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AN ANALYSIS OF RUNWAY-TAXIWAY TRANSGRESSIONS AT CONTROLLED AIRPORTS

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16. Abstract

The purpose of this study was to determine the cause of aircraft making inadvertent or unauthorized takeoffs and transgressions onto active runways during takeoff and landing operations. The study was conducted in four phases: (1) Prior studies by FAA, NASA and MITRE/METREK were reviewed; (2) Existing data bases containing information on accidents and incidents resulting from transgressions were examined and compared; (3) Investigations were carried out by the FAA Eastern, Great Lakes and Western regions of the occurrence of transgressions at selected airports within their jurisdictions; (4) A detailed analysis was carried out for 166 occurrences drawn from the Aviation Safety Reporting System (ASRS) and the National Transportation Safety Board (NTSB) data bases. A summary of the results includes some observations with respect to possible system improvements and suggestions for further work.

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PREFACE

Data and studies relating to airport runway and taxiway collisions and near-collisions were reviewed to gain insight into their underlying causes. In addition, case studies were conducted in the FAA Eastern, Great Lakes, and Western regions. All of these studies suggested that the number of incidents (airport transgressions) was larger than reported. However, no data could be provided to support this subjective finding.

The Transportation Systems Center (TSC) examined the National Transportation Safety Board (NTSB) data base to determine the number, frequency, and severity of accidents on the airport surface (Appendix B). The data showed that over a fourteen year time period (1964-1977) there were 77 accidents resulting in 16 fatalities, 12 serious injuries and 1452 minor injuries.

More recently, the review of the NTSB data base was extended by the Office of Systems Engineering Management (OSEM) to cover the 1962-1980 time period and analyzed to determine the number of accidents by type and location of collisions on or above the airport involving aircraft and other airport vehicles, and the numbers of deaths and injuries associated with these accidents. Table P-1 summarizes the OSEM review of runway/taxiway and parked aircraft accidents and reveals a total of 212 accidents, 18 fatalities, 20 serious injuries and 1982 minor injuries. These results include the conditions where 1) one aircraft was airborne during the collision, 2) both aircraft were on the ground at impact, 3) one aircraft and a ground vehicle collided and 4) one aircraft was involved in a collision with a parked aircraft. Historically, over a 19 year period an average of about 11 accidents occurred annually, resulting in about one fatality and one serious injury annually on or above the airport runways and taxiways at controlled airports in the United States. Considering that in 1977 there were 426 control towers and 66.7 million operations (total itinerant and local aircraft operations) at airports with FAA traffic control

TABLE P-1: SUMMARY OF ACCIDENT STATISTICS

Type & Location of Collision	No. of Accidents	DEATHS / INJURIES		
		Fatalities	Serious Injuries	Minor Injuries
One Aircraft Airborne	5	10	9	209
Both Aircraft on Ground	74	6	4	1067
One Aircraft and Ground Vehicle	38	1	3	212
One Aircraft and Parked Aircraft	95	1	4	494
TOTALS	212	18	20	1982

Notes:
1. Statistics at controlled airports, 1962-1980. NTSB data base analyzed by OSEM.
2. Collisions during static or taxi phase of operations for U.S. Civil Aviation at airports providing traffic control services as of 1-12-81.

services, the extent of the transgression problem does not appear to be serious.

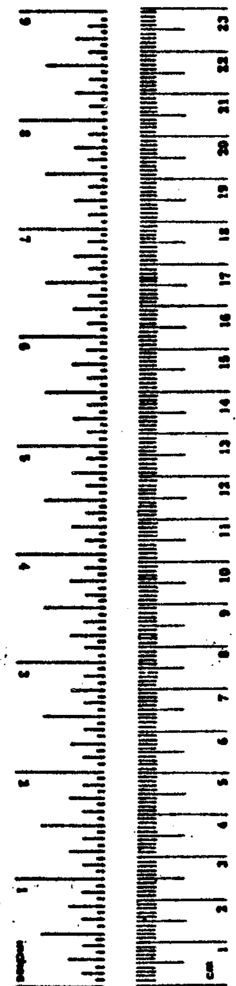
To date, there does not appear to be any pattern to the causes of runway/taxiway transgressions other than human errors on the part of both air traffic controllers and pilots. Procedural solutions could improve the efficiency with which the local and ground controllers monitor the aircraft and vehicular traffic. Also, more uniform communication and verification of messages between the pilots and controllers could serve to reduce the chance of ambiguous or erroneous commands/actions. Finally, a case can be made to improve the quality of GA pilot training as related to airport runway/taxiway and radio procedures.

Anees A. Adil
Program Manager
Federal Aviation Administration
Office of Systems Engineering Management

METRIC CONVERSION FACTORS

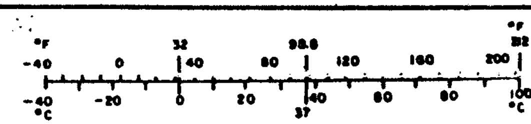
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

1.1 PROJECT OBJECTIVES

One aspect of air traffic control that has attracted increasing attention in recent years is the inadvertent transgression* of aircraft or other vehicles onto active runway/taxiway areas of the airport surface.[1] In an attempt to identify the factors that contribute to these improper movements, several sources of information were selected for study and analysis:

1. accident/incident reporting files;
2. reports and studies of related airport surface traffic control problems;
3. observation of traffic control operations at representative airports; and
4. interviews with controllers, supervisors and others involved with ground operations at towered airports.

1.2 BACKGROUND

In July 1978, the Flight Standards Service (AFS) submitted a formal request (FAA Form 9550) to the Office of Systems Engineering Management (OSEM) to undertake a study of the causes leading to runway/taxiway transgressions, in which it was stated that:

> A study is requested to determine the causes of aircraft making inadvertent or unauthorized takeoffs and transgressions onto active runways or taxiways during takeoff or landing operations. A recent study by TSC of aircraft accidents/incidents occurring on runways/taxiways indicates that over the past 10 years there have been 279 cases of

*For the purposes of this study, a transgression is defined to be any improper movement of aircraft or other vehicle on or immediately above the surface of an airport with an FAA-operated control tower.

this type reported. It is likely that many more incidents of this type have gone unreported due to various reasons. This study should be unbiased and candidly address the issues since the cause factors involve pilots, controllers, controller instructions, the pilot's understanding and execution of instructions, airport design, traffic flow, and other factors.

A Project Plan Agreement (PPA) to undertake this work was negotiated between OSEM and TSC in October 1978, and a preliminary assessment of the availability of data and information was started. On March 28, 1979, the findings of this preliminary survey were presented in a briefing to the FAA Services. As a result, the Associate Administrator for Aviation Standards organized an FAA Steering Group to coordinate and expedite work on the project. Members of the group included representatives of the following offices of the FAA:

Office of Systems Engineering Management, (AEM)

Office of Flight Operations, (AFO), Chairman

Office of Airport Standards, (AAS)

Office of Aviation Safety, (ASF)

Air Traffic Service (AAT)

Systems Research and Development Service (ARD)

Associate Administrator for Air Traffic and Airways Facilities (ATF).

The first meeting of the Steering Group took place on August 1, 1979. The following decisions were made at this meeting:

1. TSC's role would be limited to determining the causes of transgressions by collecting information, maintaining a data base, and conducting the required analysis.
2. The Steering Group would be responsible for assessing the causes and determining possible remedies.
3. Additional data is required since the data available in formal reporting systems is insufficient for the purposes of this analysis.

4. TSC should extend its data acquisition efforts to include a variety of operational facilities by examination of records and interviews with operating personnel.

1.3 TECHNICAL APPROACH

The technical approach to this study was presented in a Program Implemention Plan dated October 1978.[2] During the early phase of the project, several data bases associated with formal incident/accident reporting systems were surveyed to determine whether they contained sufficient information for the purpose of this study. At the same time, literature searches were performed to determine whether earlier studies exist which might provide useful data.

By the time the FAA Steering Group was established, two things had become apparent:

1. Except for a brief NASA report, earlier related studies touched only indirectly on airport transgressions. They were primarily concerned with classes of problems of which transgressions, as defined for this study, were a relatively small subset.

2. Historical data derived from the formal reporting systems was incomplete and not well-suited for the establishment of the causal factors leading to a transgression. Many relevant factors such as weather, visibility, or traffic density were frequently omitted from the data.

For these reasons, the Group recommended that additional information should be sought directly from those regions in which the frequency of occurrence of transgressions was greatest according to the limited historical data that was available.

Accordingly, TSC carried out a trial study of representative air traffic facilities in the FAA New England Region in order to establish the availability and usefulness of regional field data. Subsequently, similar studies were conducted in the Eastern, Great Lakes and Western Regions of the FAA. These studies involved controllers, supervisors, FAA pilots and other elements of the FAA's air traffic organization.

The work on this project was divided into four major parts, each of which is described in the sections that follow.

- o Section 2 summarizes earlier studies and assesses their relevance to the runway/taxiway transgression problem.
- o Section 3 compares the available accident/incident data base that includes airport transgressions.
- o Section 4 summarizes the results of the FAA Region studies.
- o Section 5 provides an analysis of runway transgression reports.

The principal conclusions and observations that have resulted from this effort are contained in Section 6.

2. RELATED STUDIES

Following the preparation of a program implementation plan, the initial activities undertaken during this study were the identification of prior studies (Section 2) and the evaluation of accident/incident data (Section 3).

