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An Analysis of Approach Control/Pilot Voice Communications

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16. Abstract

This report consists of an analysis of air traffic control and pilot voice communications that occurred at 3 terminal air traffic control facilities (TRACONs). Each transmission was parsed into communication elements. Each communication element was assigned to a speech act category (e.g., address, instruction, request, advisory) and aviation topic (e.g., heading, altitude, speed, readback) and evaluated using the aviation topic-speech act taxonomy (ATSAT, Prinzo, et al., 1995). A total of 12,200 communication elements in 4,500 transmissions make up the database. Communication elements appeared most frequently in the address and instruction speech act categories. Of the 2,500 controller communication elements, 40% contained at least 1 communication error. The number and types of communication errors (message content and delivery technique) located within each speech act category were determined and separate communication error analyses are reported for pilots and controllers by TRACON facility. Of the 5,900 pilot communication elements, 59% contained at least 1 communication error. More than 50% of controllers' and pilots' communication errors occurred in the instruction speech act category. Generally, controllers omitted key words that pertained to radio frequency, airspeed, or approach/departure instructions. Pilots only partially read back instructions involving heading, radio frequency, and airspeed aviation topics and grouped numbers in a radio frequency, airspeed, or heading. Pilots' and controllers' communications became more conversational and verbose when their transmissions included advisory or request speech acts. Omitting and grouping numbers in transmissions may be strategies used to minimize time on frequency. Ironically, these strategies may create the problems that pilots and controllers are trying to prevent. Frequency congestion may occur from additional transmissions that are made to resolve ambiguities or repair misunderstandings due to incomplete transmissions.

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AND THE LORD SAID, "BEHOLD THE PEOPLE ARE ONE, AND THEY ALL HAVE ONE LANGUAGE...COME, LET US GO DOWN AND THERE CONFUSE THEIR LANGUAGE, THAT THEY MAY NOT UNDERSTAND ONE ANOTHER'S SPEECH."

— Genesis 11:6-7

1.0 INTRODUCTION

Do spoken communications present a problem to air safety? The answer depends, in part, on how the question is framed. Various government agencies traditionally have inspected verbal communications as they related to filed incident reports, whereas communications researchers have analyzed and described non-eventful, routine verbal communications (Morrow, Lee, & Rodvold, 1993; Morrow, Rodvold, & Lee, 1990; and Cardosi, 1993).

In operational error, pilot deviation, or accident investigations communications often are reported as an apparent weak link. Aviation investigators scrutinize preliminary safety reports and obtain additional information, as needed, to determine if Federal Aviation Regulations (FAR) were violated, and to report the factors underlying each certified incident. For the investigator, the total number of communications or operations that occur on a daily basis may be neither important nor particularly interesting; that an incident report was filed and an investigation undertaken is sufficient.

What do the investigation data indicate? As shown in Table 1[1], communications problems were cited as causal or contributing factors in approximately 27% of the confirmed operational errors, 40% of the pilot deviations, and 15% of the near midair collisions (NMACs) reported in 1993 and 1994. Although the total number of each type of incident has decreased in 1994 from 1993 levels[2], the percentage of incidents with communications involved appeared to be constant.

Air traffic control specialists (ATCS)[3] and pilots have implicated faulty communications in airspace incidents reported to safety investigators. Thirty-six percent of the total number of full-form incident Aviation Safety Reporting System (ASRS) reports filed by pilots and controllers between 1988 and 1991 listed faulty communications as contributing or causal factors in airspace incidents. Collectively, the ASP-100 and ASRS data indicate that faulty communication is a significant factor in safety related incidents.

Unlike investigators who examine one incident at a time, communications researchers rely upon large amounts of information from many sources to draw generalized conclusions or describe a typical event. For these researchers, the total numbers of communications or operations that occur on a daily basis are important and interesting data for analysis. One important step in such analyses is the development of a framework or methodology for analyzing aviation-based communications. For example, Cardosi's (1993) analysis of Air Route Traffic Control Center (ARTCC) controller-pilot voice communications focused on message complexity. Message complexity was defined as the number of separate elements contained in a single transmission.

> *Each word, or set of words, the controller said that contained a new piece of information to the pilot, and was critical to the understanding of the message was considered to be an element. An element could be considered as an opportunity for error.*
>
> –pp. 3

[1]The data presented in Table 1 were obtained from the operational error, pilot deviation and near midair collision databases maintained by the FAA Office of Safety Information and Promotion (ASP-100).

[2]It is unlikely that the number of each type of incident for the first 9 months will double in the remaining 3 months of the calendar year.

[3]The words "Air traffic control specialist," "controller," and "ATCS" will appear interchangeably in this document to refer to the individual (s) authorized to provide air traffic control services to pilots.

TABLE 1. Pilot /Controller Communications as a Factor in Incidents During 1993-94

Type of Incident	Total Number	Number of Incidents With Communications Involved[4]	Percent of Incidents With Communications Involved
Year of Incident 1993*			
Operational Errors	747	205	27%
Pilot Deviations	1423	573	40%
Near Midair Collisions	255	38	15%
Year of Incident 1994**			
Operational Errors	476	122	26%
Pilot Deviations	791	327	41%
Near Midair Collisions	147	20	14%

*Total flight operations Jan-Dec 1993 = 142952693
**Total flight operations Jan-Oct 1994 =122669848

Citing the Cardosi example on page 3, "*United 123, fly heading 090*" was considered 1 element; whereas, "*United 123, turn left heading 090*" was counted as 2 elements because the pilot could turn right by mistake.

Morrow and Rodvold (1993) analyzed terminal radar approach control - pilot voice radio transmissions using the speech act as a global unit of analysis to examine communication as a collaborative process between the controller and the pilot. A speech act "*Roughly corresponds to an utterance serving one discourse function*" (Morrow, Clark, Lee, & Rodvold, 1990, p. 4). Morrow and Rodvold might have coded the above mentioned transmission as follows: "*United 123*" might be coded as an address, and "*Turn left heading (or fly heading) 090*" as a command.

Prinzo and Britton (1994) adopted the speech act and aviation topic as basic units of analysis and would have concluded that the transmission, "*United 123, fly heading 090*" contained 2 speech acts and 2 aviation topics. "*United 123*" would be coded as an address that identified the recipient of the transmission, and "*Turn left heading (or fly heading) 090*" would be coded as an instruction to the pilot to fly a particular heading.

What do the communications research data indicate? Morrow and co-authors' (1993) analysis of ATC/pilot routine and non-routine communications from each of 4 level-5 TRACONs revealed that incorrect, partial, or missing readbacks were infrequent events when compared to daily communications. Cardosi (1993) reported that 27 communication errors were found in 47 hours of voice tapes analyzed from 8 different ARTCCs indicating that less than 1% of the analyzed total transmissions that involved clearances contained readback errors. Of the 3,576 ATC clearances received, 3% were not acknowledged by the pilot recipient, and an additional 2.7% required repetition. Collectively, the data indicate that faulty communication is rare when it is compared to the total number of communications making up the analyzed sample.

While the base rate of communication errors is low, the consequences might still be significant. But, without the benefit or use of a standard metric and representative measures, it was difficult to accurately

[4]Aircraft communication equipment malfunction is excluded.

ascertain the impact of how the current voice-radio communications system affects air safety (Prinzo & Britton, 1993). Although incident report forms are well documented by government agencies, and controllers are required to use *FAA Order 7110.65 Air Traffic Control* when communicating with pilots, researchers traditionally have not used FAA Order 7110.65 to guide their analyses of ATC/pilot voice communications.

Prinzo, Britton, and Hendrix (1995) developed the aviation topics speech acts taxonomy (ATSAT) to analyze communication elements in accordance with FAA Order 7110.65 and the Airman's Information Manual (AIM). As shown in Figure 1, the ATSAT is a hierarchical order of communication elements, which combine to form messages that are transmitted over voice radio or data link communications systems (i.e., transmissions). The communication element is conceptualized as a fundamental unit of meaningful verbal language. In the ATSAT, communication elements are arranged by their functionality; that is, their purpose, operation, or action. A commonly referenced communication element is the speech act (Searle, 1969; Kanki and Foushee, 1989). Aviation topics are the subject matter of the speech act (Prinzo et al., 1995).

As new, digitized communication systems, such as data link appear, ATC communications may be presented as either oral or written verbal language. To reflect these changes, the Morrow and co-authors' definition of a speech act has been modified to reflect these changes. In this report, the speech act is defined as an utterance, either spoken or written, which describes one discourse function.

A transaction begins when 2 people agree to participate in meaningful, interactive communication. In a transaction, 1 person is the speaker and the other is the receiver of the transmitted message. A change in the role of the person from speaker to receiver signals that a new transmission (or turn) has begun. The transaction terminates once the speaker and receiver indicate that a mutual understanding was achieved. Often, words such as "roger" and "wilco" are used to indicate understanding.

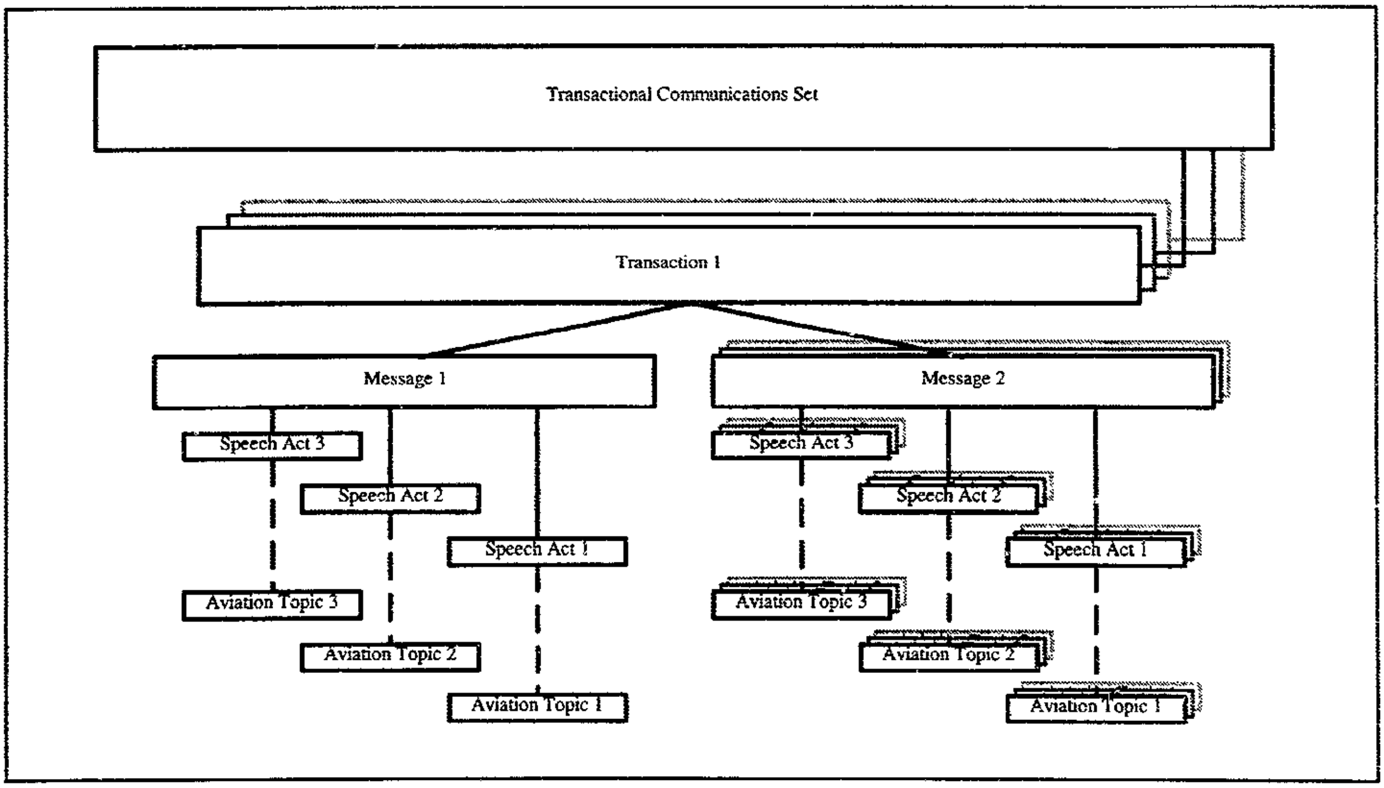

Figure 1. Hierarchical Arrangement of Communication Elements within the ATSAT

A transactional communication set is a collection of sequential transactions that occur between a controller and pilot. Presented in Table 2 is an example of a controller/pilot transactional communication set. It consists of 7 transactions that contain between 2 and 4 transmissions. In the first transmission, Universal[5] 744 initiates a transaction with Approach Control. Upon initial call-up, the pilot states the aircraft's call sign, its current and target altitudes. The transaction is established once the controller acknowledges the pilot's initial transmission. The transactional communication set is completed when communication and radar service for that aircraft are transferred to the next controller or radar service is terminated. The words "good day," "see ya," and "bye" often are used to indicate closure.

As shown in Figure 2, Transaction 1 is made up of 4 transmissions. In transmission 1, the pilot makes the initial call-up to begin the transaction. Pilot transmission 1 consists of 3 communication elements that have been placed into their corresponding aviation topic and speech act category. For example, *[Name] Approach* and *Universal 744* are the names of the participants of the transaction; each are tagged with the speech act category Address. The aviation topic places a constraint on the communication element by serving to distinguish one Address from another.

In the example, *[Name] Approach* is a communication element that identifies the intended receiver of the transmission and it is tagged with the aviation topic labeled "receiver." Likewise, *Universal 744* is a communication element that provides the name of

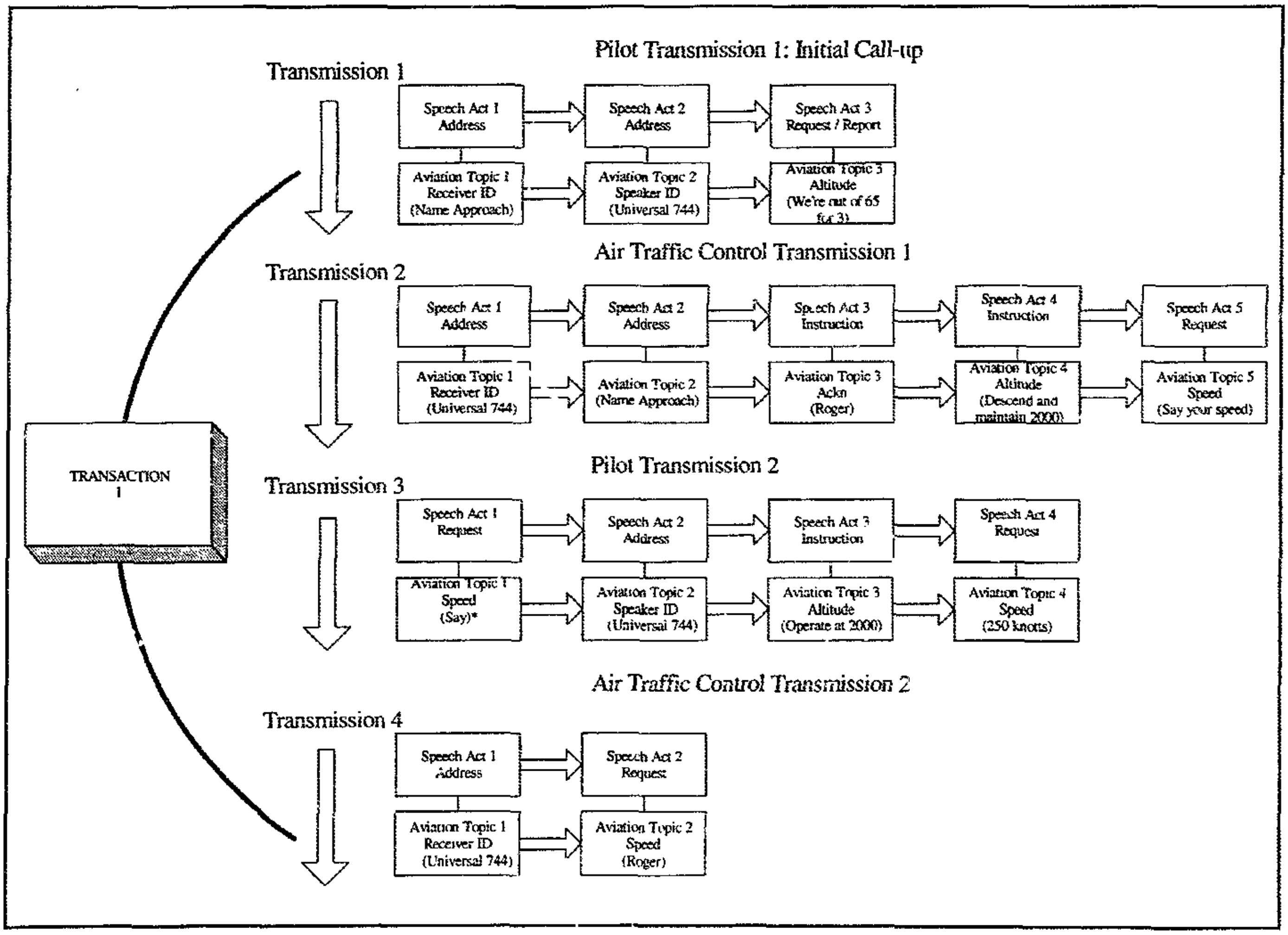

Figure 2. An Example of an ATC/Pilot Transaction.

