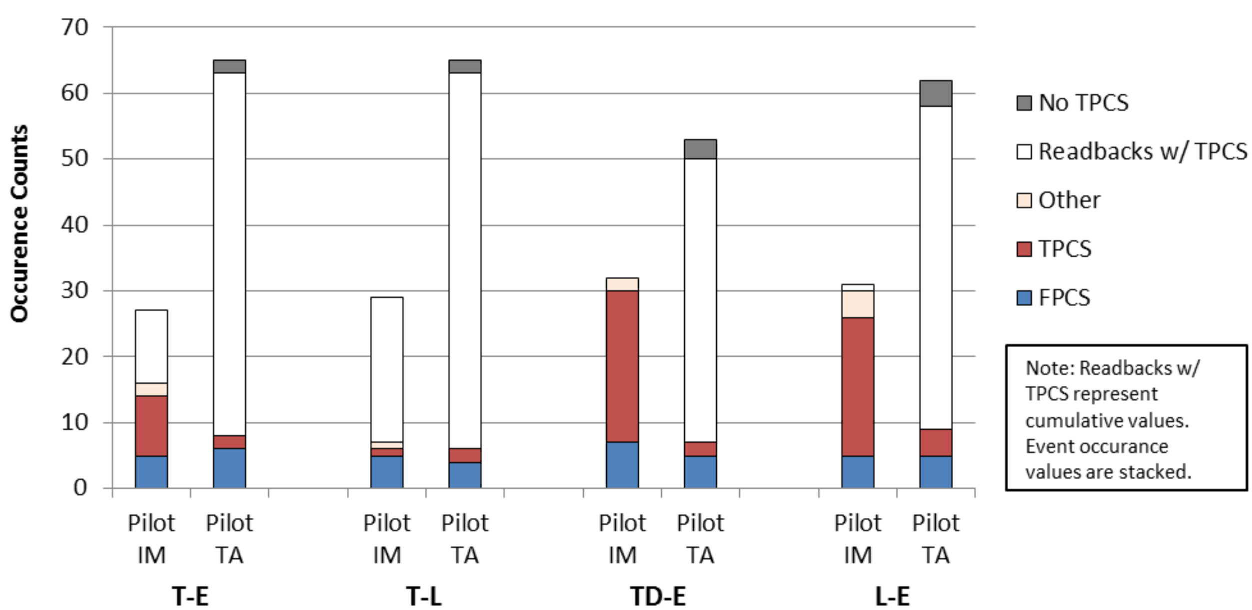

Figure 5-69. Pilot Readback Element Order Change (E) Occurrences

The results show that pilots appeared to exhibit the least amount of element order change events with the T-L alternative (14%); however, since the prescribed RB phraseology was the same for T-E and T-L, it is unclear why pilots appeared to have slightly more difficulty with T-E (26%). It may be related to pilots better grasping the IC or TA with T-L and thus being able to provide cleaner readbacks. Nearly all of the TD-E and L-E alternatives involved call sign-related element order changes for IM RBs, with TD-E showing more (46%) than L-E (42%). TPCS events with these alternatives mostly appeared to be related to pilots putting TPCS later in the RB message then earlier. When viewed in conjunction with the relative lack of order changed for the T-L alternative, this suggests that a call sign position later in the message may be easier for pilots to manage.

Pilot Execution Error (H) Events

Table 5-42 shows the occurrences of Pilot Execution Error (H) events by kind, including FPCS, TPCS, and Other resulting from usable ICs and IAs. Filtering out Not Usable ICs and TAs ensures that ATC deviations from the prescribed phraseology do not contribute to and confound the pilot's understanding of the clearance or advisory. The FPCS and TPCS events are where pilots had an error anywhere in the call sign element of their RB messages, including transposing or substituting numbers in the flight identifier, etc. The table also includes counts for the number of transmissions with one or more errors with any of the other elements of the message; for example, wrong spacing interval for an IM RB or wrong altitude for a TA RB. The table also includes the number of opportunities for each event to occur (since controllers varied in the number of ICs and IAs they provided). In this case, the possible occurrences are the total number of pilot participant (first) RBs, summed across the eight run days.

Table 5-42. Occurrence Counts for Pilot Readback Execution Error (H) Events

Alternative	Transmission Type	Observed Occurrences			Possible Occurrences	Event % of Total Possible
		FPCS	TPCS	Other	First RBs	
T-E	Pilot IM	0	4	2	27	
	Pilot TA	2	6	0	65	15%
T-L	Pilot IM	1	6	2	29	
	Pilot TA	2	3	1	65	16%
TD-E	Pilot IM	0	3	4	32	
	Pilot TA	1	5	2	53	18%
L-E	Pilot IM	2	2	3	31	13%
	Pilot TA	1	4	0	62	

Figure 5-70 portrays the occurrences of pilot RB Execution Error (H) events for each alternative and transmission type. The total height of each column represents the total number of pilot RBs for each operation type. The shaded No TPCS area at the top of the columns shows the number of RBs in which the pilot did not include a TPCS in their transmission. The other shaded areas represent Execution Error occurrence counts for FPCS, TPCS, and Other. Since FPCS or Other Execution Error events could have occurred with any RB, they should be viewed as a proportion of the entire column. However, since pilots needed to include TPCS in order for a TPCS event to occur, these counts should be viewed as a proportion of the height of the column below the No TPCS shading.

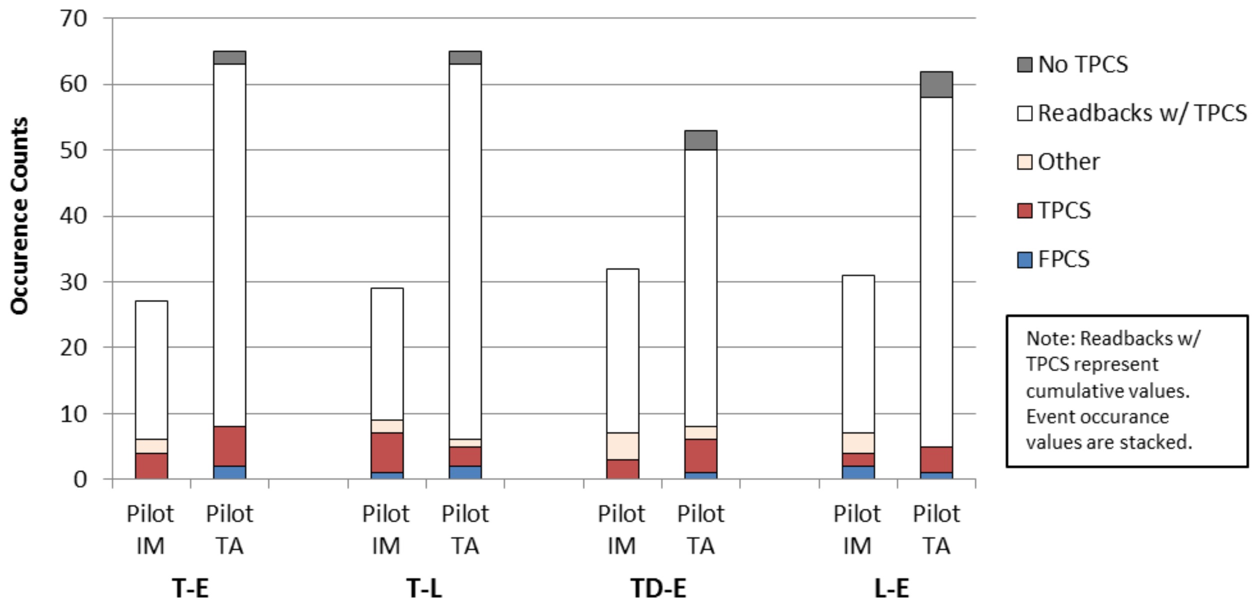

Figure 5-70. Pilot Readback Execution Error (H) Occurrences

The results show mostly similar, low levels of occurrences of pilot Execution Errors across the alternatives. The most were observed with TD-E (18%) and the fewest were observed with L-E (13%). Most of the occurrences across the alternatives were related to the TPCS element. Overall there does not appear to be a strong relationship between alternative and occurrences of this event type.

Pilot Incomplete Call Sign (I) Events

Table 5-43 shows the occurrences of pilot RB Incomplete Call Sign (I) events in response to Usable ATC ICs and IAs. Filtering out Not Usable ICs and IAs ensures that ATC deviations from the prescribed phraseology do not contribute to and confound the pilot's understanding of the clearance or advisory. This event type specifically tracks the number of times pilots did not include a portion of a call sign element in their (first) RBs. The table also includes the number of opportunities for each event to occur (since controllers varied in the number of ICs and IAs they provided). In this case, the possible occurrences are the total number of pilot participant (first) RBs, summed across the eight run days.

Table 5-43. Occurrence Counts for Pilot Readback Incomplete Call Sign (I) Events

Alternative	Transmission Type	Observed Occurrences		Possible Occurrences	Event % of Total Possible
		FPCS	TPCS	First RBs	
T-E	Pilot IM	0	2	27	4%
	Pilot TA	0	2	65	
T-L	Pilot IM	0	0	29	1%
	Pilot TA	0	1	65	
TD-E	Pilot IM	0	0	32	1%
	Pilot TA	0	1	53	
L-E	Pilot IM	0	0	31	3%
	Pilot TA	0	3	62	

Figure 5-71 portrays the occurrences of pilot RB Incomplete Call Sign (I) events for each alternative and transmission type. The total height of each column represents the total number of pilot RBs for each operation type. The shaded No TPCS area at the top of the columns shows the number of RBs in which the pilot did not include a TPCS in their transmission. The other shaded areas represent Incomplete Call Sign Error occurrence counts for FPCS and TPCS. Since Incomplete Call Sign FPCS events could have occurred with any RB, they should be viewed as a proportion of the entire column. However, since pilots needed to include TPCS in order for an TPCS event to occur, these counts should be viewed as a proportion of the height of the column below the No TPCS shading.

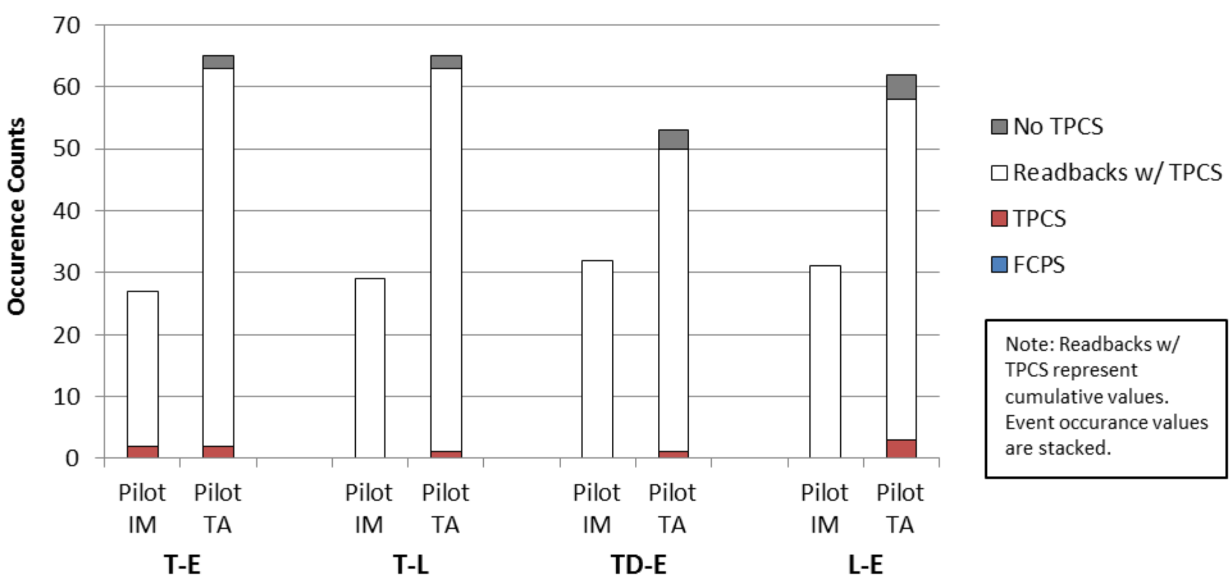

Figure 5-71. Pilot Readback Incomplete Call Sign (I) Occurrences

No pilot RB Incomplete FPCS events were observed in the simulation. The results show only a few occurrences of pilot incomplete TPCS events across the alternatives. Observed occurrences were mostly related to TAs. The most events were seen with T-E (4%). T-L and TD-E were tied with the fewest (1%). Overall the numbers of occurrences are too few to suggest a strong relationship between alternative and occurrences of this event type.

Pilot Incomplete Message (J) Events

Table 5-44 shows the occurrences of Pilot Incomplete Message (J) events by kind, including FPCS and Other, in response to Usable ATC ICs and IAs. Filtering out Not Usable ICs and TAs ensures that ATC deviations from the prescribed phraseology do not contribute to and confound the pilot's understanding of the clearance or advisory. The FPCS events are where pilots did not include ownship call sign in their RB. Other indicates the number of transmissions where any of the other prescribed message elements were not included in the RB. For example, these could be not including the Fix in response to an IM clearance or not including "identified" in response to a TA. This event type does not include TPCS. If a pilot did not include TPCS in their IC or IA, it was captured as a Format Utilization (D) / No TPCS event. The table also includes the number of opportunities for each event to occur (since controllers varied in the number of ICs and IAs they provided). In this case, the possible occurrences are the total number of (first) pilot participant RBs, summed across the eight run days.

Table 5-44. Occurrence Counts for ATC Incomplete Message (J) Events

Alternative	Transmission Type	Observed Occurrences		Possible Occurrences	Event % of Total Possible
		FPCS	Other	First RBs	
T-E	Pilot IM	2	5	27	9%
	Pilot TA	0	1	65	
T-L	Pilot IM	2	1	29	3%
	Pilot TA	0	0	65	
TD-E	Pilot IM	0	4	32	8%
	Pilot TA	2	1	53	
L-E	Pilot IM	1	2	31	6%
	Pilot TA	2	1	62	

Figure 5-72 portrays the occurrences of pilot RB Incomplete Message (J) events for each alternative and transmission type. The total height of each column represents the total number of (first) pilot participant RBs for each operation type. The shaded areas represent Incomplete Message occurrence counts for FPCS and Other. These counts should be viewed as a proportion of the height of the entire column.

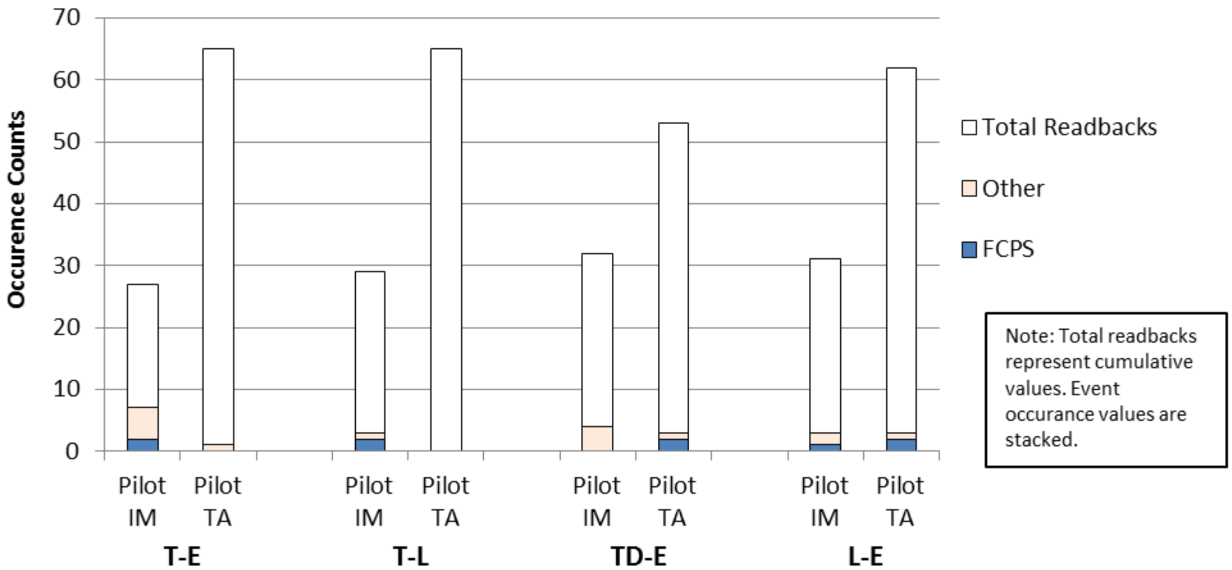

Figure 5-72. Pilot Readback Incomplete Message (J) Occurrences

The results show low overall occurrences of incomplete pilot RB messages, though T-L appeared to demonstrate fewer occurrences (3%) of Incomplete Messages than the next lowest alternative, L-E (6%). TD-E and T-E (8% and 9%, respectively) demonstrated the most. For the Telephonic alternatives, most occurrences were in response to IM clearances, though they were more evenly distributed with TD-E and L-E.