2.1 EARLY WORK

Information retrieval searches were conducted to determine the extent and applicability of earlier work to the transgression problem. Searches were made of the data bases maintained by the Transportation Research Information Services (TRIS), the Defense Documentation Center (DDC), the National Technical Information Service (NTIS), and the Scientific and Technical Aerospace Reports (STAR). These searches covered the literature of the past 10 years. In addition, queries were made of the TSC, FAA, DOT, MIT and NAFEC libraries. This effort failed to find any earlier studies that were directly concerned with the runway/taxiway transgression problem; however, it did identify a number of studies on the related topics of traffic movement and control on the airport surface. For example, some of these studies have associated portions of the surface traffic problem with deficiencies in the visual ground aids intended to facilitate ground movement. Visual ground aids, in the form of lighting, markings, and signs, have helped pilots and vehicle operators to locate themselves on the airport surface and to follow assigned routes to their destination. However, for one reason or another, these aids may be incomplete, confusing, or poorly maintained. In some reported instances, these shortcomings have created safety hazards wherein aircraft or vehicle operators have become disoriented and strayed onto active movement areas on the airport surface. Studies dating from the Air Traffic Control Advisory Committee report in 1969[3] and the program plan for airport surface traffic control in 1972,[4] among others, recognized these difficulties and stated the need for the development and deployment of adequate, standardized and well-maintained visual ground aids. The visual ground aids study in 1975[5] highlighted the following major problems affecting safety of operations:

1. the need to provide conspicious, reliable warning and stop signals on taxiways at runway crossings;
2. the non-standard development of taxi guidance signs and sign locations within the system;
3. the absence of route delineation standards within apron areas;
4. the need to provide pilots with improved charts of the taxiway configuration and standard routings;
5. development of signs with more emphasis on permanency of these components within the system; and
6. the need to update airport traffic control regulations and procedures to provide more emphasis on the movement of and separation between aircraft and between aircraft and vehicular traffic, together with more sophisticated control and guidance systems in the future.

In response to this study, an Engineering and Development plan was prepared in 1977[6] describing the method of managing the development process leading to major improvements in the then existing visual ground aids. This plan included schedules, budgets, milestones and evaluation criteria.

Some of the earlier work, the 1972 study in particular,[4] also stated a need for advanced surveillance and control systems such as Airport Surface Detection Equipment (ASDE) and Automatic Intersection Control (AIC). This need was reiterated and expanded upon in an airport surface traffic control requirements analysis report in 1979.[7] Surface surveillance and control systems could also serve to alleviate the transgression problem, particularly when visibility is restricted. However, of the options available, only ASDE has seen deployment, and that has been limited.

About the time of the visual ground aids study in 1975, the specific problem of runway intrusions began to receive increasing amounts of attention. Since that time, several important reports have appeared which have direct bearing on the problem. A brief account of this recent work is given in Section 2.2.

2.2 RECENT STUDIES

2.2.1 Atlanta Runway Crossing Committee

The maintenance of facility records on inadvertent runway crossings at Atlanta International Airport (ATL) began in March 1975. The problem of inadvertent crossings of runways continued to increase with near accidents involving taxiing, landing and departing aircraft over the next few years. In January 1978, a Runway Crossing Committee was convened to discuss this problem and to organize a joint effort to alleviate the problem. Through cooperation of the city of Atlanta, the Air Transport Association the Airline Pilots Association, the airlines, and the FAA, various methods have been tried to prevent inadvertent runway crossings. Some of the actions taken are summarized below:[8]

1. Pilot Bulletins were issued by Atlanta Tower alerting aircrews to this potentially dangerous situation.
2. Personnel were briefed periodically in order to keep the matter foremost in controllers' minds.
3. Lighted runway signs with flashing amber lights on the top were installed to alert pilots who are approaching a runway.
4. Pilots were required to read back all runway holding instructions.
5. Ground Controllers and Local Controllers were required to repeat runway crossing and/or holding instructions prior to frequency changes.
6. Facility Orders that define controller responsibilities and require coordination of runway crossings were issued.
7. Hold lines 12 inches wide, 150 feet from the runway were established. A high quality reflectorized paint is being used. Quarterly inspection of these markings will ensure they remain in excellent condition.
8. Taxiway exits were required to be closed by a string of red lights whenever the exits were not visible from the control tower.

9. Continued pilot awareness was to be stimulated by the airlines, fixed base operators, and professional aviation organizations.

The Runway Crossing Committee, established to continually review inadvertent runway crossings and to make recommendations on how to reduce and finally to eliminate this problem, has pursued the above (and other) suggestions with diligence.

Nevertheless, inadvertent runway crossings have continued to be reported at Atlanta. The number of such events reported per year is listed below.

Year	Number of Crossings
1975	11
1976	20
1977	12
1978	10
1979	24
1980	19

The decrease in the number of transgressions reported in 1978 has been attributed to the remedial actions noted above. Despite these measures, however, more transgressions were reported in 1979 than in any other year of recent record. Concerted efforts by the Runway Crossing Committee and others continue to be applied to this problem.

2.2.2 NASA Aviation Safety Reporting System (ASRS)

The FAA Aviation Safety Reporting Program utilizes the NASA as a third party to receive and analyze Aviation Safety Reports. This cooperative safety reporting program invites pilots, controllers, and other users of the National Aviation System, or any other person, to report to NASA actual or potential discrepancies and deficiencies involving the safety of aviation operations. To perform this function, NASA designed and administers the Aviation Safety Reporting System (ASRS) to provide for the receipt, analysis, and periodic reporting of findings. Studies are also conducted in specific safety related areas upon request.

In response to requests from the NTSB and the FAA, NASA conducted a study of ASRS reports relating to accidents and incidents involving incursions of aircraft or surface vehicles into action movement areas of controlled airports.[9] This study was not designed to provide quantitative data regarding the prevalence of such occurrences; rather, it focused on the behavioral aspects of potential and actual conflicts at controlled airports. This study examined 165 potential conflicts, actual conflicts, and situations which under other circumstances could have resulted in conflicts on or immediately above the aircraft movement areas of controlled airports in North America (161 domestic, 4 foreign).

All reports were categorized by the descriptive and enabling factors listed in the standard ASRS reporting form and shown in Tables 3-1 and 3-9 of this report. The frequency of occurrence of each of these factors shows that the majority of incidents involves either:

(a) lack of coordination, within or between cockpit and tower, or

(b) poor techniques by pilot or controller.

Unfortunately, these characterizations do not readily lend themselves to the formulation of specific corrective measures. In their report, however, the authors state that a problem certainly exists although they are uncertain as to its magnitude[9]. They are also of the opinion that chance alone prevented some near collisions from becoming accidents. The problem is characterized as arising from one principal common factor: the lack of a timely, unambiguous clearance. In their view this lack may have one of two outcomes:

(1) a pilot who does not have or who misunderstood a clearance executes an improper maneuver, or

(2) a controller fails to insure, before issuing a clearance,

not only that a safe separation exists but that it will continue to exist.

Although frequency congestion, shortcuts, nonstandard phraseology and operating procedures, unpredictable and unannounced flight crew actions, visibility restrictions, and other factors are cited as contributing to the problem, faulty information is seen to be at the heart of it.

It was further emphasized that although lack of clearance for takeoff or landing was noted in 14 incident reports, this could "hardly be due to a lack of knowledge of the requirements for such clearance. Data regarding the four aircraft that landed without clearance indicate two were not in contact with the tower; the reasons why the other two landed are unknown. In the case of takeoffs without clearance, however, a pattern was more evident. In 7 of 10 cases, an aircraft took off immediately after a take-off clearance was delivered to another aircraft. One case involved similar flight numbers, one involved an incomplete (no aircraft identification) repeat of a previously issued takeoff clearance, after which two aircraft took off simultaneously on intersecting runways. In the other cases, the reason for takeoff was unknown in one, a probable language problem in a second, and a crew member's misinterpretation of a question from the other pilot in the third."

2.2.3 MITRE/METREK Behavioral Study

In 1976/77, at the request of the Air Traffic Service, the Mitre Corporation conducted an analysis of the performance of controllers and first-line supervisors in the Air Traffic Control (ATC) System.[10] The purpose of this effort was the identification of the behavioral causes of system errors since prior studies had indicated that most system errors resulted from failure of the human element. Corrective actions were also to be identified. The study involved analyses of historical records of system errors and visits to facilities (ARTCCs and terminals) for direct observation of functional performance to help identify and isolate those aspects of human performance that contribute to system errors.

Analysis of historical records indicated that the reporting system is affected by several factors, notably witness by other controllers or supervisors, pilot reports, intent to draw attention to possible system deficiencies, and willingness to report when certain immunities are assured. The effects of other reporting criteria as well as the number of actual but unreported system errors was deemed largely unknown. The program for identifying, reporting, and investigating system errors was found to provide insight as to certain control actions that call for special care and attention. However, it was considered incomplete as a means for detecting the actual causes of system errors and deriving specific actions that might improve the performance of the human element. Specifically, the assessment was that the reporting system does not include enough data on those human activities that contribute to system errors, nor on the factors that underly these activities.

Work habits and techniques that contribute to the occurrence of system errors were observed at all facilities visited by the investigative team. To varying degrees, less than desirable habits and techniques were found to be standard practice among the personnel observed. These practices were attributed to convenience and lack of awareness of the possible consequences of these faults of human behavior. The underlying factors that led to system errors were found to be deficiencies in attention, judgement, and phraseology. Other factors contributing to the problem were found to include the absence of explicit, agreed-upon, preferred work habits and control techniques needed to provide a framework of acceptable behavioral patterns, distractions and diversions in the work environment, and incomplete operational supervision. These observations led to the conclusion that the necessary detail should be provided to clarify and standardize good work habits and control techniques which help to avoid human error. It was consistently observed that first-line supervisors were spending only a small portion of their on-duty period actively supervising operations, that most of these personnel had not been trained in supervisory skills, and that they had to rely on personal persuasiveness in the absence of documented, approved, and preferred work habits and control techniques. It was reported that the techniques preferred by the supervisor were not always better than those of the controller and that the controller often sees his supervisor as no better qualified than himself in such matters.