[5] Universal is the name of a fictitious air carrier. It is used for illustrative purposes only.

TABLE 2. ATC / Pilot Transactional Communication Set

Trans-action	Trans-mission	Time	Transaction Participants	Communication Elements
1	1	03:32	Universal 744	[Name] Approach, Universal Seven Forty-four, Leaving six thousand five hundred, maintain three thousand, information Echo
	2	03:35	ATC	Universal Seven Forty-four [Name] Approach, Roger, descend and maintain two thousand, say airspeed
	3	03:40	Universal 744	Seven Forty-four, Speed two five zero
	4	03:43	ATC	Universal Seven Forty-four, Roger
2	5	04:14	ATC	Universal Seven Forty-four, Turn right heading zero six zero vector to final approach course
	6	04:16	Universal 744	Seven Forty-four, turn right heading zero six zero
3	7	05:11	ATC	Universal Seven Forty-four, Traffic twelve o'clock one three miles, westbound, Heavy Delta L ten eleven descending through four thousand niner hundred to maintain four thousand, expedite descent through three thousand
	8	05:27	Universal 744	Universal Seven Forty-four, Reducing speed to one niner zero
4	9	05:56	ATC	Universal Seven Forty-four, Turn left heading three four zero
	10	06:01	Universal 744	Universal Seven Forty-four, Turn left heading three four zero
5	11	06:27	ATC	Universal Seven Forty-four, Descend and maintain two thousand
	12	06:32	Universal 744	Universal Seven Forty-four, Leaving three thousand maintain two thousand
6	13	07:16	ATC	Universal Seven Forty-four, Seven miles from outer marker, maintain two thousand until established on the localizer, cleared ILS runway three one right approach, reduce speed to one seven zero until outer marker
	14	07:23	Universal 744	Universal Seven Forty-four, Cleared ILS runway three one right approach, maintain two thousand until established on the localizer, speed one seven zero until outer marker
7	15	08:33	ATC	Universal Seven Forty-four, Contact [Name] Tower one one niner point one
	16	08:37	Universal 744	Universal Seven Forty-four, Tower one one niner point one

the speaker of the transmission, and it is tagged with the aviation topic labeled "speaker." "*leaving 6 thousand 5 hundred, maintain 3 thousand*" is a communication element identified as a Report of the aircraft's current altitude. Thus, the communication element would be tagged with the speech act Advisory/Remark and its aviation topic label is altitude.

Presented in Figure 3 is a schematic representation of the 7 transactions making up the transactional communication set between Universal 744 and a controller at the Approach Control facility. The number of transactions that make up a transactional communication set will depend on the number of transmissions needed to facilitate an aircraft's movement through the controller's sector/position.

The purpose of the present study was to develop a database of controller and pilot voice communications. Copies of TRACON audiotapes of ATC/pilot communications were provided to the authors and transcribed by a subject-matter-expert (SME). The aviation topic-speech act taxonomy (ATSAT, Prinzo, et al., 1995) was used to categorize and code ATC/pilot verbal communications. Communications that deviated from the standard communications form

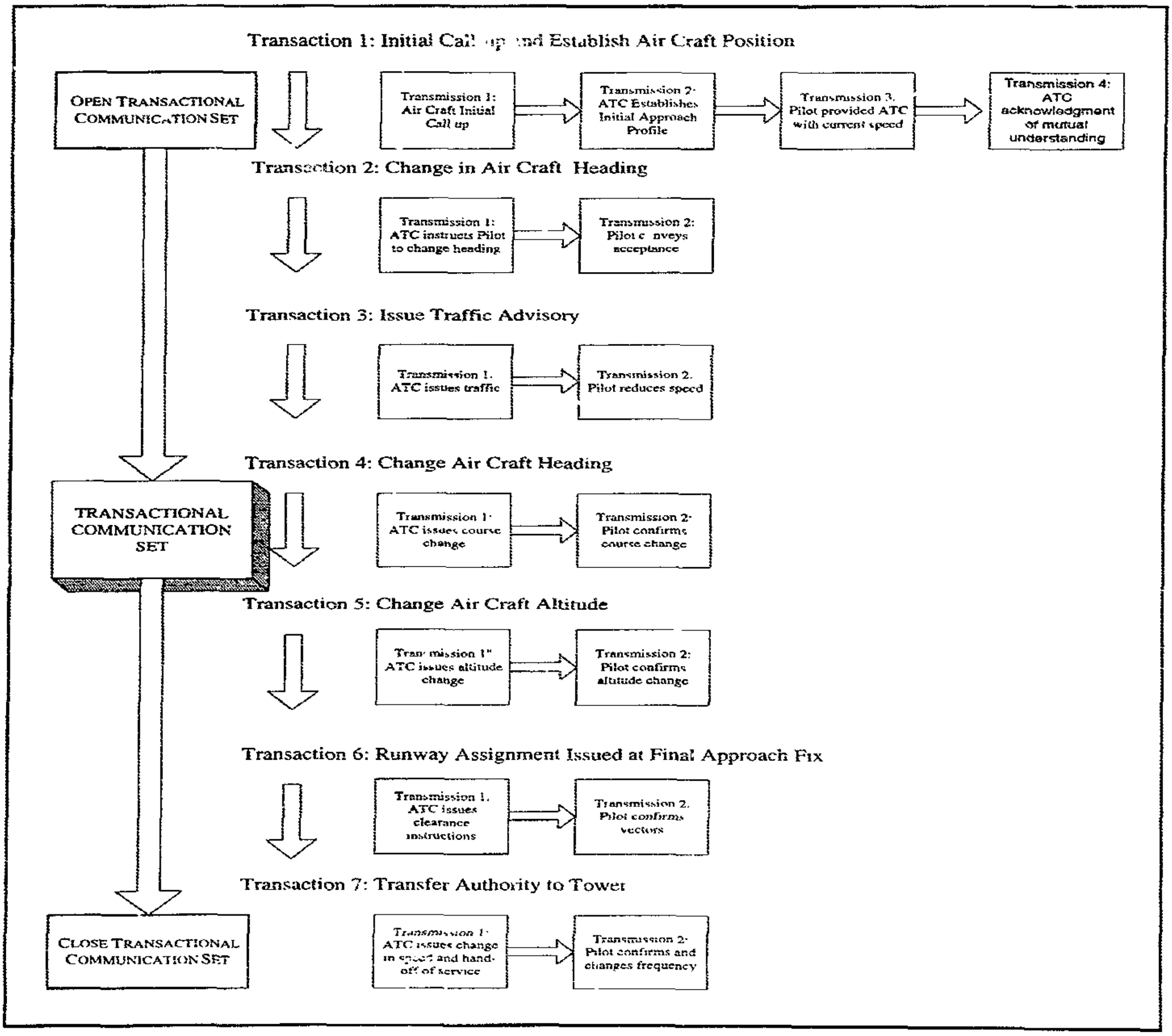

Figure 3. An Example of an ATC/Pilot Transactional Communication Set

specified in FAA Order 7110.65, or suggested pilot communication in the *Airman's Information Manual*, were identified using the error code categories included in the ATSAT.[6]

2.0 METHODS

2.1 Materials

2.1.1 Aviation Topics Speech Act Taxonomy Coding Form (ATSAT$_{CF}$). The ATSAT Coding Form is a tool for categorizing ATC/pilot communication elements according to their purpose and for labeling various types of communication errors. As shown in Table 3, the speech act categories are Address, Courtesy, Instruction, Advisory, Request, and Non-Codable. The Address is the "who" of the transmission. It references either an air traffic control facility position/sector or an aircraft. In addition to showing a level of respect, a Courtesy often signals the end of a transactional communication set between the air traffic controller and the pilot, in much the same way that a "good-bye" signals the end of a telephone conversation. The Instruction, Advisory, and Request speech act categories represent the "what" of the communication element - the action to be undertaken. They represent the "do something," "tell something," and "ask something" of an utterance. The complete titles of the speech act categories are: Address/Addressee, Instruction/Clearance—Readback/Acknowledgment, Advisory/Remark—Readback/Acknowledgment, Request—Readback/Acknowledgment, Non-Codable Remarks, and Comments.

TABLE 3. Aviation Topics/Speech Acts Taxonomy

Speech Act Category	Aviation Topics
Address/Addressee	Speaker, Receiver
Courtesy	Thanks, Greetings, Apology
Instruction/Clearance--Readback/Acknowledgment	Heading, Heading Modification, Altitude, Altitude Restriction, Speed, Approach/Departure, Frequency, Holding, Route/Position, Transponder Code, General Acknowledgment
Advisory/Remark--Readback/Acknowledgment	Heading, Heading Modification, Altitude, Altitude Restriction, Speed, Approach/Departure, Route/Position, NOTAM, ATIS, Weather, Sighting, Traffic, General Acknowledgment
Request--Readback/Acknowledgment	Heading, Altitude, Speed, Approach/Departure, Route/Position, Type, NOTAM, Traffic, Weather, Say Again, General Acknowledgment
Non-Codable Remarks	Equipment, Delivery, Other

[6] Pilots are not required to use the same standard phraseology as controllers when communicating. To achieve a standard for comparison between pilots' and controllers' communications, the following rule was established: If a pilot attempted a verbatim readback of a controller's transmission, then the same coding procedures that were used on controllers' transmissions were applied to the pilot's verbatim readback.

Within each speech act category are specific aviation topics that define the subject of each communication element. The aviation topics are listed next to their speech act category in the body of Table 3. The aviation topic constraints the communication element by imposing a restriction on its identified speech act category (who, what). For example, there are only 2 types of aviation topics listed next to the Address speech act category. Generally, there only can be 1 speaker and 1 receiver of a transmission. There are 3 types of aviation topics listed in the Courtesy speech act category: "Thanks," "Greetings," and "Apology." The aviation topics listed in the Instruction, Advisory, and Request speech act categories are not exhaustive, but represent the most frequently uttered messages that we heard from field tapes.

The communication error types and their definitions are listed in Table 4. The coder labels non-standard communications according to the type of error present in the communication element. There are 2 categories of communication errors: message content and delivery technique. Message content errors pertain to non-standard communication usage; delivery technique errors refer to stammers, stutters, or misspoken words. The types of message content errors are: grouped, sequential, omission, substitution, transposition, excessive verbiage, and partial readback. Dysfluency and misarticulation are delivery technique errors.

2.1.2 Audiotapes. Copies of audiotaped recordings of ATC/pilot communications were obtained from 2 Level 5 TRACON facilities (TRACON-1 and TRACON-2) and 1 Level 4 TRACON (TRACON-3). Each facility included a brief description of the tape's contents. For example, *"This side of the tape includes 1 hour of heavy traffic on the [name] position at [Terminal Air Traffic Control] Airport."*

A total of 9 hours of transcribed communications, representing approximately 4,500 ATC/pilot voice radio transmissions, were analyzed. There were 2,878 transmissions from TRACON-1 represented in 6 hours of normal communications recorded from the feeder and arrival ATC positions. TRACON-2 audiotapes had 654 transmissions and represented 1 hour of normal communications from the final approach position. TRACON-3 audiotapes contained a total of 1,250 communications that represented 2 hours of transmissions from the arrival and departure positions. Presented in Appendix A is a table of the total number of communication elements by speech act category; presented in Appendix B is a table of the total number of communication errors made by pilots and controllers at each approach control facility.

2.2 Procedure

The audiotapes were transcribed, and the accuracy of the transcripts was verified and, when necessary, corrected by the SME. Using the ATSAT, the SME segmented each line of transcribed communications into communication elements, numbered each one according to the order in which it was spoken, and then classified each according to its content and purpose. The encoding of communication elements into speech acts and aviation topics was not performed on transmissions in isolation. Rather the context in which a transmission was spoken was vital to how it would be encoded.

Since pilots are not required to use the same standard phraseology contained in FAA Order 7110.65 as are controllers, a rule was developed by which comparison could be made between pilot and controller transmissions: If a pilot attempted a verbatim readback of a controller's transmission, then the same coding procedures used on controllers' transmissions were applied to pilots' verbatim readbacks.

Once the communication elements were placed into their respective speech act categories, those verbal communications which deviated from the standard specified in FAA Order 7110.65, or suggested pilot communication in the *Airman's Information Manual*, were identified using the error code categories in the ATSAT. Presented in Table 5 is an example of 1 line of communication that was segmented, numbered, and communication error-coded.

Using the example on Table 5, the coder first segmented the transmission into communication elements and then determined their corresponding aviation topic and speech act category membership. The coder placed a "1" in the Receiver Identification column under the "Address" speech act category, a "2" was placed under the Speaker Identification column under the "Address" speech act category, a "3" was

TABLE 4. Types of Communication Errors in ATC/Pilot Transcripts

Communication Error Types	Code	Definition
Message Content Errors		
Grouped	G	Grouping of numerical information contrary to paragraph 2-85, FAA Order 7110.65G.
Sequential (Non-grouped)	N	Failure to group numbers in accordance with paragraphs 2-87, 2-88, 2-90, and non-use of the phonetic alphabet in accordance with paragraph 2-84, FAA Order 7110.65G.
Omission	O	Leaving out number(s), letter(s), word(s), prescribed in communication requirements in FAA Order 7110.65G.
Substitution	S	Use of word(s) or phrases(s) in lieu of communication outlined in FAA Order 7110.65G (e.g., "verify altitude" vs. "say altitude").
Transposition	T	Number(s) or word(s) used in the improper order (e.g., "Universal six forty-five" instead of "Universal *five forty-six*").
Excessive Verbiage	E	Adding word(s) or phrase(s) to communication outlined in FAA Order 7110.65G, and the communication suggested in the *Airman's Information Manual* (e.g., "Universal the number one airline six forty-five").
Partial Readback*	P	Pilot report or readback that does not include specific reference to a topic subject (i.e., altitude topic "out of six for four" would be recorded as a P).
Delivery Technique Errors		
Dysfluency	D	Pause(s), stammer(s), utterance(s), that add no meaning to the message (e.g., "uh," "ah," or "OK" when not used as a general acknowledgment.
Misarticulation	M	Improperly spoken words (i.e., slurs, stutters, mumbling, etc.).

* **Note:** A verbatim readback of a controller's instruction or advisory would not be recorded as a P, nor would a readback containing a general acknowledgment and the aircraft identifier.

TABLE 5. Example of an Air Traffic Control Transmission that was Segmented into Communication Elements, Placed into Speech Act Categories, Labeled by Aviation Topics, and Communication Error-Coded

"Universal Seven Forty-four, [Name] Approach, Roger, Descend and maintain two thousand, Say your speed"

Communication Element:	Universal Seven Forty-four/	[Name] Approach/	Roger/	Descend and maintain two thousand/	Say your speed/
Speech Act	**Address**	**Address**	**Advisory/Report**	**Instruction**	**Advisory/Report**
Aviation Topic:	**Receiver**	**Speaker**	**Gnl Ackn**	**Altitude**	**Speed**
Location No.:	**1**	**2**	**3**	**4**	**5**
Communication Error Code:					**E, S**

Aviation Topic 1, *"Universal Seven Forty-four,"* is the receiver identification.
Aviation Topic 2, *"[name] Approach,"* is the speaker identification.
Aviation Topic 3, *"Roger,"*[7] is a general acknowledgment to the previous transmission.
Aviation Topic 4, *"Descend and maintain two thousand"* is an instruction pertaining to a change in altitude.
Aviation Topic 5, *"Say your speed"* is a request for the aircraft's current speed with an excess verbiage and a substitution error designated by the letters "E"and "S."

placed under the General Acknowledgment column under the "Advisory/Report" speech act category, and so on until the location of each communication element was recorded on the $ATSAT_{CF}$. For example, the "Roger" in communication element 3 was placed in the "Advisory/Report" speech act category and labeled as a General Acknowledgment because the controller was letting the pilot know that the entire transmission was received. The previous transmission was the initial call-up.

Then, each communication element was evaluated for proper phraseology usage. If incorrect phraseology was used, the coder copied onto $ATSAT_{CF}$ the alphabet letter code corresponding to that type of communication error (see Table 4) next to the location number of the communication element that was spoken incorrectly. Aviation Topic 5, *"Say your speed"* contains both an excess verbiage and a substitution error. Excess verbiage results with the presence of the additional word "your" in the request and the word "speed" was used as a substitution for the word "airspeed." The transmission should have been spoken as, "Universal Seven Forty-four, descend and maintain two thousand, say airspeed."[8] Each step was repeated for each line of transcribed communication.

Intercoder reliability was assessed by computing the percent agreement between the segmentation and codification made by the SME and one of the ATSAT authors for a sample of 25 randomly-selected transmissions. There was 97% agreement for segmentation of the entire message into identical communication elements, 90% agreement for placement of the same location number associated with each communication element onto the $ATSAT_{CF}$, both in the proper

[7] In FAA Order 7110.65 "Roger" is defined as "I have received all of your last transmission."
[8] This is in reference to FAA Order 7110.65G Par. 5-101.

speech act category and in the proper aviation topic, and finally, 70% agreement for selection of the same communication error type associated with that communication element.

3.0 RESULTS

3.1 Data Analysis

A total of 12,200 communication elements in 4,500 transmissions was analyzed in accordance with the $ATSAT_{CF}$ procedures. Presented in Appendices A and B are tables of the total number of communication elements and types of communication errors made by pilots and controllers. Presented in Table 6 is the distribution of communication elements within each speech act category derived from all of the ATC/pilot transmissions. Communication elements appeared most frequently in the Address (37%) and Instruction (36%) speech act categories for both groups of speakers. Rarely was the Request speech act included in a transmission (2%).