5.2.4.6 Third Party Pilot Confusion Events

The TPP Readback events were intended to capture events related to the possibility of TPPs hearing their call signs being used in transmissions not intended for them. It included events such as TPPs asking ATC if a particular communication was for them as well as events where they accepted and responded to a communication that was for another aircraft.

Despite numerous opportunities for the TPPs to hear their call signs being used in communications not intended for them (subjective results indicated that they did hear their own call sign in such communications), none of these third party confusion events were observed in the simulation in response to a usable IC or IA. No alternative appeared to be less effective than any other in reducing potential cases of TPPs mistakenly believing a transmission was for them.

5.2.4.7 Words Added (O) and Utterances (P) Events

Two other event counts that were tracked include Words Added (O) and Utterances (P). The degree to which pilots and controllers added extraneous verbiage to their communications, and built in pauses with an utterance, may provide a rough index to their degree of difficulty assembling and speaking the elements for a communication. Figure 5-73 provides summary counts by alternative of the extra words and utterances that each participant added to their communications. Only RBs and RRs that follow usable preceding communications are included.

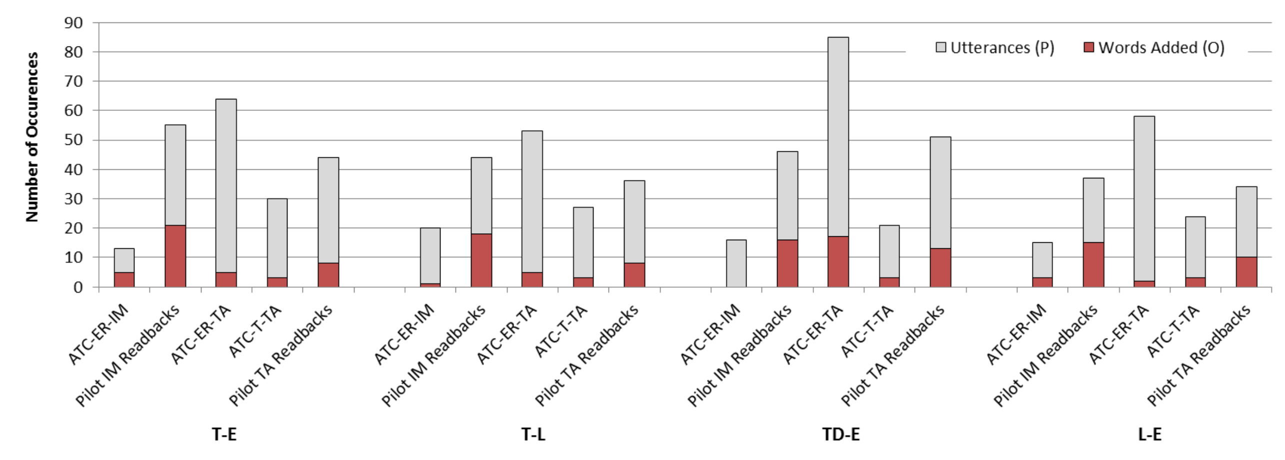

Figure 5-73. Words Added and Utterances (O and P) Occurrences

The results show that TD-E appeared to show the greatest total counts of extra communication words and utterances, though there did not appear to be a clear relationship between these events and the other alternatives.

5.2.5 Reply Lags

In addition to the error and deviation events, the transcript analysis also calculated the times between a controller providing a usable IC or TA and the start of the pilot RB. Table 5-45 summarizes these replay lag times for each of the alternatives.

Table 5-45. Readback Reply Lags in Response to Usable ATC ICs and IAs

Alternative	Transmission Type	Reply Lag (sec)		
		Mean	**SD**	**n**
T-E	**Pilot IM**	2.33	2.45	29
	Pilot TA	2.00	3.79	63
T-L	**Pilot IM**	2.46	1.31	30
	Pilot TA	1.81	1.44	62
TD-E	**Pilot IM**	2.60	2.25	31
	Pilot TA	1.60	1.24	53
L-E	**Pilot IM**	2.16	1.96	31
	Pilot TA	1.67	2.57	58

Figure 5-74 shows the distribution of pilot RB reply lags for each alternative and operation. Error bars represent the standard deviation for the lag sets.

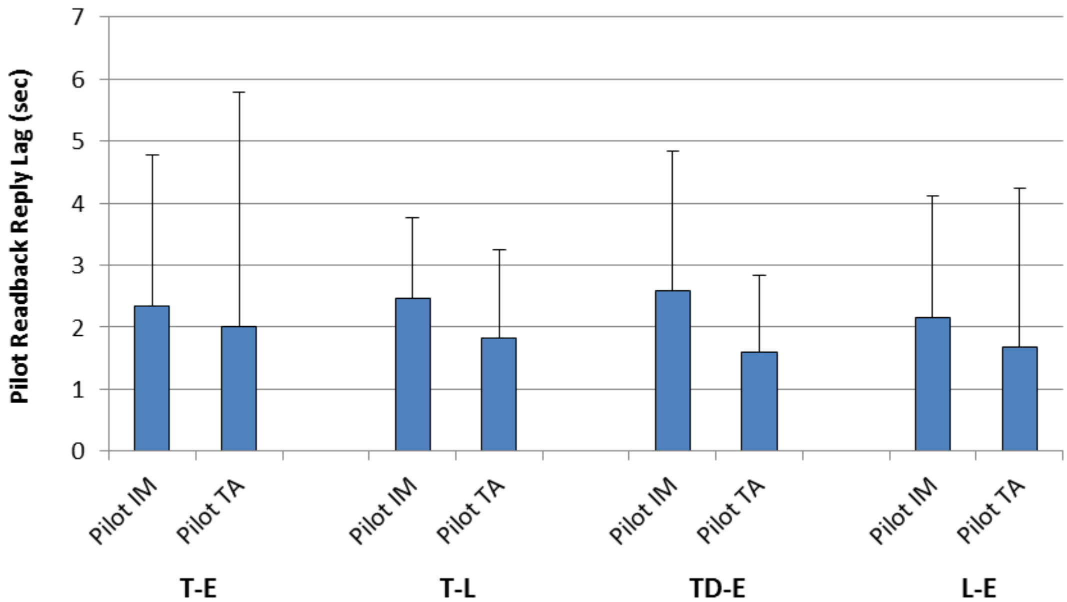

Figure 5-74. Pilot Readback Reply Lags

The results suggest that pilots took slightly less time to reply to IM clearances with the Letters format, though on average it was only tenths of a second of difference. For TAs, pilots appeared to respond up to a second less with the Telephonic Delimiter and Letters formats than with Telephonic. For Telephonic, pilots took on average about two tenths of a second less time to respond to the Later position than Earlier.

5.3 Hypothesis and Results Summary

Table 5-46 summarizes how the results supported, found a different result, or are inconclusive due to insufficient data with regard to the hypotheses. An overall discussion of the simulation results, including deviations from the hypotheses, is provided in Section 6.

Table 5-46. Hypothesis and Results Summary

Hypothesis		Subjective Data			Objective Data		
		Supported	Different Result	Insufficient Data	Supported	Different Result	Insufficient Data
1A	Controllers will subjectively prefer current call sign phraseology to convey TPCS and will make fewer clearance phraseology errors.	X-Prf			X-Err		
1B	Readbacks with two call signs in the same format are more likely to be confusing to controllers than readbacks that use a different format for FPCS versus TPCS.		X			X	
1C	FPPs will report lower workload and make fewer identification errors with the Letters format than with the Telephonic format.		X-WL		X: T-E	X: T-L	
1D	FPPs will make fewer readback errors with the Letters format than with the Telephonic format.		N/A			X	
1E	Adding a delimiter to current call sign phraseology will not affect the FPP reference aircraft identification error rate.					X	
2A	Controllers will report less workload and prefer the Telephonic Delimiter format than Letters.		X			N/A	
2B	During FPP readback, no difference in controller confusion will be observed between the Letters or Telephonic Delimiter formats.		X		X		
2C	FPPs will show reduced workload and make fewer identification errors with the Letters format than the Telephonic Delimiter format.	X			X		
3A	The Later position of TPCS in the TA messages will show reduced controller workload, phraseology errors, and increased acceptability.	X(T)		X(ER)	X(ER)	X(T)	
3B	The Later position of TPCS in the IM clearance will show reduced controller workload, phraseology errors, and increased acceptability.		X(ER)		X		
3C	With current day formats, placing TPCS in the Later position in a TA will help the FPP find the reference aircraft more quickly and will result in fewer identification errors.		N/A		X-Err	X-RL	
3D	With current day formats, placing TPCS in the Later position in an IM clearance will make it easier for the FPP to grasp the entire initiation message.		N/A				X
4	The Letters format will result in fewer FPP identification errors than the Telephonic formats in situations with non-intuitive call signs.		N/A			X	
5	Instances of TPP confusion will be higher with the Telephonic format as compared to the Letters and Telephonic Delimiter formats.		N/A			X	
6	The Letters format will be more effective in reducing TPP confusion than the Telephonic Delimiter format.		N/A				X
7	TPP confusion will be the same regardless of whether the Telephonic format is in the Earlier or Later position.		N/A		X		

X(ER) = En Route (ATC); X(T) = Terminal (ATC); X-Prf = Preference; X-Err = Error Counts; X-WL= Workload; X-RL = Reply Lag

6 Discussion

Using a method other than current day phraseology to refer to a TPA on the voice frequency may reduce the potential for confusion. An appropriate solution should minimize the potential for TPPs on the frequency to become confused about transmissions referring to them, as well as allow pilots and controllers to establish a clear awareness of the aircraft they are referencing. The following discussion of simulation results considers trade-offs between the tested alternatives from both of these perspectives. The four evaluated alternatives included combinations of format and position in the phraseology and consisted of: Telephonic – Earlier, Telephonic – Later (T-L), Telephonic Delimiter – Earlier (TD-E), and Letters – Earlier (L-E).

The alternatives were examined from both subjective acceptability and objective performance perspectives as it is possible that a preferred alternative may also result in increased user errors. In this section, the subjective results are summarized and discussed first, followed by those from the transcript analysis. However, certain transcript results may be mentioned in the subjective when they have a direct bearing on a result being discussed. It should be noted that since statistical tests were not performed on the objective results due to low sample sizes and complexities resulting from unequal opportunities for event occurrences, conclusions from that data are based on observed trends rather than statistical significance. Additionally, while statistical tests were run for controllers, low sample size and high variability yielded few statistically significant tests. Therefore, conclusions from that the subjective ATC data are also based on observed trends rather than statistical significance.

Simulation results suggest that overall, pilots and controllers were able to use TPCS in communications involving IM operations and TAs. The majority of participants reported acceptable workload levels when using TPCS. While some statistical differences were noted for pilots for workload they do not seem to be operationally significant. However, they are interesting in light of other trends.

Pilots and controllers indicated that they were able to understand each other during exchanges involving TPCS, regardless of the alternative. While most all means appeared on the agree side of the scale, pilot results showed significantly more issues with the TD-E alternative (as compared to the T-E and L-E). TPPs reported that they often heard their call sign being used as a TPCS in a communication between controllers and another pilot. In those exchanges, TPPs reported hearing their call sign from both the FPPs and the controllers. Despite this, there were no observed occasions where TPPs either asked whether a communication was for them or intercepted a communication intended for another aircraft. When pilots were asked if they could get used to being referred to as a TPA, the vast majority reported that they could and experience would help reduce any concerns.

When asked about whether TPCS could solve any current issues, the majority of terminal controllers reported that it would help reduce repeated traffic calls and would help when issuing TAs to multiple aircraft performing visual separation operations (such as that reported in Cieplak et al., 2000; Battiste et al., 2000; Bone, Helleberg, and Domino, 2003). En route controllers did not find it as useful. About forty percent of the pilots reported that it would help with situation awareness and positive identification of the reference aircraft / TPA. Pilot results showed the Letters alternative was significantly better than the other three alternatives (T-E, T-

L and TD-E) when trying to identify the reference aircraft / TPA on the CDTI traffic display. An analysis of reply lags supports this, though the reduced reply time with L-E versus T-E and T-L was only tenths of a second on average. As another benefit, both pilots and controllers reported that if TPCS were used, some of the elements of a standard TA, such as aircraft type, may no longer be necessary. In areas with high traffic density, this, along with a reduction in the number of repeated TAs, may increase frequency availability.

The primary goal of the simulation was to determine the best alternative(s) from the four that were tested. Overall, pilot results showed a preference for the L-E alternative over the other alternatives (T-E, T-L, and TD-E). The pilot results also showed a reduced preference for TD-E over the other alternatives (T-E, T-L, and TD-E). Finally, overall pilot results did not show a preference for T-E over T-L, or vice versa, in any of the questions where statistical tests were run. These results were seen over the majority of the questions. Overall, controller results were less clear based on low numbers and variability but trends indicate a preference for the Telephonic format, with the T-L alternative seeming to be the most preferred. Controller results also indicated the most dislike of TD-E alternative. The L-E alternative seemed to fall between the Telephonic formats and the TD-E alternative.

When participants were asked to rank the TPCS alternatives against each other, the en route controllers ranked the T-L alternative as their first choice most often. Terminal controllers also most often ranked the T-L alternative as their first choice. Pilots ranked the L-E alternative as their first choice most often and statistically it was significantly ranked higher than the other three alternatives (T-E, T-L and TD-E). Pilot results also showed that TD-E was statistically ranked lower than the other three alternatives (T-E, T-L and L-E). Except for en route controllers, TD-E was rarely chosen as the first preference. Pilot results did not show a significant difference of T-E as compared to T-L.

When asked which TPCS alternatives would be acceptable in line operations, both groups of controllers appeared to find the TD-E and L-E alternatives less acceptable. Terminal controller replies indicated a strongest preference for T-L while en route controllers indicated a preference for T-E. Pilots found the L-E alternative statistically more acceptable than the other three alternatives (T-E, T-L and TD-E). Pilot results also showed that TD-E was statistically less acceptable than the other three alternatives (T-E, T-L and L-E). Pilot results did not show a significant difference of T-E as compared to T-L.

When asked if they were able to sufficiently communicate the TPCS alternative, the trends were very similar. Both groups of controllers appeared to find the TD-E and L-E alternatives less acceptable. Terminal controller replies again indicated a strongest preference for T-L while en route controllers indicated similar preferences for T-L and T-E. Pilot results were the same. Pilots found the L-E alternative statistically more acceptable than the other three alternatives (T-E, T-L and TD-E). Pilot results also showed that TD-E was statistically less acceptable than the other three alternatives (T-E, T-L and L-E). Pilot results did not show a significant difference of T-E as compared to T-L.

When asked about message length, it appeared to have an influence on the acceptability of all the TPCS alternatives, but did not act as a discriminator between them. The replies to the acceptability of the length of the communications involving TPCS had much variability but the length of the L-E alternative appeared less acceptable to ATC than to the pilots. Possibly because the pilots found the Letters format more useful and therefore would be more tolerant of a longer length (if that format is actually lengthier). This question was the only one where statistical significance was found for either controller group. The en route controllers found the IM communication significantly more acceptable for length when compared to the TA communication.

When asked about the acceptability of the position of the TPCS in the communications, there did not appear to be clear trends to suggest whether later (T-L) or earlier (T-E, TD-E, and L-E) is best. Pilot results did not show a difference for the alternatives in regards to position. The question specifically asking about position had no significant results and the ranking of preferences did not show a statistical difference between T-L and T-E. It appears the pilot general preference for the Letters format was mainly base on the format and less on the position. Controller rankings did indicate a strong preference for the Later position versus the Earlier position when comparing the two telephonic formats. However, those trends are not as apparent in the actual question related to TPCS position. When asked if there is a logical location within a communication for TPCS, the majority of both controller groups and pilots, that gave a preference, reported a later location. However, there were still preferences for earlier locations and unclear replies. It may be that the TPCS format and the operational context have an influence on the acceptability of the TPCS position. This argues for ensuring that the position is considered when developing the phraseology and that it is adhered to operationally. The placement should consider the proximity of the TPCS to the FPCS and consider the possibility of pilot placing their TPCS either at the beginning or end of their readback to ATC.