In summary, this study concluded that the major causes of system errors were inappropriate work habits and control techniques. These causes were attributed to unawareness of the importance of good work habits, a lack of detail in documenting standard operating procedures, distractions in the work environment, and incomplete operational supervision. The current program for identifying, reporting and investigating system errors was found to be incomplete in the recording of occurrences and causes of system errors and in the identification of substantive causal factors.

2.2.4 The VICON (Visual Confirmation of Takeoff Clearance) Program

As a result of the Tenerife accident*, a high priority program was initiated within the FAA to develop a positive means for preventing future accidents that result from unauthorized takeoffs. An assessment of possible solutions resulted in selection for testing of the VICON concept, a visual signal designed to confirm voice communications authorizing takeoff. Early in this effort, the FAA recognized that consideration of such a major change to air traffic control procedures could benefit from air traffic controller and pilot experience and opinion. Consequently, interview forms were developed and distributed to controllers and pilots. Both interview forms were VICON oriented, but sufficient latitude was provided for the controllers and pilots to furnish additional information and relate experiences that could be used to assess other airport surface problems.

The FAA controller interviews were initiated in May 1979 following briefings at each Region Office by VICON program staff. Each Region was requested to have each towered airport complete a controller interview form. No restriction was placed on the number of forms each tower could submit and many towers submitted more than one. However, the majority elected to submit a single composite report. A total of 545 responses were received from the 420 towers.

Upon approval of the Office of Management and Budget (OMB), the pilot interview form was distributed to airline pilots in coordination with Airline Pilots Association (ALPA), general aviation pilots in coordination with the Air Safety Foundation of the Aircraft Owners and Pilots Association (AOPA), and FAA pilots in the early Fall of 1979. In addition, Air National Guard pilots at NAFEC and Bradley Field, Hartford, Connecticut were included in this survey since both groups participated in the operational

*On March 27, 1977, a tragic airport accident occurred on Tenerife Island, Spain, in which 583 people were killed in the collision of two airliners. The cause of the accident was an unauthorized attempt to take off.

testing of the VICON concept at Bradley Field. Pilot response was very limited. Only 178 completed forms were received: 48 from air carrier pilots, 55 from GA pilots, 51 from FAA pilots, and 24 from military pilots.

The data from the controller and pilot surveys were analyzed separately and comparatively.[11] The findings relative to problems on the airport surface are summarized below.

Controllers were asked to rank selected aspects of the current surface traffic operation that need improvement in the order of perceived priority. The selected aspects and resulting composite rankings in order of importance were:

Rank	Operational Aspect
1.	Misunderstanding of voice commands
2.	Rapid communications during high-density traffic periods
3.	Aircraft not exiting runways promptly
4.	Pilot delay in reporting clear of runway
5.	Pilot crossing runways without instruction to cross
6.	Pilot initiating take-off without clearance.

Controllers attributed many of the unauthorized takeoffs and runway transgressions to the misunderstanding of voice commands. They listed misinterpretation and lack of understanding, particularly of "hold" instructions as a major causal factor of such incidents. Rapid communications during high density traffic periods was a close second. These two factors are closely related since clarity and message content may be compromised during high density periods.

Individual comments were quite informative about specific airport needs, some of which were common among large groups of airports, namely:

a. A large number of airports had inadequate lighting, airport surface signs, and markings.

b. Many airports need additional taxiways.

c. Many airports need peripheral roads that would reduce or eliminate vehicular traffic crossing runways and taxiways.

d. Enforcement of vehicular traffic control on the airport surface, a driver education program, and more reliable two-way radio communications between vehicles and the tower are required.

e. Better airport security, including security fences to keep intruders off the airport surface, is needed.

Pilots were asked to rank a somewhat different set of surface traffic operations in need of improvement. These operations and the resulting composite rankings were:

Rank	Operational Aspect
1.	Rapid communications during high-density traffic periods
2.	Misunderstanding of voice commands
3.	Locating and identifying runways
4.	Communication problems with pilots from non-English speaking countries
5.	Pilots crossing runways without authorization
6.	Pilots initiating inadvertent take-offs.
7.	Pilot's difficulty in knowing whether the aircraft is clear of runway

Pilot respondants, although limited in number, expressed a deep interest in the surface traffic problem as evidenced by the detail of their comments, typical of which were:

a. Voice communications are becoming a deterrent to the safe handling of aircraft. Too many short-cuts are taken in voice communications between aircraft and the tower.

b. The most reliable safety devices are those habits and procedures that are developed through proper training and example.

c. Most airports have their individual system of naming taxiways and providing signs for them; this needs to be standardized.

d. Existing rule/procedures are satisfactory. Pilots should be trained to comply. Pilots trained in low density areas are not prepared to enter high density areas.

e. Controllers refer to runway/taxiway locations which are not clearly marked on the chart or the field. Visual ground aids should be improved.

A direct comparison cannot be made between pilot and controller groups because different overall questions were asked with only four of the total being identical. Nevertheless, two of the four common questions ranked highest in both groups. Controllers were more aware of voice command misunderstandings, ranking this first, followed by rapid communications during high-density traffic periods, which was ranked second. Pilots reversed this order - rapid communications was first and misunderstandings second - an understandable difference since pilots are on the receiving end of rapid communications. Pilots ranked locating and identifying runways in third place while controllers ranked the two questions pertaining to runway use in third place and fourth place. Both groups assigned lower priority to the remaining two questions asked in common and ranked them in the same order, with pilots crossing runways without authorization ranked as a greater problem than pilots initiating unauthorized takeoffs.

The following tentative conclusions relative to the transgression problem were drawn from the responses to the controller and pilot interview surveys.[11]

a. "Controllers and pilots indicate that radio communication problems, particularly at busy airports, prevent orderly and safe control of aircraft movements."

b. "Controllers and pilots hold strong opinions that student pilots are not sufficiently versed in radio communication procedures, phraseology, and techniques."

c. "Controllers and pilots are more concerned with hold instructions and inadvertent runway crossings than they are with unauthorized takeoffs."

d. "Controllers and pilots indicate that visual aids (signs, lighting, and markings) are inadequate at many airports and are in need of standardization."

e. "Controllers emphasize the problem of slow runway exiting, often a problem of inadequate visual aids to locating exits well in advance of arrival at the exit point."

f. "A substantial English language/dialect problem exists, particularly at airports training foreign students."

2.3 ASSESSMENT

It is of interest to assess the extent to which the prior studies discussed in this section answer the question, "What are the causes of runway transgressions?". For several reasons (to be discussed) it is concluded that these studies do not provide a satisfactory answer to the question. The major reports involved are:

(1) The NASA study (ASRS data base)

(2) The MITRE/METREK Behavioral Study (System Error data base)

(3) The VICON study.

(1) The NASA ASRS Study clearly indicated that most system errors (about 70%) were attributable to coordination problems or to deficiencies of technique. These deficiencies are characterized as part of a more general deficiency in information handling.

While such a generalization of the causes of errors is correct, it is not as useful as a particularization of the causes, i.e., a finer breakdown of coordination problems and technique deficiencies in such a way as to enable the evaluation of remedial actions. The specific problem areas pointed out in the report (clearance errors, separation assurance, taxiing) are well supported, but by anecdote rather than analysis.

(2) The MITRE/METREK Behavioral Study deals with the entire ATC operation rather than airport surface problems exclusively. The report pointed out causes apparently underlying human error for the entire ATC system. These causes apply to the runway transgression problem to the same extent that they apply to the overall system. This brings up the question: Are runway transgressions merely manifestations of pervasive system problems (such as those specified in the MITRE/METREK report) or are they the result of special factors as well? If the transgressions are influenced by special, airport surface related factors, then those factors should be identified beyond the level described in the MITRE/METREK report. It was found that the detailed documentation of pilot actions and information before and during a transgression incident is generally lacking in System Error reports, or is, at best, very difficult to extract. Thus, while the behavioral patterns noted in the MITRE report are very useful guides to remedial action, their relevance to the airport surface problem is very difficult, if not impossible to ascertain.

(3) The VICON Study was essentially an opinion survey designed to determine the acceptability of a specific remedial action. It provided, as an added benefit, some valuable insights into the transgression problem, but it cannot be considered a quantititive description of the problem. It should be noted that the priorities assigned to the contributing factors in runway transgressions are those expressed by controllers and pilots and are not derived from quantifiable criteria.

3. COMPARISON OF ACCIDENT/ INCIDENT DATA BASES

3.1 DESCRIPTION OF THE DATA BASES

For the second portion of this study, accident/incident data were obtained from formal reporting systems and screened for applicability to the analysis of runway/taxiway transgressions. These reporting systems were:

- Aviation Safety Reporting System (ASRS), maintained by NASA for the FAA (1976-78)
- National Transportation Safety Board (NTSB) accident data (1964-77)
- System Effectiveness Information System (SEIS), maintained by the FAA Air Traffic Service (1975-78)
- General Aviation/Air Carrier Accident/Incident Data System (GAADS), maintained by the FAA Flight Standards Service (1973-78)

The data contained in these systems are described briefly and compared in this section of the report.

3.1.1 The ASRS Data Base

The ASRS data base is maintained by NASA in connection with the FAA Aviation Safety Reporting Program. For each reported occurrence information is extracted from the Aviation Safety Report and categorized in accordance with the list shown in Table 3-1.

3.1.2 The NTSB Data Base

The National Transportation Safety Board maintains a file of aircraft accidents involving aircraft at U.S. airports. This file was screened for all U.S. civil aviation accidents on airports with operative towers from 1964 through 1977. The selected accidents were collisions between aircraft when one was airborne,

TABLE 3-1. ELEMENTS OF NASA ASRS DATA BASE

1. Month of occurrence
2. Location
3. Reporter
4. Types of aircraft involved
5. Types of operation involved
6. Phase of flight
7. By whom the occurrence was initiated (pilot, controller)
8. Occurrence type
9. Type of conflict
10. Outcome of occurrence
11. By whom recovery was initiated
12. Recovery actions by each participant
13. Enabling and associated factors in runway incursions

collisions between aircraft when both were on the ground, and collisions between aircraft and other vehicles on the ground. The data elements recorded by the NTSB for each accident are listed in Table 3-2.