The number of communication errors located within each speech act category was calculated and those values are reported as percentages. Separate communication error analyses were performed on each of the audiotapes. For example, 2,500 of the 6,300 controller communication elements contained at least 1 communication error (40%). The distribution of those 40% communication errors within each speech act category is presented in Table 7. For controllers, 93% of these errors involved communication elements located in the Instruction (55%), Advisory (24%), and Address (14%) speech act categories.

TABLE 6. Distribution of Controller and Pilot Communication Elements Within Each Speech Act Category

Speech Act Category	Controller (n=6,300)	Pilot (n=5,900)
Address	37%	37%
Instruction	36%	35%
Advisory	16%	18%
Courtesy	5%	5%
Request	2%	2%
Non-Codable	4%	3%

TABLE 7. Distribution of Controller and Pilot Communication Errors Within Each Speech Act Category

Speech Act Category	Controller (n=2,500)	Pilot (n=3,500)
Address	14%	25%
Instruction	55%	53%
Advisory	24%	18%
Courtesy	0%	0%
Request	4%	3%
Non-Codable	3%	1%

The same analysis was performed on pilot transmissions. Of the 5,900 pilot communication elements, 3,500 contained at least 1 communication error (59%). For pilots, 96% of the communication errors involved communication elements within the Instruction (53%), Address (25%), and Advisory (18%) speech acts categories.

3.2 Analysis of Speech Act Communication Errors

Figure 4 presents the proportion of all speech act communication errors made by pilots and controllers at each TRACON facility. Thus, 100% of the 2,255 communication errors made by pilots from TRACON-1 are distributed across Address (19%), Courtesy (0%), Instruction (61%), Advisory (17%), Request (2%), and Non-Codable (1%).

As shown in Figure 4, most of the pilot and controller communication errors from all 3 TRACON facilities involved Instructions. Pilots made more errors involving Address than controllers, and both pilots and controllers made comparable communication errors involving Advisory transmissions. TRACON-1 and TRACON-2 (Level 5) made more errors involving Instructions and TRACON-3 (Level 4) made more Address communication errors.

A series of analyses were performed on the communication errors associated with specific aviation topics in each of the speech act categories. The analyses were performed separately according to TRACON facility and speaker.

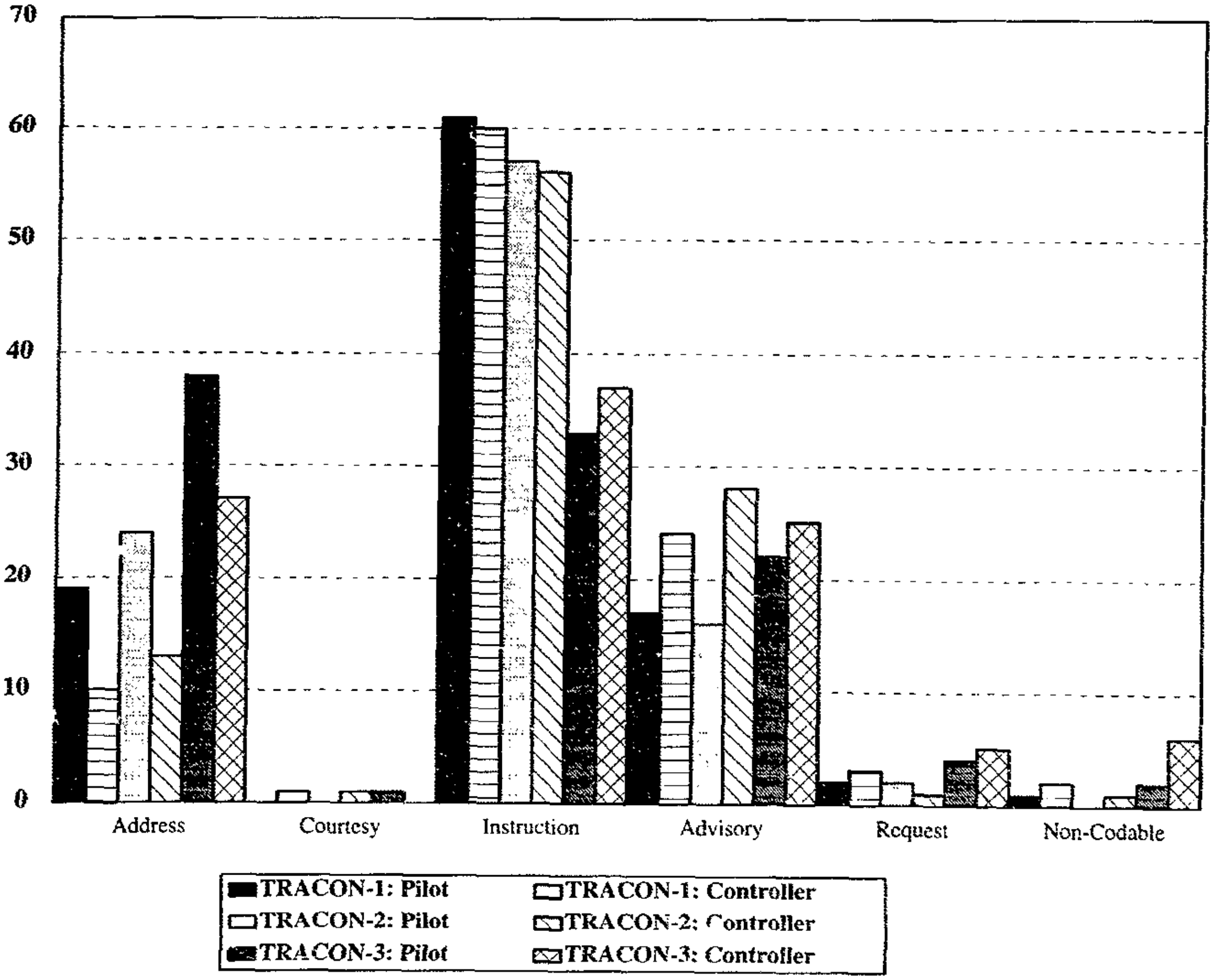

Figure 4. Proportion of All Speech Act Communication Errors Made by Pilots and Controllers at Each TRACON Facility

3.3 Analysis of Aviation Topic Communication Errors

The first set of analyses was performed to identify how communication errors were distributed within each speech act's aviation topics. For example, the previous analysis determined that 19% of the 444 communication errors made by pilots at TRACON-1 involved Addresses. This set of analyses examined how controllers' and pilots' communication errors were distributed in the speaker and receiver identification. Thus, the percentages of communication errors presented in this section were computed by grouping the errors according to TRACON facility, speaker, and speech act category.

3.3.1 **Address.** The data presented in Figure 5 clearly indicate that regardless of TRACON facility, approximately 80% of the Address communication errors made by controllers and pilots involved aircraft call signs, and not sector/position names. This is not altogether surprising since aircraft call signs contain more alpha/numeric information and they are spoken less frequently than sector addresses. Also, there are only a handful of ATC sector names, which must be learned, such as Tower, Terminal, and Center that are prefaced with location or facility names and sector functions (e.g., ground, local, departure, approach), compared to the number of call signs assigned to daily flights.

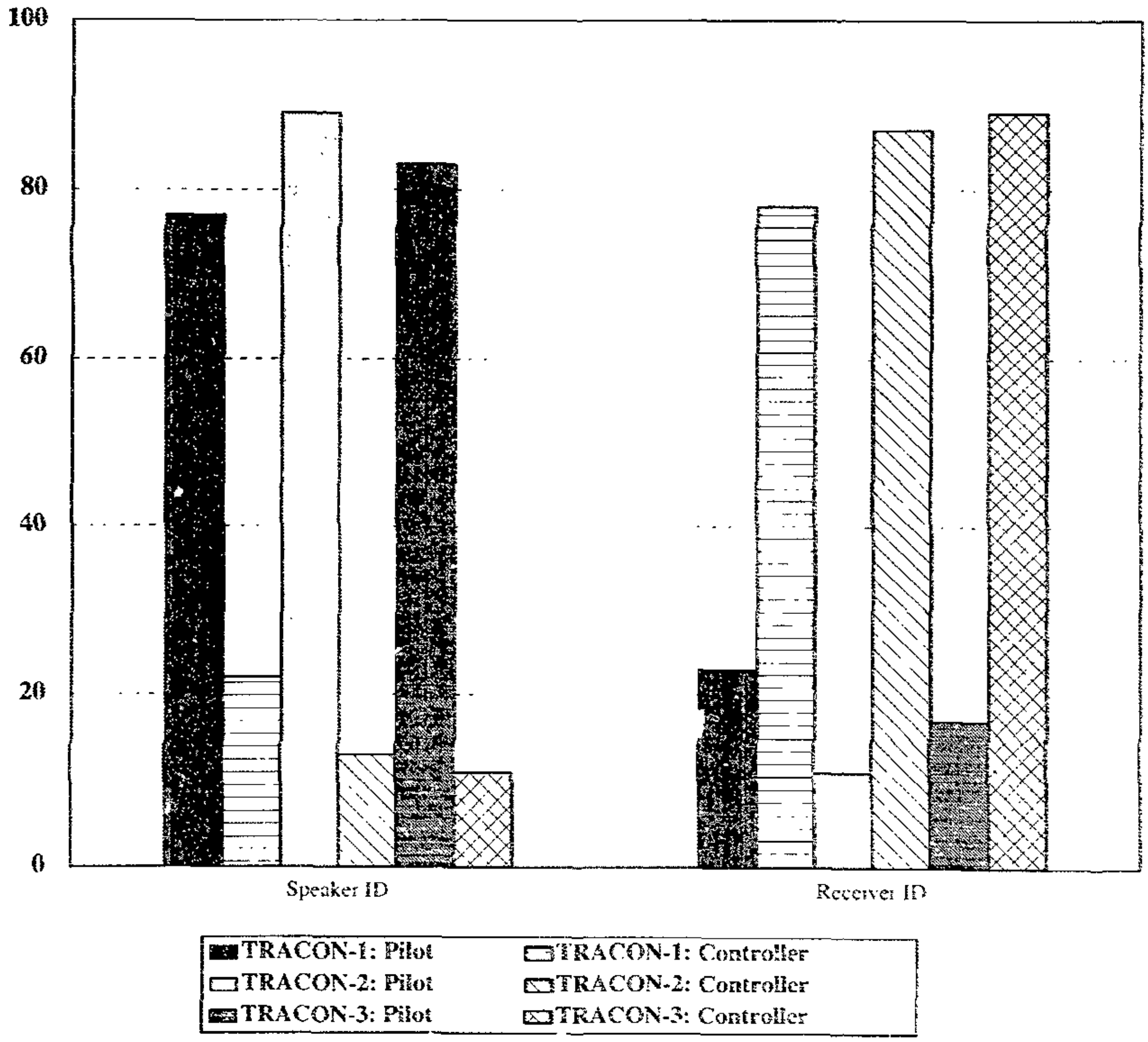

Figure 5. Proportion of Aviation Topics Within the Address Speech Act That Contained Communication Errors Made by Pilots and Controllers at each TRACON Facility

3.3.2 Instruction. Figure 6 reveals that, for pilot transmissions, the majority of the identified Instruction communication errors involved heading (28-31%), radio frequency (16-26%), air speed (1-22%), or altitude (13-21%) information. For controllers, the majority of the identified communication errors involved radio frequency (16-32%), air speed (0-26%), heading (12-20%), or approach/departure (4-10%) topics. There was no systematic pattern in communication errors that could be attributed to a Level 4 versus a Level 5 TRACON.

3.3.3 Advisory. As shown in Figure 7, most of the pilot Advisory communication errors involved altitudes (37-56%), and only pilots who flew through airspace controlled by TRACON-2 had a high advisory communication error rate pertaining to traffic (31%). For TRACON-2 controllers, advisory communication errors exceeded 65% for traffic and TRACON-1 controllers had 53% advisory communication errors represented in approach/departure (29%) and traffic (24%) topics.

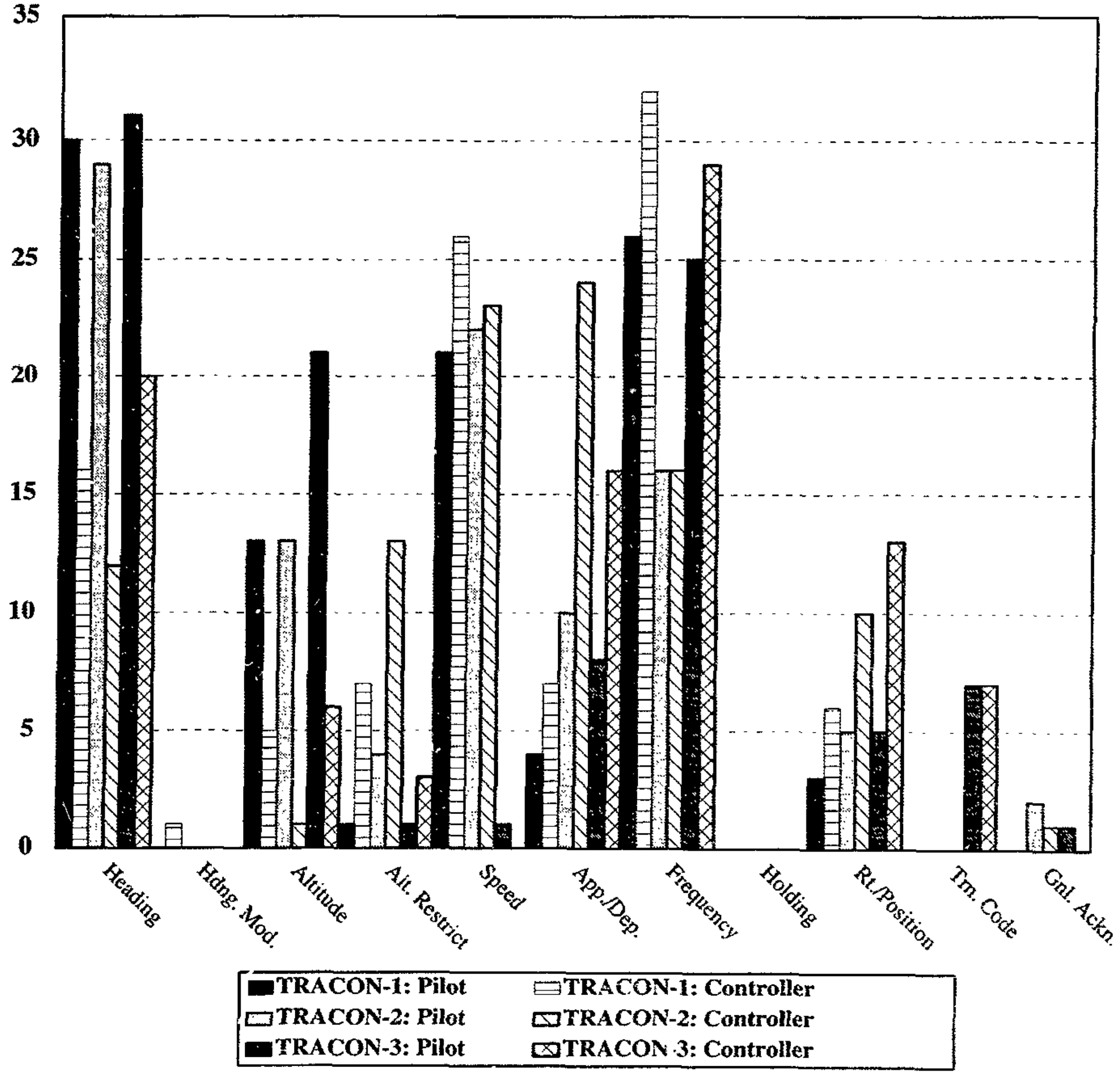

Figure 6. Proportion of Aviation Topics Within the Instruction Speech Act That Contained Communication Errors Made by Pilots and Controllers at Each TRACON Facility

3.3.4 **Request**. Figure 8 presents the percentage of Request communication errors. Generally, request communication errors clustered around airspeed, route/position, and approach topics. Pilots who flew in airspace controlled by TRACON-1 displayed more request communication errors related to airspeed (48%) and approach (24%) topics; pilots who flew in TRACON-2 airspace had more request communication errors pertaining to airspeed (50%) and approach/departure (38%) topics; and pilots who flew in airspace controlled by TRACON-3 made more request communication errors involving airspeed (36%) and route/position (36%) than approach (21%) topics.

For TRACON-1 controllers, 54% of the request communication errors pertained to airspeed, with the remaining communication errors equally distributed across the other topics. TRACON-2 controller request communication errors occurred only in air speed (68%) and approach (32%) topics. Finally, the majority of TRACON-3 controller request communication errors were in altitude (53%) and route/position (24%) topics.

