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MITRE TECHNICAL REPORT

Multiple Pilot Evaluation of Third Party Flight Identification

Communication Format Alternatives for Referring to Aircraft Depicted on a Cockpit Display of Traffic Information (CDTI)

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Abstract

Air traffic controllers have long used voice communications to refer pilots to specific air traffic of interest. This kind of communication plays an important part in the operations envisioned to evolve from cockpit applications of Automatic Dependent Surveillance-Broadcast (ADS-B) technology. In this paper we review past research on applications involving such communications and report the results of a multiple-pilot simulation study comparing three alternative communication formats. The study contrasted a baseline (Readback) format in which the controller describes relative position to point out referent traffic with alternatives which used Traffic Call Sign or a relative position (Essential) and ―Flight" combined with the trip number part of the call sign (Alternate). Formats were tested in three types of traffic conditions: (a) with normal call sign traffic, (b) with highly similar call signs and (c) with unconventional call signs. Twenty pilots participated in a series of scenarios and communicated with a controller and other pilots using each of the alternatives. The findings indicated a significant effect of format on controller and pilot transmission times, and error correction rates. Both formats in which the controller used traffic call sign to identify third party traffic –Essential and Alternate– outperformed the Readback format with fewer transmissions required to complete a communication transaction. Additionally, controller and pilot transmission times were shorter with the Essential and Alternate formats in comparison to the Readback format. The Alternate format had significantly more uncorrected errors than either the Readback or Essential formats. In terms of acceptability, the subjective measures indicated a trend favoring both Essential and Alternate formats. These findings suggest aspects of procedures and operations that influence pilots' perceptions of risk and acceptability and have implications on further development of messages and communication formats. Further, across multiple studies, results consistently showed that Essential format outperformed Alternate format, which in turn outperformed the Readback format.

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1 Introduction

Air traffic controllers have long used voice communications to refer a pilot to specific air traffic of interest. The intent of the communication is to establish mutual recognition of another aircraft and prepare the pilot being addressed to follow suit or possibly give way as the situation warrants. Although today's practice is confined to visual conditions, this coordination can be highly effective, enabling controllers and pilots to work in greater concert while pursuing their individual objectives. This kind of coordination is likely to be practiced on an increasingly larger scale as airborne surveillance is introduced in future operations.

Historically, pilots generally have had limited information on nearby traffic, the Air Traffic Control (ATC) system has developed procedures that allow a controller to expedite the traffic flow or preempt close encounters by pointing out traffic thereby directing a pilot attention to an approaching aircraft that may be of particular interest. Controllers know that such communications only work in circumstances where the aircraft are in visual range of each other, although this is not always easy to discern. When circumstances permit, the practice typically involves a controller contacting a pilot, pointing out the traffic, including its bearing, range, direction of flight, the aircraft type or company, and its altitude. Sometimes the sole purpose of the advisory is to make the pilot aware of potentially significant traffic; but at other times the controller has further instructions which are conditional upon identifying the target aircraft. Compliance with these instructions depends on the initial identification and sustained tracking of the referent aircraft. This is a relatively complex task, but one which pilots can, within limits, perform with some accuracy.

For maximum effectiveness, tools, language, and procedures for ATC must be developed simultaneously. Among other things, the impending implementation of ADS-B will make a new tool available to the pilot. A new pilot display and interface, the cockpit display of traffic information (CDTI) is envisioned for the flight deck. Presently, the plans for flight deck applications of Automatic Dependent Surveillance-Broadcast (ADS-B) indicate a need for phraseology and procedures. One area, that is characteristic of several envisioned applications, concerns the development of controller/pilot communications intended to identify third party traffic. At the concept stage in applications development, a structured assessment is timely so as to design an effective format and to ascertain if a standard phraseology will be applicable to all of the pertinent applications.

This paper describes a pilot-in-the-loop, simulation study designed to inform the development of operational communications for identifying third party traffic. Such communications are to be used in future flight deck applications of ADS-B data, shown on a Cockpit Display of Traffic Information (CDTI). The remaining parts of this introduction present a synopsis of the relevant research literature and synthesize a set of research questions and hypotheses. Section 2 describes the details of the study method. In section 3, we review the overarching rationale for the study and its technical and discuss the results. Section 4 presents the conclusions and recommendations drawn for the study findings.

1.1 Review of the Literature on Flight Deck Applications

While the prospective applications are relatively diverse in terms of operational context and concept, many share a common a procedural requirement for transferring the identity of a third party aircraft from controller to pilot using voice communications. Applications which rely on this procedural step are italicized in Table 1-1.

Table 1-1. Proposed Chronology of Development for ADS-B-enabled CDTI Capabilities and Applications

Implementation Phase	Capability-Performance Group	Sample Applications
Package 1	**I. Airborne Traffic Situational Awareness** Allows the controller to transfer traffic identification with pilot referencing CDTI in addition to out-of-the-window visual acquisition. No change in pilot's responsibility with respect to separation.	• Enhanced traffic situation awareness: airport surface • Enhanced traffic situation awareness: in-flight • *In-trail procedure: oceanic airspace*
	II. Airborne Spacing When used, allows controller to transfer traffic identification and issue instructions with respect to designated traffic.	• *Enhanced sequencing and merging operations* • *Enhanced crossing and passing*
Package 2	**III. Airborne Separation** Allows the controller to transfer all separation responsibility or transfer separation responsibility with respect to designated traffic and in conjunction with necessary restrictions on maneuvers.	• *Approach spacing for Instrument Approaches* • *Independent closely spaced parallel approaches*
	IV. Airborne Self-Separation Pilots assume responsibility for separation, taking appropriate action to resolve conflicts.	• Airborne conflict management

The focus is on controller/pilot voice communications enacted during these applications and specifically on the opening exchange which establishes a mutually identified aircraft because the outcome should have bearing on multiple applications. It is assumed that it should be possible to devise a common communication format for third party traffic identification that will serve all applications which rely on this procedure.

Recently, Bone [1] compiled the first comprehensive look at global experience with CDTI-related communications. Survey results are summarized in Table 1-2. Note the wide variation in phraseology shown in the table in column 5, "Term for Traffic Referent." According to survey respondents about four forms of traffic identifier have been tested. The number is high if differentiate by speaker–controller only, pilot only or both. Some of the variants can be ascribed to limitations of prototype equipment. Further evidence concerning operational suitability of the variants can be derived from assessments by controllers and pilots who participated in the research activities. From an operational perspective, we found overwhelming agreement that, for voice communication, identifiers which were entirely numeric (i.e. Mode A/S code) were undesirable for use in voice communications, though appropriate for use data communications.

The literature also discusses important operational considerations integral to third party traffic identification. These are reviewed in the following sections.

Table 1-2. Survey of Experience with CDTI-based Communications

Sponsoring Research Program	Method/ Approach	Application	Research Participants	Term for Traffic Referent	Mandatory/ Optional Usage by Speakers
1. Cooperative Air Traffic Services through Surveillance & Communication Applications Deployed in ECAC (CASCADE) [2]	Simulation	Sequencing & Merging	Controllers	Call Sign Element Reversal - Suffix/Prefix	Required / Controller & Pilot
2. Mediterranean Free Flight (MFF) [3]	Operational Flight Test	Sequencing & Merging	Controllers & Pilots	Traffic Call Sign/Transponder code (for non-ADS-B aircraft)	Required / Controller & Pilot
3. Safe Flight 21 (SF21) [4, 5]	Operational Flight Test	Sequencing & Merging	Controllers & Pilots	Traffic Call Sign	Optional / Controller & Pilot
4. Distributed Air/Ground Traffic Management (DAG/TM) [6,7]	Simulation	Sequencing & Merging	Controllers & Pilots	Traffic Call Sign	Required / Controller & Pilot
5. DAG/TM [8, 9]	Simulation	Sequencing & Merging	Controllers & Pilots	Traffic Call Sign	Required / Controller & Pilot
6. ADS-B Network and Applications Update Programs (NUP & NUP2) [10]	Simulation	In-trail Spacing	Controllers & Pilots	Phonetic sequential pronunciation (letter by letter) of Traffic Call Sign prefix	Required / Controller & Pilot
7. Co-SPACE [11, 12, 13]	Simulation	Sequencing & Merging	Controllers & Pilots	Transponder code	Required / Controller & Pilot
8. First Assessment of the Operational Limitations, Benefits, & Applicability for a List of package I AS Applications (FABALA) [14, 15]	Workshop	Visual Separation on Approach & Sequencing & Merging	Controllers & Pilots	Discussion/ assessment of transponder code and other issues. No final conclusions drawn.	Not Applicable
9. SF-21 [16, 17]	Simulation	CDTI Traffic acquisition for Visual Approach	Controllers & Pilots	Traffic Call Sign	Optional / Controller & Pilot

Sponsoring Research Program	Method/ Approach	Application	Research Participants	Term for Traffic Referent	Mandatory/ Optional Usage by Speakers
10. More Autonomous Aircraft in the Future ATM System (MA-AFAS) [18]	Operational Flight Test	Sequencing & Merging	Controllers & Pilots	Transponder code	Required / Controller & Pilot
11. SF-21 [19]	Operational Flight Test	Visual Acquisition; Visual Separation on Approach	Controllers & Pilots	Phonetic sequential pronunciation (letter by letter) of Traffic Call Sign prefix	Optional / Controller & Pilot
12. SF-21 [20]	Operational Flight Test	Visual Separation on Approach	Controllers & Pilots	Traffic Call Sign	Required / Pilot only

1.1.1 Say Who?

In general, the communication phraseology and dialog now used for identifying third party traffic has been adequate to distinguish the referent traffic from other nearby possibilities. But this format has not always been successful, even in visual conditions. For airborne applications, intended to be used in almost all weather conditions, day or night, positive traffic identification is a necessity for successful communication and in most cases a prerequisite for carrying out an application with adequate safety. Roughly speaking, the construct of positive identification describes a condition in which both communicators have exchanged sufficient information to assure mutual identification of the same target.

The choice of an aircraft identifier (ACID) compatible with the requirement for positive identification of referent traffic is the primal operational consideration for CDTI-based traffic identification (ACID). To an extent, operational considerations associated with positive identification have been addressed in the literature. The crux of the matter is how to adapt existing phraseology, designed for visual conditions, to an environment in which the pilot's view of the traffic situation is defined by the CDTI. The CDTI design rules out certain descriptors: for example, aircraft type and color are not likely to be available in most implementations. These data are not currently required for ADS-B reports or as display information. Consequently, these descriptors must be excluded identification from further consideration as content for phraseology.

The exchange of position information also has some significant limitations for traffic identification. Consistency between the communicators' information about temporary characteristics, such as altitude and distance, degrades over the time course of the communication loop. Additionally, design and functional differences in the pilot and controller's reciprocal displays can induce varying degrees of inconsistency depending upon the dynamics of aircraft movement and display updates. Such inconsistencies can lead to position offsets between the controller's description and the pilot's displays information. Offsets between aircraft positions on the reciprocal displays potentially affect phraseology and training. This issue is discussed further in section 1.2.

Another operational consideration to emerge from previous research concerned the use of numeric aircraft identifiers, e.g. Mode A/S codes. Currently numeric identifiers are considered less suitable than alphanumeric ones. From an operational perspective, research indicates that traffic call sign and its variants was preferred over numeric identifiers [21].

As for the variant forms of call sign, previously evaluated, the literature offers little evidence to indicate a comparative benefits or drawbacks for any of them.

1.1.1.1 Call Sign Confusion

By far, the most prominent issue surrounding phraseology for traffic identification is the heightened risk of call sign confusion. In today's operations, an error attributable to call sign confusion occurs when one pilot responds to a controller's call intended for another aircraft. For now, this will be referred to as a *type 1* error. Research on the extent of today's problem is shown in Table 1-3. As the table indicates, operational incidents and errors, involving confusion of similar sounding call signs, are ubiquitous throughout the airspace, but most prevalent in terminal airspace, Terminal radar approach control (TRACON), and tower domains [22, 23, 24, 25]. Surprisingly, studies have consistently shown that as far as could be discerned, a large majority of occurrences were never cleared up and showed no evidence of precipitating a problem. Evidence further indicates that occurrences of confusion tend to involve flights operated by the same carrier with minimal differences of only one number or letter in call sign [24].

Table 1-3. Incidence of Call Sign Discrepancies in Operational Communications

Study Date	Environment	Hourly Rate	Rate per Transmission	Percent Uncorrected
2005 [25]	TRACON	3.4	0.6	90
1996 [26]	TRACON	1.6	0.8	53
1995 [27]	Tower, Ground	2.5	0.5	48
1994 [28]	Tower, Local	1.7	1.0	52
1993 [29]	En Route	0.6	0.5	62

A recent study [24] characterized perceptually similar call sign features. Certain call sign suffixes, trip/flight number, recurred with some regularity in incident reports. These included cases where: more than one aircraft on the frequency had suffixes ending in the same two digits; more than one aircraft had identical or composed of identical digits, ordered differently; and where more than one aircraft had call signs containing the same pattern of double or triple digits, e.g., 11, 333.

In the envisioned context of CDTI applications, where call signs are used to identify third party traffic, the risk of call sign confusion expands from one to three error types. In addition to today's type 1 confusion, two more possible types of confusion can develop. A second type, type 2, can occur when an addressee pilot mistakenly identifies an aircraft other than the one intended by the controller. Call sign similarity, when present in the traffic situation, is likely to be a causal or contributing factor to an erroneous identification of third party traffic.

A third type of confusion is similar to today's type of error and will be referred to as a type 1A error. Similar to today's type 1 error, a type 1A error can occur if the pilot of a third party aircraft mistakenly responds for the intended, addressee pilot. The distinction from the type 1 error 1A lies in the fact that call sign similarity is not necessarily implicit in the type 1A error. Rather, the catalyst for the type 1A error is merely the heightened frequency with which call signs occur on the communication frequency. In turn, the difficulty of the pilot's monitoring increases. In addition to detecting the flight's own call sign, the pilot must pay further attention to determine whether the controller is talking to or about this flight.

1.1.1.2 Spoken and Written Formats

Despite its familiarity, the conventional, spoken form of call sign can be problematic when it has to be verbalized. An operational consideration, unique to flight deck applications, concerns the fact that a substantial number of call signs cannot be derived from spoken form. These are referred to as unphonetic call signs, and some examples are shown in Table 1-4. Unphonetic call signs, as well as call signs that look or sound alike constitute another operational consideration in regard to traffic identification. This issue can be considered from multiple perspectives.

Table 1-4. Comparison of Some Spoken and Written Call Signs

Airline	Spoken Call Sign	Written Prefix
Air Cargo America	Pegasus	MVM
British Airways	Speedbird	BAW
America West	Cactus	AWE
Empire Airways	Empire Air	CFS
Canadian North	Empress	MPE

Nearly all of the previous studies have reported a concern by controllers and pilots regarding about the potential increase in call sign confusion. Yet, the applications literature is generally lacking in information that directly challenges or confirms its validity.

1.1.1.3 Redundancy and Communication Assurance

According to the research, the most effective way to manage this risk of miscommunication is to incorporate appropriate redundancy into the communications transaction. Redundancy is more than repetition. It is extra information that further identifies the goal or intent of a message, often from a different or complementary perspective [30]. In a variety of ways, ATC messages employ redundancy to elaborate, explain, and verify that information is being transferred correctly. Redundancy is evident in virtually all operational communications to better ensure success.

Table 1-5 shows that relative bearing and other directional cues were common to nearly all of the phraseologies previously evaluated. Several studies also retained the full content of current phraseology. This information helps to localize the pilot’s search of the display. Additionally, the correlation of aircraft position and call sign constitutes a redundant means of confirming that both communicators have identified the same aircraft. Generally speaking, reformulation and restatement have been shown to guard against error in even the most complex ATC communications [31].

Table 1-5. Sample of Communication Formats from Previous Work

Application	Speaker/Turn 1	Speaker/Turn 2
Enhanced Visual Acquisition & Approach [11]	C1: Select, [Transponder] Code.	P1: [ASAS] Contact, azimuth, distance, altitude.
Enhanced Visual Acquisition [32]	C: Traffic, azimuth, distance, altitude, aircraft type.	P: Traffic call sign (CV2) in sight.
Enhanced Visual Acquisition and Approach Spacing [33]	C: Following, aircraft tye, azimuth, distance, altitude. Report Traffic call sign (PS) in sight.	P: Traffic call sign (PS2) in sight.
Enhanced Visual Acquisition [34]	C: Confirm visual identification of Traffic call sign (R2).	P: Confirm visual identification of Traffic call sign (R), distance, azimuth.
CDTI Assisted Visual Acquisition during Visual Approach [35]	C: Traffic, Azimuth, Distance, Traffic call sign (CV).	P: Roger, Traffic call sign (CV) in sight
Sequencing & Merging [15]	C: For spacing, select target Traffic call sign (R)	P: Traffic call sign (R) identified, Azimuth, Distance
Airborne Spacing & Merging [8]	C: Merge behind and follow Traffic call sign (CV).	