3.1.3 The SEIS Data Base

The System Effectiveness Information System is a data base extracted from the System Error Report Forms (FAA 8020-7) submitted by FAA personnel whenever an operational error results in a separation less than the appropriate minimum as specified in FAA Handbooks and Instructions. The SEIS data elements from these forms include one direct cause and, where applicable, one contributing cause. In addition such circumstantial data as facility ID, date and time are entered. The complete list of data elements that may be encoded is given in reference 10.

3.1.4 The GAADS Data Base

The General Aviation/Air Carrier Accident/Incident Data System is maintained by the Flight Standards National Field Office at Oklahoma City. The data base contains air carrier incidents from 1975, GA incidents from 1963, and GA accidents from 1975. Examination of relevant events retrieved from GAADS showed that most were duplicates of NTSB accident files for the period 1/1/73 through 12/31/77. For this reason no further use was made of the GAADS data.

3.2 COMPARISON OF THE ASRS, NTSB, AND SEIS DATA BASES

When the three principal data bases were screened for airport transgressions , the records yielded 161 occurrences from ASRS, 77 from NTSB and 49 from SEIS. Relevant events from these data

TABLE 3-2. NTSB DATA ELEMENTS

1. Data
2. Location
3. Aircraft type and ID
4. Level of damage
5. Injuries to crew and passengers
6. Purpose of flight
7. Pilot type, age, total hours, time in type and ratings
8. Probable cause(s)
9. Remarks

bases were reduced to a common format and entered into an informa-system developed for this project. The consolidated file is called the Airport Transgression Information Management System (ATIMS).

These limited data were compared in several ways in an attempt to identify causal factors. To determine the degree of correlation among the three major reporting systems, each event was classified in five different ways:

1. Type of conflict
   a. Between aircraft - both on the ground
   b. Between aircraft - one airborne
   c. Between aircraft and other surface vehicles
   d. Single vehicle violations where no pysical conflict resulted
   e. Between aircraft - both airborne
2. Type of event
   a. Collision
   b. Near Collision
   c. Unsafe separation
   d. No actual conflict
3. Probable fault
   a. Pilot
   b. Controller
   c. Vehicle operator
   d. Other party
4. Aircraft class
   a. Air carrier
   b. Air taxi
   c. General aviation

5. Hub size where event occurred

   a. Large

   b. Medium

   c. Small

   d. Non-hub

The results of this analysis are summarized in Tables 3-3 through 3-7. From Table 3-3 it is seen that most events in the NTSB and SE reports are conflicts between aircraft on the ground, 88 and 80 percent respectively. The ASRS data are more diverse with 18% of the reports indicating no conflict, i.e., single aircraft or vehicles involved in improper movement.

Table 3-4 shows that NTSB reports accidents as expected, while SE reports are primarily concerned with unsafe separation, which is the definition of a system error. ASRS is again more diverse in the types of incidents reported.

Although the three systems cite human error as the basic cause, ASRS reports identify the controller as the probable party at fault in 50% of the reports (Table 3-5), while the NTSB associated 79% of the accidents with pilot error. System errors are wholly attributed to the controller except for one instance of equipment failure.

A comparison of ASRS and NTSB data in Table 3-6 indicates that most reported incidents involved air carriers, while most accidents involved GA. System errors are evenly divided between the two classes, with air taxis included in GA.

The only element of full agreement among the three reporting systems was found when records were analyzed on the basis of hub size. All three indicated that the problem was most prevalent at large hubs. Although this may be expected on the basis of activity, the large hubs have the most sophisticated equipment and experienced controllers in the ATC system and they are used primarily by certificated air carriers with highly qualified pilots. These factors might have been expected to reduce the possibility of transgressions at large hub airports.

TABLE 3-3. PERCENT DISTRIBUTION BY CONFLICT TYPE*

Type	ASRS	NTSB	SE
Between aircraft, both on ground	45	88	80
Between aircraft, one airborne	26	7	4
Between aircraft, and surface vehicles	3	5	10
No conflict	18	0	6
Between aircraft, both airborne	8	0	0

TABLE 3-4. PERCENT DISTRIBUTION BY INCIDENT CLASSIFICATION*

Type	ASRS	NTSB	SE
Collision	1	100	0
Near Collision	22	0	2
Unsafe Separation	59	0	92
No Conflict	18	0	6

* See footnote following Table 3-7.

TABLE 3-5. PERCENT DISTRIBUTION BY PROBABLE FAULT*

Type	ASRS	NTSB	SE
Pilot	34	79	0
Controller	50	3	98
Vehicle Operator	3	3	0
Unidentified/Other	13	15	2

TABLE 3-6. PERCENT DISTRIBUTION BY AIRCRAFT CLASS*

Type	ASRS	NTSB	SE
Air Carrier	70	14	48
Air Taxi	7	17	0
General Aviation	23	69	52

* See footnote following Table 3-7.

TABLE 3-7. PERCENT DISTRIBUTION OF REPORTS BY HUB SIZE*

Type	ASRS	NTSB	SE
Large	65	60	59
Medium	17	14	23
Small	12	14	18
Non-hub	4	12	0

*Total number of occurrences, Table 3-3 through 3-7:

ASRS 160 incidents, 1 accident(1)

NTSB 77 accidents(2)

SEIS 49 incidents

Total number of accidents/incidents 287

Notes: (1) Incidents that may have been reported by both ASRS and SEIS are not readily identifiable. The reason is that while SEIS reports the year, month, day and time of the incident, the ASRS includes only the year and month in which the incident was reported but not when it happened. Nevertheless, records which are obvious duplicates in the two systems have been consolidated in ATIMS and are counted only once.

(2) The 77 airport transgression accident reports found in the NTSB data base for the years 1964-1977 are tabulated by year and severity of injury in Appendix B at the end of this report.

The 287 accidents/incidents included in this analysis occurred at 118 different airports, which constitute 30% of the domestic, towered airports. The airports showing the greatest reported susceptibility to transgressions are listed in Table 3-8.

Attention was then directed to the examination of causal factors from the records of these reporting systems, again with the hope of finding some degree of correlation among the three sources of data. The causal factors extracted by NASA from the ASRS records are summarized in Table 3-9. The probable causes and contributing factors identified in the NTSB records are summarized in Table 3-10. A similar tabulation derived from the System Error records is shown in Table 3-11.

Comparison of these tables shows little correlation of specific causal factors among the three reporting systems. However, one general element of commonality is in evidence - human error. Human error was found to be a factor in 88% of the reported transgressions. However, human factors are not dealt with in these reporting systems with the detail that permits further analysis. The human error citations state what happened but do not provide sufficient detail as to why the errors occurred to aid in the identification of primary causal factors. System Error reports cite deficiencies in attention and judgment as prevalent causal factors; NTSB reports cite such factors as pilot failed to see and avoid other aircraft, or pilot failed to follow approved procedures; the predominant factors noted in the ASRS records are pilot technique and controller technique. Citations such as these do little to identify the factors that underlie the stated causes of a transgression.

Existing reporting systems were found to function well for their intended purposes, but the data bases derived from them do not provide sufficient information to assess the transgression problem. The utility of the information provided by the existing data bases is limited due to the lack of definitive and consistent inclusion of such factors as:

TABLE 3-8. AIRPORT RANKING BY NUMBERS OF TRANSGRESSIONS

RANK	ASRS	NTSB	SE
1	ATL-20	LGB-3	HNL-8
2	ORD-8	LAX-3	LAS-3
3	LAX-6	DET-2	BOS-2
4	PHL-6	SNA-2	CLT-2
5	STL-6	JFK-2	MSP-2
7	SFO-5	BOS-2	MKE-2
8	DEN-5	EWR-2	ATL-2
9	BOS-5	ATL-2	SDF-2
10	MIA-3	LGA-2	LAX-1
11	PIA-3	ORD-2	ORD-1
12	DFW-3	HNL-2	PHL-1
13	AUS-3	SJU-2	MIA-1
14	PWK-3	PHL-1	STL-1
15	PIT-3	SFO-1	DEN-1

AIRPORTS APPEARING IN

ALL THREE	ASRS & NTSB	ASRS & SE	NTSB & SE
ATL	JFK	STL	HNL
ORD	SFO	DEN	
LAX		MIA	
PHL		PIA	
BOS			

TABLE 3-9. AVIATION SAFETY REPORTING SYSTEM FACTORS CITED IN RUNWAY INCURSIONS*

Factor	Occurrence initiated by: Pilot	Controller
Coordination problem in cockpit	11	0
Coordination problem between aircraft and ATC	17	19
Coordination problem within tower	3	29
Coordination problem between tower and approach control	1	8
Phraseology	3	2
Language problem	3	1
Frequency congestion	3	3
Similar flight numbers	1	0
Controller technique	9	61
Pilot technique	43	11
Intersection takeoff	2	4
Landing to hold short of intersection	0	2
Airport lighting and markings	4	3
Airport, other factors including staff	3	7
ATC and controller procedures	3	8
Pilot/flight procedures	7	1
Training in progress	0	5
Environment (weather)	4	6
Workload	3	2
Fatigue	0	1
Other factors	0	2

*Source: Reference 9, page 6. In this report, as many factors as were pertinent were assigned to each of the 154 occurrences

TABLE 3-10. NTSB CAUSAL/CONTRIBUTING FACTORS
(AS CITED IN NTSB REPORTS)