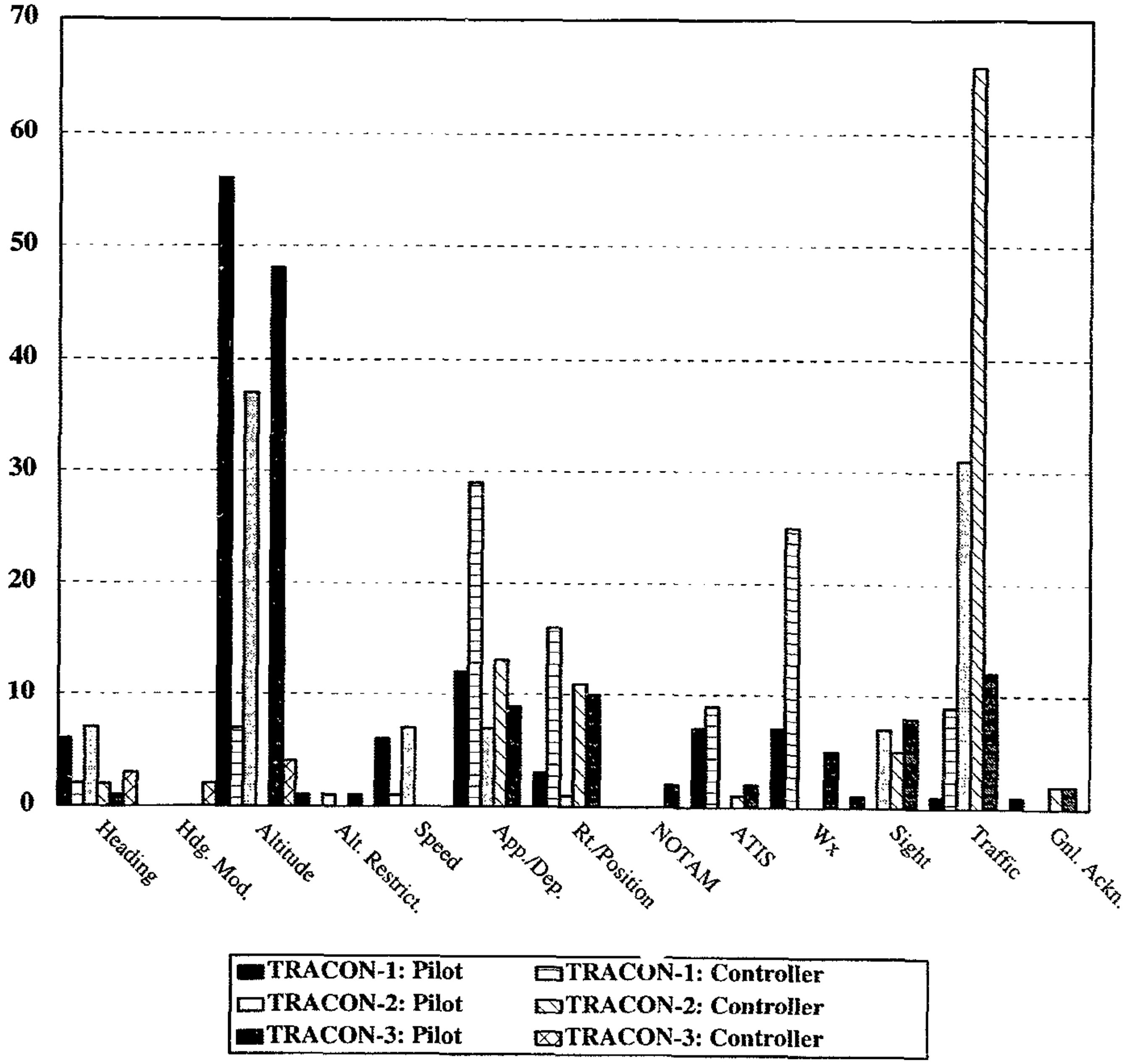

Figure 7. Proportion of Aviation Topics Within the Advisory Speech Act That Contained Communication Errors Made by Pilots and Controllers at Each TRACON Facility

3.4 Analysis of Communication Error Types

The percentage of the types of communication errors associated with each aviation topic within speech act categories was computed for each TRACON facility and speaker. For example, the distribution of communication error types within the Address speech act made by controllers at TRACON-1 equal 100 percent. To minimize clutter, communication error types equaling less than 1% of each aviation topic classification were not included in the figures.

The analyses of Address communication errors for the 3 TRACON facilities are presented collectively. As shown in Figure 9, the majority of controller message content errors resulted from omission of number(s), letter(s), or word(s) contained in the receiver address (i.e., an aircraft call sign). Substitution of "oh" for "zero," "nine" for "niner" as part of an aircraft call sign and other similar switches occurred, although infrequently. Additionally, there were problems in delivery technique, as noted by controllers generally adding pause(s), stammer(s), "uh," "ah," or "OK" to the receiver call sign.

As shown in Figure 10, the majority of pilot communication errors resulted from pilots omitting a portion of their aircraft call sign when communicating. Although controllers often use a pilot's voice qualities and radar displayed call sign to aide in speaker identification (when less than full speaker address is provided), pilots should use their full call sign to avoid confusion. Use of the full call sign when communicating with ATC would eliminate additional transmissions made by the controller to determine the speaker's address. No other Address communication errors were notable.

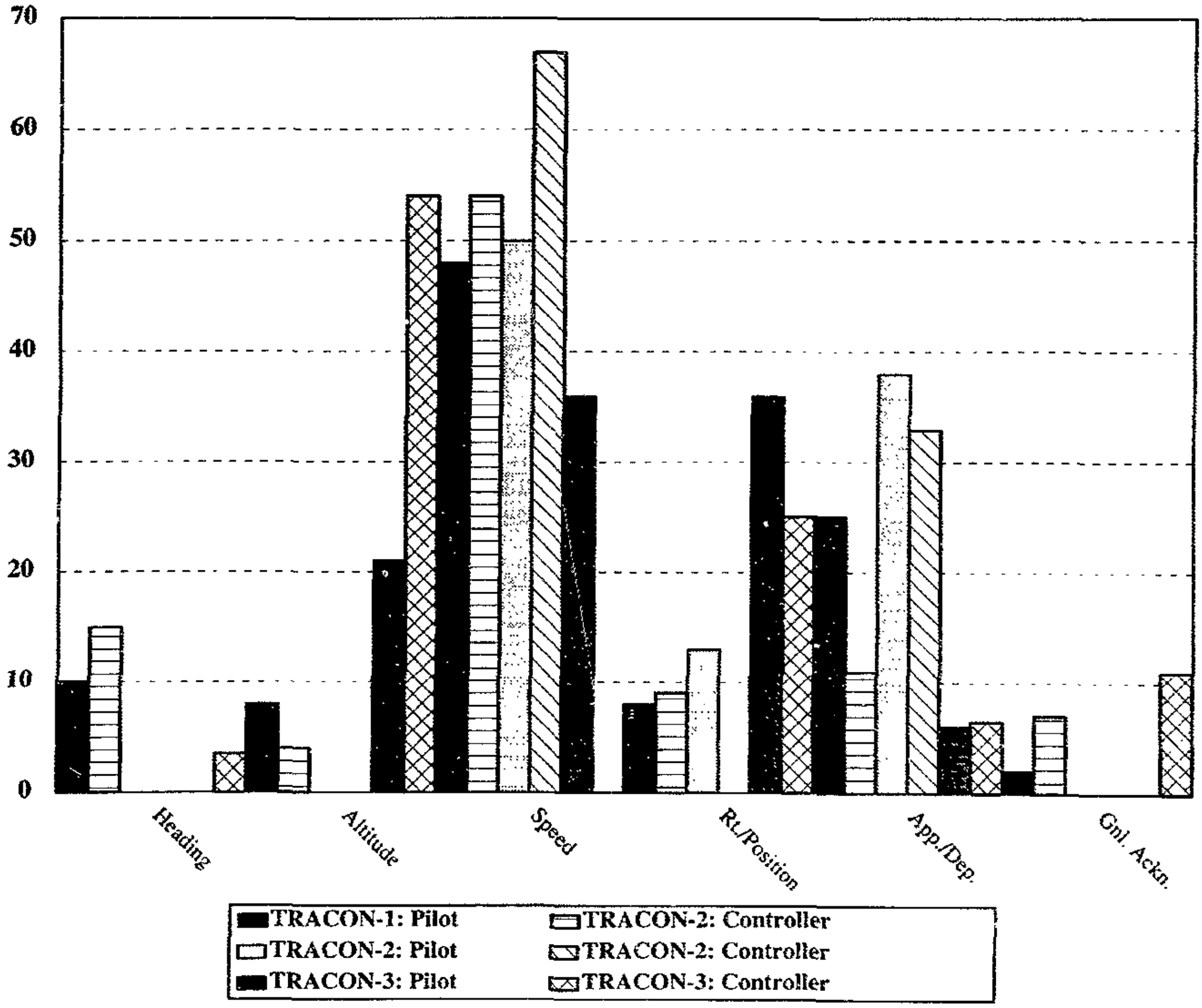

Figure 8. Proportion of Aviation Topics Within the Request Speech Act That ContainedCommunication Errors Made by Pilots and Controllers at Each TRACON Facility

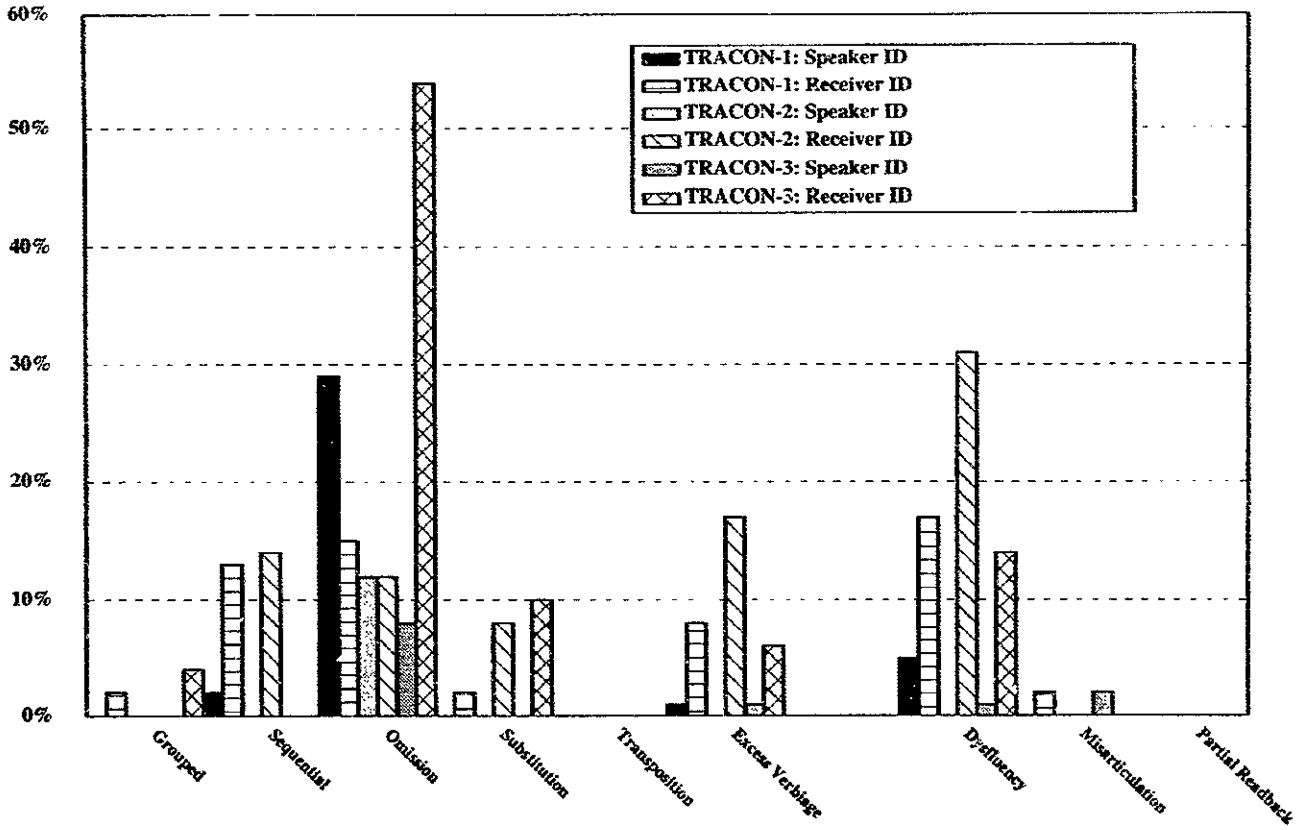

Figure 9. Distribution of Controller Address Errors

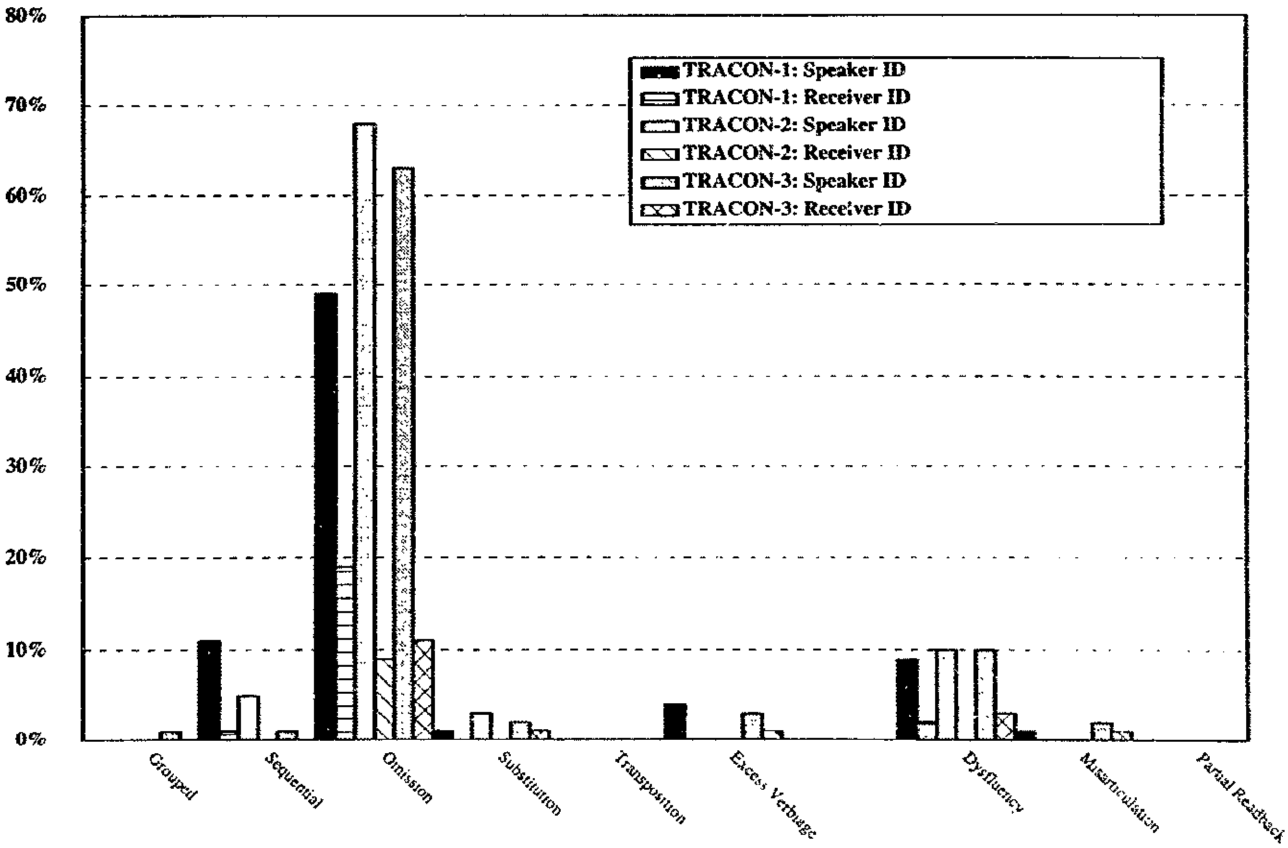

Figure 10. Distribution of Pilot Address Communication Errors

3.4.1 TRACON-1 Facility (Level 5): Controller Communications

A total of 2,878 lines of communication, each corresponding to a single transmission, make up the data set from which the accuracy of controller and pilot communication was determined. The data consisted of 3,777 controller communication elements and 3,626 pilot communication elements.

3.4.1.1. Instruction. As shown in Figure 11, most of the controllers' Instruction communication errors resulted from omissions (47%) and excess verbiage (22%). Most radio frequency errors involved omissions (24%). For example, controllers generally omitted the word "point" in a radio frequency when handing off an aircraft to an adjoining sector or facility tower. Airspeed errors resulted primarily from omissions (9%) of the words "knots" or "speed" as part of the airspeed[9] clearance. Route/position and approach/departure errors each accounted for 4% of the detected omission, and heading and altitude errors each contained 3% of the total Instruction communication errors.

Excess verbiage occurred most for airspeed (7%) and radio frequency (5%) errors. Errors involving heading, altitude, approach/departure, and route/position accounted for the remaining 9% of the Instruction communication errors. Although excess verbiage rarely alters the meaning of a transmission, it can increase frequency congestion by preventing others from making transmissions.

3.4.1.2 Advisory. As shown in Figure 12, 2 message content communication error types prevail: those arising from omissions (31%) and excessive verbiage (32%). Errors of omission involved runway information (18%) and weather conditions (13%). Primary among runway errors was controllers failing to include the word "approach" as part of the advance approach information[10]. Excess verbiage was most prevalent for route/position (13%), weather (8%), ATIS (6%), approach/departure (5%), and traffic (5%) information.