It is important to strike a balance between message complexity and redundancy because as redundancy increases, there is often a corresponding increase in the complexity of the message and in the risk of an error [36, 37, 38, 39]. Examples of communication formats from the literature, illustrate a solution that preserves appropriate redundancy in the controller/pilot transaction without employing overly complex messages (see Table 1-5, rows 2, 4 and 6). In such examples, the requisite information has been distributed between the communicators [32]. In one study, for example, the controller stated the third party aircraft's call sign while the pilot replied with its bearing, distance, and altitude.

1.2 Airborne Surveillance System and CDTI

Compared to the controller's radar display, the CDTI will present more accurate and timely position data. Aircraft positions on the radar display are updated every few seconds (about four in the terminal and twelve in the en route environment), while the CDTI updates roughly every second.[1] High performance aircraft can easily travel over a mile laterally and descend or climb 800 feet during the time between controller display updates.

For airborne applications, differences in the information displayed to the controller and pilot raise a concern in regard to coordination of position information that is referenced to one of the two displays. While studies generally show that controller/pilot coordination enormously facilitated by a common understanding of the traffic situation, for communications intimately connected to a CDTI, the chosen format must support direct comparisons across communicators' reciprocal, but not identical, views [40, 41]. As previously discussed, temporary properties of aircraft —location, orientation, altitude— are subject to change from one act of identification to

[1] As presently defined, the airborne system receives ADS-B surveillance data every second and the CDTI updates display positions more frequently

the next and so may be easily confused [42]. If such properties are used in locating and identifying a traffic referent, some displacement in the position parameters of an aircraft shown on the communicators' reciprocal displays is inevitable. While this has not been an important issue for visual conditions, for the CDTI it may indicate a need to develop additional conventions, e.g., "around" or "no more than" for phraseology or training material defining the equivalence boundaries for comparison of aircraft positions between displays. It is also possible that the communicators will intuit these equivalences after some experience.

Another concern with discrepancies between controller and pilot is based on trust in automation and pilots' expectations. Experience with Traffic Collision Avoidance Systems (TCAS)[2] over the past decade has shown that pilots place great trust in the graphic situation display and the accuracy of the aircraft positions; sometimes to an extent not entirely warranted by the system's accuracy [2, 44, 45, 46]. Additionally, experience with TCAS further illustrates that independent pictures of the situation can give rise to contradictory inferences by controller and pilot. The mid-air collision over Überlingen, Germany serves as a conspicuous, if tragic, illustration of flawed controller/pilot coordination. In the July 2002 accident, both aircraft were equipped with TCAS. While several factors contributed to this accident, ultimately it was one pilot's acceptance of the controller's instruction, contravening a resolution advisory generated by the TCAS, that sent that aircraft into the evasive path being taken by the other [47].

Moreover, the CDTI is expected to have interactive features that provide a continuous readout of the position of a selected aircraft relative to the pilot's own aircraft. For purposes of communication, this level of position detail is bound to be inconsistent with the controller's point out. As applications involving the CDTI move forward, there is a corresponding need for communication and coordination between the controller and pilot. Implicit in the procedures envisioned is an expectation of a shared understanding of each other's operating environment that supports the communication process. An overall consideration for operational communications, therefore, is the process for setting compatible expectations on the part of controllers and pilots. Frequently, the necessity of a common orientation for the participants is overlooked or underdeveloped when an innovative procedure is planned. Without it, participants will develop a personal understanding of a procedure but it may not be in total conformity with that of the intended procedure.

1.3 Research Background and Purpose

In order to make progress on an issue that has concerned developers of flight deck ADS-B applications for some time, this research was conducted to systematically evaluate the performance and acceptability of communication format alternatives for third party traffic identification in varying operational contexts. The overall goal of this research is to map out the relevant and irrelevant operational considerations and to develop viable communication content and procedures early in the applications design process. Insight into the detailed knowledge that controllers and pilots will need to make third party traffic identification effective in the operations envisioned by future applications should be useful regardless of unforeseen changes in the developing applications.

Two simulations were conducted prior to this study. The first simulation (Exploratory) was conducted to evaluate the relationship between communications formats and a pilot's ability to successfully respond with a correct traffic identifier. Pilots participated one at a time and

[2] In Europe this system is called the Airborne Collision Avoidance System (ACAS).

compared three formats which varied the communicator (controller vs. pilot) who used the traffic call sign, the point at which the identifier occurred in the process, and the language used to assure both communicators that they have identified the same aircraft. The study also varied the difficulty of communication by scripting controller errors and testing the formats in settings with and without highly similar call signs. The findings indicated that pilots responded more quickly and made fewer errors when the traffic call sign was used in the controller's initial call. Performance improved further when the traffic call sign was preceded by a clock position indicating the relative location of the referent aircraft. The study also found evidence of displacements in the traffic positions seen and referenced by controller and pilot on their reciprocal displays.[3]

A second (Controller) study examined the relative effectiveness of communication format alternatives from the controller's perspective. The purpose was to validate the findings obtained in exploratory study from the controller's perspective. Based on experience from the exploratory study, some refinements were made in the communication formats, but to the extent possible the test conditions and measurement procedures replicated those used in the earlier study. The basic hypothesis was that communications would be more effective when the controller's initial call included the call sign of the referent traffic. This improvement was expected to be more pronounced in the context of highly similar call signs. Findings were generally consistent with those of the exploratory study. Specifically, formats that included the traffic call sign in the controller's initial call resulted in shorter reply lags and fewer communications errors. Both studies consistently showed that participants' (controller and pilot) subjective perceptions of format effectiveness disagreed to an extent with the objective evidence. Perhaps the most telling example of this was the recurring finding showing that the format rated 'especially suitable' by an overwhelming majority of the pilot and controller participants was also the most error prone.

Three classes of format have been defined over the course of the previous research. Each previous study and the present study tested one representative format from each class. The specific phraseology tested in this study can be found in section 2. The three format classes were defined as follows:

- **Readback** format evaluated the effectiveness of controller use of current phraseology (only traffic position) with pilot use of third party call sign;
- **Essential** format evaluated the effectiveness of using specific content, in addition to traffic call sign, in the controller's point-out. This format was intended to identify the minimum information required for a successful controller/pilot transaction.
- **Alternate** format evaluated the effectiveness of using alternate content in addition to traffic call sign, in the controller's point out or the pilot's readback.

The present study examined the effectiveness of communication format alternatives from a party-line perspective with multiple pilot participants operating in the same airspace and sharing a communications frequency. Again, the purpose was to further validate the findings of the previous studies. In addition, this study was designed to determine if any format was more likely than another to disrupt turn taking or induce time-sharing problems (e.g., incorrect pilot replies, blocked or stepped-on transmissions) on the frequency. Previous studies have narrowed the field of candidate formats down to two that appear most promising–Essential and Alternate. At the

[3] Kerns, K. and Bone, R. (2007) Say Who? Homing in on conventions for traffic identification in communications centered around a cockpit traffic display. Unpublished paper.

same time, it is also apparent from the first two studies that neither format was consistently superior to the other across all of the performance and acceptability criteria. Based on these findings, the formats tested in this study build on those tested in the previous study but incorporate appropriate adaptations indicated by that study's results. Apart from shaping the formats tested in this study, the cumulative research findings have a useful application in clarifying the nature of the operational conditions and situations that may qualify the effectiveness of each format.

To the extent that any of the formats tested or a different format is eventually adopted, the findings can be applied to help anticipate the operational problems likely to arise with a chosen format. With findings as the raw material, procedures and training considerations can be developed to mitigate potential flaws and tailored to assure successful communication to the extent possible given the format's profile of probable operational risks.

1.4 Research Questions and Hypotheses

This study sought to answer the five research questions listed below. The questions were designed to assess the relative performance of the formats with respect to communication errors and types, communication efficiency, impact on the frequency, sensitivity to complex call signs, effectiveness, and perceived acceptability. The questions are presented in the following list:

1. Are some formats more effective in minimizing pilot traffic identification time and errors?
2. Are some formats more effective in minimizing responses by the wrong pilot responding to a controller transmission?
3. Are some formats more effective in minimizing frequency congestion (transmissions per transaction)?
4. Is the effectiveness of some formats diminished by the increased presence of unconventional and highly similar call signs?
5. Do pilots subjectively prefer certain formats?

Each of these questions is evaluated by testing one or more hypotheses against the data collected on the applicable dependent measures. The hypotheses associated with each question are described in the following sections.

1.4.1 Q1: Are some formats more effective in minimizing pilot traffic identification time and errors?

Hypothesis #1A: *Formats that contain [a form of] traffic call sign (Essential and Alternate) will result in quicker and more accurate pilot identification of the intended traffic than those that rely exclusively on a controller's description of relative traffic position (Readback).*

Previous research, including the first two TFID studies, has hypothesized that using call sign to point out third party traffic will be more effective than relying exclusively on position descriptors. This hypothesis was also tested in the present study. The experimental comparison entailed contrasts between the Readback format which used position information exclusively and each of the other formats: Essential which used traffic call sign, and Alternate which used relative clock position in conjunction with an alternate form of traffic call sign. To the extent that temporary properties of aircraft were used in the phraseology and displayed on air and ground equipment with differing characteristics (Table 1-6), it was expected that traffic identification would take longer and the outcome would more error prone.

Table 1-6. Differences Between Controller and Pilot Display Equipment

Display Characteristics	Controller Station Display	(Typical) Pilot CDTI
Perspective		
	North-up, Plan view	Track-up, ownship-centric view
Configuration		
Display Range; Vertical filters	Typically larger airspace view	Typically smaller airspace view
Display data fields	ACID=Call Sign [Beacon code, computer ID] Absolute Altitude Aircraft Type and Class	ACID=Call Sign optionally selectable Relative Altitude, optionally Absolute Aircraft Class
Cross-display dynamic characteristics		
Update rate, Relative positions	4.8 to 6 sec. update, Sweep process for display refresh	≈1 sec. update, asynchronous display refresh CDTI positions can advance multiple times during response interval

Hypothesis #1B: *To the extent that the spoken traffic call sign closely approximates the displayed CDTI traffic call sign (Essential), the format will result in quicker, more accurate traffic identification than formats containing traffic call signs dissimilar to the displayed CDTI traffic call signs (Alternate) and formats using traffic identifying information that is not always displayed or information requiring mental extrapolation or transformation by the pilot (Readback).*

Further evidence from previous studies indicates that occurrences of call sign confusion tended to correlate with all numeric call signs or flights operated by the same carrier with minimal differences in trip number. This suggests that the Alternate format could be expected to be less efficient and more error prone than the other formats. As the Alternate format uses ―Flight" in lieu of a 3-letter identifier, the number of possible aircraft matches may be expanded, which leads to a longer response time and a higher probability of identifying the wrong traffic.

In contrast, the Essential format could also be expected to be more efficient than the other formats. Since the Essential format contains a traffic call sign that bears the closest resemblance to the displayed CDTI identifier, it should eliminate all aircraft, except the intended one for identification, leading to quicker and more accurate responses in most situations.

1.4.2 Q2: Are some formats more effective in minimizing responses by the wrong pilot responding to a controller transmission?

Hypothesis #2A: *Formats that contain a form of call sign (Essential and Alternate) will induce more cases of the wrong pilot responding than formats than those that rely solely on controller's use of location information (Readback).*

The research literature cites operational concerns that using call sign to refer to third party traffic could distract and confuse other pilots listening-in on the frequency. Or worse, cause one pilot to accept an instruction intended for another aircraft. This could result in extra transmissions to recover/repair information as the controller attempts to clarify with the referent pilot that the transmission was the intended for another aircraft and ensure that the intended pilot is prepared to respond. In addition, such errors can have secondary impacts on the frequency increasing the number of transmissions, the potential for more confusion (e.g. blocked or overlapping transmissions), and possibly increase or create flight delays while the controller recovers or revises the planned flow of aircraft.

Hypothesis #2B: *The Essential format will induce more cases of the wrong pilot responding than the Alternate format.*

Given that the Essential format verbalizes call sign the same way when stating the addressee and the referent aircraft, it may be easier for the third party pilot to mistake the referent call sign for the addressee. This is in contrast to the ―Flight” form of call sign used in the Alternate format, which emphasizes the difference between the two elements making them easier to differentiate. By this reasoning it is expected that the Essential format will induce more responses from unintended pilots than the Alternate format.

1.4.3 Q3: Are some formats more effective in minimizing frequency congestion (transmissions per transaction)?

Hypothesis #3: *Formats that contain a form of call sign (Essential and Alternate) may reduce frequency congestion (transmissions per transaction) over those that rely solely on controller's use of location information (Readback)***.**

Although the addition of call sign in the controller's transmission is hypothesized to facilitate more accurate and timely aircraft identification, it could increase the probability of confusion of other pilots on the same frequency. An unfavorable impact on frequency congestion due to the addition of traffic call sign could manifest as an increase in the number transmission made by the controller and pilot to close the transaction based on errors, such as identifying the wrong aircraft or a response by the wrong pilot. It is equally possible, however, that an increase in transmissions per transaction could be ascribed to insufficient information in the point out that requires extra transmissions to pin down the intended referent. In this case, the unfavorable impact would be attributable, perhaps, to phraseology that lacks a unique traffic identifier in the point-out, i.e. Readback. The latter case was specifically tested and a higher number of transmissions were expected in the Readback format than in the other formats.

1.4.4 Q4: Is the effectiveness of some formats diminished by the increased presence of unconventional and highly similar call signs?

Hypothesis #4: *Under conditions of unconventional and highly similar call signs, formats that rely on rely exclusively on controller's use of position descriptors (Readback) will result in quicker responses and fewer errors than those that use (a form of) traffic call sign for identification (Essential and Alternate).*

When call signs on the same frequency are highly similar (e.g., UAL984, AAL894), there is a greater potential for incorrect traffic identifications or wrong responses which increase the burden on pilots and controllers to listen closely for errors. Pilots may either make additional transmissions to verify intended traffic, or they may be more likely to select the incorrect aircraft. For this reason, formats based only on position descriptors, may be less confusing in these situations.

Unconventional call signs (e.g., Citrus -TRS, Jet Link -BTA, Critter -VJA) also present a greater potential for identification errors and wrong responses. While similar call signs can interfere with the pilot's comprehension of and response to spoken communications and the visual traffic search and aircraft identification activities, the effect of unconventional call signs is principally on comprehension of the controller's message and correlating that message with the CDTI information. The extent to which the pilot will respond to unconventional calls with a question or an identification error is not yet known. Clear procedures should make the determination.

In either situation, similar or unconventional call signs, it is expected that all formats will suffer some loss in performance. However, the performance of formats that contain (some form of) traffic call sign will be disproportionately impaired (Essential and Alternate) relative to formats that rely exclusively on position descriptors.

1.4.5 Q5: Do pilots subjectively prefer certain formats?

Hypothesis #5A: *Formats that contain (a form of) traffic call sign (Essential and Alternate) will be preferred by pilots over those that rely exclusively on controller's use of position descriptors (Readback).*

Operational acceptability is a difficult construct to define and measure. As with most studies, the participants were used as measuring instruments. Since the pilot's crucial task is to identify the aircraft intended by the controller, it is reasonable to expect that they would prefer a format that completely and unambiguously identifies the aircraft and assures them that the controller agrees with their selection. Indeed pilots who participated in the exploratory study preferred a format that contained a complete position description as well as traffic call sign; although they conceded that with this format the transmissions were too long. In most cases, although traffic call sign is likely to eliminate almost all ambiguity about the intended aircraft, the exploratory study also indicated that first stating relative clock position before traffic call sign reduced search time and provided useful redundancy supporting the identification. Therefore formats containing less ambiguity and contain appropriate redundancy (either in the point or readback) to assure success could be expected to be preferable to formats that make no allowance for ambiguity and add difficulty to the identification.

Hypothesis #5B: *The Alternate format is likely to be subjectively preferred over the Essential format because the "Flight" call sign is more readily distinguished from the addressee call sign and this should limit any unfavorable impact on the frequency.*

A second hypothesis concerning operational acceptability is based on the previous TFID study. In the MITRE Controller study (TFID 1) communication formats were evaluated from the controller's perspective. The results showed a strong preference for the Alternate format and the use of ―Flight" in lieu of carrier prefix. According to their assessment, the controller's crucial concern in regard to identifying third party traffic by call sign was that it would disrupt orderly transactions by soliciting erroneous response by the referent traffic. By using the Alternate format ("Flight") call sign, this concern would be dampened reducing the need for making extra transmissions for correcting errors. To the extent that pilots perceive this risk, it is expected that they will also prefer the Alternate format.

2 Method

2.1 Participants

Twenty certified, professional pilots participated in the study, in nine groups of 2-3 pilots each. Nineteen were currently employed commercial pilots; one was a retired commercial pilot. With one exception, all were male. As a group, all were familiar with glass cockpit Electronic Flight Instrument Systems (EFIS) for either Boeing B737/757/767 or Airbus A319/320 aircraft and also with Flight Management System (FMS) Control Display Unit (CDU) operations. Each participant also had recent operational experience flying these type aircraft with this equipment in a normal operational environment.