Causal/Contributing Factors	PROBABLE CAUSE	CONTRIB. FACTOR
Pilot		
Failed to see and avoid other aircraft	49	0
Failed to follow approved procedures	11	2
Diverted attention from operation of aircraft	8	6
Pilot of other aircraft at fault	2	2
Inadequate supervision of flight	5	0
Misjudged clearance	16	0
Failed to see and avoid objects or obstructions	3	1
Operated carelessly	3	2
Inadequate preflight preparation	1	2
Lack of familiarity with aircraft	1	1
Exercised poor judgment	5	2
Misunderstanding of instructions	1	0
Controller		
Failed to advise of other traffic	4	5
Failed to retain complete congizance of traffic	2	0
Errors in calculations, incomplete posting of data	1	1
Incorrect application of a procedure	0	1
Issued improper or conflicting instructions	2	0
Failure to advise of unsafe airport condition	1	0
Inadequate spacing of aircraft	3	0
Vehicle Operator		
Driver of vehicle	5	0
Miscellaneous		
Congested traffic pattern	0	8
Weather	0	3
Poorly maintained ramp/taxiway surface	0	2
Airport conditions	0	2
Ground signalman	2	0
Operational supervisory personnel	1	2
Restricted vision, windshield	1	1
Sun glare	0	5
Landing gear, braking system	2	0

TABLE 3-11. SYSTEM ERROR CAUSAL/CONTRIBUTING FACTORS (AS CITED IN SEIS REPORTS)

Causal/Contributing Factors	PROBABLE CAUSE	CONTRIB. FACTOR
Attention		
Failure to retain complete cognizance of situation	9	2
Failure to maintain constant surveillance of data display or traffic	9	8
Errors in calculations, omissions and incomplete data posting	1	3
Failure to maintain constant vigilance while conducting on job training	1	0
Communications		
Errors due to transposition of words, numbers, letters, symbols	1	1
Failure to communicate clearly or concisely	1	0
Failure to positively acknowledge or verify exchanges on information	0	2
Failure to comprehend or confirm read-back information	1	2
Substandard quality of radio communications	0	1
Not specified	1	0
Environment		
Noise	0	1
Obstructions to visibility	0	1
Work area layout	0	1
Equipment		
Partial or complete equipment failure	1	0
External		
Distraction in immediate surroundings	0	2
Work load surges	0	2
Not specified	0	1
Judgment		
Checking and verifying incongruent data	1	1
Exchanging all pertinent data or information	6	3
Correctly planning control actions	10	6
Recognition of significance of a given situation	2	7
Incorrect application of a procedure	3	1
Taking positive action to correct a situation	1	0

TABLE 3-11. SYSTEM ERROR CAUSAL/CONTRIBUTING FACTORS (CONT.)

Causal/Contributing Factors	PROBABLE CAUSE	CONTRIB. FACTOR
Operations Management		
Combined positions of operation	0	1
Inadequate first line supervision	0	1
Procedures		
Use of incorrect or unapproved procedures	1	0

Location on airport

Time of day

Ceiling and visibility

Radar control

Local/ground control

Controller workload

Conflict message issued

Evasive action taken

Probable cause

Contributing factors

Summary of events

Despite these shortcomings, the recorded data do provide the only known quantitative measure of transgressions, and do so from quite diverse viewpoints.

In an attempt to augment the data obtained from the formal reporting systems, a field study was undertaken to determine whether more complete data on transgressions was available from FAA facilities around the country. The results are described in the next section.

4. REGION STUDIES

4.1 NEW ENGLAND REGION TRIAL STUDY

Field studies were initiated in late summer 1979 following a recommendation of the FAA Runway/Taxiway Transgression Steering Group (RTTSG) that TSC conduct a trial study in the FAA New England Region to determine whether information beyond that of the formal reporting systems did exist, and, if so, how it could best be obtained and utilized. These studies were coordinated by the Steering Group and conducted with the support of personnel within the New England Region. A trial study plan was structured by TSC to include interviews with Air Traffic personnel in the Region Office as well as with personnel at representative towers throughout the Region and supplemented by observing operational procedures and by monitoring communications at the selected towers. The selection of towered airports was made to provide the broadest practical spectrum of coverage, namely:

Boston MA	Large Hub
Windsor Locks CT	Medium Hub
Portland ME	Small Hub
Manchester NH	Non Hub
Beverly MA	General Aviation

Individuals contacted at the Region Office and at the selected Air Traffic Control Towers within the New England Region cooperated in the conduct of this study. The results were reported to the Steering Group in October 1979, and led to a recommendation that similar studies be conducted at three or more of the regions that showed a high percentage of reported system errors. As seen in Table 4-1, the primary candidates are the Southern, Western, Great Lakes, Southwestern and Eastern Regions.

TABLE 4-1. REGIONAL DISTRIBUTION OF SYSTEM ERRORS IN TERMINAL AREAS[(1)]

REGION	NUMBER OF SYSTEM ERRORS	PERCENT OF SYSTEM ERRORS	CUMULATIVE %
SOUTHERN	125	22	22
WESTERN	104	18	40
GREAT LAKES	97	17	57
SOUTHWEST	90	16	73
EASTERN	75	13	86
ROCKY MOUNTAIN	28	5	91
NORTHWEST	18	3	94
NEW ENGLAND	11	2	96
ALASKA	9	2	98
PACIFIC	8	1	99
CENTRAL	6	1	100

(1) Based on Reference 10, Supplement 2, Table 3-22

These errors represent reports covering the years 1974, 1975 and 1976.

4.2 EASTERN, GREAT LAKES AND WESTERN REGION STUDIES

Following the New England Region trial study, similar studies were undertaken in the FAA Eastern, Great Lakes, and Western Regions beginning in February 1980. Documentation was prepared by the Runway/Taxiway Transgression Steering Group and forwarded to the selected FAA Region Offices to familiarize them with the study and to indicate the type of support to be requested of them. Representatives of the RTTSG then met with representatives of the Offices of Flight Standards, Air Traffic, and Airports in these regions to review the status, plans and the role of the regions in meeting the study objectives. A study team representing these offices was formed in each of the selected regions to evaluate the problem at three or more intraregional airports. The selected airports were:

Eastern Region	Kennedy International (JFK) Philadelphia International (PHL) Teterboro, N.J. (TEB)
Great Lakes Region:	O'Hare International (ORD) Indianapolis International (IND) Pal-Waukee, Ill. (PWK)
Western Region:	Orange County, Cal. (SNA) Burbank, Cal. (BUR) Van Nuys, Cal. (VNY) San Francisco International (SFO) Los Angeles International (LAX)

The studies in each region included discussions with the FAA individuals engaged in airport planning, management and air traffic control, with FAA field offices that influence airport operations,* and with pilots. Physical characteristics of the selected airports were surveyed and facilities noted. Operations were observed and communication frequencies monitored. Problem

*These offices included:
- General Aviation District Offices (GADO)
- Air Carrier District Offices (ACDO)
- Air Carrier Inspectors (ACI)
- Principal Operating Inspectors (POI)
- Accident Prevention Specialists (APS)

areas were identified and possible remedies noted. Reports were provided to the RTTSG following the regional studies.

4.2.1 Airport Visits

Visits were made to the principal airports in these three regions by the RTTSG representatives to witness operations and to learn first hand, through discussions with tower personnel, FAA airports personnel, and airport management personnel, the problems peculiar to Kennedy, O'Hare, and Los Angeles Airports. Visits were also made to the LaGuardia and Van Nuys Airport. This experience provided valuable insight as to the unique operations, physical characteristics, and facilities at these airports and provided a helpful frame of reference for the understanding of the region reports. Some observations from three of these visits follow:

(1) The tower personnel at Kennedy Airport (JFK) believe that transgressions do occur and that they are more prevalent than formal reporting systems would indicate. Communications and runway configuration were identified as general causal factors. The specific problem of takeoffs from intersecting runways combined both factors. On occasion, pilots awaiting intersection takeoffs have anticipated or misunderstood clearance or hold instructions and entered the active runway in front of traffic rolling from the runway end. A survey of the airport noted some non-standard signs and an extremely complex physical configuration of the runways and taxiways. That complexity can lead to confusion was vividly demonstrated during RTTSG observation of night operations by the disorientation of an air carrier pilot. The pilot, who had operated from JFK on several occasions, reported that he could not find the active runway. The tower ultimately had to send a "follow-me" vehicle to lead him to the runway. The RTTSG noted that, in a similar circumstance, another pilot might very well continue moving with the full expectation that the tower would correct him should he err. During the monitoring of ground and local control frequencies a (foreign) language problem was in evidence. Instances of non-standard phraseology and poor diction were also noted.

(2) Chicago O'Hare (ORD) is the busiest airport in the world with some 170 operations in the peak hour. However, the controllers see this as manageable and pride themselves on their proficiency in expediting traffic. The biggest problem, from their perspective, is the lack of sufficient gates to accommodate all the traffic they can handle. The tower chief at ORD indicated that transgressions have been a problem, more so than reported. The RTTSG surveyed the airport after an overnight snowfall and found most of the runway/taxiway markings obliterated by the snow remaining after plowing. Many of the runway identification signs were also snow-covered and unreadable, some signs were missing and some non-standard signs were observed. It was also noted that runway identification signs were not located at taxiway hold lines - each being subject to a different FAA Standard.

(3) Informal discussions with tower personnel at Los Angeles (LAX) indicated that transgressions have been a problem, again more so than reported. Controllers believed that the primary causes of problems at this airport were language difficulties and the lack of adequate training of pilots, which lead to excessive communication loading. Transgressions have occurred primarily in the gate area due to congestion and restricted movement routes about the satellite terminals. However, they have also occurred at runway/taxiway intersections under conditions of limited visibility. LAX has an ASDE-2 which is used at night and when visibility is poor. This system reportedly is not very reliable and is out of service most of the time. Congestion in the gate areas is expected to worsen with the construction of a new satellite terminal which will interfere with the existing traffic routes. A survey of the airport surface noted the congestion about the terminals, a lack of runway identification signs, and difficulty in identifying taxiways.