If the telephonic format was to be used, pilots may need a reference source to decode the airline name into the airline three-letter designator shown on the CDTI traffic display. In this simulation, pilots were provided with a paper reference source and pilots reported using it more often than not in the T-E, T-L, and TD-E alternatives. They still reported using it for the L-E alternative but to a lesser degree. While the use of the document generally seemed acceptable, pilots did report some concerns with using it. Some pilot comments noted that those concerns appeared to lessen (and become more acceptable because of less references) as they increased their familiarity with the call signs.

When all participants were asked whether the alternatives had the *potential* to cause pilot errors, pilot results showed the L-E alternative was statistically predicted to cause less pilot errors than the other three alternatives (T-E, T-L and TD-E). Pilot results also showed that TD-E was statistically predicted to cause more pilot errors than the other three alternatives (T-E, T-L and L-E). As will be discussed later in the transcript analysis summary, TD-E proved the most problematic for pilots in terms of identifying and communicating the TPA in their readback. However, T-L proved to have notably fewer deviations and errors than T-E and L-E. Pilot results did not show a significant difference of T-E as compared to T-L. Terminal controller replies indicated that they may expect more errors for pilots when using the T-E alternative than with the T-L alternative, which is supported by the transcript analysis.

When asked whether they made any errors, pilots reported they did. Again pilot replies suggested that they had more issues with the TD-E alternative as compared to the other three. The T-E, T-L, and L-E were very similar in the number of self-reported errors, though differences were observed in objective performance. When asked if they actually heard any other pilots make errors, about half of each group reported that they did. Terminal controllers reported about the same number of issues for each of the alternatives. En route controllers and pilots reported hearing the fewest issues with the L-E alternative and the most with TD-E. For the TD-E alternative, pilots reported hearing issues such as pilots forgetting to say "reference" or putting "reference" in the wrong location relative to the call sign (e.g., outside versus inside). The presence of these issues was confirmed in the transcript analysis.

When all participants were asked if the alternatives had a potential to cause controller errors, most en route controller replies were very similar and around neutral, but with a potential for the T-L format to be better for IM operations. In the transcript analysis, T-L proved to have fewer issues with ICs than T-E, but L-E showed the fewest. Terminal controller replies were similar to those predicting pilot errors. They indicated that they may expect more errors for controllers when using the T-E alternative than with the T-L alternative, which is supported by the objective performance results. Again pilot results were the same. Pilots found L-E significantly less likely to have controller errors than the other three alternatives (T-E, T-L, and TD-E). Pilots also found TD-E significantly more likely to have controller errors than the other three alternatives (T-E, T-L, and L-E). No significant difference in the potential for pilot errors was found for T-E as compared to T-L. In only one of two times, pilots found IM to be significantly more likely to have controller errors than TA

When controllers were asked whether they made errors, both controller groups replies indicated that errors were made, but fewer occurred with the T-E and T-L alternatives. While this is supported by the transcript analysis, T-L showed notably better performance than T-E, which was closer to the performance of L-E and TD-E. When pilots were asked if they heard any controller errors related to TPCS, the fewest errors were reported for the T-L alternative, while the other alternatives were higher but very similar.

Controllers reported more confusion about who they were talking to (FPA) versus about (TPA) than the pilots reported confusion about whether they were being talked to (FPA) versus about (TPA). However, pilots had comments in several questions where they mentioned that it can be confusing to hear their own call sign. When looking across all participants, the T-E alternative had more than twice the reports of controller confusion as compared to the L-E alternative. However, there were no observed occasions where controllers requested verification about who a RB including TPCS was from.

When asked which alternative they had issues with, pilots most often called out the TD-E alternative. When participants were asked a question about which formats they would recommend against using, almost half of the participants recommended against TD-E. The T-E, T-L, and L-E alternatives were better and similar, but the fewest responses from all participants were seen for the T-L alternative. When asked which alternative would be undesirable to use in the field, TD-E stands out as the least favorable while the other alternatives appear more favorable. When asked if unacceptable formats could be made acceptable, the TD-E alternative was the one that was indicated to be least possible to be made acceptable. Pilots also seemed most concerned about TD-E exacerbating current day problems. Besides not preferring the TD-E alternative overall, the majority of participants did not recommend keeping the term "reference" even if a delimiter were used. As discussed in Section 2.9, a longer delimiter was chosen to reduce the possibility of a TPP missing it and thus becoming confused about whether the communication is for them. A shorter delimiter might have been more acceptable for ATC and FPPs, but was expected to be less effective in reducing potential TPP confusion.

When considering all the subjective feedback some trends are apparent. Across all participants, the TD-E alternative was noted most often as being the least favorable alternative. It was usually ranked the lowest and noted as causing the most errors. While the delimiter term used ("reference") could have been expected to be a primary cause of the dislike of the TD-E alternative, TD-E was reported to be the alternative that was least possible to be made acceptable with changes. This suggests that any increase in acceptability for TD-E from changing the delimiter is likely to be minor.

For pilots, the L-E alternative was noted most often as being the most favorable across all of the subjective feedback. This is consistent with the pilots ranking it first most often when ranking the alternative against each other. L-E might be more favorable because it helped the pilots identify the reference aircraft / TPA on the CDTI traffic display. Though an advantage to this format was observed in the subjective data, it was only observed in the transcript analysis results for TAs with INT call signs.

It should be noted that pilots exhibited very limited response differences between IM operations and TAs for the alternatives, indicating that any differences between the communications (e.g., communication length) did not influence their opinions of the TPCS alternative.

Finally, when considering all the subjective feedback, the most favorable alternatives for controllers emerge. For both controller groups, T-L was noted most often as being the more favorable alternative. This is consistent with controller results from Op Eval 3, who reported a preference for adding TPCS onto the end of their normal TA, rather than embedding the TPCS within the advisory (Bone et al., 2003). The en route controllers generally seemed to show a preference for all the formats in the context of IM operations versus TAs. However, the terminal controllers were generally more favorable about TPCS use in TAs and reported expected benefits from its use (e.g., improved traffic acquisition by flight crews and a reduced number of repeated TAs). It may be that TAs issued by the terminal controller at lower altitudes are more critical because they are often issued to set up an operation such as visual separation during visual approaches, whereas TAs given by en route controllers are more often provided as a courtesy to let the flight crew know that there is traffic in their vicinity and that the controller knows about and is providing separation for it. If this is the case, the more positive ratings from the en route controller on IM makes more sense because they had a real need for the TPCS (i.e., to initiate an operation). The overall controller preference for the Telephonic formats are consistent with Hassa et al. (2005), who noted that controllers in their IM study recommended the use of a telephonic / conventional format for TPCS in future studies.

For the objective data, the transcript analysis results suggest that overall, controllers were able to keep their deviations from the prescribed IM clearance phraseology relatively small across the alternatives as compared to the TAs. When speaking the IM clearance on the frequency, en route controllers appeared to have the least number of deviations and errors with L-E, despite rating it as less acceptable than the Telephonic formats. The most issues with IM were observed with the T-E alternative and overall for IM, en route controllers appeared to have notably fewer performance issues with TPCS in the Later position as opposed to Earlier.

With regard to TAs, however, en route controllers had proportionally many more errors and deviations with the Letters and Delimiter formats than with Telephonic. Between the Telephonic alternatives, en route controllers appeared to have notably fewer performance issues with TPCS in the Later position as opposed to Earlier. Roughly similar proportions of total issues across the alternatives were observed with the terminal controllers. Element order changes and missing elements were the primary causes of issues with TAs, though some TPCS format errors were observed as well with the TD-E and L-E alternatives. In these cases, controllers mostly just defaulted to using a Telephonic format or not including TPCS at all in the transmission. Across all operations and controller participants, the fewest proportional number of events occurred with the T-L alternative and the most occurred with TD-E. When pilots used TPCS in their readbacks, none of the alternatives appeared to cause any more controller confusion than any of the others.

TPCS performance in pilot readbacks were investigated from two perspectives: 1) which alternatives showed better and worse performance with facilitating the FPPs ability to identify the TPA, and 2) which formats were more difficult for the FPP to use in a readback communication. With regard to TPA identification, results show overall that pilots were able to successfully identify and communicate the TPCS most of the time, though aircraft identification appeared to generally be more successful with IM operations than with TAs. Across both operations, it appeared that the fewest identification issues were observed with the T-L alternative and the most were observed with T-E. This is consistent with pilots in the CAVS simulations, who reported that appending TPCS to the end of a standard TA aided in the positive identification of the reference aircraft and that it was beneficial (Bone et al., 2003; Bone et al., 2003a). Overall, display selection errors were the main contributors, especially with the TAs, meaning that pilots selected a different aircraft on the display than what was specified in the initial ATC communication. This is likely due to potentially more variability in the TPA position with a TA versus an IM operation. Though an attempt was made to vary the starting position of the reference aircraft relative to each participant, it still may have had fewer logical proximate locations than with the TAs and thus have been easier to locate. Very few verbal aircraft selection errors were observed, meaning the call sign used by the speaker was intentional, but for an incorrect aircraft (as could best be inferred by the authors from the rest of the transaction). When it occurred, however, T-E demonstrated the most events.

There were few cases of pilots requesting full IC or IA repeats, but most occurred with L-E. When pilots requested a repeat of a particular element from the IC or IA, which also did not happen often, TPCS was the element most requested. Most of these partial repeat requests occurred with TD-E, and the fewest were observed with T-L. T-E and L-E were in between and showed the same amount, proportionally. There were zero observed occurrences across all the alternatives of pilots saying that they were not able to identify the TPA in response to an IC or IA and also zero instances of failing to report that they had identified the traffic.

The L-E alternative only showed an advantage with regard to TPA identification for TAs with INT call signs. For most alternatives, identification issues for TPA with NI call signs were less than those with INT call signs. However for the L-E alternative, aircraft identification issues, due primarily to display selection errors, were proportionally greater with NI call signs than with INT. This was an unexpected result, as it was hypothesized that Letters should help pilots identify the TPA more accurately – especially when the (displayed) airline three letter designator could not be clearly inferred from the (spoken) airline telephony designator. Pianetti et al. (2007) noted that pilots did report some difficulties correlating the telephonic format used by ATC and the three letters shown on the CDTI traffic display. It is unclear why pilots in the current study appeared to have greater issues with Letters with NI call signs. Though L-E did appear to have some advantage over the others in TPA identification overall, it might not be as effective as anticipated in helping crews identify aircraft with unfamiliar or NI call signs. Although it should be noted that some pilots commented that when they had issues with the NI calls signs and were not using the L-E alternative, they simply relied upon the numeric flight identification alone. This may be very undesirable and even a potential safety issue.

Pilot use of TPCS was also evaluated for events related to the pilots' verbal communication of information provided in the ATC IC or IA. This includes events such as pilot use of the correct TPCS Format and whether they had other errors and deviations in their RBs relative to the phraseology element order suggested by the experimenters. The results suggest that overall, pilots had notably fewer RB issues with the T-L alternative than the others and especially TD-E. There appeared to be a far greater proportion of issues with IM clearance RBs than with TAs across all the alternatives, which is understandable since the IM RBs were much more complex with many more elements. The IM clearance had five elements and the pilot had to readback all five whereas the TA had seven elements but the pilot only had to read back one and add the word "identified."

The higher number of pilot readback issues for TD-E and L-E in particular appear to be driven by format utilization deviations and element order changes. With the Delimiter and Letters formats, deviations mostly consisted of using the Telephonic format. For TD-E, this was usually just the pilot not including the delimiter term in the transmission. However, there were several observed occurrences in which the pilot put the delimiter term either before the airline designator or after the numeric flight identification, instead of between them. For L-E, there were a few cases where the pilot used a Telephonic format instead of Letters, and a few observed cases where a pilot used the phonetic alphabet instead of just pronouncing the letters. This may be due to pilots normally using the phonetic alphabet versus it be a conscious alternate choice. With training and experience, however, pilot difficulty in using these alternatives may decrease.

Element order changes were also a major contributor to pilot readback events. Pilots appeared to exhibit the least amount of element order change events with the T-L alternative; however, since the prescribed RB phraseology was the same for T-E and T-L, it is unclear why they appeared to have slightly more difficulty with T-E. It may be related to pilots better grasping the overall IC or IA with T-L, and thus being able to provide cleaner readbacks. Nearly all of the TD-E and L-E alternatives involved call sign-related element order changes for IM RBs, with TD-E showing more than L-E. TPCS events with these alternatives mostly appeared to be related to pilots putting TPCS later in the RB message then specified by the prescribed phraseology. When viewed in conjunction with the relative lack of order changes for the T-L alternative, this suggests that a call sign position later in the message, which may be most closely aligned with today's communications, may be a more logical position and thus easier for pilots to manage.

There were also notably more dropped elements (partial readbacks) with T-E than with the other alternatives. However, the percentage of pilot partial readbacks seen in the simulation across all TPCS alternatives (3 – 9%) was lower than that seen in past communication work (e.g., 12% in the en route [Cardosi, 1993], and 26% in the TRACON [Cardosi et al., 1996]). This suggests that TPCS does not increase the number of partial readbacks over communications that do not involve TPCS.

The insertion of TPCS into already complex communications should also be considered since past research shows that messages with three to five or more elements have more communication errors (e.g., Cardosi, 1993; Barshi and Farris, 2013; Morrow et al. 1993). In the en route environment, Cardosi (1993) found approximately 4.5% of the readbacks had errors when the message had 5 or more elements (such as the IM clearance phraseology in this simulation). This is comparable to the 3.6% execution error rate observed for T-E and the 6.3% execution error rate observed for T-L. However, deviations from Telephonic, such as Delimiter and Letters, showed execution error rates as high as 9.4% and 15.6%, respectively. Though the results suggest that deviating from current day, telephonic phraseology could increase the number of pilot readback errors, it is also possible that this effect could be reduced with training and experience.

For a TA, considerations should be given to reducing the number of elements in the communication. Pilots and controllers in this simulation both seemed receptive to this idea. For a transmission like the IM clearance, the identification of the reference aircraft / TPA could be broken out as a separate communication (as done in some research such as Bousier et al., 2006; Nyberg, 2006; Bone et al., 2013). Some pilots and controllers in this simulation actually made the recommendation for one communication for traffic identification and another for the actual instruction / clearance. This message could also act as an advanced organizer to prepare the flight crew for the potentially complex IM clearance to follow.

The overall trends from the transcript analysis suggest that T-L was the least problematic alternative for pilots and controllers and TD-E was the most. This is consistent with the controller subjective preference and acceptability results, which disfavored TD-E and suggested that T-L is the most suitable. Though there was not a clear trend in the questionnaire results to suggest that Later is a better position for TPCS than earlier, T-L appeared to have better performance for pilots and controllers than T-E. This suggests that a later placement of the TPCS element may be advantageous for all parties. Although L-E appeared to only have a limited advantage with regard to TPA identification, and despite lower overall readback performance, pilots showed a subjective preference for the alternative. However, since pilots also exhibited better performance with T-L than T-E, the performance of the Letters format may have been degraded by having it in an Earlier position. A Letters – Later alternative might prove to have better performance than what was observed in this simulation. One other consideration is that pilots in the subjective data admitted to at times ignoring the airline designator and making selections based on the numeric flight identifier alone. This is a safety concern that L-E may help mitigate.

7 Conclusions and Recommendations

To take advantage of projected benefits afforded by ASAs, the use of call sign has been proposed as the method for pilots and controllers to refer to other (third party) aircraft on a common voice frequency. However, using call sign to talk about (rather than talking to) other aircraft on the same frequency introduces a potential for confusion among controllers and pilots. The FAA SBS program office identified TPCS as a program risk and initiated an activity to examine the topic. To help determine how to proceed with further research and the development of communications phraseology and procedures for ASAs, a HITL simulation was conducted to evaluate TPCS voice communications alternative candidates proposed by the TFID OFG using two ASAs during an arrival and approach operation. The overall simulation objective was to provide research results that establish a basis for narrowing down the alternatives and employed pilots, en route controllers, and terminal controllers as participants.