2.2 Airspace and Traffic Scenarios

A single radar position handling traffic operations in a terminal airspace environment (called "Louisville Approach") was replicated. Two generic applications, arrival and approach, were simulated in order to test communications and identify any effects, such as response time, that might be peculiar to the operating context. Eleven equivalent versions of the same basic scenario were developed. The versions were created by varying the time that aircraft appeared and the directions they came from as they approached the sector. Two versions of the scenario were used for training and nine were used for testing and data collection. Of the nine data collection scenarios, three represented normal call sign similarity and were based on actual recorded traffic. Three scenarios representing high call sign similarity were created by changing the aircraft call signs in three normal similarity test scenarios so that they were highly similar. Three scenarios representing unconventional call signs were created by changing the aircraft call signs in the three normal test scenarios so that they utilized irregular call signs, or call signs that have unusual conversions for their phonetic or written aircraft identifier (ACID) prefixes. The training scenarios were based on two of the normal similarity scenarios, but were shorter in duration.

The flow of arrival traffic in each 35 minute scenario was structured to create two distinct segments: an arrival segment and an approach segment. (Figure 2-1) In the arrival portion, eastbound traffic was brought in from the west, flying a Standard Terminal Arrival Route (STAR) called CSIGN 3. The CSIGN 3 Arrival allows eastbound aircraft to enter from the west at approximately 10,000-11,000 feet to the arrival fix PTINO. The controller provided decent instructions to the aircraft at initial contact. At PTINO, the approach portion of the scenario began and the controller vectored the eastbound aircraft to a southerly heading. Once established on this heading, the controller provided sequencing of the eastbound traffic with northbound traffic landing on ILS 35L or ILS 35R at Louisville International Airport (SDF). Then the controller would point out an aircraft for participants to follow on approach. Once the preceding aircraft was identified, the pilot was cleared for the approach, and handed off to the Tower.

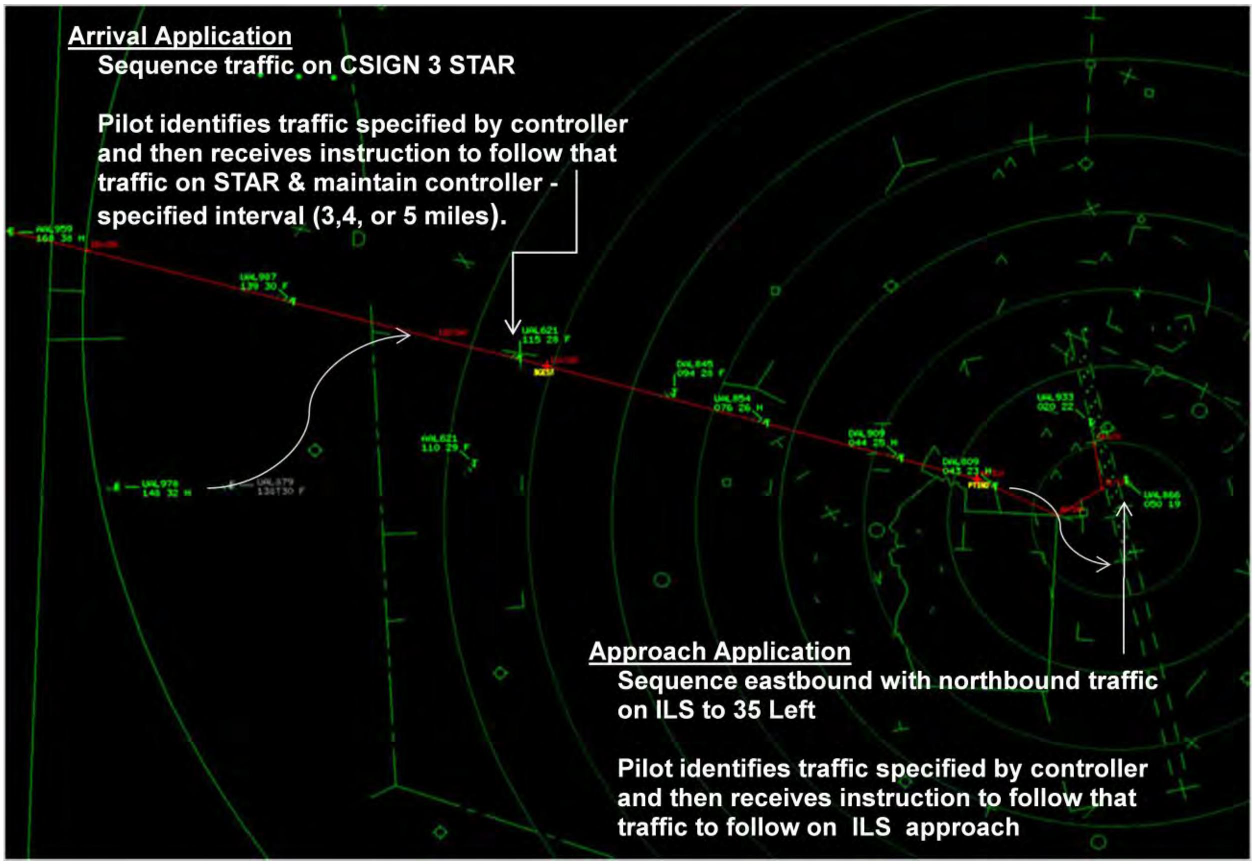

Figure 2-1. Simulation Airspace

In the arrival segment, the pilot's primary task was to identify traffic specified by the controller and then to receive and execute instructions to follow that traffic on the CSIGN 3 STAR and maintain controller-specified spacing intervals. In this segment, the controller's task was to merge traffic entering the sector from various directions on direct routes to PTINO with aircraft already flying CSIGN 3. The controller used vectoring and speed control to establish the relative position the off route aircraft in the sequence. For each participant pilot, the controller pointed out an aircraft to follow on the CSIGN 3 Arrival. Once the preceding aircraft was identified by the participant pilot, the controller issued a minimum spacing interval to maintain (i.e., get no closer than) and cleared the pilot to PTINO.

In the approach segment, the pilot's primary task was to identify traffic specified by the controller and then to receive and execute instructions to follow traffic on the ILS approach to runway 35L at Louisville International Airport. Once the pilot arrived at PTINO, the controller would issue headings for the pilot to follow for sequencing into the approach flow. A pseudo-pilot provided communications for non-participant aircraft, to establish and maintain normal operational communications traffic on the frequency.

As a final manipulation, controller and pseudo-pilot errors in communication were scripted with aircraft in the scenarios to evaluate error detection and repair. In each of the scenarios, two errors were embedded in the identification of referent traffic. The types of error varied, but included:

- Controller misidentification of the call sign for the referent traffic;
- Controller providing an incorrect clock position for the aircraft point-out;

- Controller transposing numbers for the referent aircraft (e.g., Flight-2779 for Flight-2797), and;
- Pseudo-pilot incorrectly responding to a controller's call (intended for a participant pilot).

2.3 Test Facility

The test facility, shown in Figure 2-2, was an ATC simulation environment consisting of a controller station, a pseudo-pilot station, and up to three participant pilot stations and associated computer functions. The controller position resembled a Standard Terminal Automation Replacement System (STARS) workstation comprising a situation display of radar targets, keyboard and cursor control device, radio communications headset and handset/footset with push-to-talk (PTT) functions.

The pseudo-pilot station was located adjacent to the controller's station, and consisted of a display showing a list of flights and control functions for all simulated aircraft in the test scenarios as well as a second display, replicating the controller's situation display (used to identify traffic that was pointed out in the test scenarios). Because simulating the pilot and controller functions comprised a relatively high workload, a coordinator supported these positions as needed.

The participant pilot stations were located in a separate room from the controller and pseudo-pilot stations. Each participant pilot station consisted of a PC-based cockpit that approximated a Boeing B-757 twin-engine aircraft, equipped with a Primary Flight Display (PFD), Flight Management System (FMS), Mode Control Panel (MCP), electronic flight instruments (EFIS) and CDTI on a navigation display and a radio communications headset and footset with PTT functionality.

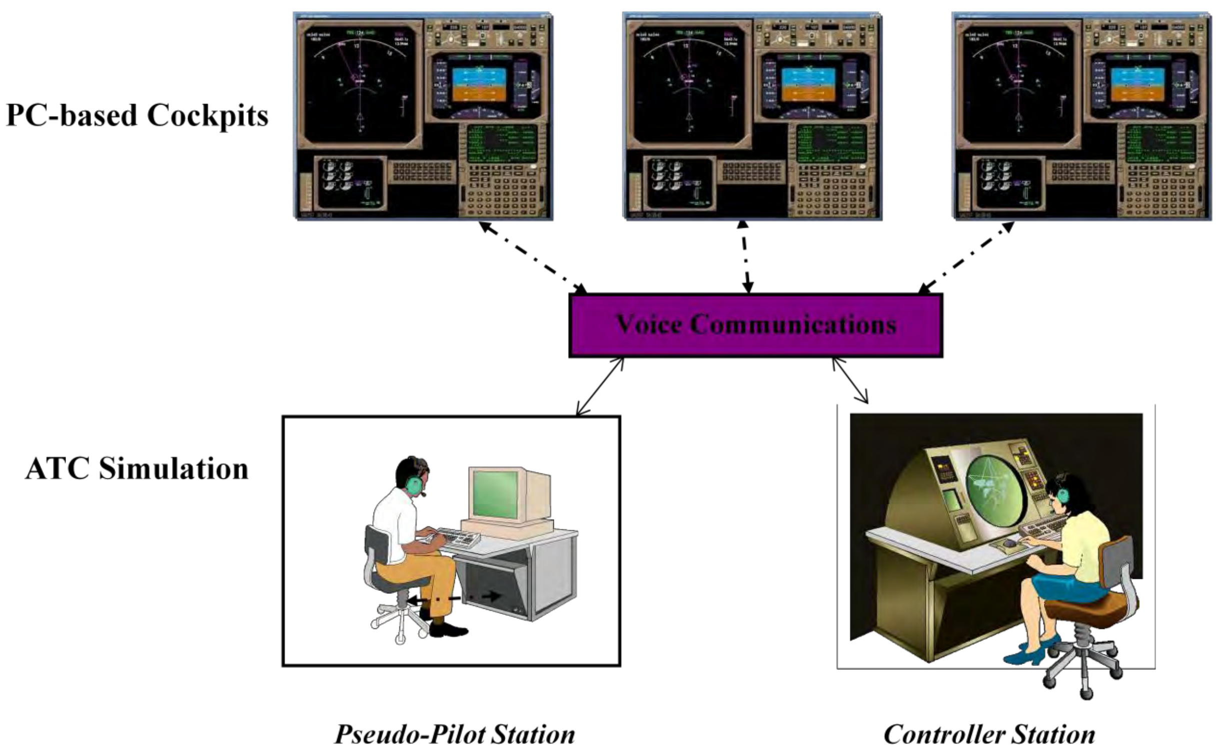

Figure 2-2. Schematic Diagram of Test Facility Simulation Environment

2.4 Experimental Design

Pilots participated in a part-task simulation, where single pilots operated PC-based cockpits equipped with a CDTI on a navigation display (ND) (Figure 2-3). The study was designed to compare three third party call sign communication formats with normal call sign traffic and either highly-similar or unconventional call sign traffic. Participants were instructed to perform piloting tasks consistent with normal flight operations. Their principal activity during the study was to communicate with ATC and to interact with the CDTI. Specifically, they were instructed to:

- Monitor the frequency and respond when ATC calls them and identifies traffic;
- Identify traffic on the CDTI and use controls to select that traffic on the CDTI, and;
- Reply to the controller using the appropriate phraseology based upon communications format.

Figure 2-3. PC-based Cockpit

2.4.1 Independent Variables

The independent variables were *communications format* and *call sign similarity*. Each is described in the following subsections.

2.4.1.1 Communications Formats

The communications formats used in the study are shown in Table 2-1.

Table 2-1. Examples of the Three Communications Formats

Format	Application	Phraseology
Readback	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
Essential	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
Alternate	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

It is important to note that in the Readback format, the pilot's response used the call sign of the referent traffic with the carrier prefix letters spoken phonetically. This served two purposes: 1) it distinguished this usage from the controller's use when addressing pilots, and 2) it corresponded to the CDTI aircraft label, allowing the pilot to read the identifier directly from the screen.

In the Essential format, however, the conventional pronunciation of call sign was used in reference to third party traffic. There were two reasons for using the conventional pronunciation in one format but not the other. First, experience from the exploratory study in which both controller and pilot used the phonetic pronunciation for third party traffic indicated that pilots had some difficulty retaining all of the information when the controller gave a letter by letter reading of the call sign of the referent. The phonetic pronunciation by pilots was maintained in the Readback format because of its other potential advantages. A second reason for eliminating phonetic pronunciation of call signs by controllers was the anticipated burden it would place on them to switch between the two pronunciations based on usage.

The Alternate format was a compromise wording that preserved part of identifier but was easily distinguished it from the addressee's call sign. The concern with this format was the loss of information that would uniquely identify the third party traffic. To an extent, it was attempted to mitigate for this by including the clock position of the referent traffic.

2.4.1.2 Call Sign Similarity

Scenarios with highly similar call signs were purposely designed to exaggerate the degree of similarity likely to occur in the actual operational environment. Since the evaluation focused on relative differences between formats, such exaggeration afforded the best opportunity to assess potential strengths and weaknesses associated with any of the candidates. To create highly similar call signs, nearly all of the traffic in the similar scenarios was restricted to one of three airlines, with a majority representing a single airline. With a few exceptions, the rest of the traffic was split between the other two airlines. Airlines were chosen with written designators that looked alike, i.e., American (AAL), Delta (DAL), and United (UAL). Next, similar trip numbers were created. The numbers were chosen to reflect known confusion problems such as identical digits in a different order and two or more identical digits. Examples of highly similar call signs are shown in Table 2-2.

Table 2-2. Highly Similar Call Signs

Traffic Set 1	Traffic Set 2	Traffic Set 3
UAL957	AAL925	USA355
UAL951	AAL919	USA955
UAL941	AAL991	USA855
AAL797	DAL895	ACA855
DAL879	AAL955	COA797
UAL859	DAL907	USA957
UAL855	AAL907	COA997
UAL907	DAL919	ACA797
UAL843	AAL981	USA857
UAL921	AAL945	ACA973
AAL859	AAL973	COA845
UAL879	AAL957	COA945
UAL917	AAL941	USA941
UAL971	AAL917	USA914
AAL981	DAL903	USA419
DAL905	AAL803	USA919
UAL805	AAL857	ACA479
UAL977	DAL855	ACA719

Scenarios with unconventional call signs were also purposely designed to reflect operators with call signs that have unusual conversions for their phonetic or written ACID prefixes. To create unconventional call signs, traffic in the irregular scenarios utilized carrier designators for 20 airlines comprising 4 groups of unconventional flight identifiers:

- 6 calls involve dissimilar sounding/looking IDs, and;
- 3 calls involve different prefixes that look similar

The unconventional call signs used in the study are presented in Table 2-3.

Table 2-3. Unconventional Call Signs

Prefix	Call Sign
ABX	Abex
AMW	Air Midwest
APW	Big A
AWB	Airnat
BLU	Blue Nose
BSY	Big sky
BTA	Jet Link
CCD	Cascade
CCI	Cappy
CCP	Champion Air
CPX	Capair
CXS	Clipper Connection
JBU	Jet Blue
JIA	Blue Streak
JUS	Jet USA
TCN	Transcon
TRS	Citrus
TRZ	Transmeridian
TSC	Transat
VJA	Critter

2.4.2 Dependent Variables

2.4.2.1 Objective Measures

All communications between the pseudo-pilot and controller during the test scenarios were recorded. Audio recordings were transcribed and analyzed to derive the objective dependent measures described below. The set of dependent variables measured in this study were standard indicators of communications effectiveness [36]. The fundamental unit of analysis for the transcripts was the communications transaction [37]. A transaction consists of the set of controller and pilot transmissions conducted to close the loop on a given ATC instruction or request. In addition to transmissions, a transaction also encompasses characteristic pauses during which the pilot and controller process and act on the preceding message, and, if appropriate, formulate a reply. Two intervals were important for this study. One of them was the time taken by the pilot to reply to the controller's call pointing out third party traffic. The other was the time taken by the controller to verify that the pilot had in fact identified the intended aircraft.