4.2.2 Study Team Findings

The Region study teams found evidence of transgressions at every airport surveyed, many of which have gone unreported. Findings on this subject were summarized in the Eastern Region report:[14]

"Although the scope, as perceived by different groups and individuals, varied, the consensus from the interviews confirmed that a runway/taxiway transgression problem does exist. Further, an almost unanimous opinion held that only a very small percentage of transgressions are reported. The reasons for nonreporting exactly paralleled those given in the Washington team briefing*, i.e., marginal violation, personal feelings, unawareness/dismissal, learning experience, complexity of situation. However, perhaps the single most important factor centered on time. That is, the inability of the controller to take time to document the incident during heavy traffic periods, as well as the time involved in formalizing the incident for Flight Standards. This, of course, requires gathering statements, making re-recordings, and transcripts."

"All controllers interviewed expressed willingness to document transgressions if a simplified format, preferably informal, were available. The majority felt that the controller should have the discretionary authority to determine, on the spot, which transgressions should be reported. Obviously this is a request for formal recognition of this authority since in fact it is being widely exercised currently." This point of discretionary authority for reporting was echoed emphatically in the Western Region report.[16]

Some of the more pertinent observations made in the course of these studies are noted below. The Eastern Region noted:[14]

"1. The Ground control position is generally associated with taxiway and runway transgressions. Historically, ground control is a controller's first position of qualification.

*The trial study, as reported in Section 4.1.

We therefore conclude that this position is being operated with the lowest skill and experience level of all the control position within a tower.

2. Most air traffic facilities utilize only one ground control position with little regard to workload (1 aircraft or 60 aircraft on the frequency), weather conditions, runway configurations, or daylight or night time hours. This can result in less attention being paid to individual aircraft, a faster rate of speech which can result in pilot confusion and frequency congestion resulting in partially "cutout" or blocked transmissions.

3. Controllers reiterated that pilots do have problems following the taxi route to the runway. Contributing factors could be language, signing, experience, controller instructions and rate of speech, airport layout, pilot experience level, etc. The final safeguard of visual confirmation by the tower was severely impaired by the combinations of distance, darkness, size of aircraft, and ambient lighting behind the control area.

4. Several past transgressions, both reported and unreported have occurred because of a breakdown in communications between the ground and local controller. A review of the state of the art of an advancement of technology which will eliminate the verbal coordination for every runway crossing would be a big aid in reducing or eliminating this type of transgression.

5. It was generally recognized that much of the aviation communication process is based on anticipated actions. The controller anticipates what the pilot should do. The pilot anticipates what the controller will say, what the clearance should be. We believe that this occurs to the extent that transgressions occur because of what is anticipated rather than what actually transpires. Routine sets this trap."

The Great Lakes Region noted that:[15]

"1. Adverse weather conditions can be a prime factor in causing transgressions. Adverse weather can create traffic build-up, cover runway and taxiway markings, and make it impossible to see signs.

2. Airport security at non-certificated airports is a major problem. Ground vehicles are operating on active movement areas without being controlled by airport authorities."

And the Western Region stated:[16]

"1. In general, runway transgressions/encroachments, although they do occur at General Aviation airports, are not considered a major hazard by Air Traffic Control. This would account for the many incidents that are not being reported. The probable reason for not considering the transgression situation a problem at General Aviation airports is due to the separation margin between small-type aircraft which precludes any imminent danger. We believe, though, that this transgression problem should be addressed at General Aviation airports as well as major air carrier airports to ensure pilot compliance with nontransgression rules at large hub airports where transgressions are a major problem and could create a hazard. This is mentioned because, at joint-use airports, the larger percentage of encroachments are caused by General Aviation pilots due to lack of training in the purpose of hold lines and tower procedures.

2. The controllers' ability to call the correct aircraft number is hampered by the advent of the small "N" numbers on the aircraft. This is backed up by the information submitted on the air traffic survey sheets for each facility inspected.

3. In spite of the active work of the Accident Prevention Specialist (APS) Program there is, in general, a lack of interest in the flying community in the transgression problem and in the safety program in general. In most cases the APS will send out announcements of pilot meetings and at most 10% of the pilot population will attend. It is recognized that many of the pilots in a metropolitan area are also in the airline business and have their accident prevention meetings through their company or ALPA groups. Other pilots in so-called professional executive, business, or certified flight instructor categories apparently feel their position or experience is such that a flight safety seminar would not be productive for them. There is also the general aviation pilot who will not attend any meetings, regardless of how attractive and timely the scheduled program may be."

In their concluding summary, the Eastern Region stated:

"We believe that the single most important element to reduce transgressions is standardization. Standardization of terminology, signing, configurations, communications and procedures should significantly reduce transgressions. Where required, enforcement in all areas, Flight Standards, Airports, and Air Traffic, should be used."

5. ANALYSIS OF RUNWAY TRANSGRESSION REPORTS

The preceding sections of this report have reviewed the literature, prior studies, existing data bases, and three regional studies dealing with the question of runway transgressions. In an attempt to gain more explicit information, further analysis was made of the Aviation Safety Reports and the NTSB accident data. Attention was restricted to occurrences in which at least one aircraft was (1) on or immediately over an active runway, or (2) leaving or entering an active runway. This selection eliminated ramp, apron and taxiway incidents, which have less potential to create serious damage, injuries or fatalities.

Each relevant ASRS report from July 1, 1976 to June 30, 1978 as well as all NTSB accidents from January 1, 1964 to December 31, 1978 were reviewed and a set of data elements was developed that makes possible a unique characterization of each reported occurrence. These elements were grouped under the following headings:

I. Type of Incident or Accident

II. Phase of Flight or Location on the Airport Surface

III. Type of Aircraft or Other Vehicle

IV. Errors and Factors

The last group of elements was organized into an "error tree", and all the elements were coded for easy analysis. The coded data elements are listed in Appendix A.

To classify each of the 166 reports, one and only one code was selected from each list and assigned to each occurrence on the basis of the reported information. Codes from the lower levels of the hierarchy were assigned only when the available information justified their use. In many cases coding decisions required subjective interpretation, and in a few cases the assignment of a cause or factor could not be made.

5.1 WHAT IS A 'CAUSE'?

It is convenient to distinguish three levels of detail in describing the 'cause' of an airport transgression. At the first level are circumstantial causes, such as the location on the airport and the operation being carried out by the aircraft. In Appendix A, the circumstantial causes are contained in the data elements listed under "Phase of Flight/Location on Surface", one of which is assigned to each vehicle involved.

At the next level of detail are the errors/factors. These data elements simply identify which part or operation of the aircraft-pilot-airport-ATC system failed to perform properly. They are, in other words, a list of possible malfunctions of specific links in the system.

At the third, and deepest level of detail, lie the "true causes" of the occurrence. They may be described generally as the reasons underlying the second-level malfunctions defined above. These underlying reasons include the "error elements" referred to in the MITRE report[10], i.e., behavior patterns that lead to system errors or malfunctions. In brief, then, the three levels of cause are:

(1) the circumstances of the occurrence

(2) the specific malfunctions (system error)

(3) the reason for the malfunction (underlying cause)

Appendix A and the analysis of this section are based primarily on 'system errors', rather than on 'underlying causes'. In some categories, such as C6 (Controller failed to transmit instruction correctly), the system function involved is more explicit than in others, such as C1 (two or more aircraft or vehicles cleared to the same active runway). Thus, the categories of Appendix A are more accurately described as 'system errors' of varying levels of detail, rather than as 'underlying causes'. There are two reasons for this approach.

First, and primarily, are the reports themselves from which the causes are assigned. While it is usually possible to determine from a narrative or report that a certain error occurred (e.g., the pilot crossed the runway without a clearance), it is not usually possible to extract from the narrative the underlying cause for the error (i.e., to answer the question "why did the pilot cross the runway without a clearance?"). The difficulty is usually that the report was submitted by someone other than the transgressing pilot (or controller), and the reporter has no way of knowing the underlying cause. Further, NTSB cause/factors seldom go beyond the objectively determined action or omission to ascertain the underlying causes. Although such an analysis is not impossible, it requires an investigation beyond that which can be achieved with available reports. In a few cases, however, the reports did give some insight into basic causes, and what can be extracted from such cases will be discussed. No statistical significance can be attached to them, however, since the sample size is too small.

A second reason for employing a list of 'malfunctions' rather than 'real causes' is that a corrective change in the system sometimes may be made before the underlying causes are understood. In some cases this may be done by (1) instituting a more reliable procedure or equipment for the faulty element, or by (2) adding redundancy by an additional procedure or equipment. Such system level cures may be evaluated with the help of a suitable error/factor list such as Appendix A contains, but only if a set of candidate modifications is specified. Analysis of the historic system error reports could then set upper limits to the reduction of system errors achievable by each candidate modification. The advantage of such an approach is that it works with available data and does not require the identification of underlying causes.

5.2 ERROR SOURCE VS REPORTING SYSTEM

5.2.1 General Features

It was previously noted (Table 3-5) that ASRS reports identify the controller as the source of error in 50% of ASRS cases and the pilot in 34 percent, while NTSB reports cite the controller in only 3% of NTSB cases and the pilot in 79%. This same pattern holds in the present analysis, in which only incidents on or immediately above an active runway are considered. Table 5-1 shows that, for the restricted set of incidents, approximately the same distribution of pilot/controller error exists in both the ASRS and NTSB reports as in Table 3-5.

The excess of pilot versus controller errors as reported by the NTSB compared to the ASRS is traceable to the fact that 60 percent of the NTSB occurrences involve general aviation aircraft compared with only 23 percent for the ASRS (Table 5-2). The effect of this imbalance is made clear by a simple calculation. If the occurrences attributed to pilot error or controller error were to be separated by aircraft class, a new set of percentages (P) could be found in accordance with the following matrix:

	AC+AT	GA
Pilot error	P_{PA}	P_{PG}
Controller error	P_{CA}	P_{CG}

where P_{PA} is the percentage of pilot error in air carrier or air taxi (AC+AT) occurrences, P_{CG} is the percentage of controller error in general aviation (GA) occurrences, etc.