The study was framed around three central research objectives. The first was to determine whether deviating from the use of the Telephonic (current day) format was necessary to reference a TPA. Since there were no instances of TPP confusion observed in the simulation (the same is true of most to all of the past research activities), there is no evidence to suggest that deviating from current phraseology is necessary to reduce TPP confusion. Additionally, controllers generally preferred and had the least number of issues with the Telephonic format, particularly with TPCS in the Later position.

While the pilots in this simulation preferred the Letters format, they were also generally positive about the T-E and T-L formats. However, this may have been based on having access to a call sign look up reference, either in electronic or paper form. Based on feedback received by one of the authors (Bone) from the FAA, it is not an option to have the CDTI traffic display show the Telephonic format for airline designator instead of, or in addition to, the current Letters format. It is believed to be cost prohibitive to develop and maintain such a database for the flight deck avionics and would also require a change to current standards for the ADS-B equipment. Pilot acceptability for the Telephonic formats must be considered in conjunction with the availability and usability of call sign reference material. However, in some cases a Letters format may help pilots more accurately identify the TPA on their CDTI traffic display than current Telephonic phraseology. Use of the Letters format may also lead to fewer shortcut errors such as selecting an aircraft simply based on the numeric flight identification. As such, and despite reported ATC misgivings, there may be advantages for the First Party Loop to deviate from the Telephonic format for conveying TPCS.

The second objective was to determine whether user acceptability and performance trade-offs existed between the chosen TPCS alternatives (i.e., Letters and Delimiter). The Delimiter format was consistently rated poorly and associated with the most performance issues for both pilots and controllers. Pilots showed a subjective preference for the Letters format, and comments indicated it was because they felt it helped them better identify the TPA on the CDTI traffic display. Though this proved to generally be true for IM operations and TAs with intuitive call signs, no apparent advantage with the letters format was observed for non-intuitive call signs. In a recent pilot / controller workshop examining IM clearance complexity, flight crews reported difficulties trying to decode the (Telephonic) TPA call sign and still pay attention / write down the remainder of the clearance (Bone et al., 2013). Overall, this simulation found that the Letters format appeared to provide some advantage over the other alternatives in allowing pilots to successfully identify the TPA, though it did result in more readback errors than Telephonic (though still less than Delimiter). It is possible that the readback errors may decrease with experience; however, since they are problematic communications it may be desirable to further evaluate the potentially negative impact of TPCS on pilot readbacks in future research. While it may be desirable from a TPP and FPP perspective to use the Letters format to reduce confusion about who is being talked to (FPP) versus about (TPP) and to possibly help with reference aircraft / TPA identification on the CDTI traffic display, the Letters format appeared more difficult for controllers to use in their ICs and IAs. Despite these misgivings, Letters appeared to be superior to the Delimiter format and it is not recommended that Delimiter formats be explored any further.

The third objective was to determine the user acceptability and performance trade-offs related to the placement of TPCS within the controller clearance or advisory (i.e. earlier versus later). Simulation results show that TPCS in the later position was more acceptable and had fewer performance issues than in the earlier position. The improved performance could be because the later position allowed for a more natural and logical flow, and provided the least deviation from how pilots and controllers currently convey information in voice communications. As such, the authors recommend that phraseology involving TPCS should be designed for a natural flow. For IM, this may mean positioning TPCS in the middle or end of the clearance. For a communication such as a TA, this may mean making TPCS the final element in the transmission. These placements may be the least disruptive to how controllers are currently used to conveying information and how pilots are currently used to hearing it. It may also allow controllers to add on TPCS to TAs for operational like visual separation when its use is determined to be operationally advantageous. With this in mind, TPCS placement should be carefully considered to not detract from the natural flow of standard pilot and controller phraseology.

An appropriate phraseology solution needs to minimize the potential for TPPs on the frequency to become confused about transmissions referring to them, as well as allow pilots and controllers to establish a clear awareness of the aircraft being referenced. Based on the results of this simulation, two possible approaches with respect to TPCS format are recommended for the next and final activity in the SBS effort.

1) There were no TPP issues observed in the simulation and no evidence was found in the literature about documented TPP issues leading to a problematic outcome. Assuming that TPP confusion will be rare and solvable as it occurs, it may be best for controllers to use a Telephonic format as the normal method of conveyance, but to have the option to use the Letters format when the controller believes there may be pilot confusion about the airline three letter designator (similar to that done in Hassa et al., 2005 while following the controller recommendation of using the telephonic format). The pilot would be expected to reply with the format used by the controller. However, if situations arise where the controller uses the Telephonic format and the pilot has confusion about the TPCS on the CDTI traffic display, the pilot could reply with a question asking for clarification of the TPA using the Letters format to resolve any ambiguity. While the Letter format overall was less desirable from the controllers' perspective, no ATC confusion was observed with pilot use of Letters and it is expected

that it would be more palatable if it were an option for the controller versus a requirement (as it was in this simulation so that format could be tested). This type of TPCS communication method may reduce or eliminate the need for the TPCS reference material for decoding the Telephonic format into the airline three-letter designator or vice versa. Using the Letter format may overcome some of the issues with using the phonetic format reported by Raynaud et al. (2007). This type of look up was noted by pilots as challenging especially during periods of high workload. This proposal also allows controllers and pilots to only use letters when necessary. That is advantageous because while the Letters format initially help identify aircraft on the CDTI traffic display, the Letters format may become less useful once pilots learn the airline three letter designators.

2) A second approach, that proactively mitigates the potential for TPP confusion, involves a required controller deviation from the current phraseology for TPCS. It may be desirable even if no issues were seen in this simulation (or much of the TPCS-related literature) because problems are seen today with similar call signs for FPPs (e.g., Cardosi et al., 1999; Van Es, 2004) that one could speculate would be applicable to TPCS operations. Simulation results suggest that the Letters format is less problematic overall than adding a Delimiter, and despite less ATC acceptability than Telephonic, Letters showed fewer performance issues for IM, similar performance for terminal TAs, though worse performance for en route TAs. In this case, if concerns remain about the potential for TPP confusion, follow-on research should explore the acceptability of mandating the use of the Letters format for TPCS, particularly with ATC.

For either approach, TPCS placement should be carefully considered to maintain a natural flow and minimize the deviations from current phraseology for the individual clearance, instruction, or advisory in which it is expected to be used. As TPP confusion always remains a possibility, however, a safety analysis may be desirable to fully understand the likelihood and impact in voice communications.

For the Phase 3 effort, the authors suggest examining TPCS alternatives as suggested above in a high fidelity communications environment, in addition to the proposed high fidelity simulation environment. A high fidelity communication environment with numerous participants and different voices will create an environment where the rare errors have the potential to be realized. The authors also recommend generating non-intuitive airline designators that do not exist in the real world, as was done in this simulation, since some flight crews may know, and some may not, certain non-intuitive airline designators. Although the numeric flight identification is not directly relevant to airline designator, it should be considered when developing TPCSs in order to ensure it does not confound the potential for errors. It is recommended that the Phase 3 simulation examine the potential safety issue of flight crews using only the numeric flight identification to identify the TPA when they have difficulty with non-Letter TPCS formats. It may be desirable to have the same numeric flight identification, or two very similar numeric flight identifications, with two different airline designators. With these call signs, pilots may make errors or may have a more challenging time determining which aircraft is the TPA. Overall however, different numeric flight identifications should not be included in such a way that it will be a significant confounding factor in the simulation.

The authors also recommend considering which ASAs are appropriate for the Phase 3 examination of TPCS. Operations should be chosen that are realistic (including intuitive benefits and advantages) and complex enough to make for rich communications. If using an operation like IM, it is recommended to have an FPA communication that uses the TPCS separated in time and sequence from a communication to that TPA. In other words, avoid having a communication to a FPA be immediately followed by a communication about that same aircraft. Although that sequential order may occur naturally in line operations, in simulations it may give undesirable predictability where errors are desirable for insight into particular TPCS issues. If TAs are used, consider the possibility of truncating the current TA communication (as done in Olmos and Mundra, 1999). TPCS adds a significant informational element and may be able to replace certain other elements. As mentioned previously, it is also worth considering breaking out the identification of the reference aircraft / TPA as a separate communication to reduce the complexity of communications such as the IM clearance. Traffic identification may be easier and the message could also act as an advanced organizer to prepare the flight crew for the potentially complex IM clearance to follow. For TA communications where visual acquisition is required, TPCS should only be used when the controller or pilot finds it operationally advantageous to do so (as with Pianetti et al., 2007 and Bone et al., 2003b)

Finally, it may be desirable in Phase 3 to provide both flight crews and controllers an understanding of each other's traffic displays. With such an understanding, participants may better understand the limitations of the displays and how that should impact their thoughts on the ultimate TPCS solution. In this simulation, at least one controller reported finding it useful to understand that the flight crew had only the airline three letter designator on the CDTI traffic display.

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Appendix A Summary of Possible Pilot and Controller Identification and Execution Errors

Table A-1. TPP TPCS Errors

Operational Error	Error Source	Error Type	Explanation	Primary Contributing Factors	Further Contributing Factors	Example of Error	Problem Formats*
TPP becomes confused about whether a clearance was for them (no ATC or FPP mistakes)	**TPP wrongly hears TPCS match their Call Sign**	**Auditory Transposition** (Perceptual)	Hearing letters or numbers in a call sign in an out of order position in a verbal communication	Call signs in frequency range that contain similar sounding airline three letter designators	Individual letter pronunciation	Hearing "AJL" instead of "JAL"	L
				Call signs in frequency range that contain similar sounding digits in flight identifications	Four-digit flight identifications	Hearing DAL159 instead of DAL195	L, T, TD
				Call signs in frequency range with that contain similar sounding groups in flight identifications	Four-digit flight identifications	DAL2529 heard as DAL2925	L, T, TD
		Auditory Substitution (Perceptual)	Hearing a word, letter or number that is not in original call sign	Call signs in frequency range that contain similar sounding designator words	Telephonic pronunciation	Hearing "Skylink" instead of "Flylink"	T, TD
				Call signs in frequency range that contain similar sounding airline three letter designators	Individual letter pronunciation	Hearing JAL937 instead of DHL937	L
				Call signs in frequency range that contain similar sounding digits in flight identifications	Four-digit flight identifications; only difference is in first digit	Hearing DAL537 instead of DAL937	L, T, TD
				Call signs in frequency range with that contain similar sounding groups in flight identifications	Four-digit flight identifications	DAL *Sixteen* zero seven heard as DAL *Sixty* zero seven	L, T, TD
				The use of call sign digits that are similar to altitude, heading, speed		SWA270	L, T, TD
	TPP correctly hears TPCS match their Call Sign	**Intended Recipient Confusion**	TPP hears their call sign spoken in a radio communication and either accepts the communication or questions if it was for them	No difference in the way call sign is presented between FPPS and TPPs.	Location in message and information that follows.	"United 123, for interval spacing, traffic is *United 456*. Cross PECHY 120 seconds behind that traffic."	L, T
					Use of call signs where airline designator letters are individually pronounced	"United 123, for interval spacing, traffic is *UPS 456*. Cross PECHY 120 seconds behind that traffic."	L, T

*Problem formats included here are limited to those used in the simulation.

Table A-2. FPP TPCS Identification Errors

Operational Error	Error Mode	Error Source	Error Type	Explanation	Primary Contributing Factors	Further Contributing Factors	Example of Error	Problem Formats*
FPP Selects Wrong TPA (no ATC mistakes)	**Identification Execution (Mistake)** Intended target correctly selected, but target is not the ATC-intended TPA	**FPP hears TPCS wrong** (over frequency)	**Auditory Transposition** (Perceptual)	Hearing letters or numbers in a call sign in an out of order position in a verbal communication	Call Signs in frequency range that contain similar sounding airline three letter designators	Individual letter pronunciation	Hearing "AJL" instead of "JAL"	L
					Call Signs in frequency range that contain similar sounding digits in flight identifications	Four-digit flight identifications	Hearing DAL1595 instead of DAL1959	L, T, TD
					Call Signs in frequency range with that contain similar sounding groups in flight identifications	Four-digit flight identifications	DAL2529 heard as DAL2925	L, T, TD
			Auditory Substitution (Perceptual)	Hearing a word, letter or number that is not in original call sign	Call Signs in frequency range that contain similar sounding designator words	Telephonic pronunciation	Hearing "Skylink" instead of "Flylink"	T, TD
					Call Signs in frequency range that contain similar sounding airline three letter designators	Individual letter pronunciation (ONLY)	Hearing JAL937 instead of AAL937	L
					Call Signs in frequency range that contain similar sounding digits in flight identifications	Four-digit flight identifications; only difference is in first digit	Hearing DAL5537 instead of DAL9537	L, T, TD
					Call Signs in frequency range with that contain similar sounding groups in flight identifications	Four-digit flight identifications	DAL *Sixteen* zero seven heard as DAL *Sixty* zero seven	L, T, TD
					The use of call sign digits that are similar to altitude, heading, speed		SWA270	L, T, TD
		FPP sees TPCS wrong (on display)	**Visual Transposition** (Perceptual)	Seeing letters or numbers in a call sign in an out of order position while reading CDTI traffic display	Call Signs in display range that contain similar appearing airline three letter designators	Display font selection	Seeing "PUV" instead of "PVU"	L, T, TD
					Call Signs in display range that contain similar appearing flight identification digits	Display font selection	Seeing DAL149 instead of DAL194	L, T, TD
			Visual Substitution (Perceptual)	Seeing a word, letter or number on the CDTI that is not in original call sign	Call Signs in display range that contain similar appearing airline three letter designators	Display font selection	Seeing "DAL" instead of "DHL"	L
					Call Signs in display range that contain similar appearing flight identification digits	Display font selection	Seeing DAL788 instead of DAL766	L, T, TD
					More intuitive call sign designator in display range than assigned TPCS	Non-intuitive call sign designators with telephonic pronunciation	ATC assigns "Cactus" (AWE) as TPCS; but Conquest (CAC) is also on display and in logical position.	T, TD
	Selection Execution		**Motor Execution**	Intended target is correct TPCS, but is incorrectly selected on the display	Screen clutter		Accidental selection of wrong aircraft on CDTI traffic display when mentally knowing correct aircraft call sign designator and numeric identifier	L, T, TD

*Problem formats included here are limited to those used in the simulation.

Table A-3. ATC TPCS Execution Errors

Operational Error	Error Source	Error Type	Explanation	Primary Contributing Factors	Further Contributing Factors	Example of Error	Problem Formats*
ATC Misidentifies Intended TPA	ATC says wrong TPCS	**Visual Transposition** (Perceptual)	Seeing letters or numbers in a call sign in an out of order position while reading display	Call signs in display range that contain similar appearing airline three letter designators	Display font selection	Seeing “PUV” instead of “PVU”	L, T, TD
				Call signs in display range that contain similar appearing flight identification digits	Display font selection	Seeing DAL149 instead of DAL194	L, T, TD
		Visual Substitution (Perceptual)	Seeing a word, letter or number on the display that is not in original call sign	Call signs in display range that contain similar appearing airline three letter designators	Display font selection	Seeing “DAL” instead of “DHL”	L, T, TD
				Call signs in display range that contain similar appearing flight identifications digits	Display font selection	Seeing DAL788 instead of DAL766	L, T, TD
		Verbal Execution (Slip)	Controller intends to say correct TPCS, but makes a verbal error	Call signs with similar sounding designator words	TPCS is in the midst of several similar-sounding call signs from a different carrier	Saying “Skylink” instead of “Flylink”	T, TD
				Call signs that contain similar sounding airline three letter designators	Individual letter pronunciation	Saying JAL937 instead of DHL937	L
				Call signs in frequency range that contain similar sounding digits in flight identifications	Four-digit flight identifications	Saying DAL1595 instead of DAL1959	L, T, TD
				Call signs with similar sounding groups in flight identifications	Four-digit flight identifications	Saying DAL1595 instead of DAL1959	L, T, TD
	ATC hears (correct) FPP readback incorrectly / ATC fails to catch incorrect FPP readback	**Auditory Transposition** (Perceptual)	Hearing letters or numbers in a call sign in an out of order position in a verbal communication	Call signs in frequency range that contain similar sounding airline three letter designators	Individual letter pronunciation	Hearing “AJL” instead of “JAL”	L
				Call signs in frequency range that contain similar sounding digits in flight identifications	Four-digit flight identifications	Hearing DAL159 instead of DAL195	L, T, TD
				Call signs in frequency range with that contain similar sounding groups in flight identifications	Four-digit flight identifications	DAL2529 heard as DAL2925	L, T, TD
		Auditory Substitution (Perceptual)	Hearing a word, letter or number that is not in original call sign	Call signs in frequency range that contain similar sounding designator words	Telephonic pronunciation	Hearing “Skylink” instead of “Flylink”	T, TD
				Call signs in frequency range that contain similar sounding airline three letter designators	Individual letter pronunciation	Hearing JAL937 instead of DHL937	L
				Call signs in frequency range that contain similar sounding digits in flight identifications	Only difference is in first digit	Hearing DAL537 instead of DAL937	L, T, TD
				Call signs in frequency range with that contain similar sounding groups in flight identifications	Four-digit flight identifications	DAL *Sixteen* zero seven heard as DAL *Sixty* zero seven	L, T, TD

*Problem formats included here are limited to those used in the simulation.