Operational definitions and measurement procedures for six dependent variables used to assess communications effectiveness appear in the following list:

- **Pilot Time on Frequency:** The cumulative duration of all pilot transmissions related to approach and arrival transactions.
- **Reply Lag:** Reply Lag was defined as the average delay interval between the end of the controller's call and pilot's reply identifying the referent traffic in the approach and arrival transactions. Longer delays indicated greater difficulty in locating and identifying the intended referent.
- **Transmissions per Transaction:** The number of approach and arrival transactions and the number of transmissions made in connection with each transaction were tallied for each scenario. The number of transmissions in a transaction was used as an index of effectiveness. Fewer transmissions per transaction indicated greater effectiveness since more transmissions meant that additional discussion was required as a result of a miscommunication or a request for clarification.
- **Communication Errors:** Communication errors were the count of all miscommunications related to approach and arrival transactions occurring in the test scenario.

Transcripts were further analyzed to describe the communication errors. Each error was coded to indicate whether the error was caught and corrected or missed and assigned them to one of the following categories:

- **Traffic ID Error**: where the pilot's reply stated the wrong call sign for the referent traffic.
- **Respondent Error**: where the wrong pilot replied to the controller's call.

2.4.2.2 Subjective Measures

Participants rated the acceptability of the joint pilot-system performance using the pilot acceptability rating scale (PARS) [48]. The PARS rated joint system performance on a 10-point scale indicating the degree of acceptability and extent of the deficiencies encountered.

An exit questionnaire was developed to solicit detailed comparative assessments of the three alternative formats. Participants rated the performance of each format on a scale from 1 (extremely low) to 7 (extremely high) with respect to the following criteria:

1. Easy to discriminate who is being addressed/what traffic is being referenced
2. Wording is appropriate, unambiguous, arranged in a logical order
3. All essential information is transferred efficiently with few excess words
4. Ensures listener correctly perceives intended meaning

5. Corrects discrepancies in a timely manner
6. Verifies mutual agreement on traffic identity
7. Does not disrupt orderly turn taking among users sharing the frequency

On the questionnaire participants also gave a summary assessment by assigning each format to one of three categories: ―generally unsuitable”, ―some possibility but has more errors than others”, or ―especially suitable”. More than one format could be assigned to the same category.

The final data collection instrument was a survey of general attitudes toward communications that use call sign in reference to third party traffic (see [49]). The survey asked participants to rate their agreement with six statements describing the operation impact (positive and negative) of using call sign to identify referent traffic. Both forms of call sign, conventional call sign and Flight, were rated.

2.4.3 Scenario Presentation Order

Under the design, the two experimental factors were manipulated within subjects so that each participant experienced all combinations of the format/call sign similarity test conditions. This design required six test runs. Participants always worked the full block of normal and high similarity scenarios for one communications format before moving to another format. The presentation order of similarity levels within format and of the communications formats across participants was counterbalanced, as shown in Table 2-4.

Table 2-4. Scenario Order

Run	Group								
	1	2	3	4	5	6	7	8	9
Familiarization	TR1	TR1	TR1	TR1	TR1	TR1	TR1	TR2	TR2
Training	TR2R	TR2A	TR2R	TR2E	TR2E	TR2E	TR2R	TR2A	TR2R
Scenario	1NR	3NA	2NR	3NE	3NE	3NE	1SR	2NA	1NR
Scenario	1UR	3UA	2UR	3UE	3UE	3SE		2SA	1SR
Scenario								3SA	1UR
Training	TR2E	TR2E	TR2A	TR2R	TR2R	TR2A	TR2A	TR2R	TR2E
Scenario	2NR	1NE	1NA	2NR	2NR	1NA	2NA	3NR	2NE
Scenario	2UR	1UE	1UA	2UR	2UR	1SA	2SA	3SR	2SE
Training	TR2A	TR2R	TR2E	TR2E	TR2A	TR2R	TR2E	TR2E	TR2A
Scenario	3NA	2NR	3UE	1NE	1NA	2NR	3NE	1NE	3NA
Scenario	3UA	2UR		1UE	1UA	2SR	3SE	1SE	3SA

Key - Format: TR=Training, R=Readback, E=Essential, A=Alternate; Call Sign Similarity: N=Normal, S=Similar, U=Unconventional

2.4.4 Training

The first step during training was an orientation session. During this session, participants reviewed and signed an informed consent agreement and were given a short introductory briefing. The introductory briefing included background information explaining ADS-B technology and how it could be used in the operational environment. The briefing also provided a description of the initial applications with special focus on applications which involve a transfer of traffic identification. The introductory briefing concluded with a description of the study and the role of the participant.

The briefing was followed by an initial laboratory practice session, during which participants worked training scenarios and communicated with the pseudo-pilots to familiarize them with the airspace procedures and the equipment. Participants practiced until they felt sufficiently comfortable to control traffic in the test scenarios.

2.4.5 Test Procedures

Before testing a format, the format and phraseology for the upcoming test scenarios were reviewed with each participant. A practice session was then conducted, during which the participant worked a training scenario using the format. Practice was terminated when the participant felt comfortable with the format. After the practice session, a block of two test scenarios with that format was run. Immediately after a scenario was completed, each participant provided a workload and acceptability rating. This sequence was repeated for each format.

After all test scenarios were run, a debriefing session was conducted. Participants first completed the exit questionnaire and attitude survey. Afterward, an unstructured discussion was held with each participant to elicit final comments about their experience and impressions of the study.

3 Results and Discussion

3.1 Methodology for Data Analysis: Background and Rationale

Statistical inference testing is logical-mathematical method for drawing conclusions about the extent to which research results prove or disprove a hypothesis. The method is probabilistic in nature. It uses a small sample result to test the truth of statements that apply broadly to an entire population. The logic of statistical inference is based on establishing a statistical null hypothesis and an alternative hypothesis for testing. The hypothesis identifies specific parameters in the data that will be compared. This study tested whether alternate communications formats were equally effective, under normal and high call sign similarity conditions. The effectiveness of the operational communications system was measured on multiple indicators.

The accuracy and validity of the conclusions drawn from the results of statistical tests depend on the probability of two types of errors. A Type I error is the risk of mistakenly rejecting the null hypothesis. This is analogous to a false positive or mistakenly concluding that there is a difference between the format/call sign similarity test conditions when there is no difference. This probability is defined by the significance criterion used to decide whether to reject the null hypothesis. Conversely, a Type II error is the risk of mistakenly accepting the null hypothesis. This is analogous to a false negative or mistakenly concluding that there is no difference between the test conditions stems when there is a difference. The probability is defined by the complement of the power (1-power) of the statistical test.

Section 3.2 discusses the applied context for this research, including the practical constraints on the design and the consequences of Type I and II errors for further development. This was the basis for the statistical inference strategy. Section 3.3 describes the approach to drawing statistically valid conclusions from the study findings. Sections 3.4, 3.5, and 3.6 present a description of the analytic approach and statistical procedures applied to test relationships between the multiple and single independent and dependent variables. These descriptions take up the analyses and results associated with each measurement construct in turn. Section 3.7 compares format attribute assessments from this study with those from previous studies.

3.2 Research Context

This was the third study of communications formats for identifying third party traffic in airborne CDTI applications. Each study was designed to provide the FAA SBS Program Office with information, recommendations and guidance regarding the content and the risk to benefit performance of the format alternatives. The audience was the SBS Program Office, researchers, developers and the operational community involved in flight deck applications of ADS-B.

The general strategy underlying the series was to examine how human performance characteristics and the operator's task environment interact with features of the communications format. These features included the structure of the dialog and the content of the phraseology allocated to the controller and pilot. The purpose of each successive study was to answer questions of relative effectiveness in order to progressively refine the formats and build a base of contextual knowledge that could be used to further develop the laboratory-based format abstractions to accommodate the complexities of ATC practice.

Seen in this perspective, the study results did not necessarily need to have operational significance. The sufficient condition for success was to reliably indicate a relative advantage or disadvantage for a given format, i.e., a statistically significant result.

One of the foremost concerns about using call signs in voice communication to refer to third party traffic is call sign similarity and confusion. Accordingly, scenarios used in the study focused on creating traffic situations and conditions that would reveal whether any of the formats was particularly sensitive to call sign similarity. The interaction between call sign similarity and format was examined by comparing format effectiveness in traffic scenarios with and without highly similar call signs.

As a way to discriminate format alternatives, high call sign similarity was defined theoretically as an abstract construct. The operational fidelity of traffic in scenarios that simulated high call sign similarity was relatively low but construct validity was relatively high. The effect of scenarios with high call sign similarity was generally consistent across the format alternatives, indicating some construct validity. The simulation high call sign similarity behaved consistently and in a way that was compatible with hypothesized relationship between the construct of call sign similarity and its expected affect on the dependent variables. This was sufficient to reliably indicate a relative format advantage.

Throughout the analysis of the study data, a fundamental validity threat was the limited number of cases available. Because the operational expertise required for this research tends to be scarce, the size of the participant sample was small. And sample size constrains the power of the statistical tests and increases the chance of a false positive result (Type I error).

Another factor that had implications for the validity was the meager base of empirical research pertaining specifically to this type of communication. Given the lack of prior knowledge, estimating the size of any potential effect was tenuous. Effect size is a key determinant of statistical power. The lack of comparable research also meant that there was little in the literature to help define the priorities for research variables and scenario conditions. Because this was a relatively unexplored topic, the consequences of both types of statistical error were deemed equally serious. If the results erroneously indicated that one format was more effective than the others when it was not, the FAA might adopt communications procedures and phraseology that later would prove to be unjustified and unacceptable. Conversely, if the results failed to show that one format was more effective than the others when in fact it was, controllers and pilots might fail to gain access to a beneficial, safety enhancing communications procedures and phraseology. In addition, it was also important at this early stage not to overlook potentially relevant issues. Yet, guidance from previous, suggesting which research variables were likely to be most influential, was virtually nonexistent.

3.3 Technical Approach

A critical choice in experimental research involves selecting the criterion for statistical significance, called alpha (α).This choice, however, presents the researcher with a dilemma. If α is set at 0.05, this will result in a relatively low, 5% chance making a Type I error or rejecting a hypothesis which is true. At the same time this decision produces a relatively high risk of a Type II error, called beta (β) occurring in the analysis. But a high risk of a Type II error results in a statistical test with limited ability to react to a real effect because of the inflated probability of accepting a false [null] hypothesis. The researcher's dilemma arises because the risks of the two error types are interdependent. If we select a high α value such as 0.05, to reduce the risk of a Type I error, we also the increase the risk of a Type II error (e.g., $\beta = 0.95$).

Aside from the statistical criterion, power is another parameter that gives an indication of the extent to which a statistical test will yield a valid result. Power can be conceptualized as the inverse of β (Power = 1-β). A test with high power has greater sensitivity to the presence of a real effect of the experimental factor (s) in the study design. To the extent that a test has adequate power, we can rely on the significance decision (accept or reject) designated by the result.

In practice, the researcher ordinarily adapts the significance and power criteria to suit the research context (e.g. exploratory or confirmatory). For this context, the analytic strategy was tailored to moderate the heavy bias of the conventional α levels toward minimizing Type I errors. Since the risks of either type of error were judged as equivalent, the significance criterion was lowered somewhat to $\alpha \leq 1$. Additionally, a power criterion, power ≥ 0.80, was also applied to the interpretation of test results. Significance decisions based on low power tests were excluded from this presentation of study results.

Multivariate methods were chosen for the data analysis. The choice of an appropriate statistical technique also bears on the reliability and validity of test results. In studies with multiple dependent variables, it is possible to produce an erroneous result by performing multiple tests on each individual dependent variable. Although this approach is relatively simple, it can produce results that misleading and in violation of the acceptable risk level of Type I errors as multiple testing raises probability that some of the results will be significant simply by chance. And if the dependent measures are interrelated, which is often the case, it is likely that many separate tests overlap, reanalyzing some of the same variance. Univariate tests are insensitive to the complex interrelationships among the dependent variables. With multivariate techniques these interrelationships are revealed and assessed in statistical inference without violation of acceptable levels of Type I errors [50].

This analysis applied multivariate techniques to keep the Type I error rate at 10% for all the variables tested. The dependent variables were bundled into three groups for simultaneous multivariate analysis, which were formed based on common measurement scales (i.e., interval, ordinal, or nominal), and common data collection schedules (i.e., post-scenario v. post-study). A separate Multivariate Analysis of Variance (MANOVA) was performed on each bundle. Subsequent testing proceeded according to the significance decisions indicated by multivariate results.

In all statistical comparisons, the significance criterion was set at $\alpha = p \leq 0.10$ and a power level of ≥ 0.80 was the cutoff for a valid significance decision. The actual significance and power levels associated with significant results were then reported.

3.3.1 Statistical Analysis

The MANOVAs analyzed a bundle of objective measures that were collected after each test scenario. For analysis of these dependent variables, a two-way, repeated measures multivariate analysis of variance (MANOVA) was performed. The between-subjects, independent variable was *format* with three levels, Readback, Essential and Alternate (Flight), and the within-subjects independent variable was *call sign complexity* (i.e. both similar and unconventional scenarios) with two levels, normal and high. Specific dependent measures analyzed in this MANOVA were as follows:

- Controller time on frequency
- Pilot time on frequency

- Pilot Reply lag
- Transmissions per transaction

A second MANOVA analyzed the bundle of variables that were collected at the end of the study. In this one complexity was not a factor. The analysis was a one-way repeated measures MANOVA with format as the between subjects independent variable and dependent variables comprising participant ratings of formats on seven attributes. Specific dependent measures for this MANOVA were ratings of the following attributes:

- Easy to discriminate who is being addressed and what traffic is being referenced
- Wording is appropriate, unambiguous, arranged in a logical order
- All essential information is transferred efficiently with few excess words
- Ensures listener correctly perceives intended meaning
- Corrects discrepancies in a timely manner
- Verifies mutual agreement on traffic identity
- Does not disrupt orderly turn taking among users sharing the frequency

In both MANOVAs, a simple multivariate contrast was performed to compare the Essential and the Alternate formats to the Readback format on each dependent measure. If a contrast was significant for one format, either Alternate or Essential, but not the other, then this format significantly differed from the Readback format but Readback and the other format were statistically equivalent. If both Essential and Alternate differed significantly from Readback, a repeated multivariate contrast was performed to compare the Essential and Alternate formats.

Apart from the MANOVAs, separate analyses of three other data sets were also conducted. Different statistical techniques were applied in each analysis and they are described with the results. The specific data sets were as follows:

- Number of errors, error type and status
- Summary assessments of format suitability
- Attitudes toward operational use of call sign for identifying third party traffic

In the next sections, the study hypotheses are reviewed and the results pertinent to each are presented. In general, the test results of the MANOVA effects are presented first. Then the follow-on format contrasts, univariate or post hoc test results associated with the significant multivariate effects are presented.

3.4 Analysis #1: Communication Effectiveness

The results of a two-way repeated measures multivariate analysis of Controller transmission time, Pilot Transmission Time, Reply Lag and Transmissions per transaction are shown in Table 3-1. The multivariate tests showed a significant result for the main effect of format. This multivariate result also contains adequate power to support the significance decision. Neither the complexity main effect nor the interaction of call sign similarity was significant **[Result 1-1]**. This indicates that all of the format effects were consistent across normal and high call sign complexity.

Table 3-1. Multivariate Analysis of Objective Measures

Effect	F	Degrees of freedom (hypothesis, error)	Significance	Power
Format	3.39	(8, 88)	**0.003***	0.98
Complexity	1.76	(4, 43)	0.15	0.63
Format * Complexity	1.05	(8, 88)	0.40	0.59

Given that on average formats differed significantly with respect to these variables, the multivariate contrasts between formats were next reviewed. The contrast analysis compared the Readback to the Essential format and to the Alternate format. Results showed a significant multivariate test result ($F\{8, 86\} = 3.39$; $p \leq 0.0002$ with power ≥ 0.98). Individual contrasts showed which variables accounted for the overall format differences (see Table 3-2).

Table 3-2. Significance Levels of Format Contrasts

Contrast	Controller Transmission Time	Pilot Transmission Time	Reply Lag	Transmissions per Transaction
Readback vs. Essential	0.14	0.14	0.16	**0.04***
Readback vs. Alternate	**0.03***	**0.01***	0.70	**0.07***

As the table indicates, four contrasts were significant. A significant difference was found between the Readback and Alternate formats with respect to controller and pilot transmission times. The Readback also differed from the Essential and Alternate formats on transmissions per transaction. No significant results were found with respect to reply lag.

A Bonferroni test was run to test for significant differences between the Essential and Alternate formats since they were significantly different from Readback with respect to Transmissions per transaction. The test showed that the Essential and Alternate formats were statistically equivalent on all measures **[Result 1-2]**.

Estimated marginal means, summarized in Table 3-3, are format means averaged over the two similarity conditions and adjusted for any covariation between the dependent measures. Since repeated measures designs characteristically have a relatively high degree of intercorrelation among the dependent variables, such adjustments are especially advantageous to eliminate overlap and error variance attributable to the relationships among measures.