These percentages (or fractions) cannot be obtained directly from the data since the public ASRS reports do not identify the aircraft class. However, the desired fractions can be related by virtue of the data in Tables 5-2 and 5-3. For the ASRS data:

$$0.77\ P_{PA} + 0.23\ P_{PG} = 0.32$$

$$0.77\ P_{CA} + 0.23\ P_{CG} = 0.51$$

For the NTSB data:

$$0.40\ P_{PA} + 0.60\ P_{PG} = 0.60$$

$$0.40\ P_{CA} + 0.60\ P_{CG} = 0.25$$

TABLE 5-1. DISTRIBUTION OF TRANSGRESSION REPORTS AMONG ERROR SOURCES AND REPORTING SYSTEMS.

	Reporting System		
ERROR SOURCE	ASRS[1]	NTSB[2]	BOTH
Pilot	46 (32%)	12 (60%)	58 (35%)
Controller	74 (51%)	5 (25%)	79 (47%)
Pilot or Controller*	21 (14%)	0 (0%)	21 (13%)
Other	5 (3%)	3 (15%)	8 (5%)
	146 (100%)	20 (100%)	166 (100%)

*Error attributable to either pilot or controller; narrative inadequate to determine which.

(1) ASRS: Transgression incidents
(2) NTSB: Transgression accidents

TABLE 5-2. DISTRIBUTION OF TRANSGRESSION REPORTS AMONG AVIATION CLASSES AND REPORTING SYSTEMS.

	Reporting System		
AVIATION CLASS	ASRS (1)	NTSB (2)	BOTH
Air Carrier (AC)	70%	24%	57%
Air Taxi (AT)	7%	16%	9%
General Aviation (GA)	23%	60%	33%
Total	100%	100%	100%

(1) Taken from Table 3-6, column 1.

(2) Based on aircraft involvements in accidents or incidents reported. Each aircraft in an accident or incident is counted separately.

TABLE 5-3. ANALYSIS OF ERROR SOURCES VS REPORTER

Error Source	Number Reported By Pilots	Controller	NTSB	Other	All
Pilot	27	18	12	1	58
Controller	48	26	5	0	79
Airport	1	0	1	1	3
Equipment	0	0	2	0	2
Uncertain[1]	20	1	0	3	24[1]
All	98	45	20	5	166

[1] All cases of uncertain error source were either controller/pilot (21 cases) or controller/airport (3 cases).

From this set of equations the four unknowns turn out to be:

$P_{PA} = 0.15$ $\qquad$ $P_{PG} = 0.90$

$P_{CA} = 0.67$ $\qquad$ $P_{CG} = 0.00$

Thus, the results indicate that in the combined data bases 90 percent of the general aviation involvements were attributed to pilot error, none to controller error (the remaining 10 percent were indeterminate). On the other hand, for air carrier/air taxi involvements 67 percent could be attributed to controller error and only 15 percent to pilot error (18 percent indeterminate). From this result it is clear why the NTSB reports, which include a preponderance of general aviation accidents, attribute most of the reported occurrences to pilots.

If the ASRS and NTSB reports contain a representative sample of a much larger number of transgressions that took place but were not reported over the past 20 years, the message is unequivocal. If the pattern of the past persists, about 90% of future transgressions involving general aviation are likely to be due to pilot error; about 67% of those involving air carriers/taxis, are likely to be due to controller error.

Underlying these results is the assumption that the probability of a pilot or controller being at fault in a runway transgression is the same whether the occurrence was an accident (reported by NTSB) or an incident (reported through ASRS), and depends only on whether the aircraft was an aircarrier/taxi or a general aviation vehicle. This is a plausible assumption because the difference between an accident and an incident is often a matter of a few hundred feet, which distance is not likely to be related to whether the fault lies (according to the ASRS report) with the controller or with the pilot. Further, since air carrier and taxi pilots are on average more proficient than general aviation pilots,* the type of aircraft <u>is</u> likely to affect the distri-

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*Based on accidents per vehicle mile, Reference 13, Chart 17 and Chart 23.

bution of reported fault between pilot and controller.

5.2.2 Specific Details

One may suspect that for the ASRS, pilots tended to submit reports that identified the controller as the source of errors, and vice-versa. A glance at Table 5-3, however, will remove such suspicions. The controller was judged to be the error source in 50 percent (48/96) of the pilot reports and 56 percent (26/45) of the controller reports, hardly a substantial difference. The pilot was judged to be the error source in about 28 percent (27/96) of the pilot reports, and 39 percent (18/45) of the controller reports. This discrepancy, however, may be related to the fact that in about 20 percent of the pilot reports it was not clear what the error source was (See footnote to Table 5-3), while such uncertainty was found in only 2 percent of the controller reports. Thus one may conclude that:

(1) Both pilot and controller reports identify the controller as the error source in about 50-55 percent of the ASRS runway transgression reports examined, and

(2) Pilot reports, as a group, tended to be less explicit than controller reports in identifying error sources.

5.3 ANALYSIS OF ERROR SOURCES

When considerations of reporting are set aside, it is possible to analyze the errors committed in the 166 cases of runway transgression that were examined. Figure 5-1 shows the resulting overall breakdown. It must be emphasized that this breakdown results from the assignment of error sources based on an interpretation of the available incident reports. These interpretations are necessarily subject both to inaccuracies, omissions and distortions in the reports and to errors in interpretation.

Figure 5-1 shows that the predominance of human error reported in Reference 10 and 12 and in Section 3 for system errors and air-

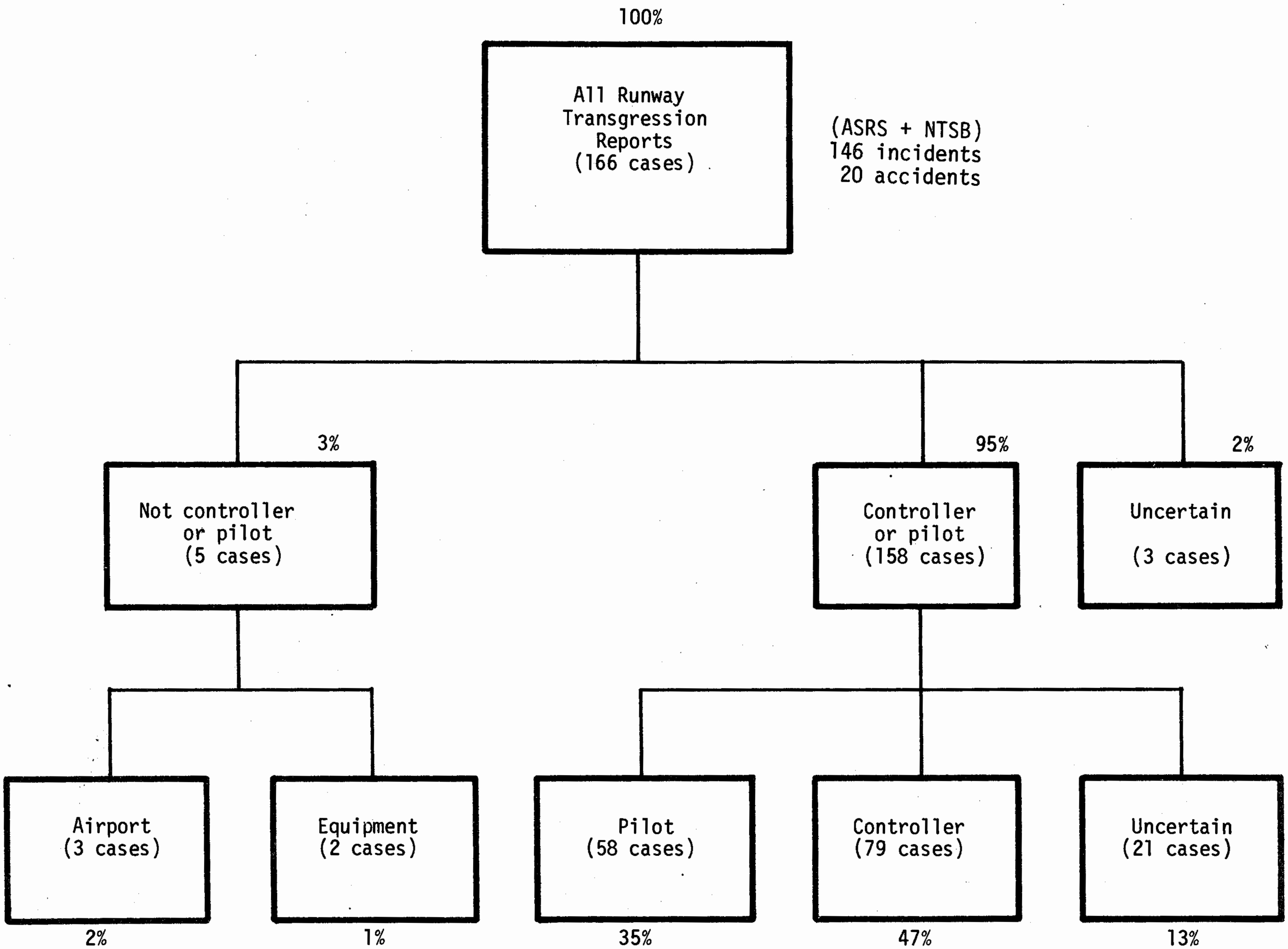

FIGURE 5-1. CLASSIFICATION OF SYSTEM ERRORS AS DETERMINED FROM RUNWAY TRANSGRESSION REPORTS.

port transgressions, holds also for the restricted set of 166 runway transgressions examined. Errors committed by pilots or controllers accounted for 158 or 95 percent of the 166 cases. Of the 8 remaining cases, all but 2 could also be attributed to human errors. (See Table 5-3) The 2 remaining cases were attributed to equipment failures, but it is equally plausible to attribute the errors to the human being (pilot) who did not adequately compensate for the equipment failure.