Appendix B Demographic Questionnaires

Third Party Call Sign <u>Controller</u> Demographics

1. How many years of experience do you have actively controlling air traffic?
   _________ Years

2. How many months out of the past 12 have you actively controlled air traffic?
   __________ Months

3. At which facility do you now (or did you last) work?

4. At what other types of facilities have you worked? ____ Tower _____ TRACON ______ Center
   ______ Other

5. What is your current position?

6. What other positions have you held within the FAA (e.g., TMC, airspace operations, etc.)?

7. Have you ever been a controller at Atlanta Hartsfield International Airport (ATL)? (circle one)
   YES **NO**

   If yes, approximately how many months / years:

8. Do you have any experience with concepts where aircraft are using cockpit tools to space from another aircraft (e.g., Interval Management [IM], Merging and Spacing), such as demos, other simulations, etc.? (circle one)
   YES **NO**

   If yes, please describe your previous experience:

9. Do you mind if we follow up with you after the simulation if we have any questions on the data you provided? (circle one)
   YES **NO**

Third Party Call Sign Pilot Demographics

Please complete the following background questionnaire. Your identity will be kept completely confidential and will not be included in any of the reports or documents that will be produced as a result of this study.

1. Airline Affiliation(s):

2. Age: ____Years

3. Gender (circle one) **Male** **Female**

4. Estimated total flight hours: _____________

5. Aircraft Type Ratings:

6. Current aircraft qualification position (circle one) **Captain** **First Officer** **Flight Engineer**

7. Have you ever operated at Atlanta Hartsfield International Airport (ATL)? (circle one) **YES** **NO**

   If yes, approximately how many times:

8. Do you frequently fly internationally? (circle one) **YES** **NO**

   If yes, where:

9. Do you have any experiences with concepts where aircraft are using cockpit tools to space from another aircraft (e.g., Interval Management (IM), Merging and Spacing)? (circle one)

   YES **NO**

   If yes, describe:

10. Have you ever participated in other MITRE flight-deck based simulations? (circle one) **YES** **NO**

    If yes, which one(s)?

11. Do you mind if we follow up with you after the simulation if we have any questions on the data you provided? (circle one)

    YES **NO**

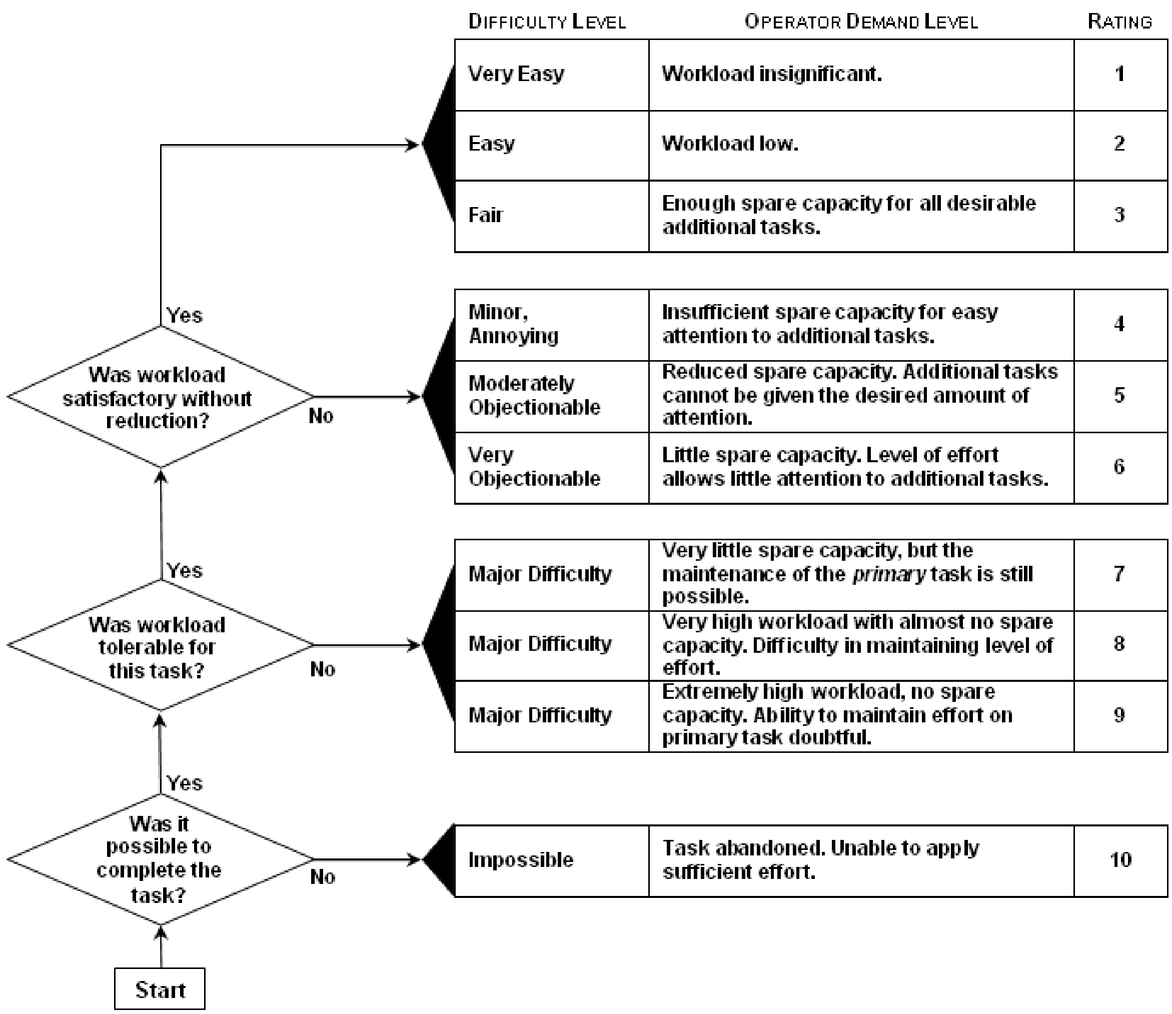
Appendix C Post-Scenario Questionnaires

THIRD PARTY CALL SIGN <u>EN ROUTE CONTROLLER</u> POST SCENARIO QUESTIONNAIRE

<u>Instructions</u>: Please answer the questions by selecting the option on each of the scales at the point which matched your experience. C*onsider only the most recent scenario when answering*. If you have any questions, please ask the experimenter.

1. Using the chart below, how would you rate your *average* level of workload?

   (a) Working up from the bottom, answer each yes/no question.
   (b) Select the numerical rating that best reflects your experience.



2. My overall workload was acceptable. (circle one)

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

3. How would you rate the scenario overall traffic load? (circle one)

1	2	3	4	5	6	7
Very Low						Very High

Third Party Call Sign Format Questions

4. I was able to sufficiently communicate the third party call sign using the format. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7
Traffic Advisory	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

5. Did use of the third party call sign cause you to make any errors? (circle one)

Yes **No** **Don't Know**

6. Did you observe any errors made by flight crews related to call signs? (circle one)

Yes **No**

7. I was able to understand pilot readbacks of third party call sign. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7
Traffic Advisory	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

8. I was able to remember what third party call sign format to use when referencing a third party aircraft. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7
Traffic Advisory	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

9. Did you have any specific issues with the third party call sign format? (circle one)

Yes **No** **Don't Know**

10. Did you ever experience confusion about who you were talking **to** vs. who you were talking **about**? (circle one)

Yes **No**

11. Did you ever have a desire to use a third party call sign format different than the one specified? (circle one)

Yes **No**

12. Do you think that the use of this third party call sign format will cause errors? (circle one)

Yes **No** **Don't Know**

Third Party Call Sign in Context of Broader Communication Questions

13. The third party call sign position within the communication was acceptable. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7	O Don't know
Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

14. The third party call sign acceptability is affected by its position in the communication. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7	O Don't know
Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

15. The third party call sign acceptability was affected by the other elements (e.g., assigned spacing goal or altitude) in the communication. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7	O Don't know
Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

16. The <u>length</u> of the communication that included third party call sign affected the acceptability of the third party call sign format. (circle one)

Yes **No** **Don't Know**

17. The <u>length</u> of the communication that included third party call sign was acceptable. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7	O Don't know
Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

18. The <u>complexity</u> of the communication that included third party call sign affected the acceptability of the third party call sign format. (circle one)

Yes **No** **Don't Know**

19. The <u>complexity</u> of the communication that included third party call sign was acceptable. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7	O Don't know
Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

Third Party Call Sign Overall Impression Questions

20. The third party call sign format would be acceptable in the field. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7	O Don't know
Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

21. Do you have any concerns about employing the third party call sign format in the field? (circle one)

Yes **No**

Other Questions

22. Were there any factors that led to confusion with regards to third party call sign phraseology (e.g., unusual call signs, traffic situations, etc.) (circle one)

Yes **No** **Don't Know**

23. Are there any additional observations (relative to equipment, automation, traffic situations, instructions or performance) that the experimenters need to be aware of? (circle one)

Yes **No**

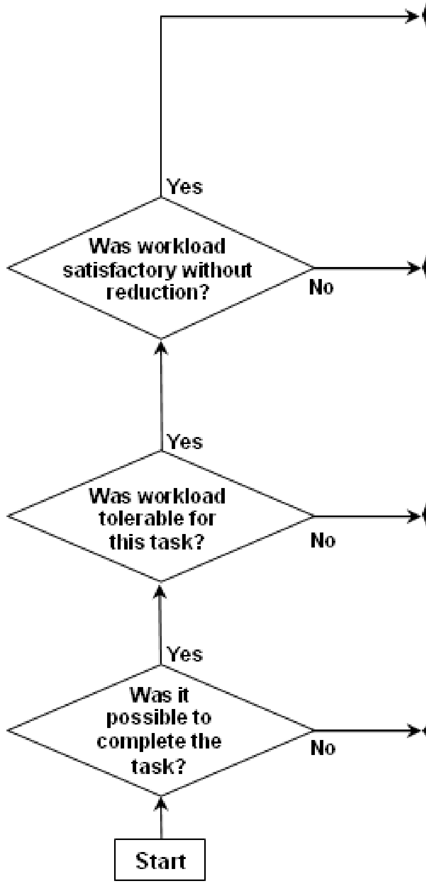
THIRD PARTY CALL SIGN TERMINAL CONTROLLER POST SCENARIO QUESTIONNAIRE

Instructions: Please answer the questions by selecting the option on each of the scales at the point which matched your experience. C*onsider only the most recent scenario when answering*. If you have any questions, please ask the experimenter.

1. Using the chart below, how would you rate your *average* level of workload?

    (a) Working up from the bottom, answer each yes/no question.

    (b) Select the numerical rating that best reflects your experience.



DIFFICULTY LEVEL	OPERATOR DEMAND LEVEL	RATING
Very Easy	Workload insignificant.	1
Easy	Workload low.	2
Fair	Enough spare capacity for all desirable additional tasks.	3
Minor, Annoying	Insufficient spare capacity for easy attention to additional tasks.	4
Moderately Objectionable	Reduced spare capacity. Additional tasks cannot be given the desired amount of attention.	5
Very Objectionable	Little spare capacity. Level of effort allows little attention to additional tasks.	6
Major Difficulty	Very little spare capacity, but the maintenance of the *primary* task is still possible.	7
Major Difficulty	Very high workload with almost no spare capacity. Difficulty in maintaining level of effort.	8
Major Difficulty	Extremely high workload, no spare capacity. Ability to maintain effort on primary task doubtful.	9
Impossible	Task abandoned. Unable to apply sufficient effort.	10

2. My overall workload was acceptable. (circle one)

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

3. How would you rate the scenario overall traffic load? (circle one)

1	2	3	4	5	6	7
Very Low						Very High

Third Party Call Sign Format Questions

4. I was able to sufficiently communicate the third party call sign using the format. (circle one for each row)

Traffic Advisory	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

5. Did use of the third party call sign cause you to make any errors? (circle one)

Yes **No** **Don't Know**

6. Did you observe any errors made by flight crews related to call signs? (circle one)

Yes **No**

7. I was able to understand pilot readbacks of third party call sign. (circle one for each row)

Traffic Advisory	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

8. I was able to remember what third party call sign format to use when referencing a third party aircraft. (circle one for each row)

Traffic Advisory	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

9. Did you have any specific issues with the third party call sign format? (circle one)

Yes **No** **Don't Know**

10. Did you ever experience confusion about who you were talking **<u>to</u>** vs. who you were talking **<u>about</u>**? (circle one)

Yes **No**

11. Did you ever have a desire to use a third party call sign format different than the one specified? (circle one)

Yes **No**

12. Do you think that the use of this third party call sign format will cause errors? (circle one)

Yes **No** **Don't Know**

Third Party Call Sign in Context of Broader Communication Questions

13. The third party call sign <u>position</u> within the communication was acceptable. (circle one for each row)

Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

14. The third party call sign acceptability is affected by its <u>position</u> in the communication. (circle one for each row)

Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

15. The third party call sign acceptability was affected by the other elements (e.g., assigned spacing goal or altitude) in the communication. (circle one for each row)

Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

16. The <u>length</u> of the communication that included third party call sign affected the acceptability of the third party call sign format. (circle one)

Yes **No** **Don't Know**

If yes, explain: ____

17. The <u>length</u> of the communication that included third party call sign was acceptable. (circle one for each row)

	1	2	3	4	5	6	7	
Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

18. The <u>complexity</u> of the communication that included third party call sign affected the acceptability of the third party call sign format. (circle one)

Yes **No** **Don't Know**

If yes, explain: ____

19. The <u>complexity</u> of the communication that included third party call sign was acceptable. (circle one for each row)

Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

Third Party Call Sign Overall Impression Questions

20. The third party call sign format would be acceptable in the field. (circle one for each row)

Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

21. Do you have any concerns about employing the third party call sign format in the field? (circle one)

Yes **No**

Other Questions

22. Were there any factors that led to confusion with regards to third party call sign phraseology (e.g., unusual call signs, traffic situations, etc.) (circle one)

    Yes **No** **Don't Know**

23. Are there any additional observations (relative to equipment, automation, traffic situations, instructions or performance) that the experimenters need to be aware of? (circle one)

    Yes **No**

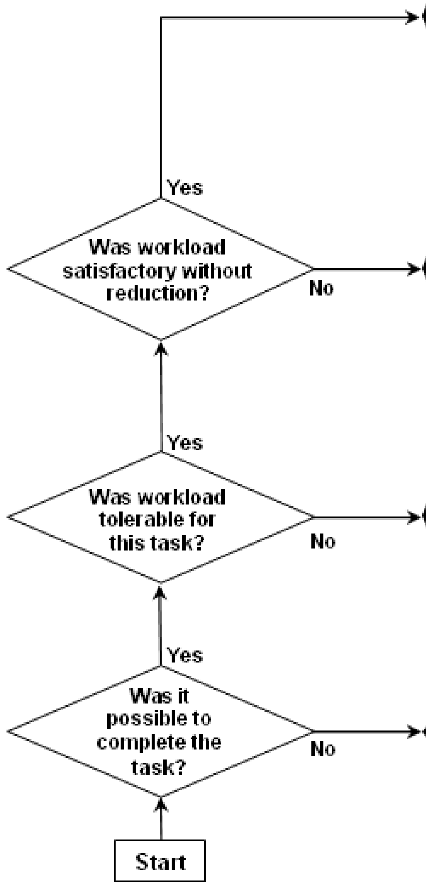
THIRD PARTY CALL SIGN <u>PILOT</u> POST SCENARIO QUESTIONNAIRE

<u>Instructions</u>: Please answer the questions by selecting the option on each of the scales at the point which matched your experience. C*onsider only the most recent scenario when answering*. Unless otherwise noted, the term "you" in a question is asking about your personal experience, not that of both you and your fellow crew member. If you have any questions, please ask the experimenter.