Table 3-3. Marginal Means and Standard Errors(SE) on Dependent Variables

Dependent Variable	Readback Mean (SE)	Essential Mean (SE)	Alternate Mean (SE)
Controller Transmission Time	5.47 (.133)	5.19 (.133)	5.06 (.129)
Pilot Transmission Time	4.16 (.175)	3.78 (.175)	3.53 (.170)
Reply Lag	2.81 (.311)	2.19 (.311)	2.65 (.302)
Transmissions per Transaction	4.34 (.168)	3.84 (.168)	3.91 (163)

Figure 3-1 plots the profile of estimated marginal means of each dependent variable for each format. The dependent measures that showed significant effects are circled on the figure; Reply Lag is the only measure not demonstrating significance **[Result 1-3]**. In the figure, the separation between the two formats in which the controller uses traffic call sign (Essential and Alternate) and the format in which only the pilot uses it (Readback) is readily apparent.

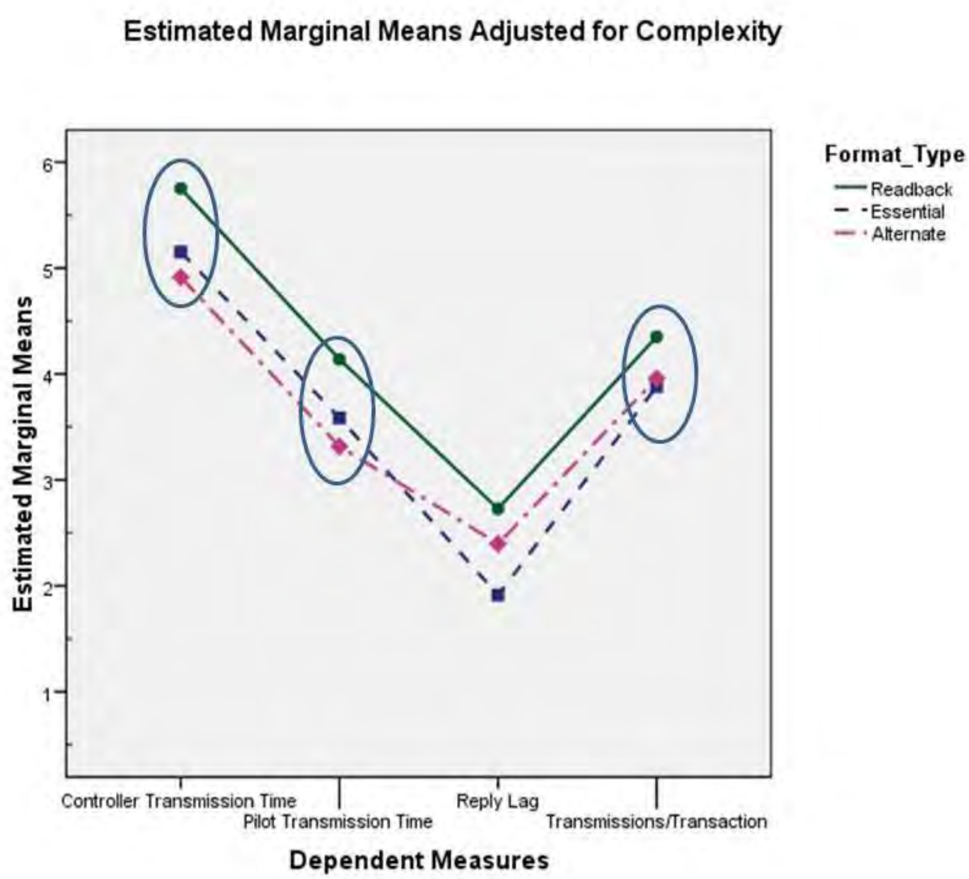

Figure 3-1. Multivariate Effects: Format Main Effect

Figure 3-2 and Figure 3-3 shows the transmission times (in seconds) for controller and pilot based on format. Figure 3-4 shows the number of Transmissions per Transaction based on format.

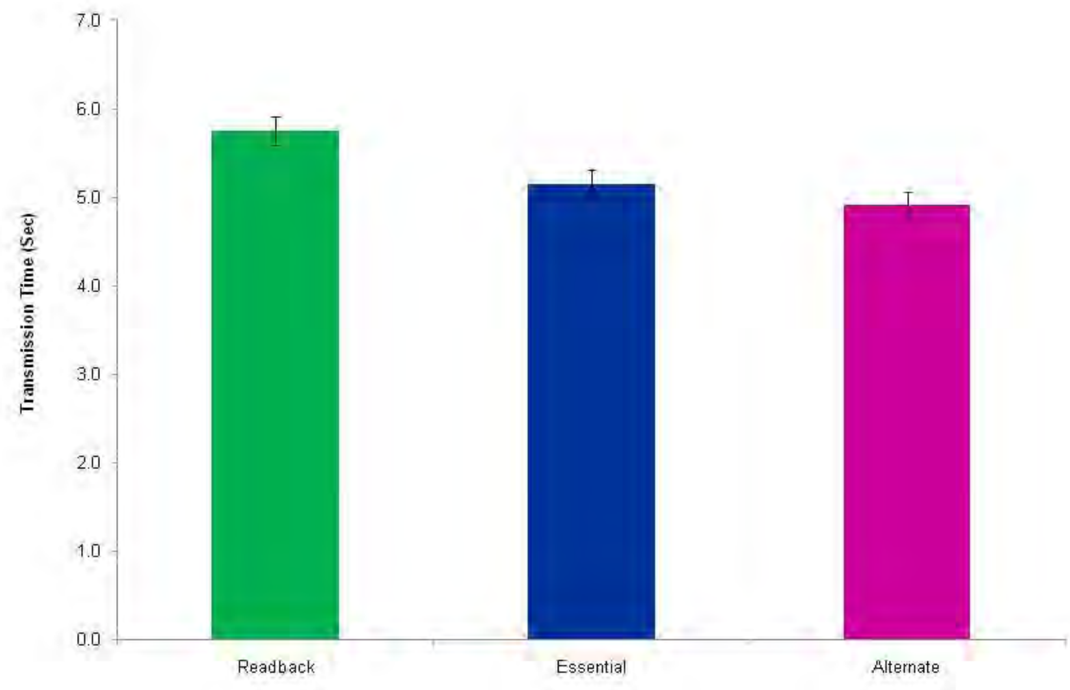

Figure 3-2. Controller Transmission Time

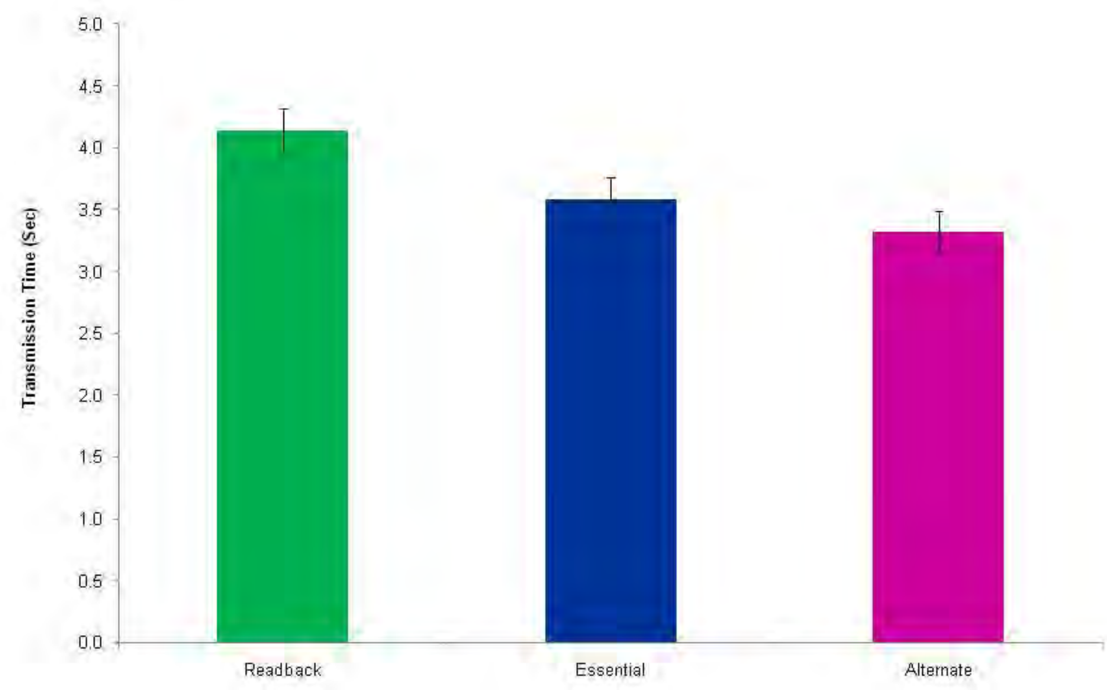

Figure 3-3. Pilot Transmission Time

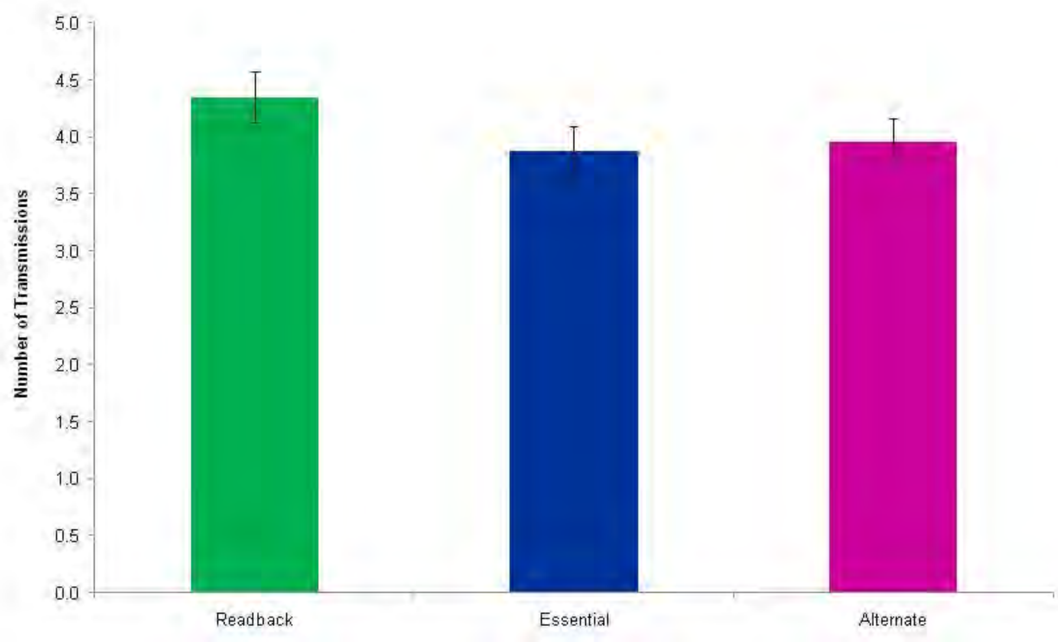

Figure 3-4. Transmissions per Transaction

In order to determine which conditions accounted for the significant differences, a contrast analysis was performed comparing the Readback format with the Essential format and the Alternate format. The results provided an overall assessment of the differential effects of call sign similarity on formats across all of the dependent variables.

The contrast analysis indicated a significant difference between the Essential and the Readback and Alternate formats on Pilot Transmission Time and Transmissions per Transaction, and between the Alternate and the Readback formats on Controller Transmission Time and Pilot Transmission Time **[Result 1-2]**. The difference between the Essential and the Readback formats on Controller Transmission Time was marginally significant **[Result 1-2]**. All of these tests had sufficient power (power = 0.99) to be confident that the results were valid.

3.4.1 Summary of Results on Communication Effectiveness

The analysis of communication effectiveness supported the following results:

1. [Result 1-1] No evidence was found to suggest that the effectiveness of any of the formats decreased disproportionately in the presence of unconventional and highly similar call signs.
2. [Result 1-2] On all of the dependent variables with significant format effects, the Essential and Alternate formats were statistically equivalent and consistently outperformed the Readback format:
    - Controller and Pilot transmissions were significantly longer with the Readback format than for either the Essential or Alternate format.
    - Significantly more Transmissions per Transaction were required for the Readback format than were required for either the Essential or Alternate format.
3. [Result 1-3] The reply lags for all formats were statistically equivalent.

3.5 Analysis #2: Communication Errors

Audio transcripts of all voice communications were reviewed to identify errors. The following two types of errors were tracked and analyzed:

1. Incorrect Traffic Identification: pilots replied with the wrong call sign for the referent traffic
2. Wrong Respondent: *wrong pilot replied* to the controller's call

Each error was also assigned a status of corrected or missed. Since the data set was small, results of Normal and Complex scenarios were combined; therefore, any effects of call sign similarity could not be examined, separately. Figure 3-5 plots the profile of estimated marginal means of Incorrect ID and Wrong Respondent errors across the three formats.

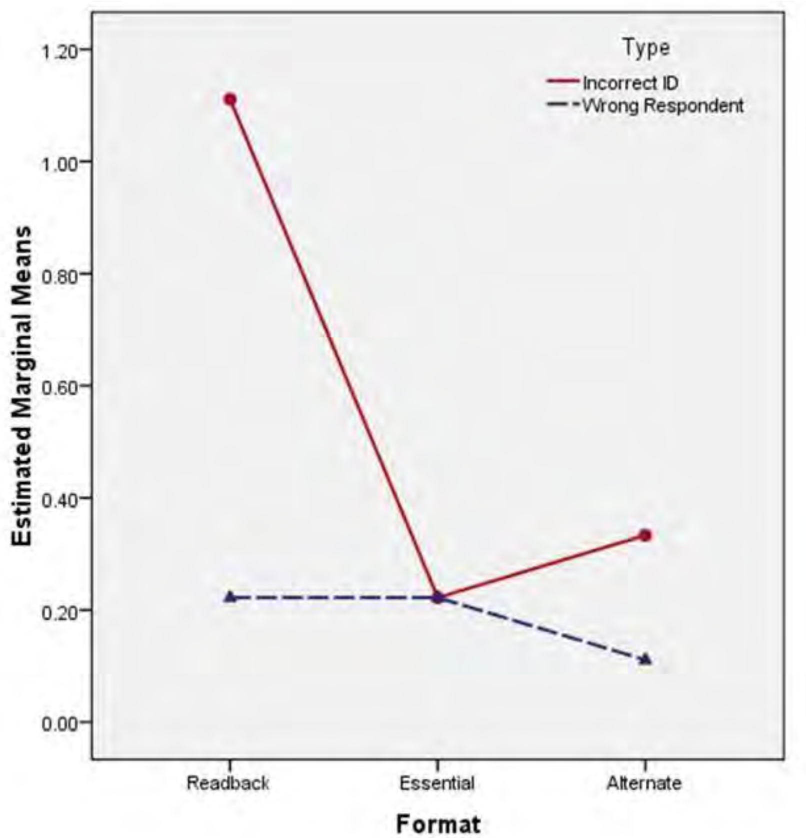

Figure 3-5. Multivariate Effects: Incidence of Error Types by Format

Due to limited data, both error types were combined for an initial multivariate analysis of variance that compared the main effect of format with respect to the incidence and status of errors (Table 3-4).

Table 3-4. Multivariate Analysis of Errors

Effect	F	Degrees of freedom (hypothesis, error)	Significance	Power
Format	2.76	(4,164)	$p \leq 0.03$	0.84

The multivariate results showed a significant main effect of format with sufficient power (.84) to confirm the finding.

A contrast analysis revealed a single significant format effect on error correction performance (Table 3-5). Compared to the Readback and Essential formats, the proportion of errors corrected with the Alternate format differed significantly. As is shown in Table 3-6, proportionately fewer errors were corrected under the Alternate format than in the Readback and Essential formats.

Table 3-5. Significance Levels of Format Contrasts

Contrast	Errors	Error Correction
Readback vs. Essential	1.00	0.69
Readback vs. Alternate	0.18	**0.005***

Table 3-6. Estimated Marginal Means for Error Counts and Correction Rates by Format

Format	Measure	Mean	Standard Error
Errors	Readback	1.50	0.11
	Essential	1.50	0.25
	Alternate	1.70	0.13
Proportion Corrected	Readback	0.60	0.10
	Essential	0.50	0.23
	Alternate	0.13	0.12

As noted earlier, two types of communication errors were crucial to this experiment: incorrect traffic identifications and responses to controller calls by the wrong pilot. Figure 3-6 and Figure 3-7 present the traffic identification and wrong respondent errors and their breakdown into corrected and uncorrected statuses. Once the error data was divided into these types, an already small data set became even smaller. Since a sample of this size would not have sufficient power to confirm a statistical decision, a nonparametric χ^2 test was applied to evaluate format effects on counts and correction rates by error type. Consistent with the results on total errors, a significant result was found indicating significant format difference on correction rates for each type of error ($\chi^2(2, 39) = 7.66$; $p \leq 0.02$).