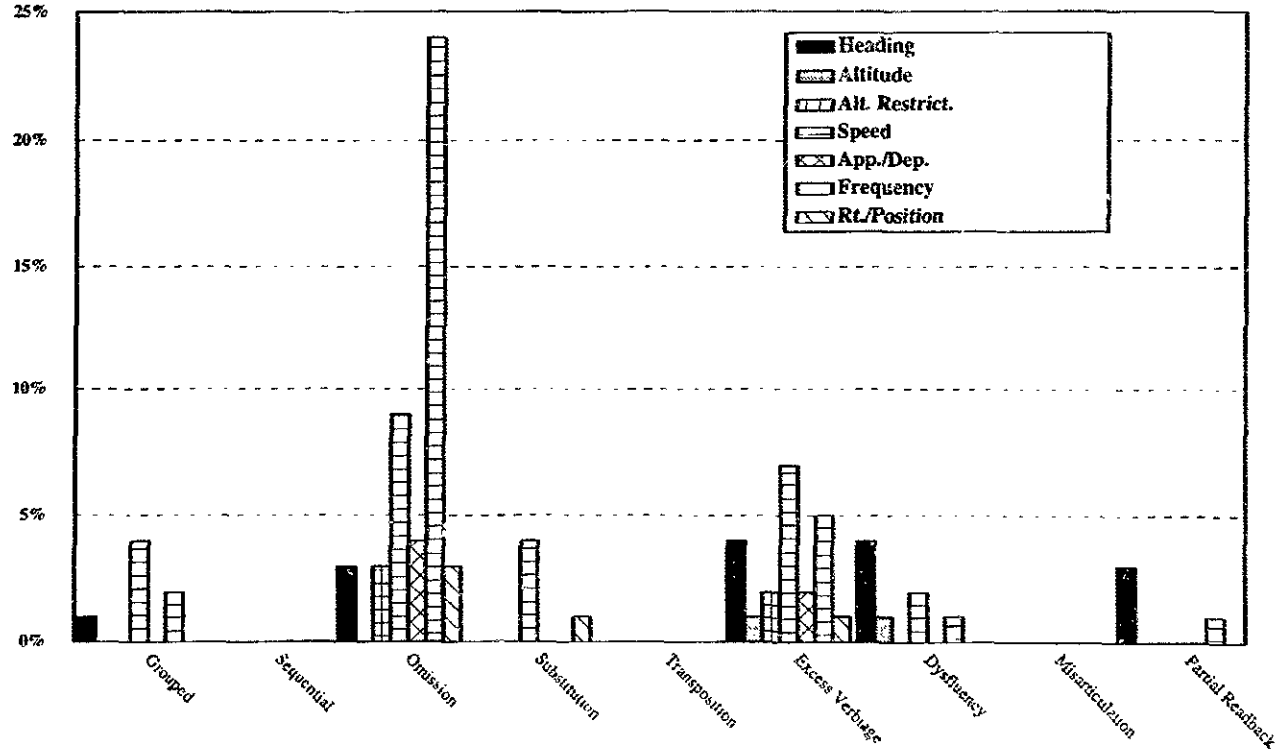

Figure 11. TRACON-1: Distribution of Controller Instruction Communication Errors

[9] FAA Order 7110.65J Par.5-7214 states "Increase or reduce to a specified speed or a specified number of knots." For example, "Reduce speed twenty knots.," and "Maintain one eight zero knots."

[10] Phraseology was evaluated in accordance with FAA Order 7110.65G Par. 4-72a1; but see Advance Approach Information Par. 4-65.

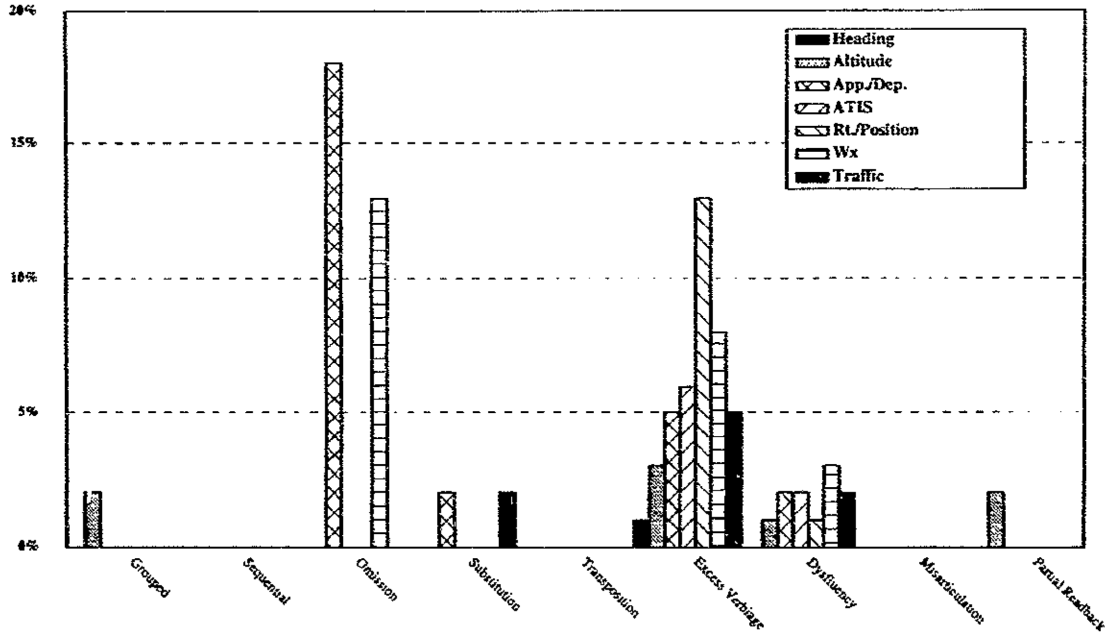

Figure 12. TRACON-1: Distribution of Controller Advisory Communication Errors

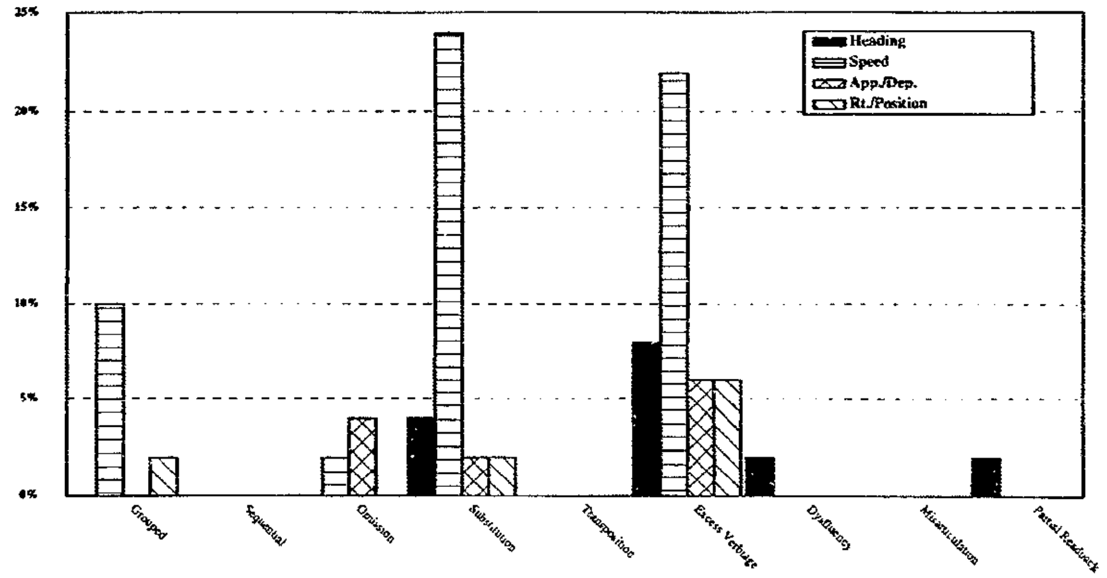

Figure 13. TRACON-1: Distribution of Controller Request Communication Errors

3.4.1.3 **Request.** As shown in Figure 13, most of the airspeed communication errors resulted from substitution (24%) and excess verbiage (22%). Speaking numbers in a grouped format contributed an additional 10%. For example, "...and ah just verify that you're at a hundred and ninety on the speed...."

3.4.2 TRACON-1 Facility (Level 5): Pilot Communications

3.4.2.1 **Instruction.** The same analyses were performed on pilot instruction transmissions (i.e., readbacks of controller generated transmissions); the results are displayed in Figure 14. The Instruction

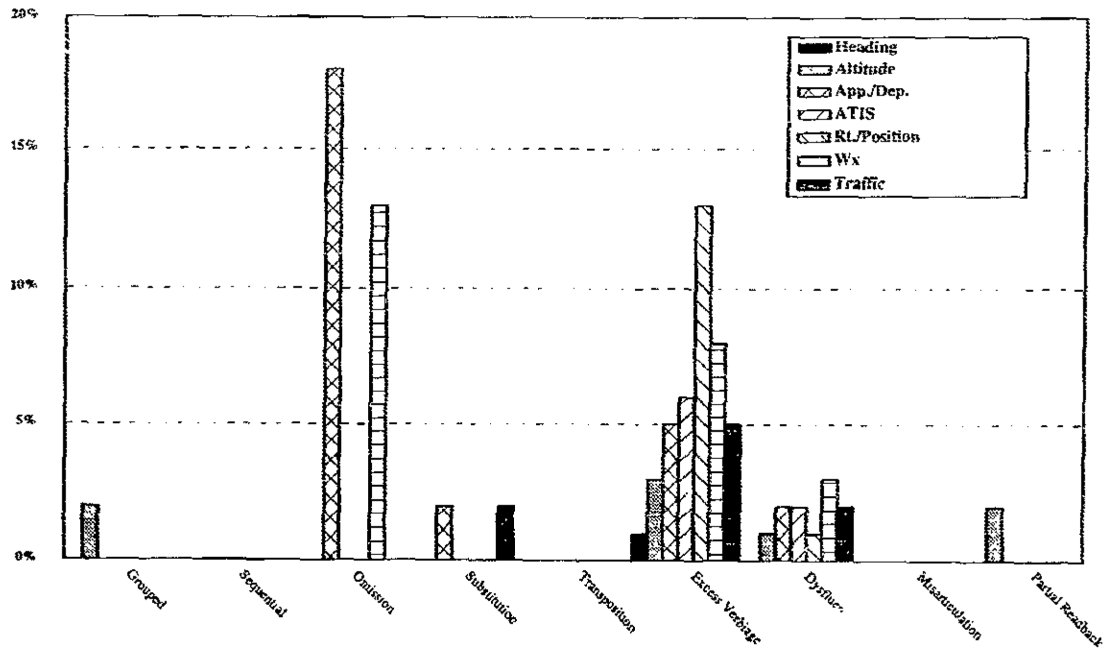

Figure 12. TRACON-1: Distribution of Controller Advisory Communication Errors

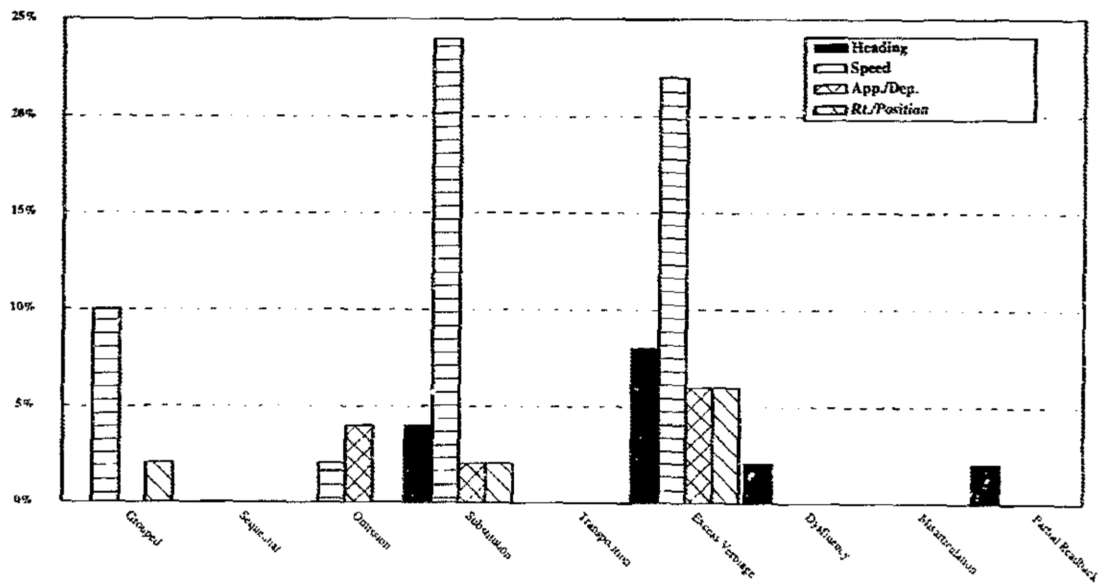

Figure 13. TRACON-1: Distribution of Controller Request Communication Errors

communication errors are distributed across partial readback (56%), grouping (24%), and substitution (9%). For pilots, heading errors resulted primarily from partial readbacks (22%,) and grouped format (6%); for example, "one thirty out of [intersection]...." Radio frequency errors also resulted from partial readbacks (14%) and grouped format (10%). Altitude errors were due mostly to substitutions (6%) and partial readbacks (6%). Airspeed errors resulted from partial readbacks (8%), grouped format (8%), and substitutions (3%). A composite readback error might sound something like, "...one seventy, for six, twenty-one twenty...."

3.4.2.2 **Advisory.** As shown in Figure 15, pilot Advisory communication errors involved grouped format (19%), excess verbiage (21%) and partial readback (26%) more than omission (3%), substitution (3%), or dysfluency (9%). Altitude errors were