1. Using the chart below, how would you rate your *average* level of workload?

   (a) Working up from the bottom, answer each yes/no question.

   (b) Select the numerical rating that best reflects your experience.



DIFFICULTY LEVEL	OPERATOR DEMAND LEVEL	RATING
Very Easy	Workload insignificant.	1
Easy	Workload low.	2
Fair	Enough spare capacity for all desirable additional tasks.	3
Minor, Annoying	Insufficient spare capacity for easy attention to additional tasks.	4
Moderately Objectionable	Reduced spare capacity. Additional tasks cannot be given the desired amount of attention.	5
Very Objectionable	Little spare capacity. Level of effort allows little attention to additional tasks.	6
Major Difficulty	Very little spare capacity, but the maintenance of the *primary* task is still possible.	7
Major Difficulty	Very high workload with almost no spare capacity. Difficulty in maintaining level of effort.	8
Major Difficulty	Extremely high workload, no spare capacity. Ability to maintain effort on primary task doubtful.	9
Impossible	Task abandoned. Unable to apply sufficient effort.	10

2. My overall workload was acceptable. (circle one)

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Third Party Call Sign Format Questions

3. Did you use the third party call sign format in a communication with ATC? (circle one)

IM Clearance	**Yes**	**No**
Traffic Advisory	**Yes**	**No**

4. When communicating with ATC, I was able to sufficiently communicate the third party call sign using the format. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7	O NA
Traffic Advisory	1	2	3	4	5	6	7	O NA
	Strongly Disagree						Strongly Agree	

5. Did use of the third party call sign cause <u>you</u> to make any errors? (circle one)

Yes **No** **Don't Know**

6. Did you observe any errors made <u>by other flight crews</u> related to call signs? (circle one)

Yes **No**

7. Did you observe any errors made <u>by ATC</u> related to call signs? (circle one)

Yes **No**

8. I was able to understand ATC communications involving third party call sign. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7
Traffic Advisory	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

9. I was able to remember what third party call sign format to use when communicating with ATC about a third party aircraft. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7	O NA
Traffic Advisory	1	2	3	4	5	6	7	O NA
	Strongly Disagree						Strongly Agree	

10. Did you have any specific issues with the third party call sign format? (circle one)

Yes **No**

If, yes describe:____

11. Did you ever hear your call sign being used where you were being talked **about** (i.e., being addressed as a third party aircraft)? (circle one)

Yes **No**

a) By whom? (circle all that apply)

ATC **Another Pilot**

12. Did you ever experience confusion about whether your aircraft were being talked **to** (i.e., receiving an ATC communication) vs. talked **about** (i.e., being addressed as a third party aircraft)? (circle one for each row)

IM Clearance	**Yes**	**No**
Traffic Advisory	**Yes**	**No**

13. Did you ever have a desire to use a third party call sign format different than the one specified? (circle one)

Yes **No**

a) In a communication to: (circle all that apply)

ATC **Another Pilot**

14. Do you think that the use of this third party call sign format will cause errors? (circle one)

Yes **No** **Don't Know**

If yes, explain:____

15. Did the third party call sign format help you find the aircraft on the CDTI? (circle one)

Yes **No**

16. Did the third party call sign format cause any confusion when trying to find aircraft on the CDTI? (circle one)

Yes **No**

If yes, explain: ____

17. Did your crew ever have to reference your call sign reference document? (circle one)

Yes **No**

a) How many times? _________________

b) Was that acceptable? (circle one)

Yes **No** **Don't Know**

Third Party Call Sign in Context of Broader Communication Questions

18. The third party call sign <u>position</u> within the communication was acceptable. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7	O Don't know
Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

19. The third party call sign acceptability is affected by its <u>position</u> in the communication. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7	O Don't know
Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

20. The third party call sign acceptability is affected by the other elements (e.g., assigned spacing goal or altitude) in the communication. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7	O Don't know
Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

21. The <u>length</u> of the communication that included third party call sign affected the acceptability of the third party call sign format. (circle one)

Yes **No** **Don't Know**

If yes, explain: ____

22. The <u>length</u> of the communication that included third party call sign was acceptable. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7	O Don't know
Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

23. The <u>complexity</u> of the communication that included third party call sign affected the acceptability of the third party call sign format. (circle one)

Yes **No** **Don't Know**

If yes, explain: ____

24. The <u>complexity</u> of the communication that included third party call sign was acceptable. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7	O Don't know
Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

Third Party Call Sign Overall Impression Questions

25. The third party call sign format would be acceptable in line operations. (circle one for each row)

IM Clearance	1	2	3	4	5	6	7	O Don't know
Traffic Advisory	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

26. Do you have any concerns about employing the third party call sign format in line operations? (circle one)

Yes **No**

Other Questions

27. Did you ever accidentally push or forget to push the button when thought you heard your call sign in a communication? (circle one)

Yes **No** **Don't Know**

28. Were there any factors that led to confusion with regards to third party call sign phraseology (e.g., unusual call signs, traffic situations, etc.) (circle one)

Yes **No**

29. Are there any additional observations (relative to equipment, automation, traffic situations, instructions or performance) that the experimenters need to be aware of? (circle one)

Yes **No**

Appendix D Post-Simulation Questionnaires

THIRD PARTY CALL SIGN EN ROUTE CONTROLLER POST SIMULATION QUESTIONNAIRE

Instructions: Please answer the questions by circling the option on each of the scales at the point which matched your experience. Unless otherwise indicated, *consider all scenarios when answering*. If you have any questions, please ask the experimenter.

Comparative Assessment of Third Party Call Sign Formats

1. I was able to sufficiently communicate the third party call sign using the format. (circle one per row)

IM Clearance

Telephonic - Early	1	2	3	4	5	6	7
Telephonic - Late	1	2	3	4	5	6	7
Telephonic - Delimiter	1	2	3	4	5	6	7
Letters	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7
Telephonic - Late	1	2	3	4	5	6	7
Telephonic - Delimiter	1	2	3	4	5	6	7
Letters	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

2. I was able to remember when to use the third party call sign format when referencing a third party aircraft. (circle one per row)

IM Clearance

Telephonic - Early	1	2	3	4	5	6	7
Telephonic - Late	1	2	3	4	5	6	7
Telephonic - Delimiter	1	2	3	4	5	6	7
Letters	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7
Telephonic - Late	1	2	3	4	5	6	7
Telephonic - Delimiter	1	2	3	4	5	6	7
Letters	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

3. I think the third party call sign format has the potential for <u>pilot errors</u>. (circle one per row)

IM Clearance

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

4. I think the third party call sign format has the potential for <u>controller errors</u>. (circle one per row)

IM Clearance

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

5. The third party call sign format would be acceptable overall in line operations. (circle one per row)

IM Clearance

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

6. If you found any of the third party call sign formats unacceptable, do you think that some changes could make them acceptable?

Telephonic - Early	**Yes**, would be acceptable with changes	**No**, would not be acceptable with any changes	**NA**, Acceptable as test
Telephonic - Late	**Yes**, would be acceptable with changes	**No**, would not be acceptable with any changes	**NA**, Acceptable as test
Telephonic - Delimiter	**Yes**, would be acceptable with changes	**No**, would not be acceptable with any changes	**NA**, Acceptable as test
Letters	**Yes**, would be acceptable with changes	**No**, would not be acceptable with any changes	**NA**, Acceptable as test

If yes, please describe the changes:

Telephonic – Early:____

Telephonic – Late: ____

Telephonic – Delimiter:____

Letters: ____

7. Do you believe there is a logical location within a communication for the third party call sign? (circle one)

Yes **No** **Don't Know**

If yes, explain and describe: ____

8. Rank each format, in order of preference, for communicating third party call sign. (draw a line from the format to the rank number)

	Best
Telephonic - Early	1
Telephonic - Late	2
Telephonic - Delimiter	3
Letters	4
	Worst

9. Would you recommend AGAINST using any of the formats in the real world? (circle one)

   Yes **No** **Don't Know**

   If yes, please choose a format you recommend AGAINST using: (circle all that apply)

   Telephonic - Early
   Telephonic - Late
   Telephonic - Delimiter
   Letters

   Explain: ____

10. Does traffic density affect your acceptability of the third party call sign format? (circle one)

   Yes **No** **Don't Know**

   If yes, describe how: ____

11. If delimiters were used to convey third party call signs, would you recommend keeping "Reference" as the delimiter term? (circle one)

Yes **No** **Don't Know**

If no, do you have another recommendation?________________________________

12. With the introduction of third party call sign into the traffic advisory and the ability of pilots to see the third party call sign on the traffic display, do you believe other elements of the traffic advisory could be removed? (place an "x" in the appropriate column for each element that could be removed)

Element	"x" if can be removed
Azimuth	
Range	
Direction / Relative	
Movement	
Aircraft Type	
Altitude	
Carrier name	

Explain: ____

13. Are there call sign problems that exist in today's environment that would be exacerbated by one of the third party call sign formats? (circle one)

Yes **No** **Don't Know**

What current day problem?____

a) Which, if any, format exacerbates the problem? (circle all that apply)

Telephonic - Early
Telephonic - Late
Telephonic - Delimiter
Letters

Explain (if more than one, are certain ones worse?): ________________________

14. Do you think that the use of third party call sign can solve any current day problems? (circle one)

Yes **No** **Don't Know**

What current day problem?____

a) Which format(s), if any, help solve the problem? (circle all that apply)

Telephonic - Early
Telephonic - Late
Telephonic - Delimiter
Letters

Explain (if more than one, are certain ones better?): ________________________

15. Have you ever previously used a third party call sign in a real world environment? (circle one)

Yes **No** **Don't Remember**

Describe:____

Simulation Assessment

Please indicate on the scale how each of the following areas of the simulation influenced your impression of communication performance.

16. The overall simulation was effective as a context for evaluating different ways to convey third party call sign. (circle one)

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

O Don't know

17. The traffic scenarios were effective as a context for evaluating different ways to convey third party call sign. (circle one)

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

O Don't know

18. Was there anything about the simulation that artificially affected using it as a context for evaluating different ways to convey third party call sign? (circle one)

Yes **No** **Don't Know**

If yes, describe: ____

19. The length of the **questionnaire after each scenario** caused me to have difficulty answering the questions.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

O Don't know

20. If you have any other comments about anything else in the simulation, please provide them:____

THIRD PARTY CALL SIGN <u>TERMINAL CONTROLLER</u> POST SIMULATION QUESTIONNAIRE

<u>Instructions</u>: Please answer the questions by circling the option on each of the scales at the point which matched your experience. Unless otherwise indicated, *consider all scenarios when answering*. If you have any questions, please ask the experimenter.

Comparative Assessment of Third Party Call Sign Formats

1. I was able to sufficiently communicate the third party call sign using the format. (circle one per row)

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7
Telephonic - Late	1	2	3	4	5	6	7
Telephonic - Delimiter	1	2	3	4	5	6	7
Letters	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

Comments: ____
____
____

2. I was able to remember when to use the third party call sign format when referencing a third party aircraft. (circle one per row)

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7
Telephonic - Late	1	2	3	4	5	6	7
Telephonic - Delimiter	1	2	3	4	5	6	7
Letters	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

Comments: ____
____
____

3. I think the third party call sign format has the potential for <u>pilot errors</u>. (circle one per row)

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

4. I think the third party call sign format has the potential for <u>controller errors</u>. (circle one per row)

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

5. The third party call sign format would be acceptable overall in line operations. (circle one per row)

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

6. If you found any of the third party call sign formats unacceptable, do you think that some changes could make them acceptable?

Telephonic - Early	**Yes**, would be acceptable with changes	**No**, would not be acceptable with any changes	**NA**, Acceptable as test
Telephonic - Late	**Yes**, would be acceptable with changes	**No**, would not be acceptable with any changes	**NA**, Acceptable as test
Telephonic - Delimiter	**Yes**, would be acceptable with changes	**No**, would not be acceptable with any changes	**NA**, Acceptable as test
Letters	**Yes**, would be acceptable with changes	**No**, would not be acceptable with any changes	**NA**, Acceptable as test

If yes, please describe the changes:

Telephonic – Early:____

Telephonic – Late: ____

Telephonic – Delimiter:____

Letters: ____

7. Do you believe there is a logical location within a communication for the third party call sign? (circle one)

Yes **No** **Don't Know**

If yes, explain and describe: ____

8. Rank each format, in order of preference, for communicating third party call sign. (draw a line from the format to the rank number)

	Best
Telephonic - Early	1
Telephonic - Late	2
Telephonic - Delimiter	3
Letters	4
	Worst

9. Would you recommend AGAINST using any of the formats in the real world? (circle one)

Yes **No** **Don't Know**

If yes, please choose a format you recommend AGAINST using: (circle all that apply)

Telephonic - Early
Telephonic - Late
Telephonic - Delimiter
Letters

Explain: ____

10. Does traffic density affect your acceptability of the third party call sign format? (circle one)

Yes **No** **Don't Know**

If yes, describe how: ____

11. If delimiters were used to convey third party call signs, would you recommend keeping "Reference" as the delimiter term? (circle one)

    Yes **No** **Don't Know**

    If no, do you have another recommendation?________________________________

12. With the introduction of third party call sign into the traffic advisory and the ability of pilots to see the third party call sign on the traffic display, do you believe other elements of the traffic advisory could be removed? (place an "x" in the appropriate column for each element that could be removed)

Element	**"x" if can be removed**
Azimuth	
Range	
Direction / Relative Movement	
Aircraft Type	
Altitude	
Carrier name	

    Explain: ____

13. Are there call sign problems that exist in today's environment that would be exacerbated by one of the third party call sign formats? (circle all that apply)

    Yes **No**

    What current day problem?____

    a) Which, if any, format exacerbates the problem? (circle one or more)

    Telephonic - Early
    Telephonic - Late
    Telephonic - Delimiter
    Letters

    Explain (if more than one, are certain ones worse?): ________________________

14. Do you think that the use of third party call sign can solve any current day problems? (circle one)

Yes **No** **Don't Know**

What current day problem?____

a) Which format(s), if any, help solve the problem? (circle all that apply)

Telephonic - Early
Telephonic - Late
Telephonic - Delimiter
Letters

Explain (if more than one, are certain ones better?): ________________________

15. Have you ever previously used a third party call sign in a real world environment? (circle one)

Yes **No** **Don't Remember**

Describe:____

Simulation Assessment

Please indicate on the scale how each of the following areas of the simulation influenced your impression of communication performance.

16. The overall simulation was effective as a context for evaluating different ways to convey third party call sign. (circle one)

1	2	3	4	5	6	7	
Strongly Disagree						Strongly Agree	O Don't know

17. The traffic scenarios were effective as a context for evaluating different ways to convey third party call sign. (circle one)

1	2	3	4	5	6	7	
Strongly Disagree						Strongly Agree	O Don't know

18. Was there anything about the simulation that artificially affected using it as a context for evaluating different ways to convey third party call sign? (circle one)

Yes **No** **Don't Know**

If yes, describe: ____

19. The length of the **questionnaire after each scenario** caused me to have difficulty answering the questions.

1	2	3	4	5	6	7	
Strongly Disagree						Strongly Agree	O Don't know

20. If you have any other comments about anything else in the simulation, please provide them:____

Third Party Call Sign Pilot Post Simulation Questionnaire

Instructions: Please answer the questions by circling the option on each of the scales at the point which matched your experience. Unless otherwise indicated, *consider all scenarios when answering*. If you have any questions, please ask the experimenter.