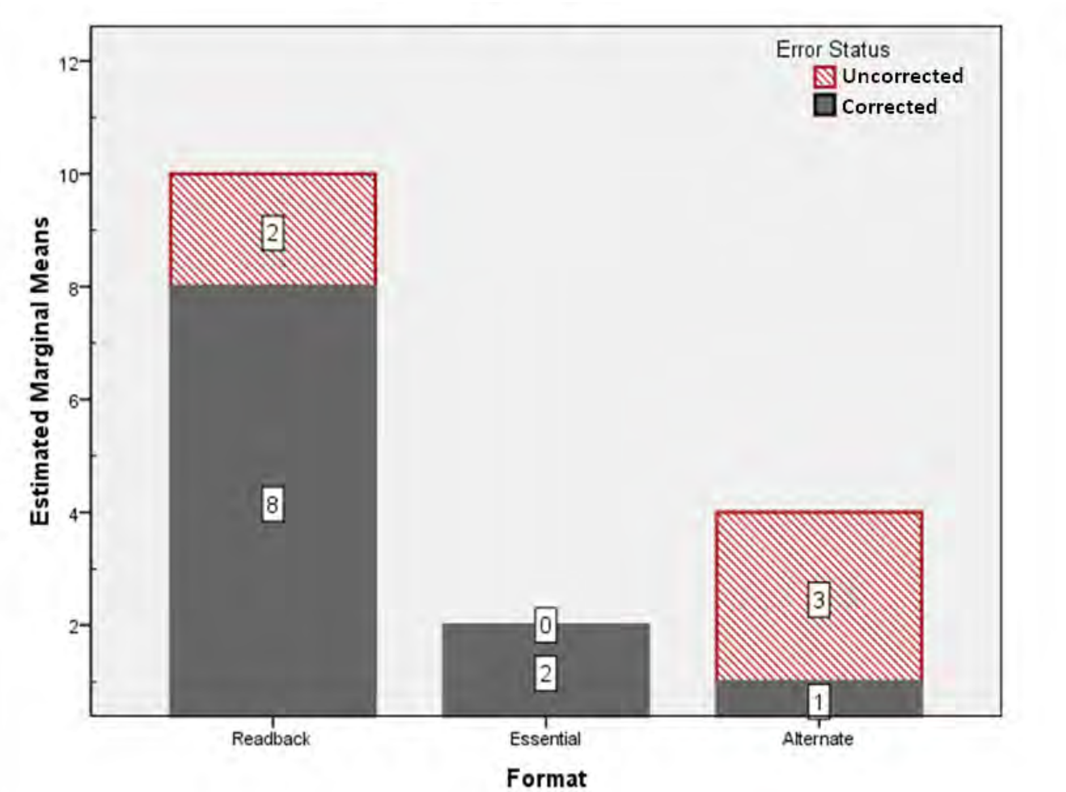

Figure 3-6. Incorrect Traffic Identification Errors and Correction Status by Format

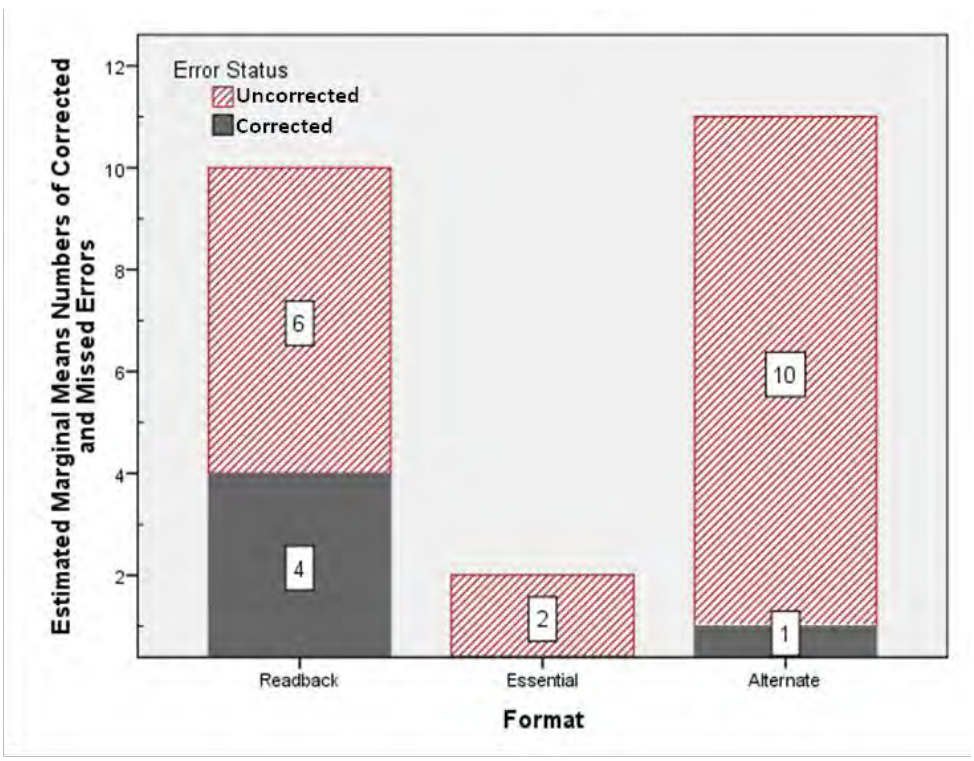

Figure 3-7. Wrong Respondent Errors and Correction Status by Format

Although the incidence of traffic identification errors appeared to be lower under the formats which used some form of call sign (Essential and Alternate) **[Result 2-1]**, this difference did not reach the level of statistical significance and should be viewed with caution. Additionally, although the Alternate and Readback formats appeared to have wrong more respondent errors than Essential **[Result 2-2]**, the difference was not found to be statistically significant.

As the analysis suggests and the figures illustrate, proportionately fewer of each type of error were corrected under the Alternate format than under the Readback and Essential formats, which were statistically equivalent. This suggests that the alternate format is the least effective in facilitating error corrections of both types once they occur **[Result 2-3]**, but that Essential may be no more effective than Readback **[Result 2-4]**.

3.5.1 Summary of Results on Communication Errors

The analysis of communication errors suggested:

1. [Result 2-1] The incidence of traffic identification errors appeared to be lower under the Essential and Alternate formats vs. Readback, but this difference did not reach the level of statistical significance. No apparent difference in incidence of traffic identification errors was observed between the Essential and Alternate formats.
2. [Result 2-2] The Alternate and Readback formats appeared to have more wrong respondent errors than Essential, but this difference did not reach the level of statistical significance.
3. [Result 2-3] The alternate format is the least effective in trapping and facilitating error corrections of both types once they occur.
4. [Result 2-4] The Essential format may be no more effective than Readback in trapping and facilitating error corrections of both types once they occur.

3.6 Analysis #3: Communications Acceptability

Seven attribute ratings and six attitude ratings were analyzed separately. Table 3-7 shows the attribute ratings and associated attribute descriptions.

Table 3-7. Subjective Measures: Attributes Assessed by Participants

Attribute	Description
1. Easily Understood	Easy to discriminate who the message is for and what traffic is being referenced
2. Unambiguous	Wording is appropriate, unambiguous, transmission follows a logical order
3. Efficient	All essential information is transferred efficiently with few excess words
4. Ensures Understanding	Ensures listener correctly perceives intended meaning
5. Detects Discrepancies	Corrects discrepancies in a timely manner
6. Verifies Mutual ID	Verifies mutual agreement on traffic identity
7. No Frequency Impact	Does not constrain timely communications on the frequency

A one-way, repeated measures MANOVA was conducted on participant ratings of formats on seven attributes. As Table 3-8 indicates, the main effect of format reached statistical significance, but had insufficient power to confirm this decision. The interaction effect, however, was significant and power sufficient to support this finding.

Table 3-8. Multivariate Analysis of Format Attribute Ratings

Effect	F	Degrees of freedom (hypothesis, error)	Significance	Power
Format	3.54	(2,57)	0.035	0.750
Format * Similarity	1.75	(12,34)	**0.008***	0.97

The results from the multivariate analysis of three formats are illustrated graphically in Figure 3-8 and highlight the differences in the attribute ratings.

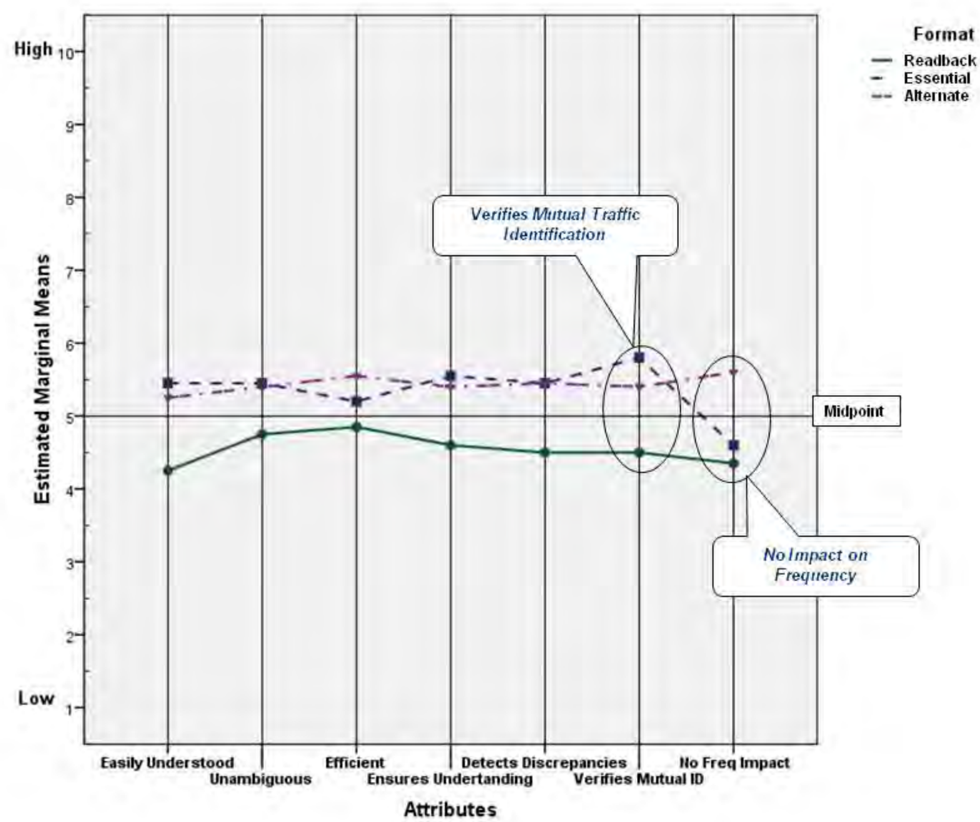

Figure 3-8. Multivariate Effects: Format Subjective Ratings

The analysis showed significant format differences on two attributes: Verifies Mutual Traffic Identification and Minimal Impact on Frequency. The results for the rest of the attributes, including Unambiguous, showed that format ratings were statistically equivalent **[Result 3-1]**.

A subsequent analysis of Verifies Mutual Traffic Identification (see Figure 3-9) found that the Essential and Alternate formats were rated superior to Readback format **[Result 3-2]**.

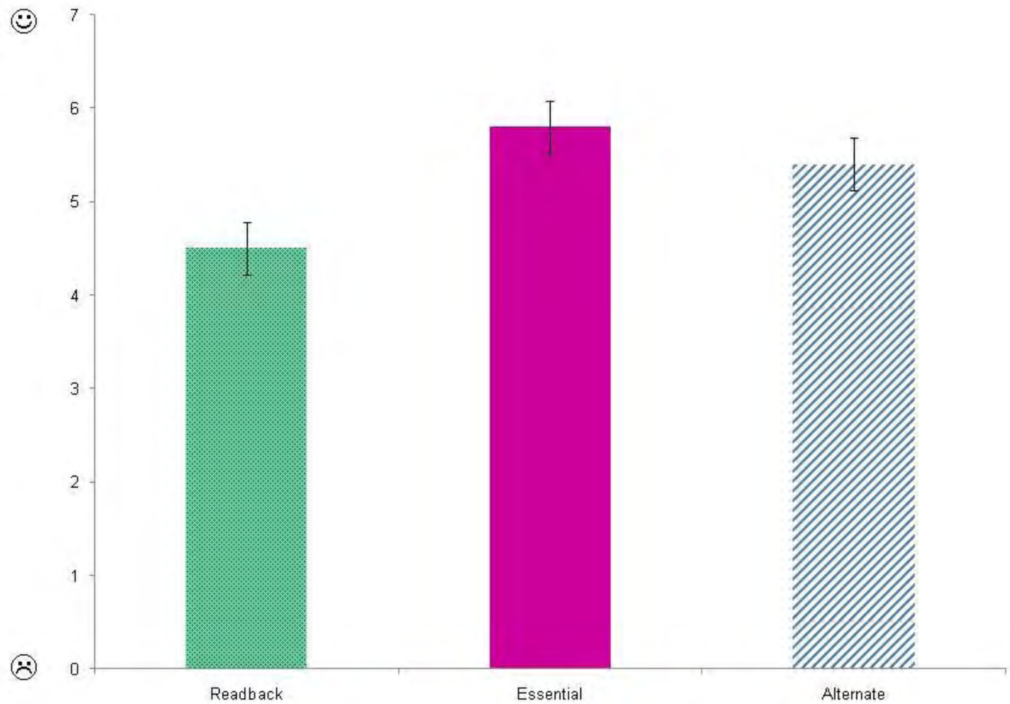

Figure 3-9. Verifies Mutual Traffic Identification

A subsequent analysis of Minimal Impact on Frequency (Figure 3-10) showed that the Alternate format was rated superior to Readback and Essential formats with respect to ―Impact on Frequency" **[Result 3-3]**.

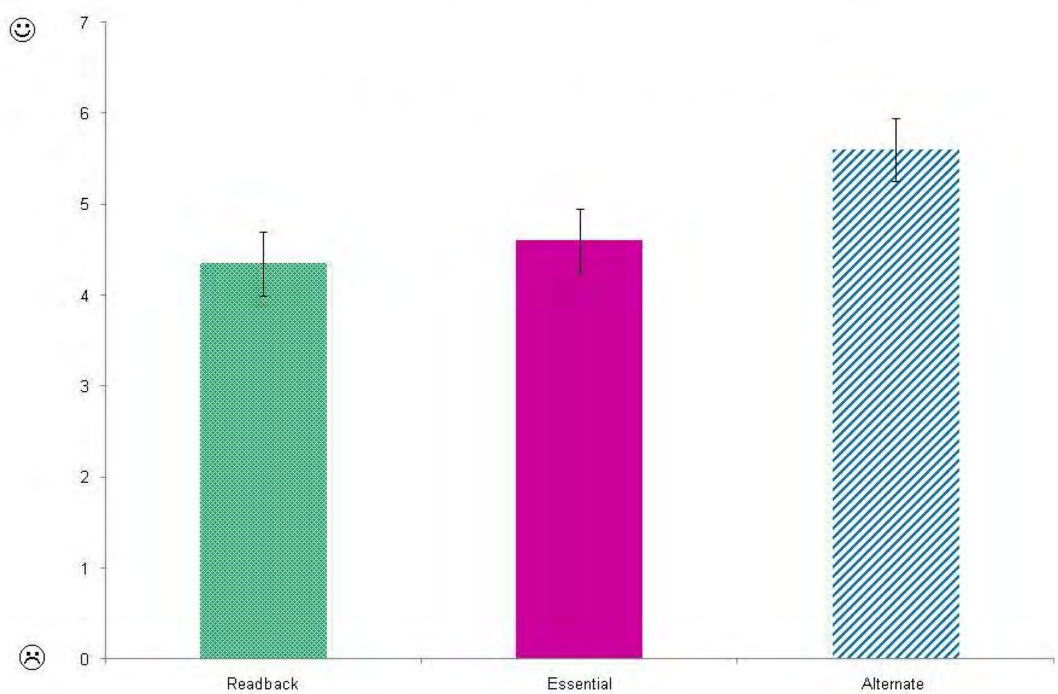

Figure 3-10. Minimal Impact on Frequency

As a summary assessment, pilots were then asked to classify each format into one of three possible categories: *Unsuitable*, *Needs Work*, and *Especially Suitable*. More than one format could be assigned to the same category. As Figure 3-11 shows, there was a dominant category associated with each format. It was assumed that each participant's classification represented a comparative assessment of suitability or lack of it regarding a given format. The order of formats' relative suitability is clear, although a test for statistical significance was not conducted. Alternate and Essential formats earned more ―Especially Suitable" ratings than the Readback format, and the Alternate format received the most especially suitable ratings while the Readback format received the most unsuitable and needs work ratings **[Result 3-4]**. To the extent that controllers were not unanimous in their assessments, however, this result should be interpreted with some caution.