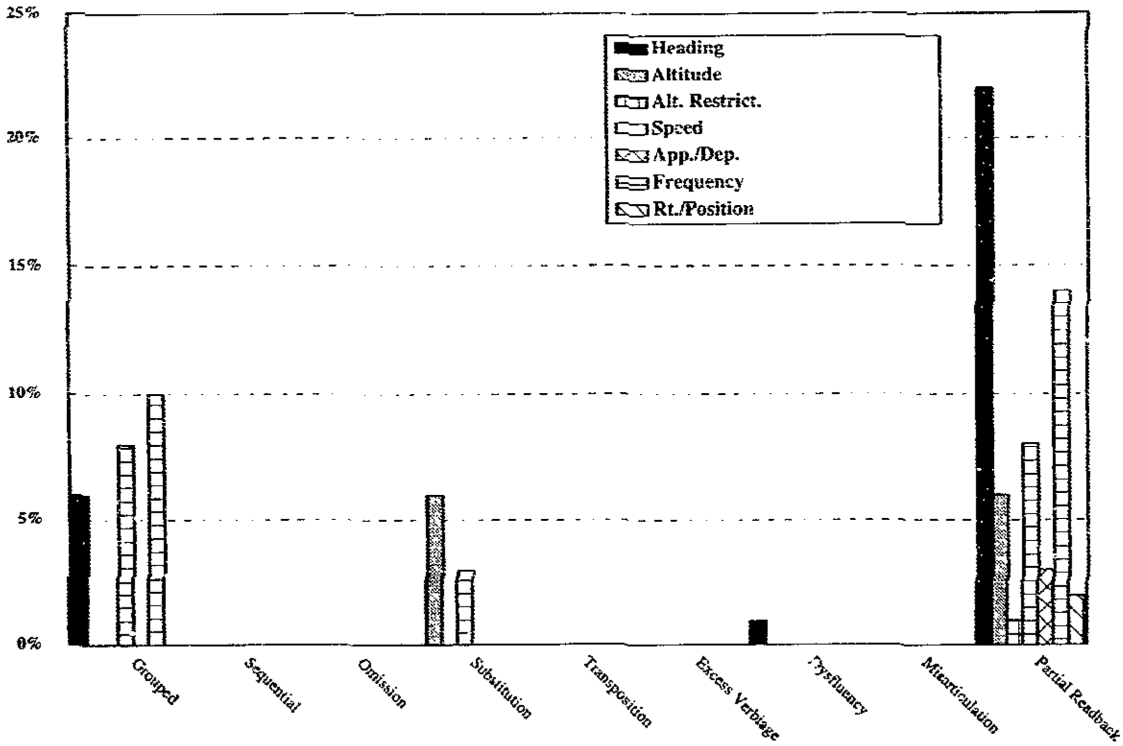

Figure 14. TRACON-1: Distribution of Pilot Instruction Communication Errors

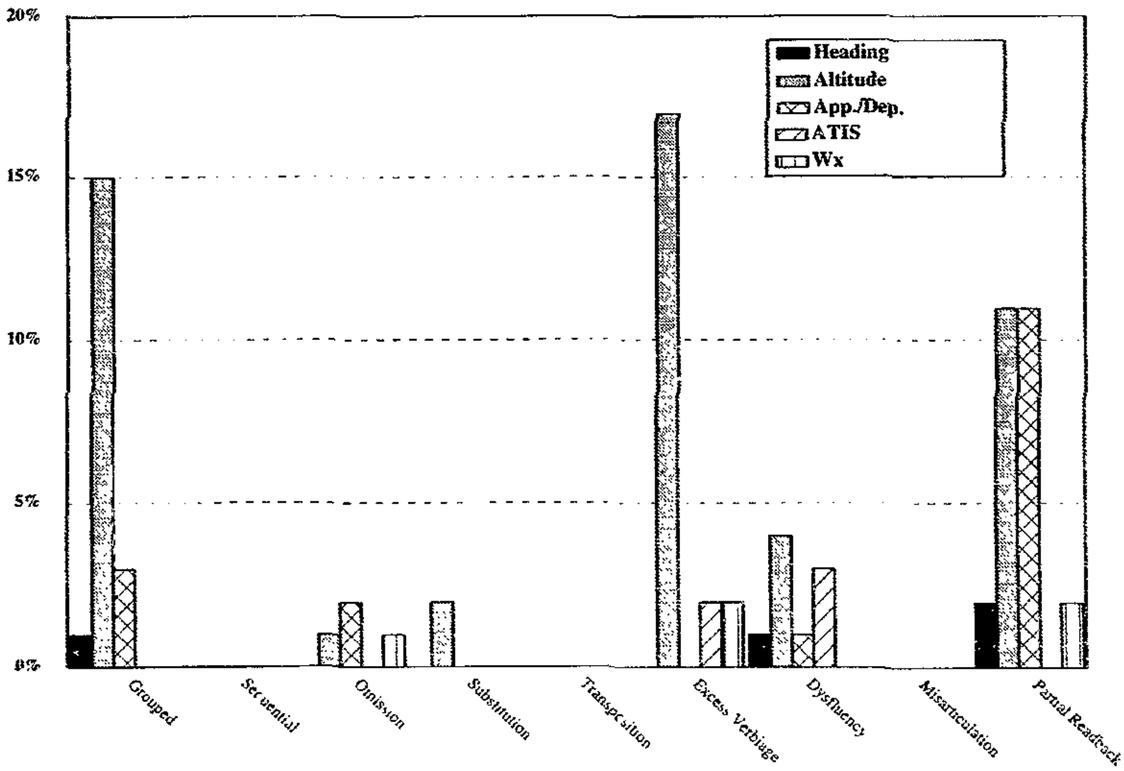

Figure 15. TRACON-1: Distribution of Pilot Advisory Communication Errors

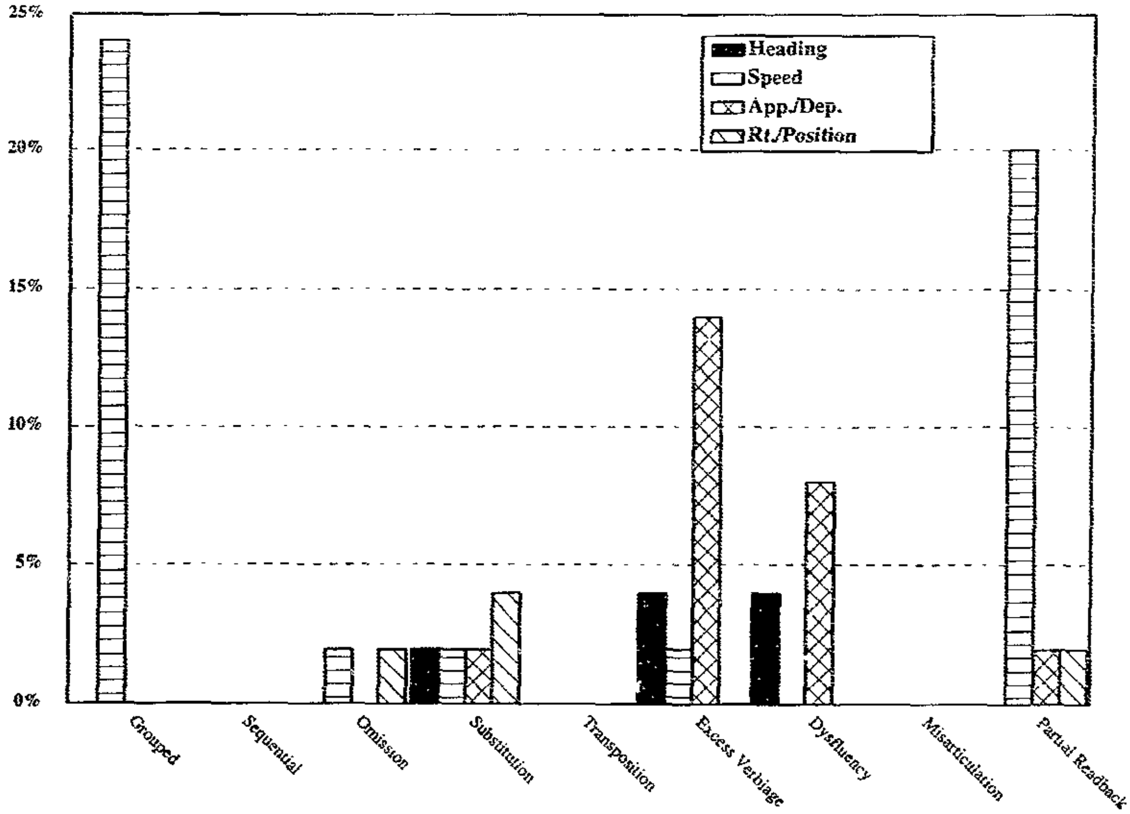

Figure 16. TRACON-1: Distribution of Pilot Request Communication Errors

due mostly to excess verbiage (17%), grouped format (15%), and partial readback (11%). Additional altitude errors resulted from dysfluency (4%), substitution (2%), and omission (1%). Approach/departure errors were due to partial readback (11%), grouped format (3%), dysfluency (3%), and omission (2%).

3.4.2.3 **Request.** As shown in Figure 16, pilot Request communication errors involved grouped format (24%), partial readback (24%), and excess verbiage (20%) - more than omission (4%), substitution (10%), or dysfluency (12%). Airspeed errors resulted from grouped format, partial readback, and rarely omission, substitution, or excess verbiage (1% each). Approach/departure request communication errors resulted from excess verbiage and dysfluency - more than substitution or partial readback. Route/position and heading communication errors were rare.

3.4.3 TRACON-2 Facility (Level 5): Controller Communications

3.4.3.1 **Instruction.** As shown in Figure 17, 76% of the controllers' Instruction communication errors resulted from omission within the heading (10%), altitude restriction (10%), speed (20%), approach/departure (21%), frequency (9%), and route/position (6%) aviation topics. Only radio frequency errors resulted from a grouped format (8%). Substitution, excess verbiage, and dysfluency had only a minor impact on the remaining Instruction aviation topic communication errors.

3.4.3.2 **Advisory.** Figure 18 displays the distribution of controller Advisory communication errors. In this analysis, omission (22%) and excess verbiage (56%) predominate and 65% of all of the communication errors involved traffic advisory. For example,

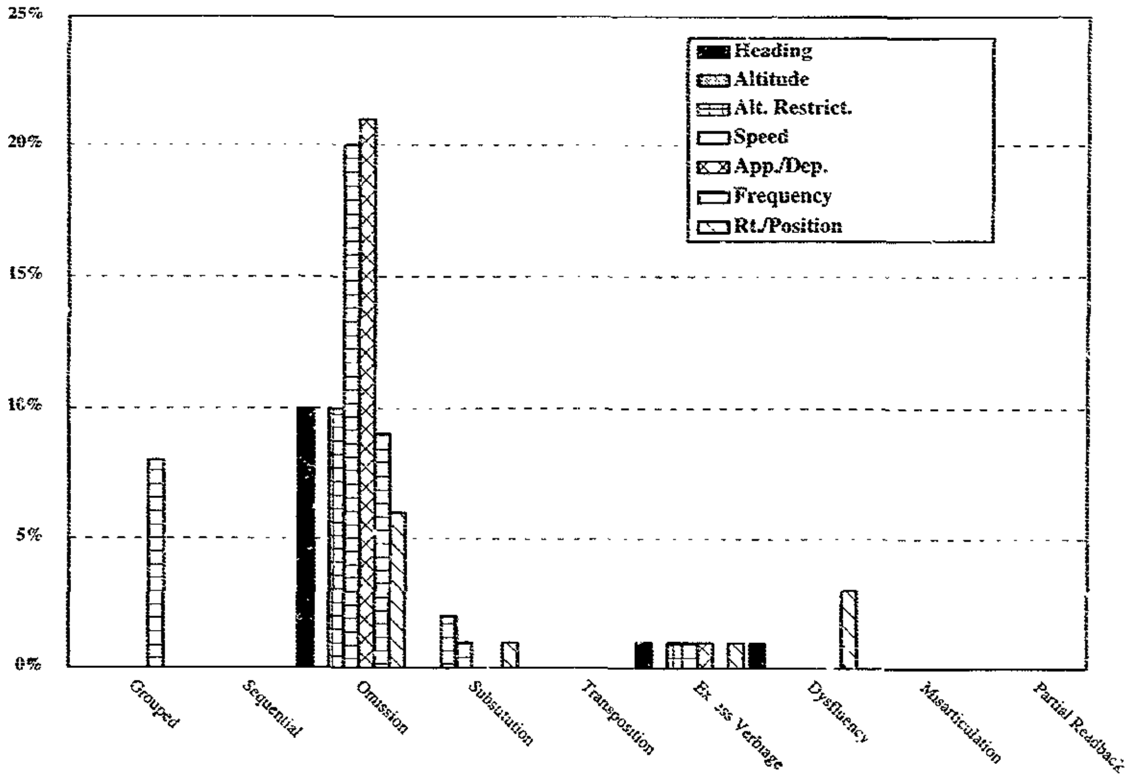

Figure 17. TRACON-2: Distribution of Controller Instruction Communication Errors

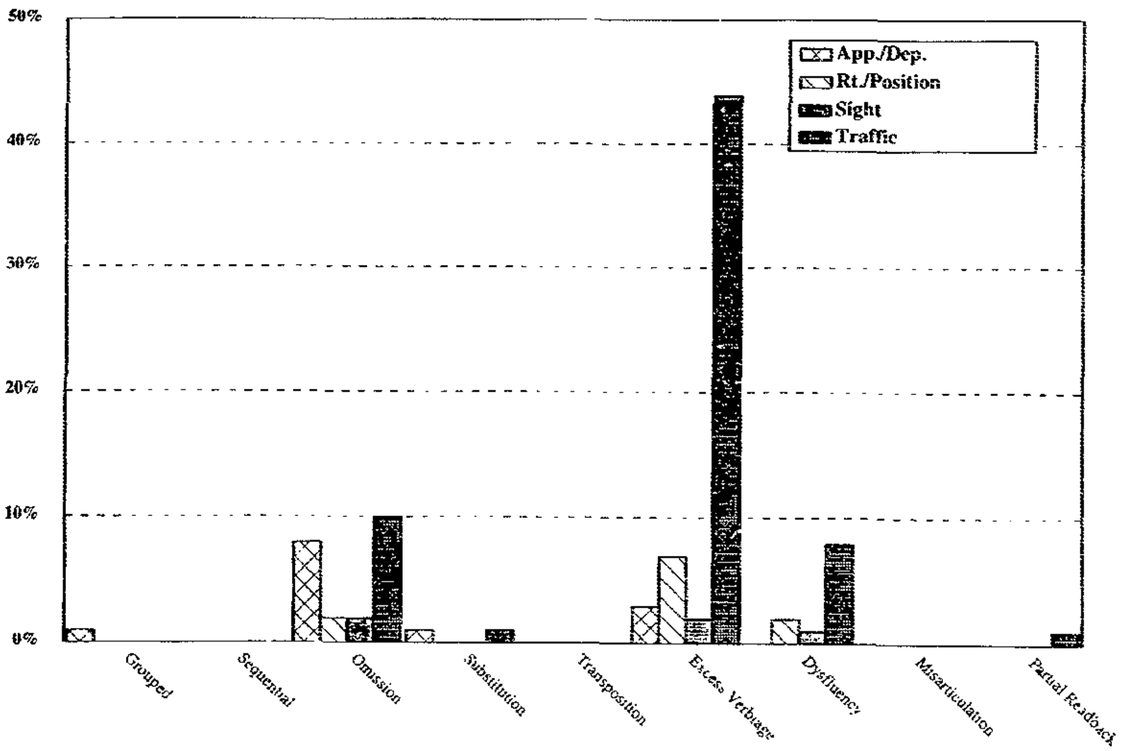

Figure 18. TRACON-2: Distribution of Controller Advisory Communication Errors

"...you'll need to stay at seven for about the next ten miles for traffic at six...." Approach/departure communication errors were due to omission (8%), excess verbiage (3%), and dysfluency (8%). Route/position and sighting errors were uncommon.

3.4.3.3 **Request.** There were not enough communication errors to analyze meaningfully.

3.4.4 TRACON-2 Facility (Level 5): Pilot Communications

3.4.4.1 **Instruction.** See Figure 19. Most of the pilot communication errors were distributed in grouped format (21%), substitution (11%), and partial readback (55%) involving communication errors pertaining to heading (26%), altitude (14%), speed (21%), approach/departure (8%), and frequency (15%) aviation topics. Heading errors resulted from partial readback (20%) and grouped format (6%), whereas airspeed errors resulted from grouped format and partial readback equally (9%); substitution errors were infrequent (3%). Frequency errors involved grouped format (6%) to a lesser degree than partial readback (7%). Altitude errors were more likely to result from substitution or partial readback (5% each) than from transposition, excess verbiage, dysfluency, or misarticulation (1% each).

3.4.4.2 **Advisory.** See Figure 20. In this analysis, most of the pilot advisory communication errors occurred within the aviation topics traffic (30%) and altitude (36%). Heading (6%), speed (6%), approach/departure (7%), and sighting (6%) accounted for an additional 23% of the advisory pilot errors. Most communication errors resulted from partial readback (28%) and substitution (24%). Traffic advisory communication errors resulted from substitution (18%), dysfluency (7%), and partial readback (4%). For example, "yea, ah, I got him...." Altitude errors were due to grouped format (7%), excess verbiage (10%), dysfluency (4%), and partial readback (15%). For example, in response to ATC "maintain four thousand" the pilot readbacks, "...okay, we'll maintain four till advised...."

3.4.4.3 **Request.** There were insufficient communication errors to produce meaningful results.