Comparative Assessment of Third Party Call Sign Formats

1. When communicating with ATC, I was able to sufficiently communicate the third party call sign using the format. (circle one per row)

IM Clearance

Telephonic - Early	1	2	3	4	5	6	7	O NA
Telephonic - Late	1	2	3	4	5	6	7	O NA
Telephonic - Delimiter	1	2	3	4	5	6	7	O NA
Letters	1	2	3	4	5	6	7	O NA
	Strongly Disagree						Strongly Agree	

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7	O Don’t know
Telephonic - Late	1	2	3	4	5	6	7	O Don’t know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don’t know
Letters	1	2	3	4	5	6	7	O Don’t know
	Strongly Disagree						Strongly Agree	

2. I was able to remember when to use the third party call sign format when communicating with ATC about a third party aircraft. (circle one per row)

IM Clearance

Telephonic - Early	1	2	3	4	5	6	7	O NA
Telephonic - Late	1	2	3	4	5	6	7	O NA
Telephonic - Delimiter	1	2	3	4	5	6	7	O NA
Letters	1	2	3	4	5	6	7	O NA
	Strongly Disagree						Strongly Agree	

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7	O NA
Telephonic - Late	1	2	3	4	5	6	7	O NA
Telephonic - Delimiter	1	2	3	4	5	6	7	O NA
Letters	1	2	3	4	5	6	7	O NA
	Strongly Disagree						Strongly Agree	

3. I think the third party call sign format has the potential for <u>pilot errors</u>. (circle one per row)

IM Clearance

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

4. I think the third party call sign format has the potential for <u>controller errors</u>. (circle one per row)

IM Clearance

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

5. I experienced confusion about whether my aircraft was being talked **<u>to</u>** (i.e., receiving an ATC communication) vs. talked **<u>about</u>** (i.e., being addressed as a third party aircraft)? (circle one per row)

IM Clearance

Telephonic - Early	1	2	3	4	5	6	7
Telephonic - Late	1	2	3	4	5	6	7
Telephonic - Delimiter	1	2	3	4	5	6	7
Letters	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7
Telephonic - Late	1	2	3	4	5	6	7
Telephonic - Delimiter	1	2	3	4	5	6	7
Letters	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

6. Do you believe you would get used to being talked **about** (i.e., being addressed as a third party aircraft) and not just **to** (i.e., receiving an ATC communication)? (circle one)

   Yes **No** **Don't Know**

   a) Would that experience reduce any concerns? (circle one)

   Yes **No** **Don't Know**

   Explain: ____

7. The third party call sign format helped me find the aircraft on the CDTI. (circle one per row)

   IM Clearance

Telephonic - Early	1	2	3	4	5	6	7
Telephonic - Late	1	2	3	4	5	6	7
Telephonic - Delimiter	1	2	3	4	5	6	7
Letters	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

   Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7
Telephonic - Late	1	2	3	4	5	6	7
Telephonic - Delimiter	1	2	3	4	5	6	7
Letters	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

8. The third party call sign format caused confusion when trying to find aircraft on the CDTI. (circle one per row)

IM Clearance

Telephonic - Early	1	2	3	4	5	6	7
Telephonic - Late	1	2	3	4	5	6	7
Telephonic - Delimiter	1	2	3	4	5	6	7
Letters	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7
Telephonic - Late	1	2	3	4	5	6	7
Telephonic - Delimiter	1	2	3	4	5	6	7
Letters	1	2	3	4	5	6	7
	Strongly Disagree						Strongly Agree

9. The third party call sign format would be acceptable overall in line operations. (circle one per row)

IM Clearance

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

Traffic Advisory

Telephonic - Early	1	2	3	4	5	6	7	O Don't know
Telephonic - Late	1	2	3	4	5	6	7	O Don't know
Telephonic - Delimiter	1	2	3	4	5	6	7	O Don't know
Letters	1	2	3	4	5	6	7	O Don't know
	Strongly Disagree						Strongly Agree	

10. If you found any of the third party call sign formats unacceptable, do you think that some changes could make them acceptable?

Telephonic - Early	**Yes**, would be acceptable with changes	**No**, would not be acceptable with any changes	**NA**, Acceptable as test
Telephonic - Late	**Yes**, would be acceptable with changes	**No**, would not be acceptable with any changes	**NA**, Acceptable as test
Telephonic - Delimiter	**Yes**, would be acceptable with changes	**No**, would not be acceptable with any changes	**NA**, Acceptable as test
Letters	**Yes**, would be acceptable with changes	**No**, would not be acceptable with any changes	**NA**, Acceptable as test

If yes, please describe the changes:

Telephonic – Early:____

Telephonic – Late: ____

Telephonic – Delimiter:____

Letters: ____

11. Do you believe there is a logical location within a communication for the third party call sign? (circle one)

Yes **No** **Don't Know**

If yes, explain and describe: ____

12. Rank each format, in order of preference, for communicating third party call sign. (draw a line from the format to the rank number)

	Best
Telephonic - Early	1
Telephonic - Late	2
Telephonic - Delimiter	3
Letters	4
	Worst

13. Would you recommend AGAINST using any of the formats in the real world? (circle one)

Yes **No** **Don't Know**

If yes, please choose a format you recommend AGAINST using: (circle all that apply)

Telephonic - Early
Telephonic - Late
Telephonic - Delimiter
Letters

Explain: ____

14. If delimiters were used to convey third party call signs, would you recommend keeping "Reference" as the delimiter term? (circle one)

Yes **No** **Don't Know**

If no, do you have another recommendation?______________________________

15. With the introduction of third party call sign into the traffic advisory and the ability to see the third party call sign on the traffic display, do you believe other elements of the traffic advisory could be removed? (place an "x" in the appropriate column for each element that could be removed)

Element	**"x" if can be removed**
Azimuth	
Range	
Direction / Relative	
Movement	
Aircraft Type	
Altitude	
Carrier name	

Explain: ____

16. Are there call sign problems that exist in today's environment that would be exacerbated by one of the third party call sign formats? (circle one)

Yes **No** **Don't Know**

What current day problem?____

a) Which format, if any, exacerbates the problem? (circle all that apply)

Telephonic - Early
Telephonic - Late
Telephonic - Delimiter
Letters

Explain (if more than one, are certain ones worse?):_______________________

17. Do you think that the use of third party call sign can solve any current day problems? (circle one)

Yes **No** **Don't Know**

What current day problem?____

a) Which format(s), if any help solve the problem? (circle all that apply)

Telephonic - Early
Telephonic - Late
Telephonic - Delimiter
Letters

Explain (if more than one, are certain ones better?): ________________________

18. Have you ever previously used a third party call sign in a real world environment? (circle one)

Yes **No** **Don't Remember**

Describe:____

19. As compared to current operations, how much attention did you pay to ATC communications that were not directed toward your aircraft (i.e., you were a third party or were not included in the communication)? (circle one)

1	2	3	4	5	6	7
Much Less Attention						Much More Attention

O Don't know

a) Do you think you would pay the same level of attention in the real world when the use of third party call sign becomes a reality? (circle one)

Yes **No** **Don't Know**

Simulation Assessment

Please indicate on the scale how each of the following areas of the simulation influenced your impression of communication performance.

20. The overall simulation was effective as a context for evaluating different ways to convey third party call sign. (circle one)

1	2	3	4	5	6	7

Strongly Disagree — Strongly Agree — O Don't know

21. The traffic scenarios were effective as a context for evaluating different ways to convey third party call sign. (circle one)

1	2	3	4	5	6	7

Strongly Disagree — Strongly Agree — O Don't know

22. Was there anything about the simulation that artificially affected using it as a context for evaluating different ways to convey third party call sign? (circle one)

Yes **No** **Don't Know**

If yes, describe: ____

23. The length of the **questionnaire after each scenario** caused me to have difficulty answering the questions.

1	2	3	4	5	6	7

Strongly Disagree — Strongly Agree — O Don't know

24. If you have any other comments about anything else in the simulation, please provide them:____

Appendix E Transcription Service Instructions

In order to protect the confidentiality of the participant data, a privacy and security agreement was established with the transcription provider. This included requirements to not provide the data beyond any person who absolutely needed to view it as well as transferring audio and transcription files through a secure file transfer interface. Also, the service was instructed to delete the audio files when the transcripts were complete.

In addition, the following rules were provided to the transcription service to govern the production of the transcripts:

1. When the air traffic controller is speaking, the text shall be marked "ATC."
2. When anyone else speaks, the text shall be marked "PILOT."
3. In the event a person's real name is present in the audio, the transcriber shall not include the name in the transcription. In place of the name, the transcriber shall substitute "[NAME]".
4. Up to 8 voices may be present per file. The Simulation Director speaks at the beginning and ends of the run, but once the run starts, the transcriber should hear one (1) air traffic controller and seven (7) pilots. Five (5) of those pilots were distinct (the pilots for American 883, United 428, Southwest 521, Citrus 762, and Cactus 934). The remaining two (2) pilots used a variety of voices and accents throughout. In the absence of knowing all of the voices, the transcriber shall identify the voice for the controller, and mark it as ATC, then mark remaining voices as PILOT. Any further classifications, differentiations or identifications were finalized by MITRE after transcriptions were complete.
5. Timestamps shall be marked at the beginning and end of EACH speaker turn. Given that no "MARK" is present at the beginning of the audio file, the transcriber shall provide timestamps relative to the beginning of the audio file.
6. An automated simulation voice that indicates that the simulation is resuming or pausing ("Simulation resuming" or "Simulation pause") was present on all recordings. The automated simulation voice had a French accent, so any unintelligible French in the speech files shall be marked as [Unintelligible French].
7. PECHY and KEEEN are fix names that the aircraft flew to or flew over. The transcriber shall label these as "PECHY" and "KEEEN" accordingly.
8. The numbers in aircraft names do not have to be spelled out, but capital letters shall be used, as appropriate (e.g., RJ-1, CRJ, Boeing 737, MD-80, Cheyenne, Dash-8, A320, etc.).

Appendix F Usable vs. Not Usable Transmission Classification Rules

The following lines show how messages were classified as usable or not usable based on which event was involved, which portion of the message contained the event, and whether and how it was corrected.

Initial ATC-T Messages

If ATC-ER	IM Clearance	has	D	event					then	Not Usable
If ATC-ER	IM Clearance	has	E	event					then	Not Usable
If ATC-ER	IM Clearance	has	G	event			which is	immediately self-corrected	then	Usable
If ATC-ER	IM Clearance	has	G	event			which is	not corrected	then	Not Usable
If ATC-ER	IM Clearance	has	H	event	involving	TFID	which is	immediately self-corrected	then	Usable
If ATC-ER	IM Clearance	has	H	event	involving	TFID	which is	not corrected	then	Not Usable
If ATC-ER	IM Clearance	has	H	event	involving	FFID	which is	immediately self-corrected	then	Usable
If ATC-ER	IM Clearance	has	H	event	involving	FFID	which is	not corrected	then	Not Usable
If ATC-ER	IM Clearance	has	H	event	involving	Other	which is	immediately or later self-corrected	then	Usable
If ATC-ER	IM Clearance	has	H	event	involving	Other	which is	not corrected	then	Not Usable
If ATC-ER	IM Clearance	has	I	event	involving	TFID	which is	immediately self-corrected	then	Usable
If ATC-ER	IM Clearance	has	I	event	involving	TFID	which is	not corrected	then	Not Usable
If ATC-ER	IM Clearance	has	I	event	involving	FFID	which is	immediately self-corrected	then	Usable
If ATC-ER	IM Clearance	has	I	event	involving	FFID	which is	not corrected	then	Not Usable
If ATC-ER	IM Clearance	has	J	event	involving	FFID			then	Not Usable
If ATC-ER	IM Clearance	has	J	event	involving	Other	which is	corrected	then	Usable
If ATC-ER	IM Clearance	has	J	event	involving	Other	which is	not corrected	then	Not Usable
If ATC-ER	IM Clearance	has	O	event					then	Usable
If ATC-ER	IM Clearance	has	P	event					then	Usable
If ATC-ER	Traffic Advisory	has	D	event					then	Not Usable
If ATC-ER	Traffic Advisory	has	E	event	involving	TFID	which is	immediately self-corrected	then	Usable
If ATC-ER	Traffic Advisory	has	E	event	involving	TFID	which is	not corrected	then	Not Usable
If ATC-ER	Traffic Advisory	has	E	event	involving	FFID	which is	immediately self-corrected	then	Usable
If ATC-ER	Traffic Advisory	has	E	event	involving	FFID	which is	not corrected	then	Not Usable
If ATC-ER	Traffic Advisory	has	E	event	involving	Other			then	Usable
If ATC-ER	Traffic Advisory	has	G	event			which is	immediately or later self-corrected	then	Usable

If ATC-ER	Traffic Advisory	has	G	event			which is	not corrected	then	Not Usable
If ATC-ER	Traffic Advisory	has	H	event	involving	TFID	which is	immediately self-corrected	then	Usable
If ATC-ER	Traffic Advisory	has	H	event	involving	TFID	which is	not corrected	then	Not Usable
If ATC-ER	Traffic Advisory	has	H	event	involving	FFID	which is	immediately self-corrected	then	Usable
If ATC-ER	Traffic Advisory	has	H	event	involving	FFID	which is	not corrected	then	Not Usable
If ATC-ER	Traffic Advisory	has	H	event	involving	Other			then	Usable
If ATC-ER	Traffic Advisory	has	I	event	involving	TFID	which is	immediately self-corrected	then	Usable
If ATC-ER	Traffic Advisory	has	I	event	involving	TFID	which is	not corrected	then	Not Usable
If ATC-ER	Traffic Advisory	has	I	event	involving	FFID	which is	immediately self-corrected	then	Usable
If ATC-ER	Traffic Advisory	has	I	event	involving	FFID	which is	not corrected	then	Not Usable
If ATC-ER	Traffic Advisory	has	J	event	involving	FFID			then	Not Usable
If ATC-ER	Traffic Advisory	has	J	event	involving	Report Identified			then	Not Usable
If ATC-ER	Traffic Advisory	has	J	event	involving	Other			then	Usable
If ATC-ER	Traffic Advisory	has	O	event					then	Usable
If ATC-ER	Traffic Advisory	has	P	event					then	Usable

Initial ATC-T Messages

If ATC-T	Traffic Advisory	has	D	event					then	Not Usable
If ATC-T	Traffic Advisory	has	E	event	involving	TFID	which is	immediately self-corrected	then	Usable
If ATC-T	Traffic Advisory	has	E	event	involving	TFID	which is	not corrected	then	Not Usable
If ATC-T	Traffic Advisory	has	E	event	involving	FFID	which is	immediately self-corrected	then	Usable
If ATC-T	Traffic Advisory	has	E	event	involving	FFID	which is	not corrected	then	Not Usable
If ATC-T	Traffic Advisory	has	E	event	involving	Other			then	Usable
If ATC-T	Traffic Advisory	has	G	event			which is	immediately or later self-corrected	then	Usable
If ATC-T	Traffic Advisory	has	G	event			which is	not corrected	then	Not Usable
If ATC-T	Traffic Advisory	has	H	event	involving	TFID	which is	immediately self-corrected	then	Usable
If ATC-T	Traffic Advisory	has	H	event	involving	TFID	which is	not corrected	then	Not Usable
If ATC-T	Traffic Advisory	has	H	event	involving	FFID	which is	immediately self-corrected	then	Usable
If ATC-T	Traffic Advisory	has	H	event	involving	FFID	which is	not corrected	then	Not Usable
If ATC-T	Traffic Advisory	has	H	event	involving	Other			then	Usable
If ATC-T	Traffic Advisory	has	I	event	involving	TFID	which is	immediately self-corrected	then	Usable
If ATC-T	Traffic Advisory	has	I	event	involving	TFID	which is	not corrected	then	Not Usable
If ATC-T	Traffic Advisory	has	I	event	involving	FFID	which is	immediately self-corrected	then	Usable
If ATC-T	Traffic Advisory	has	I	event	involving	FFID	which is	not corrected	then	Not Usable
If ATC-T	Traffic Advisory	has	J	event	involving	FFID			then	Not Usable
If ATC-T	Traffic Advisory	has	J	event	involving	Report Identified			then	Not Usable
If ATC-T	Traffic Advisory	has	J	event	involving	Other			then	Usable
If ATC-T	Traffic Advisory	has	O	event					then	Usable
If ATC-T	Traffic Advisory	has	P	event					then	Usable