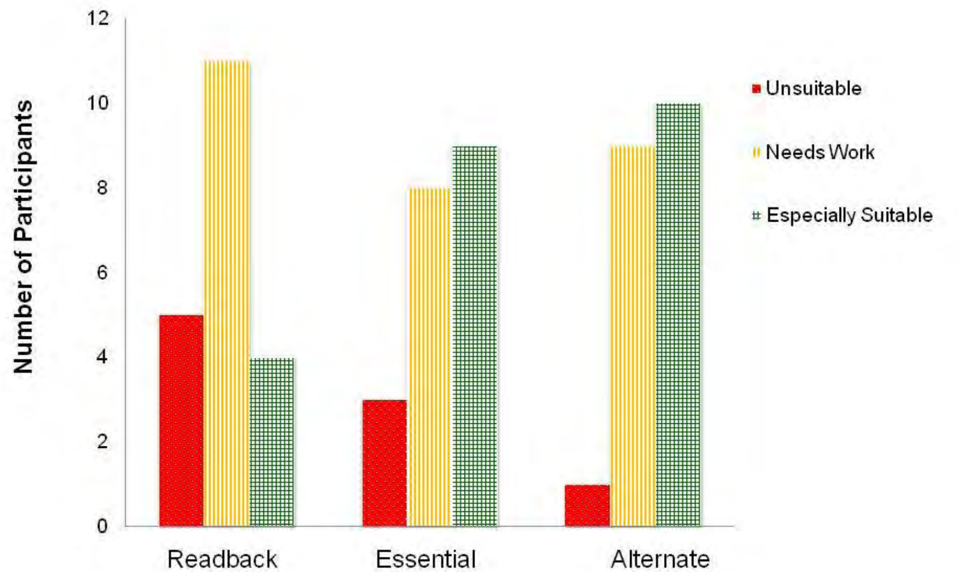

Figure 3-11. Summary Assessments

An attitude survey collected general opinions about using call sign in reference to third party traffic, and were asked to consider both the conventional call sign and Alternate formats of call sign in the ratings. Participants answered Likert-scaled items about operational use of call sign as an identifier for referent traffic. Table 3-9 and Figure 3-12 show the items and the overall results.

Table 3-9. Participants Attitudes Toward Using Alternate or Essential in Operational Communications

Statement	Alternate Mean (Standard Error)	Essential Mean (Standard Error)
Use Operationally Acceptable	5.27 (0.54)	5.20 (0.56)
Use made communications difficult	3.55 (0.59)	3.10 (0.61)
Use made it easy to resolve confusion	5.00 (0.41)	5.60 (0.43)
Pilot use made it easy to detect errors	4.91 (0.51)	4.90 (0.53)
Benefits are worthwhile	4.82 (0.50)	5.20 (0.52)
Use created too much congestion	3.36 (0.60)	3.80 (0.63)

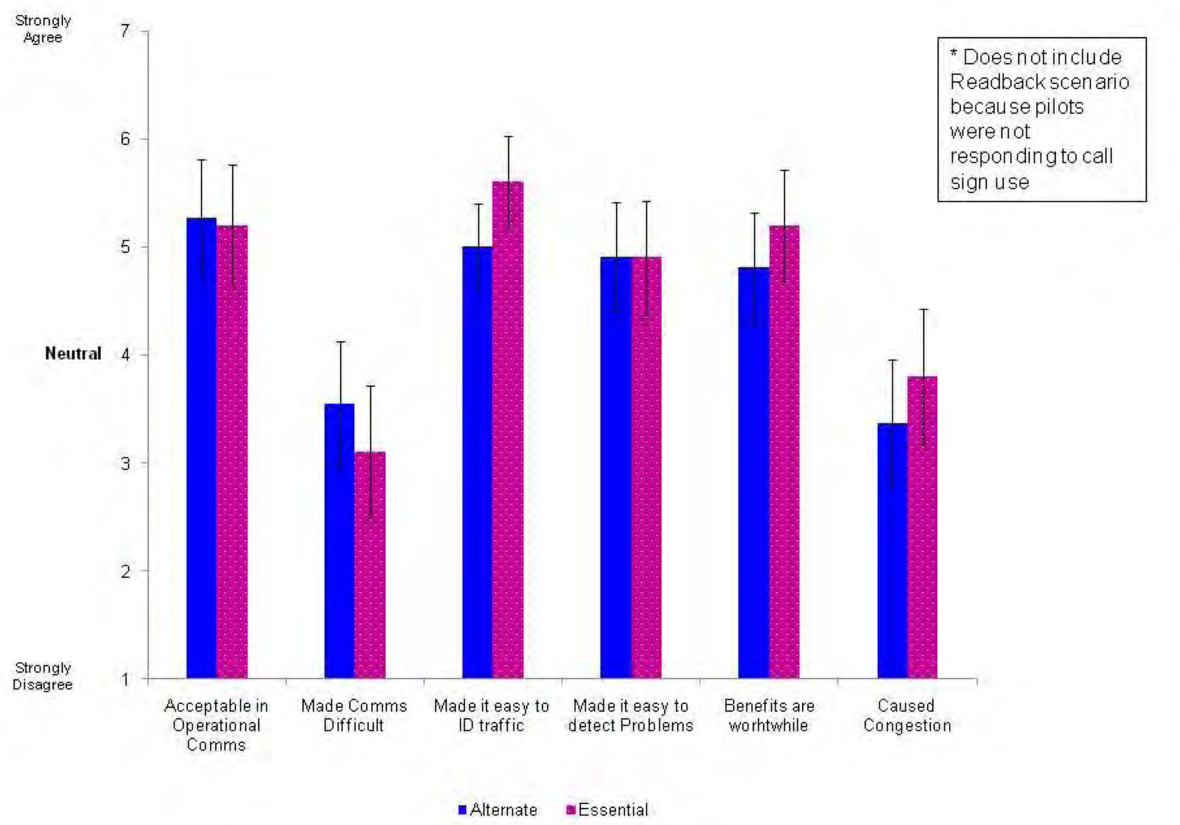

Figure 3-12. General Attitudes Toward Third Party Call Sign Usage

An analysis of the results of the survey suggested that attitudes towards using call sign for identification of third party traffic were generally positive **[Result 3-5]** and that there were no significant differences between Essential and Alternate formats on any of the general attitude measures **[Result 3-6]**.

3.6.1 Summary of Results on Communication Acceptability

The communication acceptability results suggest:

1. [Result 3-1] Format ratings were statistically equivalent for "Unambiguous".
2. [Result 3-2] The Essential and Alternate formats were rated superior to Readback format with respect to ―Verifies Mutual Traffic Identification".
3. [Result 3-3] The Alternate format was rated superior to Readback and Essential formats with respect to ―Impact on Frequency".
4. [Result 3-4] Analysis of summary assessments showed that Alternate and Essential formats earned more ―Especially Suitable" ratings than the Readback format.
5. [Result 3-5] Attitudes towards using call sign for identification of third party traffic were generally positive.
6. [Result 3-6] Analysis showed the Essential and Alternate formats were equally acceptable with regard to general attitudes regarding third party call sign use.

3.7 Comparison of Results across Studies

Format attribute assessments from this study were compared to attribute assessments from previous studies. The details of this comparison are shown in Table 3-10.

Table 3-10. Format Attribute Assessments Across Studies

Study	Results
Exploratory, 2007 (TFID 0)	Pilots found controller use of traffic call sign to be more effective than position information alone. Reasons were: Call sign was easy to interpret and correlate with display target. Attribute ratings with significant differences were ease of comprehension, mutual identification of traffic, and minimal frequency impact.
Controller, 2008 (TFID 1)	Controllers found formats which clearly distinguished addressee ID from referent traffic ID to be more effective. This results in two different ways of saying call sign: one for the aircraft receiving the communication, and another when referring to the third party. Reasons were: Reduced risk of response by pilot of third party flight. Attribute ratings with significant differences were: efficiency, lack of ambiguity, assures message received, and minimal frequency impact.
Multipilot, 2008 (TFID 2)	For multiple pilots, formats using either full or partial (Flight) traffic call sign viewed as more effective than just position information (Readback). Reasons were: Facilitated and verified mutual identification of same aircraft. Attributes ratings with significant differences were: verifies mutual traffic identification and minimal Frequency impact.

The comparison revealed that although both controllers and pilots in all studies considered their preferred format to be the one that had minimal impact on the frequency, their preferred formats were not the same. Pilots preferred a format that used traffic call sign to assure mutual identification (i.e., Essential), while Controllers preferred a format (i.e., that used a partial call sign (i.e., Alternate) to minimize confusion due to mistaken responses by pilot of referent flight.

Attitude ratings concerning the use of call sign for traffic identification were also compared to those from previous studies (Figure 3-13). The comparison found that attitudes were consistently favorable across all studies.

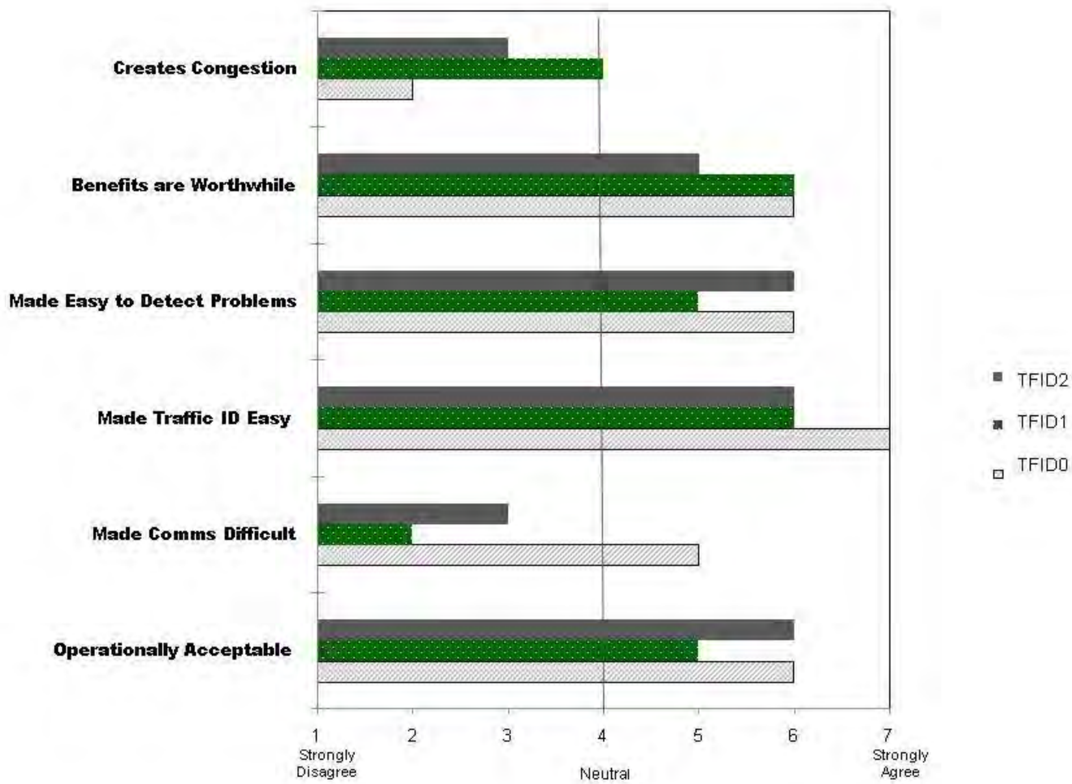

Figure 3-13. Attitudes Toward Using Call Sign for Traffic Identification Across Studies

4 Conclusions and Recommendations

The following sections will present the final conclusions in context with the research questions and hypotheses.

4.1 Research Question #1: Are some formats more effective in minimizing pilot traffic identification time and errors?

Hypothesis #1A: *Formats that contain [a form of] traffic call sign (Essential and Alternate) will result in quicker and more accurate pilot identification of the intended traffic than those that rely exclusively on a controller's description of relative traffic position (Readback).*

The findings from this study indicate that Hypothesis #1A is partially supported by the results. Result 2-1 indicates that pilots may have made fewer total Incorrect Traffic ID errors in the Essential and Alternate formats than in Readback. However, Result 1-3 suggests that the time required for pilots to find the target aircraft on their display was not reduced due to the introduction of the Essential and Alternate formats. Result 2-3 found that the Readback format was more effective than Alternate in facilitating traffic identification error correction, but Result 2-4 suggests that it was no more or less effective than Essential.

Bottom Line: The Essential and Alternate formats may be more effective in facilitating accurate pilot target traffic identification as opposed to the Readback format; however, the Alternate format was less effective than Readback and Essential in trapping and facilitating error corrections once they occurred. No significant difference in the time required for pilots to find the target aircraft on their display difference was observed among the formats.

Hypothesis #1B: *To the extent that the spoken traffic call sign closely approximates the displayed CDTI traffic call sign (Essential), the format will result in quicker, more accurate traffic identification than formats containing traffic call signs dissimilar to the displayed CDTI traffic call signs (Alternate) and formats using traffic identifying information that is not always displayed or information requiring mental extrapolation or transformation by the pilot (Readback)***.**

The findings from this study show that Hypothesis #1B is not supported by the results. Result 2-2 found no significant difference between the Essential and Alternate formats in terms of Incorrect Traffic ID errors. Result 1-3 found no significant difference between the Essential and Alternate formats in terms of the time required for pilots to find the target aircraft on their display. Result 2-3, however, found that the Essential format was more effective in facilitating error correction than Alternate.

Bottom Line: Of the two formats using call sign, no evidence was found to suggest that either one was more effective in allowing for faster and more accurate traffic identification by pilots. However, when incorrect traffic ID errors occur, the full use of call sign in the Essential format was more effective in facilitating error correction.

4.2 Research Question #2: Are some formats more effective in minimizing responses by the wrong pilot responding to a controller transmission?

Hypothesis #2A: *Formats that contain a form of call sign (Essential and Alternate) will induce more cases of the wrong pilot responding than formats than those that rely solely on controller's use of location information (Readback)***.**

The findings from this study indicate that Hypothesis #2A is <u>not</u> supported by the results. Result 2-2 indicates that that there was no significant difference in the incidence of wrong respondent errors among any of the formats. Although the Essential format appeared to have the fewest number of wrong respondent errors, this difference did not reach the level of statistical significance. Result 2-3 found that the Readback format was more effective than Alternate in facilitating wrong respondent error correction, but Result 2-4 suggests that it was no more or less effective than Essential.

Bottom Line: No evidence was found to suggest that the use of call sign may increase the likelihood of the wrong pilots responding to controller transmissions. When wrong respondent errors did occur, the Alternate format was less effective than Readback and Essential in trapping and facilitating error corrections.

Hypothesis #2B: *The Essential format will induce more cases of the wrong pilot responding than the Alternate format.*

The findings from this study indicate that Hypothesis #2B is <u>not</u> supported by the results. Result 2-2 indicates that that there was no significant difference in the incidence of wrong respondent errors among any of the formats. Although the Essential appeared to have fewer wrong respondent errors than Alternate, this difference did not reach the level of statistical significance. Result 2-3 found that the Alternate format was less effective than Essential in trapping and facilitating wrong respondent error corrections.

Bottom Line: No evidence was found to suggest that the Essential format increases the likelihood of the wrong pilots responding to controller transmissions over Alternate. When wrong respondent errors did occur, the Alternate format was less effective than Essential in trapping and facilitating error corrections.

4.3 Research Question #3: Are some formats more effective in minimizing frequency congestion (transmissions per transaction)?

Hypothesis #3: *Formats that contain a form of call sign (Essential and Alternate) may reduce frequency congestion (transmissions per transaction) over those that rely solely on controller's use of location information (Readback)***.**

The findings from this study show that Hypothesis #3 is fully supported by the results. Result 1-2 found that the Readback format required significantly more Transmissions per transaction than the Essential and Alternate formats, which were found to be statistically equivalent. Result 1-2 also suggests that the Readback format resulted in significantly longer controller and pilot transmissions than the Essential or Alternate formats which were found to be statistically equivalent.

Bottom Line: The use of call sign can help reduce frequency congestion by 1) shortening average controller and pilot transmission times, and 2) reducing the average number of transmissions per transaction. Although statistically significant, the effect as seen in the simulation is not dramatic.

4.4 Research Question #4: Is the effectiveness of some formats diminished by the increased presence of unconventional and highly similar call signs?

Hypothesis #4: *Under conditions of unconventional and highly similar call signs, formats that rely on rely exclusively on controller's use of position descriptors (Readback) will result in quicker responses and fewer errors than those that use (a form of) traffic call sign for identification (Essential and Alternate).*

The findings of this study show that Hypothesis #4 is not supported by the results. Result 1-1 found no evidence to suggest that the effectiveness of any of the formats decreased disproportionately in the presence of unconventional and highly similar call signs.

The study did not find evidence to suggest that any of the formats were more or less sensitive to errors or reply lag in the increased presence of unconventional and highly similar call signs.

4.5 Research Question #5: Do pilots subjectively prefer certain formats?

Hypothesis #5A: *Formats that contain (a form of) traffic call sign (Essential and Alternate) will be preferred by pilots over those that rely exclusively on controller's use of position descriptors (Readback).*

The findings of this study show that Hypothesis #5A is fully supported by the results. Result 3-4 indicates that Alternate and Essential formats earned significantly more ―Especially Suitable" ratings than the Readback format. This does not appear, however, to be due to perceived differences in ambiguity (Result 3-1). Instead, pilots likely preferred the Essential and Alternate formats as they felt that formats using call sign were superior in verifying mutual traffic ID (Result 3-2).