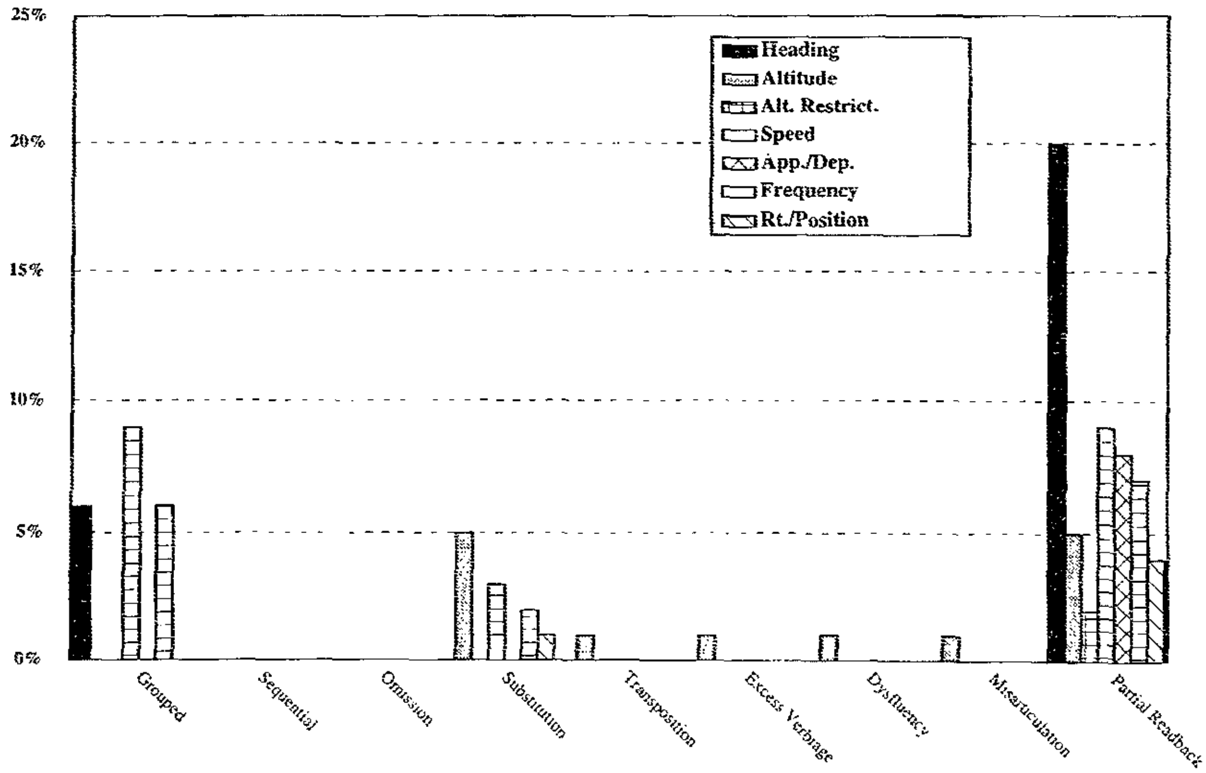

Figure 19. TRACON-2: Distribution of Pilot Instruction Communication Errors

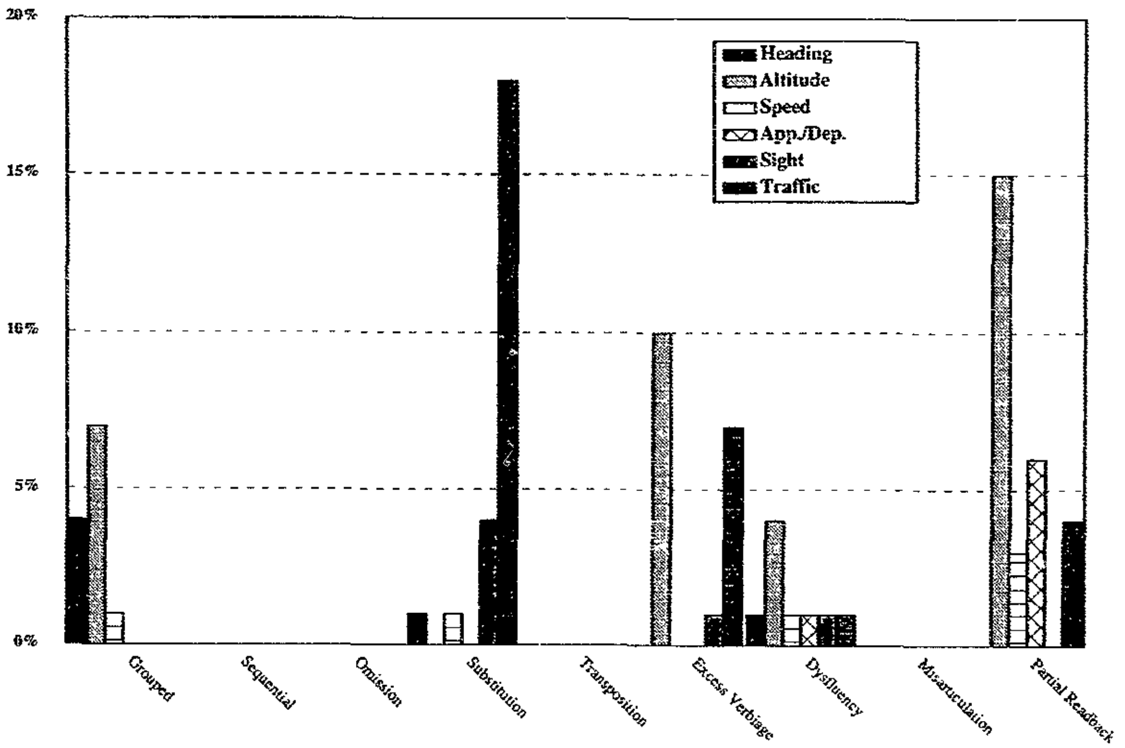

Figure 20. TRACON-2: Distribution of Pilot Advisory Communication Errors

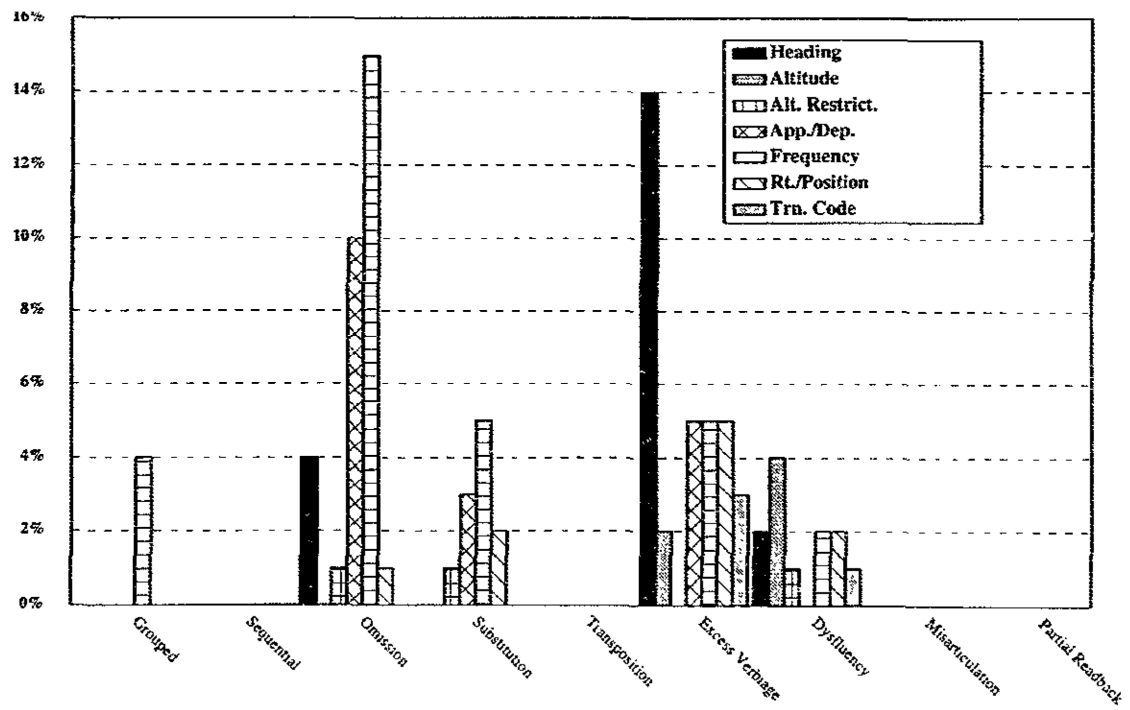

Figure 21. TRACON-3: Distribution of Controller Instruction Communication Errors

3.4.5 TRACON-3 Facility (Level 4): Controller Communications

3.4.5.1 Instruction. See Figure 21. Within the Instruction speech act category most of the communication errors occurred within the aviation topics frequency (29%), heading (16%), approach/departure (16), and route/position (13%). Once again, many of the errors resulted from excess verbiage (34%) and omission (31%). Extra words were added to heading (14%), approach/departure (5%), frequency (5%),

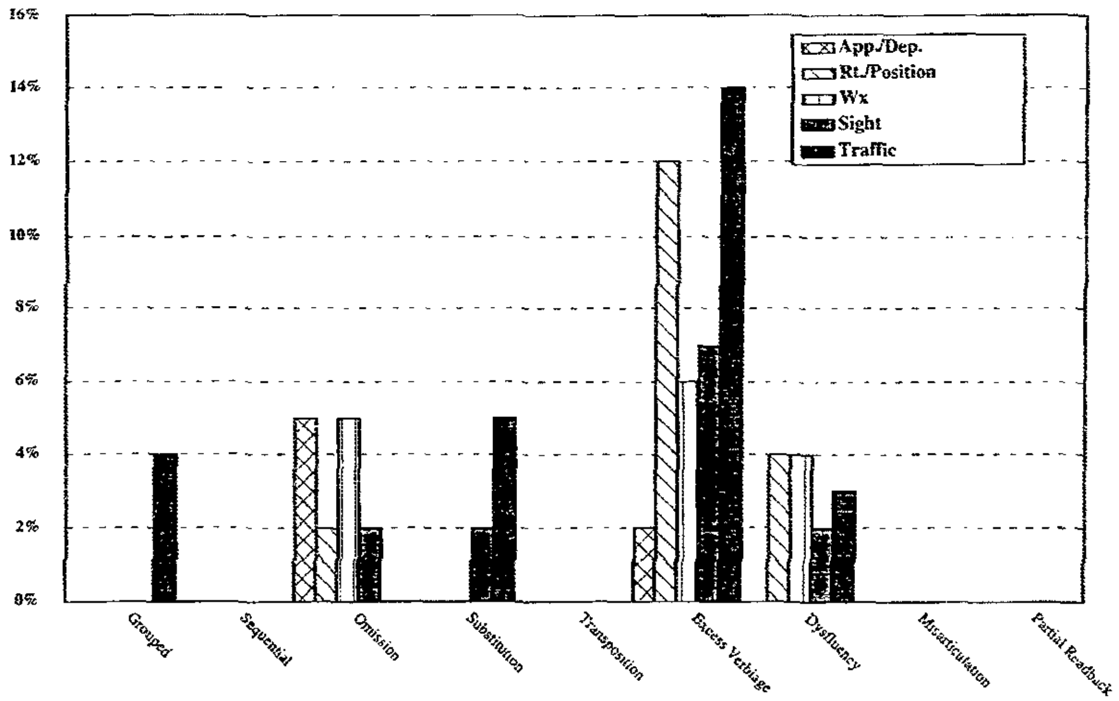

Figure 22. TRACON-3: Distribution of Controller Advisory Communication Errors

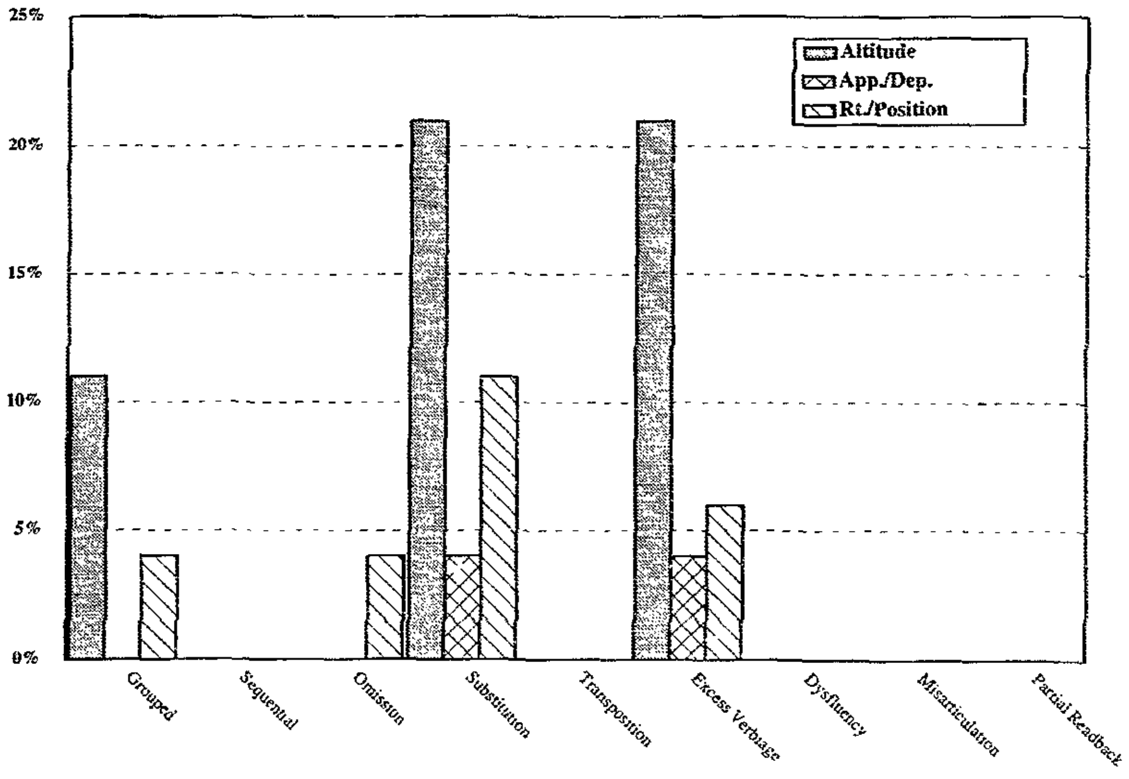

Figure 23. TRACON-3: Distribution of Controller Request Communication Errors

route/position (5%), and transponder code (4%) aviation topics that *did* not improve the comprehensibility of the transmission. For example, "...turn right to a heading of three two zero" adds time on frequency compared to "...turn right heading three two zero." Omission errors (10%) were common in approach/departure clearances. Controllers omitted the word "runway" in "...cleared ILS one two left approach." Radio frequency errors often involved grouped format (4%) and omission (15%) of numbers and/or words "...contact [name] tower one twenty-three four" or "...contact tower twenty-three four." Substitution

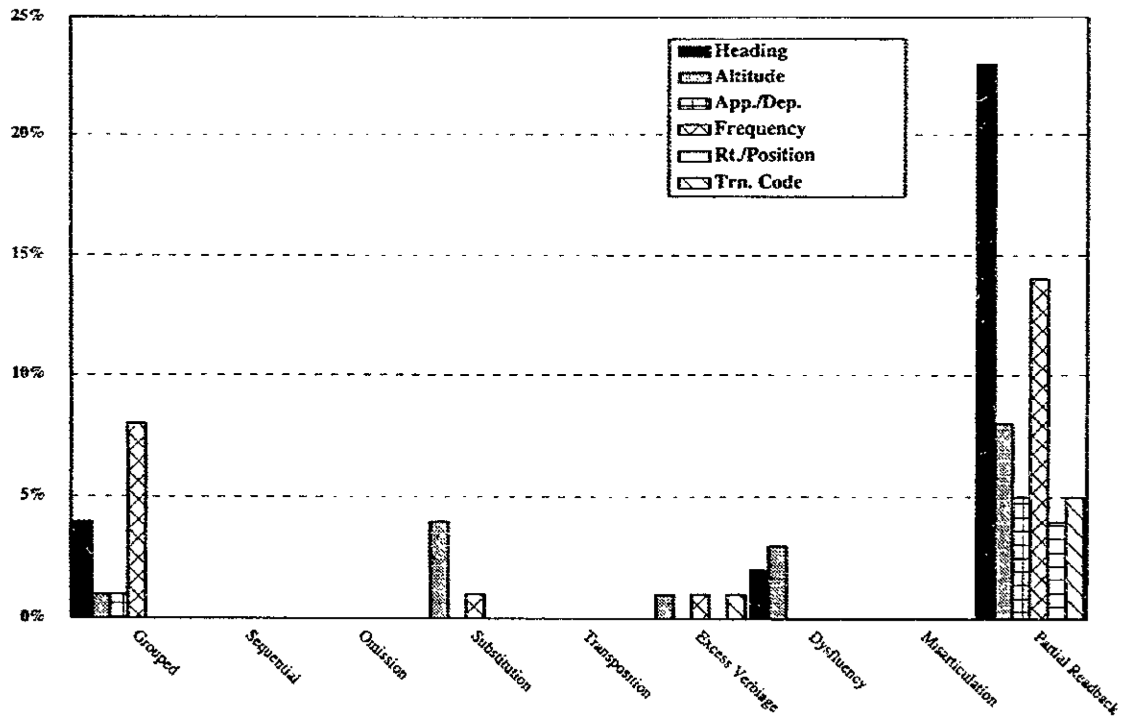

Figure 24. TRACON-3: Distribution of Pilot Instruction Communication Errors

errors involved use of non-standard communication, such as "...go direct to [fix]" and "make it straight in runway one two."

3.4.5.2 **Advisory.** Figure 22 displays the results of the analysis performed on Advisory communication errors. Most of the errors resulted from excess verbiage (41%), omission (14%), and dysfluency (13%). Traffic (26) and route/position (18%) information contained most of the communication errors. Traffic information errors resulted from grouped format (4%), substitution (5%), excess verbiage 14%), and dysfluency (3%). In the following example ATC is providing a traffic advisory, "Yeah, the [aircraft] is at uh eleven to ten o'clock now and...." Like traffic, route/position and weather advisory errors resulted from omission (2%, 4%), excess verbiage (12%, 6%) and dysfluency (4%, 4%). General sighting errors resulted from omission (2%), substitution (2%), excess verbiage (7%), and dysfluency (2%).

3.4.5.3 **Request.** The results of the analysis performed on Request communication errors are presented in Figure 23. The largest percentage of errors resulted from substitution (36%), followed by excess verbiage (31%). Fifty-three percent of the Request communication errors involved altitude, 21% pertained to route/position, and 8% involved approach/departure aviation topics. Altitude communication errors resulted from grouped format (11%), substitution (21%), and excess verbiage (21%). Examples include, "...and what's the on course heading to [town]?," and "...say your altitude now out of forty-eight."

3.4.6 TRACON-3 Facility (Level 4): Pilot Communications

3.4.6.1 **Instruction.** See Figure 24. The majority of pilot Instruction errors resulted from partial readback (59%) and grouped format (15%). The aviation topics heading (29%), frequency (25%), and altitude (17%) contained the most communication errors. Pilot heading errors resulted from grouped format (45%), dysfluency (2%), and partial readback (23%). "Three five zero [call sign] to the right" and "...three fifty one the heading down to four [call sign]" are examples of partial readback, excess verbiage, and grouped format. In contrast, there were more frequency communication errors that involved partial readback errors (14%) than grouped format (8%), with substitution and excess verbiage rarely involved (1% each). "Twenty-three four [call sign] you have a

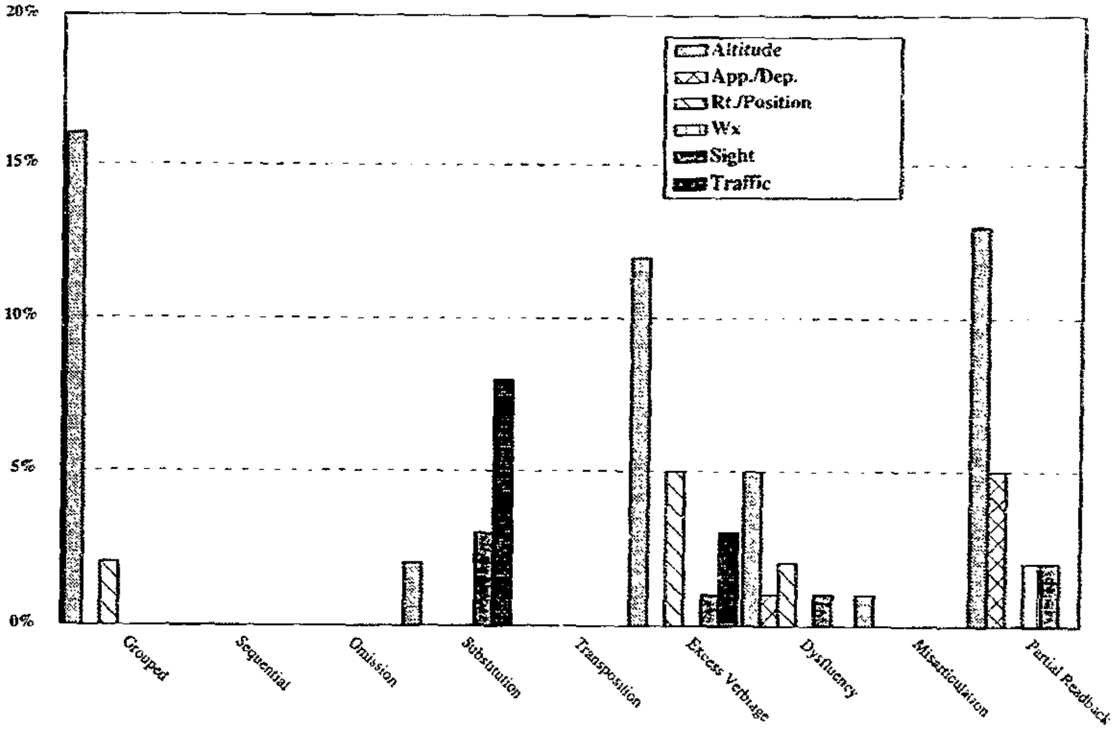

Figure 25. TRACON-3: Distribution of Pilot Advisory Communication Errors

nice day" and "Two three point four good day" are two examples of partial readback frequency errors. The first example also contains a grouped format error. Altitude errors resulted from substitution (4%) and partial readback (8%). The phrase "down to" was substituted for "descend to" in the readback of an ATC instruction.