Pilot Readbacks

If FPP	IM Readback	has	D	event					then	Not Usable
If FPP	IM Readback	has	E	event	involving	TFID			then	Not Usable
If FPP	IM Readback	has	E	event	involving	FFID			then	Not Usable
If FPP	IM Readback	has	E	event	involving	Other			then	Usable
If FPP	IM Readback	has	G	event			which is	immediately or later self-corrected	then	Usable
If FPP	IM Readback	has	G	event			which is	not corrected	then	Not Usable
If FPP	IM Readback	has	H	event	involving	TFID	which is	immediately self-corrected	then	Usable
If FPP	IM Readback	has	H	event	involving	TFID	which is	not corrected	then	Not Usable
If FPP	IM Readback	has	H	event	involving	FFID	which is	immediately self-corrected	then	Usable
If FPP	IM Readback	has	H	event	involving	FFID	which is	not corrected	then	Not Usable
If FPP	IM Readback	has	H	event	involving	Other			then	Usable
If FPP	IM Readback	has	I	event					then	Not Usable
If FPP	IM Readback	has	J	event	involving	FFID			then	Not Usable
If FPP	IM Readback	has	J	event	involving	Other			then	Usable
If FPP	IM Readback	has	O	event					then	Usable
If FPP	IM Readback	has	P	event					then	Usable

If FPP	TA Readback	has	D	event					then	Not Usable
If FPP	TA Readback	has	E	event					then	Not Usable
If FPP	TA Readback	has	G	event			which is	immediately self-corrected	then	Usable
If FPP	TA Readback	has	G	event			which is	not corrected	then	Not Usable
If FPP	TA Readback	has	H	event	involving	TFID	which is	immediately self-corrected	then	Usable
If FPP	TA Readback	has	H	event	involving	TFID	which is	not corrected	then	Not Usable
If FPP	TA Readback	has	H	event	involving	FFID	which is	immediately self-corrected	then	Usable
If FPP	TA Readback	has	H	event	involving	FFID	which is	not corrected	then	Not Usable
If FPP	TA Readback	has	H	event	involving	Other			then	Usable
If FPP	TA Readback	has	I	event					then	Not Usable
If FPP	TA Readback	has	J	event					then	Not Usable
If FPP	TA Readback	has	M	event					then	Not Usable
If FPP	TA Readback	has	O	event					then	Usable
If FPP	TA Readback	has	P	event					then	Usable

Appendix G Event Summaries

Table G-1. Event Occurrences for T-E Transmissions

Transmission Type	Transmissions	Events	A	B INT	B NI	C TPCS-INT	C TPCS-NI	C FPCS	C Other	D TPCS	D FPCS	D No TPCS	E TPCS	E FPCS	E Other	F INT	F NI	G INT	G NI	H TPCS	H FPCS	H Other	I TPCS	I FPCS	J TPCS	J FPCS	J Other	K FPP	K TPP	L	M INT	M NI	N INT	N NI	O	P
IM Operations																																				
Usable ATC IM Clearances	66	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	4	0	0	0	0	2	0	0	0	0	0	0	0	5	7
Not Usable ATC IM Clearances	13	16	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	3	0	2	0	0	0	0	8	0	0	0	0	0	0	0	0	1
Usable Pilot IM Readbacks *(from Usable IM Clearances)*	11	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	6	7
Not Usable Pilot IM Readbacks *(from Usable IM Clearances)*	16	79	0	0	0	0	0	0	0	2	0	0	9	5	3	2	0	2	0	3	0	2	2	0	0	2	5	0	0	0	0	0	0	0	15	27
Other Pilot IM Comms	21	10	0	0	0	0	0	0	1	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4
ATC IM Readback Responses *(from Usable Pilot IM Readbacks)*	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Traffic Advisory Operations																																				
ATC-ER Usable Traffic Advisories	86	97	0	0	0	0	0	0	0	0	0	0	1	0	35	0	0	1	3	1	0	1	0	0	0	0	8	0	0	0	0	0	0	0	3	44
ATC-ER Not Usable Traffic Advisories	15	46	0	0	0	0	0	0	0	0	0	0	6	0	9	0	0	2	1	0	0	1	0	0	0	0	10	0	0	0	0	0	0	0	2	15
ATC-T Usable Traffic Advisories	138	103	0	0	0	0	0	0	0	0	0	0	2	0	57	0	0	1	0	2	2	5	0	0	0	0	9	0	0	0	0	0	0	0	2	23
ATC-T Not Usable Traffic Advisories	21	37	0	0	0	0	0	0	0	0	0	3	1	0	8	0	0	0	0	1	0	0	0	0	0	0	19	0	0	0	0	0	0	0	1	4
Usable Pilot TA Readbacks *(from Usable Traffic Advisories)*	41	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	4	19
Not Usable Pilot TA Readbacks *(from Usable Traffic Advisories)*	24	56	0	0	0	0	0	0	0	0	0	2	2	6	0	7	7	1	3	4	0	0	2	0	0	0	1	0	0	0	0	0	0	0	4	17
Other Pilot TA Comms	17	14	0	0	0	2	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	5
ATC-ER-TA Readback Responses *(from Usable Pilot TA Readbacks)*	1	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ATC-T-TA Readback Responses *(from Usable Pilot TA Readbacks)*	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table G-2. Event Occurrences for T-L Transmissions

Transmission Type	Transmissions	Events	A	B		C				D			E			F		G		H			I		J			K		L	M		N		O	P
				INT	NI	TPCS-INT	TPCS-NI	FPCS	Other	TPCS	FPCS	No TPCS	TPCS	FPCS	Other	INT	NI	INT	NI	TPCS	FPCS	Other	TPCS	FPCS	TPCS	FPCS	Other	FPP	TPP		INT	NI	INT	NI		
IM Operations																																				
Usable ATC IM Clearances	79	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	16
Not Usable ATC IM Clearances	4	8	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	3
Usable Pilot IM Readbacks *(from Usable IM Clearances)*	22	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	1	0	0	0	0	0	0	0	13	19
Not Usable Pilot IM Readbacks *(from Usable IM Clearances)*	7	27	0	0	0	0	0	0	0	0	0	0	1	5	1	0	0	1	0	4	1	0	0	0	0	2	0	0	0	0	0	0	0	0	5	7
Other Pilot IM Comms	9	7	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3
ATC IM Readback Responses *(from Usable Pilot IM Readbacks)*	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Traffic Advisory Operations																																				
ATC-ER Usable Traffic Advisories	101	81	0	0	0	0	0	0	0	0	0	0	0	1	23	0	0	1	0	1	0	4	1	0	0	0	1	0	0	0	0	0	0	0	5	44
ATC-ER Not Usable Traffic Advisories	8	18	0	0	0	0	0	0	0	0	0	1	0	2	2	0	0	3	1	1	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	4
ATC-T Usable Traffic Advisories	115	85	0	0	0	0	0	0	0	0	0	0	0	0	31	0	0	1	0	2	2	1	0	0	0	0	29	0	0	0	0	0	0	0	2	17
ATC-T Not Usable Traffic Advisories	22	40	0	0	0	0	0	0	0	0	0	1	1	0	5	0	0	0	0	0	1	4	0	0	0	0	20	0	0	0	0	0	0	0	1	7
Usable Pilot TA Readbacks *(from Usable Traffic Advisories)*	44	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	5	18
Not Usable Pilot TA Readbacks *(from Usable Traffic Advisories)*	21	46	1	2	0	0	0	0	0	1	0	2	2	4	0	8	6	1	0	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0	3	10
Other Pilot TA Comms	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
ATC-ER-TA Readback Responses *(from Usable Pilot TA Readbacks)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ATC-T-TA Readback Responses *(from Usable Pilot TA Readbacks)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Events / Attributes: columns A through P.

Table G-3. Event Occurrences for TD-E Transmissions

Transmission Type	Transmissions	Events	A	B		C				D			E			F		G		H			I		J			K		L	M		N		O	P
				INT	NI	TPCS-INT	TPCS-NI	FPCS	Other	TPCS	FPCS	No TPCS	TPCS	FPCS	Other	INT	NI	INT	NI	TPCS	FPCS	Other	TPCS	FPCS	TPCS	FPCS	Other	FPP	TPP		INT	NI	INT	NI		
IM Operations																																				
Usable ATC IM Clearances	73	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Not Usable ATC IM Clearances	8	17	0	0	0	0	0	0	0	4	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	8
Usable Pilot IM Readbacks *(from Usable IM Clearances)*	5	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	4	5
Not Usable Pilot IM Readbacks *(from Usable IM Clearances)*	27	89	0	0	0	0	0	0	1	10	0	0	23	7	2	0	0	0	0	3	0	2	0	0	0	0	4	0	0	0	0	0	0	0	12	25
Other Pilot IM Comms	16	13	0	1	0	1	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	2	4
ATC IM Readback Responses *(from Usable Pilot IM Readbacks)*	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Traffic Advisory Operations																																				
ATC-ER Usable Traffic Advisories	55	80	0	0	0	0	0	0	0	0	0	0	1	0	19	0	0	0	0	0	1	1	0	0	0	0	3	0	0	0	0	0	0	0	3	52
ATC-ER Not Usable Traffic Advisories	39	109	0	0	0	0	0	0	0	3	0	13	19	0	14	0	0	0	1	1	0	1	0	0	0	0	27	0	0	0	0	0	0	0	14	16
ATC-T Usable Traffic Advisories	132	97	0	0	0	0	0	0	0	0	0	0	1	0	40	0	0	1	0	1	1	2	0	0	0	0	36	0	0	0	0	0	0	0	2	13
ATC-T Not Usable Traffic Advisories	22	40	0	0	0	0	0	0	0	9	0	1	1	0	7	0	0	1	0	1	0	0	0	0	0	0	14	0	0	0	0	0	0	0	1	5
Usable Pilot TA Readbacks *(from Usable Traffic Advisories)*	14	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6
Not Usable Pilot TA Readbacks *(from Usable Traffic Advisories)*	39	105	1	0	0	0	0	0	0	22	0	3	2	5	0	12	5	0	0	5	1	2	1	0	0	2	1	0	0	0	0	0	0	0	11	32
Other Pilot TA Comms	18	18	0	0	0	2	2	0	0	3	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	8
ATC-ER-TA Readback Responses *(from Usable Pilot TA Readbacks)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ATC-T-TA Readback Responses *(from Usable Pilot TA Readbacks)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table G-4. Event Occurrences for L-E Transmissions

Transmission Type	Transmissions	Events	A	B INT	B NI	C TPCS-INT	C TPCS-NI	C FPCS	C Other	D TPCS	D FPCS	D No TPCS	E TPCS	E FPCS	E Other	F INT	F NI	G INT	G NI	H TPCS	H FPCS	H Other	I TPCS	I FPCS	J TPCS	J FPCS	J Other	K FPP	K TPP	L	M INT	M NI	N INT	N NI	O	P
IM Operations																																				
Usable ATC IM Clearances	74	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	9
Not Usable ATC IM Clearances	5	9	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	3
Usable Pilot IM Readbacks *(from Usable IM Clearances)*	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Not Usable Pilot IM Readbacks *(from Usable IM Clearances)*	28	89	0	2	0	1	0	0	1	6	0	0	21	5	5	0	0	1	0	2	2	4	0	0	0	1	2	0	0	0	0	0	0	0	14	22
Other Pilot IM Comms	5	5	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
ATC IM Readback Responses *(from Usable Pilot IM Readbacks)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Traffic Advisory Operations																																				
ATC-ER Usable Traffic Advisories	66	82	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	2	1	0	2	0	0	0	0	2	0	0	0	0	0	0	0	2	43
ATC-ER Not Usable Traffic Advisories	30	78	0	0	0	0	0	0	0	2	0	15	6	0	12	0	0	0	3	1	1	1	1	0	0	0	23	0	0	0	0	0	0	0	0	13
ATC-T Usable Traffic Advisories	135	105	0	0	0	0	0	0	0	0	0	0	1	0	55	0	0	0	0	3	4	6	0	0	0	0	16	0	0	0	0	0	0	0	3	17
ATC-T Not Usable Traffic Advisories	18	33	0	0	0	0	0	0	0	4	0	2	1	0	7	0	0	0	0	0	0	1	0	0	0	0	14	0	0	0	0	0	0	0	0	4
Usable Pilot TA Readbacks *(from Usable Traffic Advisories)*	35	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7
Not Usable Pilot TA Readbacks *(from Usable Traffic Advisories)*	27	67	1	0	0	0	0	0	0	4	0	4	4	5	0	8	7	1	1	1	0	0	2	0	0	2	1	0	0	0	0	0	0	0	9	17
Other Pilot TA Comms	3	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
ATC-ER-TA Readback Responses *(from Usable Pilot TA Readbacks)*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ATC-T-TA Readback Responses *(from Usable Pilot TA Readbacks)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix H Acronyms and Abbreviations

Acronym	Definition
ADS-B	Automatic Dependent Surveillance-Broadcast
AFS	Flight Standards Service
AGD	ADS-B Guidance Display
AGL	Above Ground Level
AIC	Aeronautical Information Circular
AIM	Aeronautical Information Manual
ALPA	Air Line Pilots Association
ARC	ADS-B In Aviation Rulemaking Committee
ARTCC	Air Route Traffic Control Center
ASA	Aircraft Surveillance Application
ASIA	Approach Spacing for Instrument Approach
ASRS	Aviation Safety Reporting System
ASSA	Airport Surface Situational Awareness
ATC	Air Traffic Control
ATC – ER	Air Traffic Controller – En Route
ATC – ER – IM	Air Traffic Controller – En Route – Interval Management
ATC – ER – TA	Air Traffic Controller – En Route – Traffic Advisory
ATC – T	Air Traffic Controller – Terminal
ATC – T – TA	Air Traffic Controller – Terminal – Traffic Advisory
ATIS	Automated Terminal Information Service
ATO	Air Traffic Operations
ATP	Air Transport Pilot
ATSA-AIRB	Enhanced Traffic Situation Awareness during Flight Operations
ATSA-SURF	Enhanced Traffic Situational Awareness on the Airport Surface
ATSA-VSA	Enhanced Visual Separation on Approach
B	Boeing
CARTS	Common Automated Radar Terminal System
CAVS	CDTI Assisted Visual Separation
CEFR	CDTI Enhanced Flight Rules

CDTI	Cockpit Display of Traffic Information
CDU	Control and Display Unit
CHIRP	Confidential Human Factors Incident Reporting Programme
CPDLC	Controller Pilot Data Link Communications
DCB	Display Control Bar
DIK	Display Interface Keypad
DOT	Department of Transportation
DSI	Display System Integration
DSR	Display System Replacement
EICAS	Engine-Indicating and Crew-Alerting System
EFB	Electronic Flight Bag
ERAM	En Route Automation Modernization
Err	Error Counts
EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FAROA	Final Approach and Runway Occupancy Awareness
FIM	Flight deck Interval Management
FPA	First Party Aircraft
FPCS	First Party Call Sign
FPP	First Party Pilot
GIM	Ground Interval Management
HITL	Human-in-the-loop
IA	Initial Advisory
IC	Initial Clearance
ICAO	International Civil Aviation Organization
IDEA	Integration Demonstration and Experimentation for Aeronautics
IM	Interval Management
IMC	Instrument Meteorological Conditions
INT	Intuitive
KATL	Atlanta-Hartsfield International Airport
L-E	Letters – Early

LNAV	Lateral Navigation
m	mean
MCP	Mode Control Panel
MITRE	MITRE
MOPS	Minimum Operational Performance Standards
MSL	Mean Sea Level
NASA	National Aeronautics and Space Administration
n	Number of observations
ND	Navigation Display
NEAN	North European ADS-B Network
NextGen	Next Generation Air Transportation System
NI	Non-Intuitive
NUP	NEAN Update Programme
OFG	Operational Focus Group
Op Eval	Operational Evaluation
P – IM	Pilot – Interval Management
P – TA	Pilot – Traffic Advisory
PF	Pilot Flying
PFD	Primary Flight Display
PM	Pilot Monitoring
Prf	Preference
RB	Readback
RFG	Requirements Focus Group
RL	Reply Lag
RMP	Radio Management Panels
RNAV	Area Navigation
RR	Readback Response
RTCA	RTCA
RTF	Radiotelephonic
SA	Situation Awareness
SBS	Surveillance and Broadcast Services
SD	Standard Deviation

STAR	Standard Terminal Arrival Route
STARS	Standard Terminal Automation Replacement System
T-E	Telephonic – Early
T-L	Telephonic – Late
TA	Traffic Advisory
TCAS	Traffic alert and Collision Avoidance System
TD-E	Telephonic Delimiter – Early
TFID	Traffic Flight Identification
TRACON	Terminal Radar Approach Control
TPA	Third Party Aircraft
TPCS	Third Party Call Sign
TPP	Third Party Pilot
UK	United Kingdom
US	United States
USAPA	United States Airline Pilots Association
VNAV	Vertical Navigation
WL	Workload

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