Bottom Line: Pilots are likely to subjectively prefer formats that use some form of call sign identification over formats that rely on positional information alone.

Hypothesis #5B: *The Alternate format is likely to be subjectively preferred over the Essential format because the "Flight" call sign is more readily distinguished from the addressee call sign and this should limit any unfavorable impact on the frequency.*

The findings of this study show that Hypothesis #5B is fully supported by the results. Result 3-4 shows that pilots had a subjective preference for the Alternate format over the Essential format, although Result 3-6 suggests that the preference was slight. Result 3-3 shows that pilots rated the Alternate format superior to the Readback and Essential formats with respect to Impact on Frequency.

Bottom Line: Pilots are likely to subjectively prefer shorter formats that they perceive as more efficient.

4.6 Discussion

Controller use of traffic identifier (Essential or Alternate formats) was associated with superior results relative to pilot use of traffic ID (Readback format) in terms of pilot traffic identification errors and frequency congestion. Comparing formats with traffic IDs, no significant objective differences were observed between the Essential and Alternate formats on any of the measures. However, when incorrect traffic ID errors occur, the Essential format may be more effective in facilitating error correction than the other formats.

Pilots' attribute ratings indicated that formats with traffic identifiers in controller's call were preferred because they assure mutual identification of same aircraft. Pilots' attribute ratings also indicated that the Alternate traffic identifier (Flight) was slightly preferred over the Essential traffic identifier (call sign) because it should have less impact on the frequency.

Subjective ratings slightly favor Alternate (Flight) format, while objective performance indicators found no major performance difference between the two formats. Alternate (Flight) is a leading candidate from a pilot standpoint; however, inferior error trapping and poorer objective performance from the controller study suggests examining a combination of the two phraseologies. (For example, "Jet Blue 877 Traffic to follow is at 10 o'clock, Flight United 805.") Pilot and controller attitudes were generally consistent and positive regarding use of traffic call sign. Pilots were more concerned about checking and verifying accuracy of traffic identification, while controllers more concerned over impact on frequency congestion

4.7 Recommendations

Presently, further research is needed in a few areas. One area is aimed at discovering how formats react to non-standard situations such as a controller resequencing a traffic flow or a pilot mistakenly identifying a third party aircraft. Since previous studies evaluated either controller or pilot performance, assessments of non-standard events provided insight to either the pilot's or controller's response but did not reveal the potential chain reaction that might occur with both operators involved.

Another area concerns understanding how new formats perform relative to a true baseline in which neither controller nor pilot use call sign to refer to third party traffic. Since previous studies focused on developing new formats, none made this comparison. A comparison of new formats with a baseline format could furnish evidence showing that a new format is necessary or sufficiently beneficial to justify implementation.

Based on these considerations, it is critical that both air and ground system components and their respective operators be representative and connected interactively in the simulation to identify system issues and impacts that cannot be addressed in simulations of the ground or aircraft systems in isolation.

An end-to-end simulation, involving controllers and pilots interacting with representative ground and aircraft system components in a realistic operational context would provide a satisfactory means of assessing the preceding issues. It should allow for capturing the influence of factors such as information and procedural consistency and compatibility, system response time, and operator errors on overall performance of communications formats. Such factors have been shown to affect the human user's ability and willingness to use the system.

Results of this study would be used to compile recommendations and guidance for flight deck applications, such as the following:

- Specific phraseology, task sequences for controllers and pilots to ensure that communications transferring third party traffic identity can be conducted efficiently and with minimum error.
- Specific phraseology format alternatives for GA-type call signs
- Descriptions of operating assumptions and procedures that provide for crosscheck and verification by pilot/crew and controller of display information.
- Recommendations with respect to CDTI lateral and vertical range settings and display fields.
- Human factors considerations that should be taught as part of a training program.

The human factors considerations could include issues resulting from introduction of the CDTI into the communications loop to assist field inspectors who evaluate operational procedures for flight deck applications, equipment, and training programs. These include changes in expectations and behavior that affect the way controllers and flight crews interact and communicate with each other.

5 References

[1] Bone, R. (2004a). [Requirements Focus Group Traffic Flight Identification Questionnaire Results]. Unpublished survey data.

[2] Rotundo, P. (2005). Mediterranean Free Flight Operational Benefits Assessment (MFF810TR002-D811B). Mediterranean Free Flight Program, http://medff.it/public/archive.

[3] Operational Evaluation Coordination Group (2000). Phase I-Operational evaluation. Cargo Airline Association ADS-B Program/FAA Safe Flight Program. Washington, DC.

[4] Operational Evaluation Coordination Group (2001). Operational evaluation-2 final report. Cargo Airline Association ADS-B Program/FAA Safe Flight Program. Washington, DC.

[5] Battiste, V., Ashford, R. and Olmos, B. (2000). Initial evaluation of CDTI/ADS-B for Commercial Carriers: CAA's Ohio Valley Operational Evaluation (SAE Paper No. 2000-01-5520). Presented at the 5th World Aviation Congress and Exposition. San Diego, CA.

[6] Prevot, T., Callantine, T., Kopardekar, P., Smith, N., Palmer, E. and Battiste, V. (2004). Trajectory-Oriented operations with limited delegation: An evolutionary path to NAS modernization (AIAA-2005-6043). AIAA 4th Aviation Technology, Integration and Operations Forum, Chicago, IL.

[7] Callentine, T. J., Lee, P. U., Mercer, J., Prevot, T. and Palmer, E. (2005) Air and Ground Simulation of Terminal-Area FMS Arrivals with Airborne Spacing and Merging. 6th USA-Europe ATM R&D Seminar. Baltimore, MD.

[8] Barmore, B. T., Abbott, T. and Krishnamurthy, K. (2004). Airborne managed spacing in multiple arrival streams. Presented at the 24th International Congress of the Aeronautical Sciences, Yokohama, Japan.

[9] NEAN Update Program (NUP) (2000). ATC simulation of delegated airborne separation during approach and climb out. Malmo-Sturup, Sweden: Swedish Air Traffic Services Academy.

[10] Grimaud, I., Hoffman, E., Rognin, L. and Zeghal, K. (2001). Assessing the impact on the flight deck of delegation of separation tasks. 20th Digital Avionics Systems Conference, Daytona Beach, FL.

[11] Grimaud, I., Hoffman, E., Rognin, L. and Zeghal, K. (2004). Spacing instructions in approach: Benefits and limits from an air traffic controller perspective. American Institute of Aeronautics and Astronautics (AIAA) Guidance Navigation and Control Conference, Providence, RI.

[12] Hebraud, C., Hoffman, E., Pere, N., Rognin, L. and Zeghal, K. (2004). Assessing the impact of a new air traffic control instruction on flight crew activity. American Institute of Aeronautics and Astronautics (AIAA) Guidance Navigation and Control Conference, Providence, RI.

[13] Raynaud, B. (2004). First assessment of operational limitations, benefits and applicability for a list of initial airborne surveillance applications: Final Project Report (FALBALA/WP5/FPR/D).

[14] Pugh, R. and Watson, M. (2004). First assessment of operational limitations, benefits and applicability for a list of initial airborne surveillance applications: Final Project Report (FALBALA/WP5/FPR/D) Appendix C: Results of Operational Workshop, Eurocontrol.

[15] Bone, R., Domino, D., Hahn, E., and Narkus-Kramer, M. (2002). Cockpit Display of Traffic Information (CDTI) Enhanced Flight Rules (CEFR). Proceedings of the 2002 IEEE/AIAA 21st Digital Avionics Systems (DASC) Conference, Oct. 2002, Irvine, CA: IEEE Press, 2002.

[16] Bone, R., Helleberg, J., Domino, D. A., and Johnson, N. (2003). Cockpit display based visual separation during an instrument approach: Effect of traffic display size and location (MTR-03W000030). McLean, VA: The MITRE Corporation.

[17] Hassa, O., Haugg, E. and Udovic, A. (2005). Sequencing and Merging Simulations: Final Report Volume I. DFS Langen, Germany.

[18] McAnulty, D. M. and Zingale, C. M. (2005). Pilot-based spacing and separation on approach to landing: The effect on air traffic controller workload and performance (DOT/FAA/CT-05/14). William J. Hughes Technical Center, Atlantic City, NJ: Federal Aviation Administration.

[19] Olmos, B. O., Bone, R. S. and Domino, D. (2001). Cargo Airline & Safe Flight 21 operational evaluation (Opeval-2). 4th USA-Europe ATM R&D Seminar. Santa Fe, NM.

[20] Clark, H. H. and Wilkes-Gibbs, D. (1986). Referring as a collaborative process. In Cognition (Chapter 22, pp 1-39). The Netherlands: Elsevier Sequoia.

[21] Kerns, K., Benson, L., and Penhallegon, W. (2009). Controller Evaluation of Third Party Flight Identification: Communication Format Alternatives for Referring to Aircraft Depicted on a Cockpit Display of Traffic Identification. The MITRE Corporation.

[22] Monan, W.P. (1983). Cleared for the visual approach: Human factors problems in air carrier operations (NASA Contractor Report 166573). Moffett Field, CA: NASA Ames Research Center.

[23] Monan, W.P. (1986). Human factors in Aviation operations: The hearback problem (NASA Contractor Report 177398). Moffett Field, CA: NASA Ames Research Center.

[24] Civil Aviation Authority (2000). Aircraft Call Sign Confusion Evaluation Safety Study (CAP 704). www.caa.co.uk.

[25] Prinzo, V., Hendrix, A. M. and Hendrix, R. (2005). The outcome of ATC message complexity on pilot readback performance (DOT/FAA/AM-05/19) Oklahoma City, OK: Civil Aeromedical Institute U.S. Department of Transportation

[26] Cardosi, K., Brett, B. and Han, S.(1996). An analysis of TRACON (terminal radar approach control) controller-pilot voice communications (DOT/FAA/AR-96/66). Washington, DC: Federal Aviation Administration.

[27] Burki-Cohen, J. (1995) An analysis of tower (Ground) controller-pilot voice communications (DOT/FAA/AR-96/19). Washington, DC: Federal Aviation Administration.

[28] Cardosi, K. (1994). An analysis of tower (Local) controller-pilot voice communications (DOT/FAA/RD-94/15). Washington, DC: Federal Aviation Administration.

[29] Cardosi, K. (1993). An analysis of en route controller-pilot voice communications (DOT/FAA/RD-93/11). Washington, DC: Federal Aviation Administration.

[30] Fields, R. E., Wright, P. C., Marti, P., and Palmonari, M. (1988). Air traffic control as a distributed cognitive system: A study of external representations. Proceedings of ECCE-9, the 9th European Conference on Cognitive Ergonomics, pp 85-90. Roquencort: EACE Press.

[31] Burki-Cohen, J. (1994). Say Again? How complexity and format of air traffic control instructions affect pilot recall. 40th Annual Air Traffic Control Association Conference Proceedings (pp 225-229). Las Vegas, NV.

[32] Prinzo, O. V. (2001). Innovation in pilot visual acquisition of traffic: New phraseology for air traffic control operational communication (DOT/FAA/AM-01/19). Washington, DC: FAA Office of Aerospace Medicine.

[33] Prinzo, O. V. and Hendrix, A. M. (2003). Automatic dependent surveillance/cockpit display of traffic information: Pilot use of the approach spacing application (DOT/FAA/AM-03/13). Washington, DC: FAA Office of Aerospace Medicine.

[34] DFS (2003). Traffic Awareness for General Aviation (TAGA) Results of flight trials—First and second phase, Version 2.2, Deutsche Flugsicherung GmbH, Euro Telematik AG, Avionik Straubing GmbH, Langen, Germany.

[35] Bone, R. (2004b). Cockpit Display of Traffic Information (CDTI) Assisted Visual Separation (CAVS) during visual approach. Proceedings of the International Advanced Technologies Conference. Anchorage, AK.

[36] Cardosi, K. and DiFiori, A. (2004). Communications Metrics. ATC Quarterly, 12 (4), 297-314.

[37] Prinzo, O. V. (1996). An analysis of approach control/pilot voice communications (Report No DOT/FAA/AM-96/26). Washington, DC: Federal Aviation Administration.

[38] Morrow, D., Lee, A. and Rodvold, M. (1993). Analysis of problems in routine controller-pilot communications. The International Journal of Aviation Psychology, 3(4), 285-302.

[39] Williams, D.H., & Green, S. (1991). Airborne Four Dimensional Flight Management in a Time-Based Air Traffic Control Environment. (NASA TM-4249). Springfield, VA: National Technical Information Service.

[40] Béguin, P. and Rabardel, P. (2001). Designing for instrument mediated activity. In O. Bertelsen and S. Bødker (Eds) Information technology in human activity, Designing for instrument mediated activity. Scandinavian Journal of Information Systems, 12 (1-2).

[41] Kreifeldt, J. G. (1980). Cockpit displayed traffic information and distributed management in air traffic control. Human Factors, 22(6), 671-691.

[42] Clark, H. H. and Wilkes-Gibbs, D. (1986). Referring as a collaborative process. In Cognition (Chapter 22, pp 1-39). The Netherlands: Elsevier Sequoia.

[43] Operational Evaluation Coordination Group (2000). Phase I-Operational evaluation. Cargo Airline Association ADS-B Program/FAA Safe Flight Program. Washington, DC.

[44] Operational Evaluation Coordination Group (2001). Operational evaluation-2 final report. Cargo Airline Association ADS-B Program/FAA Safe Flight Program. Washington, DC.

[45] Battiste, V., Ashford, R. and Olmos, B. (2000). Initial evaluation of CDTI/ADS-B for Commercial Carriers: CAA's Ohio Valley Operational Evaluation (SAE Paper No. 2000-01-5520). Presented at the 5th World Aviation Congress and Exposition. San Diego, CA.

[46] Prevot, T., Callantine, T., Kopardekar, P., Smith, N., Palmer, E. and Battiste, V. (2004). Trajectory-Oriented operations with limited delegation: An evolutionary path to NAS modernization (AIAA-2005-6043). AIAA 4th Aviation Technology, Integration and Operations Forum, Chicago, IL.

[47] Moll, N. and Gilson, C. (2002). Midair collision reveals gap in international ACAS procedures. Aviation International News, Farnborough

[48] Lee, K. K., K. Kerns, R. Bone (2001) ―Development and Validation of the Controller Acceptance Rating Scale (CARS): Evidence From Empirical Research", Proceedings of the 4th USA/Europe Air Traffic Management R&D Seminar, Santa Fe, NM.

[49] Bone, R., Domino, D., Hahn, E., and Narkus-Kramer, M. (2002). Cockpit Display of Traffic Information (CDTI) Enhanced Flight Rules (CEFR). Proceedings of the 2002 IEEE/AIAA 21st Digital Avionics Systems (DASC) Conference, Oct. 2002, Irvine, CA: IEEE Press, 2002.

[50] Tabachnick, B. G. & Fidell, L. S. (1996) Using Multivariate Statistics. Allyn and Bacon, Needham Heights, MA, p 3.

Appendix A Acronyms List

Acronym	Definition
AAL	American Airlines
ABX	Abex
ACID	Aircraft Identifier
ADS-B	Automatic Dependent Surveillance Broadcast
AMW	Air Midwest
APW	Big A
ASAS	Airborne Separation Assistance System
ATC	Air Traffic Control
AWB	Airnat
BA	Big A
BLU	Blue Nose
BSY	Big sky
BTA	Jet Link
CAL	Continental Airlines
CCD	Cascade
CCI	Cappy
CCP	Champion Air
CDTI	Cockpit Display of Traffic Information
CDU	Control Display Unit
CPX	Capair
CXS	Clipper Connection
DAL	Delta Airlines
EFIS	Electronic Flight Instrument Systems
FAA	Federal Aviation Administration
FL	Flight level
FMS	Flight Management System
HITL	Human-in-the-loop
ILS	Instrument Landing System
JBU	Jet Blue
JIA	Blue Streak

JUS	Jet USA
MANOVA	Multivariate analysis of variance
MCP	Mode Control Panel
ND	Navigation Display
PARS	Pilot Acceptance Rating Scale
PFD	Primary Flight Display
PTT	Push-to-talk
SBS	Surveillance and Broadcast Services
SDF	Louisville International Airport, Standiford Field
STAR	Standard Terminal Arrival Route
STARS	Standard Terminal Automation Replacement System
TCAS	Traffic Collision Avoidance System
TCN	Transcon
TFID	Third Party Flight Identification
TLI	Task Load Index
TRACON	Terminal Radar Approach Control
TRS	Citrus
TRZ	Transmeridian
TSC	Transat
UAL	United Airlines
USA	US Airways
VJA	ValueJet (Critter)
VJA	Critter