3.4.6.2 **Advisory.** As shown in Figure 25, most of the pilot communication errors resulted from grouped format (18%), substitution (13%), excess verbiage (21%), and partial readback (22%). Communication errors occurred to a greater extent within the aviation topics altitude (49%), traffic (11%), route/position (9%), and sighting (7%). Altitude communication errors resulted from grouped format (16%), partial readback (13%), excess verbiage (12%), dysfluency (5%), and misarticulation (1%). For example, "...[call sign] sir with you going through eighteen hundred" contained grouped format, partial readback, and excess verbiage communication errors. The majority of the traffic Advisory errors resulted from substitutions (8%) like: "Got the traffic," "We're looking for him," and "...we're looking for both those traffics...." Route/position communication errors stemmed from excess verbiage (5%), dysfluency (2%) and grouped format (2%). For example, "...we're thirty-two and a half miles north of [tower] uh with echo..." suggests that pilots had some difficulty constructing and delivering a position report. Speakers recognize that most presentations have an *ideal delivery* — one that is fluent, correct, and optimal for identification (Clark & Clark, 1977). If they foresee an unavoidable delay or interruption, they use "uh" and "um" to warn addressees about the size of the interruption. They use "uh" to signal short interruptions, and "um" to signal more lengthy ones.

3.4.6.3 **Request.** As shown in Figure 26, pilot Request communication errors involved excess verbiage (36%), substitution (18%), and dysfluency (18%), more than partial readback (15%), or grouped format (9%). Route/position communication errors (39%) resulted from excess verbiage (21%), dysfluency (9%), partial readback (6%), and grouped format (3%). Approach/departure Request communication errors resulted more from excess verbiage (15%) than substitution (6%), dysfluency (6%), partial readback

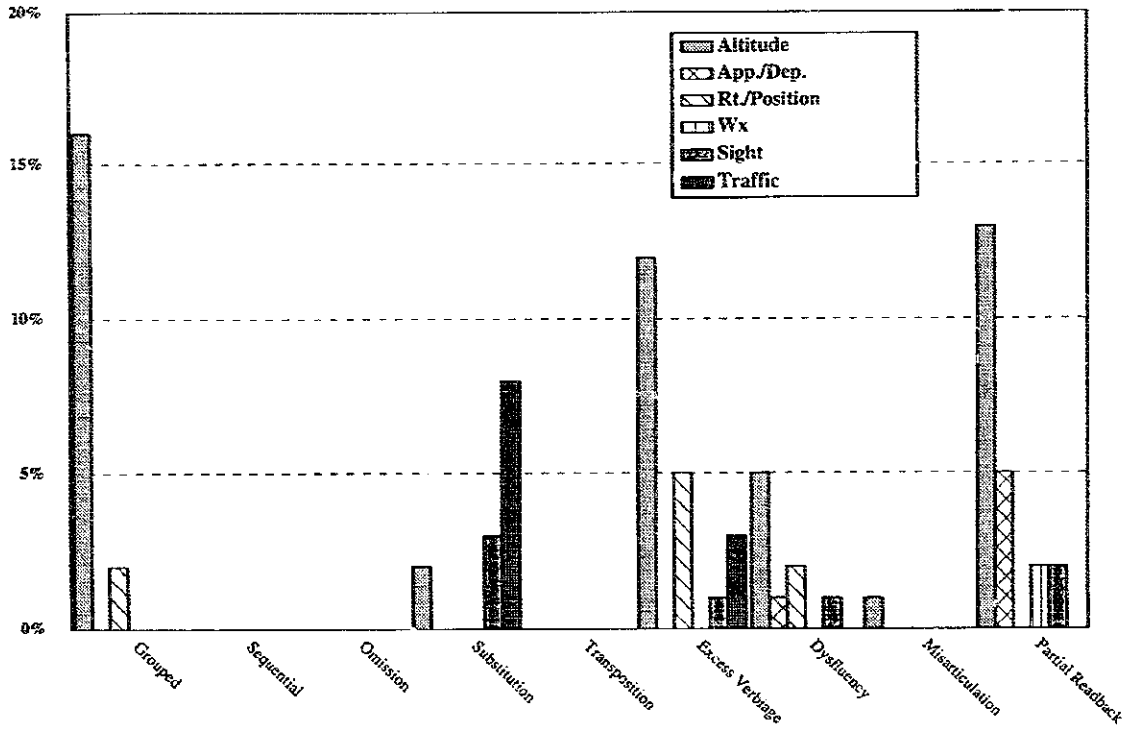

Figure 26. TRACON-3: Distribution of Pilot Request Communication Errors

(6%), or grouped format (3%). In response to ATC asking which runway the pilot would like, the pilot states, "OK, [call sign], I'd just as soon come on thirteen one three no problem on that." Altitude request errors resulted mainly from substitution (12%) although grouped format, dysfluency, and partial readback each contributed 3%. Pilots substituted the word "lower" in a request or in a readback, "Can you approve a lower for [call sign]," and "Yeah level six we'll take lower when it's available."

4.0 DISCUSSION

The purpose of this study was to develop baseline data on typical controller and pilot voice communications. Although other researchers have analyzed ATC/pilot communications, what made this study unique is that FAA Order 7110.65 guided the development of the ATSAT, which was used to categorize the communication elements in their transmissions. The analyses focused on verbal communications that deviated from the standard specified in FAA Order 7110.65G (or suggested pilot communication in the *Airman's Information Manual*). Problematic communications involved mode C malfunctions, call sign ambiguity, call sign confusion, controller confusion, pilot confusion, 2 aircraft on frequency talking to each other, report of an ELT, open mike, traffic, weather, and so on.

Do spoken communications present a problem to air safety? Knowing that communication errors are cited time and time again in operational errors, pilot deviations, and near midair collisions, that the errors occur with regularity, and that the errors can create frequency congestion, the answer is yes.

An examination of the aviation topic communication errors revealed that controllers often omitted key words that pertained to frequency, airspeed, or approach/departure Instructions. Often, pilots only partially read back Instructions involving heading, radio frequency, and airspeed aviation topics, and grouped the numbers in a radio frequency, airspeed, or heading. Pilots' and controllers' communications became more conversational and verbose when their transmissions included Advisory or Request speech acts. Advisory communication errors that resulted from excess verbiage was facility specific: For controllers at TRACON-1, it involved routes/position; for

TRACON-2, it pertained to traffic; and for TRACON-3, it involved both traffic and route/position Advisories. Pilots experienced the most difficulty responding to altitude Advisory communications. Their altitude communication errors generally fell into 3 types: excess verbiage, partial readback, and grouped format. Only the pilots at the TRACON-2 facility made more substitution communication errors involving traffic Advisory information.

Only the TRACON-1 and TRACON-3 facilities had Request communication errors. The form of their errors were facility specific. The preponderance of TRACON-1 controllers' communication errors centered around airspeed, and involved substitution, excess verbiage, and grouped format. Although "...and ah just verify that you're at a hundred and ninety on the speed ..." conveys the same intended meaning as "say airspeed," it requires substantially more time to transmit. Additionally, the message is wordy and contains both grouped and omission communication errors. "...and ah just verify that you're at a hundred and ninety on the speed..." is more likely to be misunderstood or misinterpreted than "say airspeed" if the transmission is clipped or garbled. Pilot transmissions also contained grouped format, partial readback, and excess verbiage involving airspeed. At TRACON-3, controllers made the most communication errors involving altitude. Their errors stemmed from substitution, excess verbiage, and grouped format. Pilots' route/position and approach/departure transmissions contained excessive verbiage.

It is intuitively obvious that excess verbiage lengthened the amount of time required to transmit, understand, and respond to a message by pilots and controllers. Yet, an examination of the verbal content of requests revealed that requests such as "say again," often clarified who was on frequency, who was the intended recipient of a transmission, and improved overall understanding. However, these additional communications also contributed to frequency congestion by increasing the number of transmissions needed to create a mutual understanding (or common ground) of the pilot's intentions. Without these additional communications, the pilot and controller would not have reached a mutual belief, called the "grounding criterion," that the receiver had understood what the speaker meant (Clark & Schaefer, 1989; Clark & Wilkes-Gibbs, 1986). These types of errors can result in trade-offs between frequency congestion and failure to reach a common understanding; both of which can lead to problems.

Effective and accurate communications are crucial to air safety. As aircraft approach their destination airport, they converge and operate under reduced separation minima[11]. Commercial aircraft may be flying at speeds in excess of 380 knots during their en route phase of flight and reduce to speeds of 180 knots (i.e., traveling at speeds greater than 3.5 nautical miles per minute) in the terminal environment. Under these circumstances, there is little margin for error. When ambiguities arise from poorly constructed messages, it is critical for pilots and controllers to transfer information to one another as quickly and as efficiently as possible so as to maintain or re-establish a common ground of understanding and to maintain their margins of safety.

If air safety is dependent upon efficient and accurate communications, then we should be able to measure how safe the system is from a simple mathematical equation. For example, safety could be determined from an equation that uses "total number of faulty communications" as the numerator, and "total number of communications," or "total number of operations," as the denominator in a simple ratio. In such a case, the conclusions drawn by Cardosi (1993) and Morrow and co-authors (1993) are borne out: Miscommunications seem to be rare events and spoken communications do not present a problem to air safety (but then again, operational errors, pilot deviations, and NMACs also are rare when total number of operations serve as the common denominator). On the other hand, if an equation is developed that reflects the number of communication errors occurring per hour, then the data are more startling. Cardosi (1993) reported that 27 communication errors were found in 47 hours of ARTCCs' recorded radio communications. This translates to about 13 communication errors per day; or about 1 error every 2 hours.

[11] In the terminal environment, separation minima are 3 miles and 1,000 feet and within the en route environment it is 5 miles and 2 thousand feet. However, see FAA Order 7110.65J Par.5-5-3d-f for exceptions.

5.0 CONCLUSIONS

The results suggest that controllers and pilots need to improve their operational communication practices. The AIM provides pilots with an 8-page section on radio communications and communication techniques, which stress the importance of pilots and controllers reaching the same understanding of their transmissions. "Brevity is important, and contacts should be kept as brief as possible, but the controller must know what you want to do" (AIM, 1994, par 4-31b). Pilots may be using omission and grouping as strategies to create brief, yet concise ATC communications. However, these strategies could create miscommunications and increase frequency congestion. Using established communication procedures and practices could eliminate some ambiguity and confusion.

A reduction in the frequency of operational errors, pilot deviations, and near midair collisions might be attainable if pilots and controllers used standard communication operational procedures and practices. For example, standard communications, such as "say speed," "say altitude," and "verify assigned altitude" meet the requirement for brevity on the part of the controller. Pilots need to reply only with "[one two three] knots" or "[one two] thousand [three] hundred." Use of words such as "knots," "speed," "degrees," "point," "flight level," and "runway" constrain the possible meaning of communication elements in a message. Controllers should practice transmitting complete radio frequency, airspeed, and approach/departure Instructions and be less verbose when delivering traffic and route/position Advisories. Pilots should practice constructing and transmitting altitude information to air traffic control — and would also benefit from additional practice in responding to traffic Advisories.

The ATSAT was used to analyze ATC/pilot communications from 3 TRACON facilities. It could be used to evaluate the communications skills of individual speakers and to identify the types and frequency of communication errors in their transmissions. For example, weaknesses in a pilot's or controller's existing communications skills could be identified by the ATSAT; instruction, training, and practice then could be implemented to correct the identified deficiency.

6. REFERENCES

Airman's Information Manual, Official Guide to Basic Flight Information and ATC Procedures. (June, 1992). Washington, DC: U.S. Government Printing Office.

Airman's Information Manual, Official Guide to Basic Flight Information and ATC Procedures. (1994). Washington, DC: U.S. Government Printing Office.

Cardosi, K. (1993). *An analysis of en route controller-pilot voice communications.* Washington, DC: FAA Office of Research and Development. DOT/FAA/RD-93/11.

Clark, H. H., & Clark, E. V. (1977). *Psychology and language.* New York: Harcourt Brace Jovanovich.

Clark, H. H., & Schaefer, E. F. (1989). Contributing to discourse. *Cognitive Science*, 13, pp. 259-294.

Clark, H. H., & Wilkes-Gibbs, D. (1986). Referring as a collaborative process. *Cognition*, 22, pp. 1-39.

FAA Order 7110.65G Air Traffic Control. (March, 1992). Washington, DC: Air Traffic Rules and Procedures Service.

Kanki, B. G., & Foushee, H. C. (1989). Communication as group process mediator in aircrew performance. *Aviation, Space, and Environmental Medicine*, 60, pp. 402-410.

Monan, W. P. (Mar., 1986, Nov., 1988). *Human factors in aviation operations: The hearback problem.* Moffett Field, CA: NASA Contractor Report 177398.

Morrow, D., Lee, A. & Rodvold, M. (1993). Analysis of problems in routine controller-pilot communication. *International Journal of Aviation Psychology*, 3, pp. 285-302.

Morrow, D., Clark, H. H., Lee, A., & Rodvold, M. (Nov., 1990). *Collaboration in Controller-Pilot Communications.* Presented at the 1990 Meeting of the Psychonomic Society, New Orleans, LA.

Morrow, D., Rodvold, M., & Lee, A. (1990). *Nonroutine transactions in controller-pilot communication.* Unpublished manuscript.

Prinzo, O. V. & Britton, T. W. (1993). *ATC/Pilot Voice Communications - A Survey of the Literature*. Washington, DC: FAA Office of Aviation Medicine Report, DOT/FAA/AM-93/20.

Prinzo, O. V. & Britton, T. W (1994). A Taxonomic Analysis of Terminal Air Traffic Control/Pilot Communications. In: *Aerospace Systems Integration Through Technology and Training* (SP-1051), pp. 71-75. Warrendale, PA: Society of Automotive Engineers, Inc.

Prinzo, O. V., Britton, T. W., & Hendrix, A. (1995). *Development of a coding form for approach control/pilot voice communications*. Washington, DC: FAA Office of Aviation Medicine Report, DOT/FAA/AM-95/15.

Searl, J. R. (1969). *Speech Acts*. London: Cambridge University Press.

APPENDICES

APPENDIX A

Total Number of Speech Acts Made by Pilots and Controllers at Three Approach Control Facilities

FACILITY AND SPEAKER	ADDRESS	COURTESY	INSTRUCTION	ADVISORY	REQUEST	NON CODABLE	TOTAL
TRACON1 - PILOT	1357	165	1368	615	71	67	3643
TRACON1 - ATCS	1378	206	1422	566	60	110	3742
TOTAL	2735	371	2790	1181	131	177	7385
TRACON2 - PILOT	282	42	291	130	8	19	772
TRACON2 - ATCS	349	55	350	149	5	25	933
TOTAL	631	97	641	279	13	44	1705
TRACON3 - PILOT	561	78	395	295	72	99	1500
TRACON3 - ATCS	548	34	518	309	70	115	1594
TOTAL	1109	112	913	604	142	214	3094
GRAND TOTAL	4475	580	4344	2064	286	435	12184

APPENDIX B

Total Number of Phraseology Errors Made by Pilots and Controllers at Three Approach Control Facilities

FACILITY AND SPEAKER	ADDRESS	COURTESY	INSTRUCTION	ADVISORY	REQUEST	NON CODABLE	TOTAL
TRACON1 - PILOT	444*	3	1356	387	52	13	2255
TRACON1 - ATCS	160	10	974	371	54	39	1608
TOTAL	604	13	2330	758	106	52	3863
TRACON2 - PILOT	109	0	255	68	8	1	441
TRACON2 - ATCS	45	3	196	96	3	2	345
TOTAL	154	3	450	164	11	3	786
TRACON3 - PILOT	313	5	273	180	33	29	833
TRACON3 - ATCS	147	0	203	136	28	35	549
TOTAL	450	5	476	316	61	64	1382
GRAND TOTAL	1218	21	3257	1238	178	119	6031

*The values represent the total number of errors occuring in each aviation topic. There may be more than one error occuring in an aviation topic

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