Of the 158 cases of pilot or controller error, 58 were assigned to the pilot, 79 to the controller, and 21 could not be assigned with certainty to one or the other. (Nineteen of the 21 were based on pilot reports). An analysis of pilot and controller errors yielded the results shown in Figures 5-2 through 5-5.

5.3.1 Pilot Errors

The predominant pilot error was to proceed without proper clearance when clearance was required. In about half of the cases, (16/29) the aircraft entered an active runway without clearance; in the other half (13/29) the pilot landed the aircraft or took off without proper clearance. (See Figure 5-1) The other sources of pilot error were substantially less significant (See Figure 5-3).

In the great majority (26/29) of reports classed as "Proceeded without Clearance" it was virtually impossible to extract from the narrative the exact system error with enough certainty to assign it to one of the other, more specific, categories. The three cases in which a more specific error was suggested (but not clearly stated) were:

- pilot may not have been English-speaking
- pilot may have mistaken the clearance given to another aircraft as given to him
- pilot may not have heard the message.

These cases might have been classified as "Failed to Understand Message" if more evidence were available. The remaining 26 of the 29 cases simply could not be described more accurately because

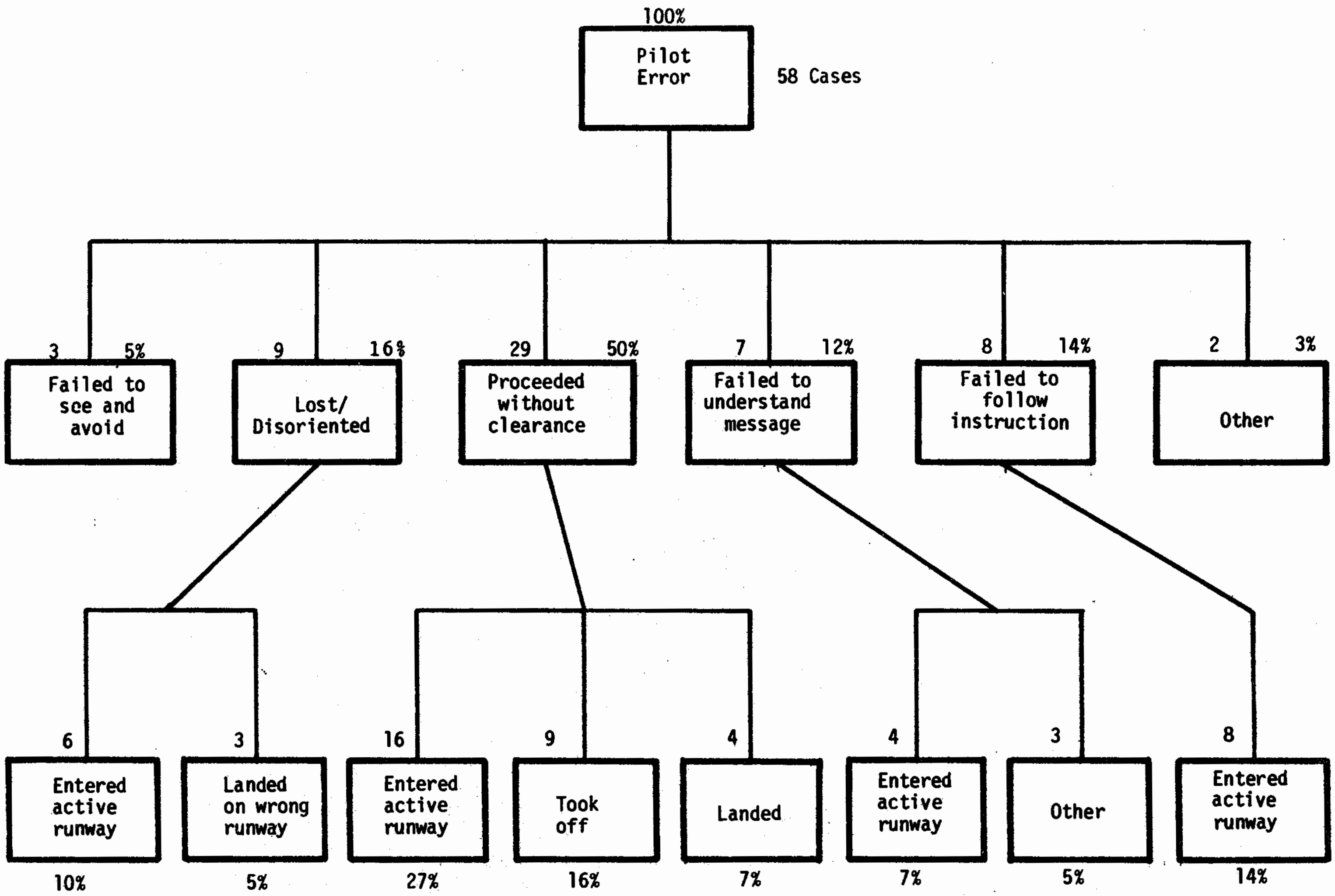

FIGURE 5-2. CLASSIFICATION OF PILOT ERRORS

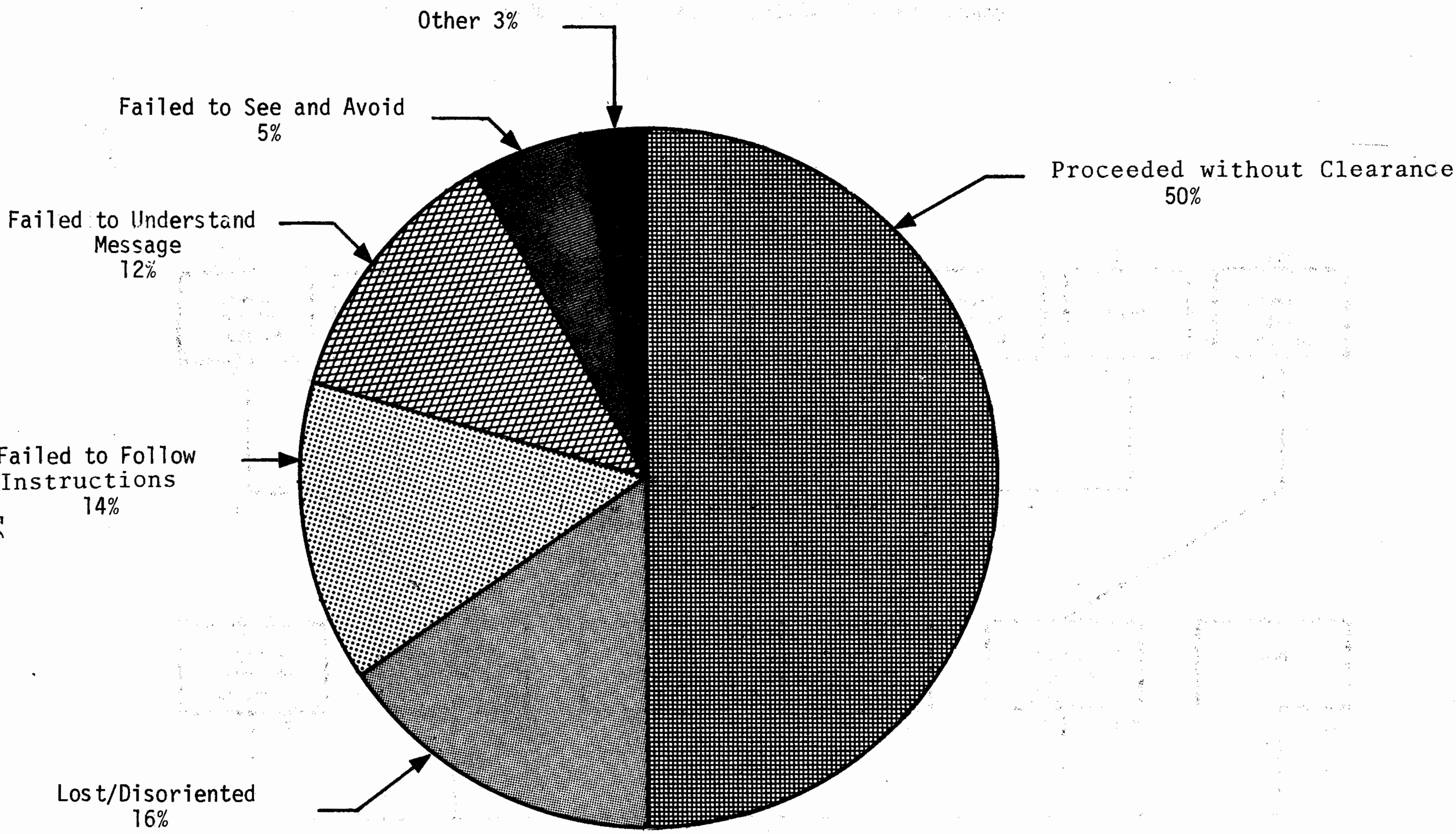

FIGURE 5-3. MAJOR PILOT ERROR CATEGORIES (58 CASES)

the reports were made by someone other than the pilot to whom the error was assigned.

In the 8 cases of pilots who received, but failed to follow an instruction, two prominent reasons were given:

- habit; the pilot followed the instruction he was accustomed to receive, rather than the one he actually received (2 cases)
- distracted by other cockpit duties (2 cases)

The 9 cases of pilots who became lost or disoriented offer little doubt about the cause of the transgression. In 6 of the 9 cases the pilot, sometimes with the aid of the controller, came to believe his aircraft was elsewhere than where it actually was and thereby crossed onto an active runway. In the other three cases the pilot landed (or attempted to land) on the wrong runway.

There were 7 cases in which pilots failed to understand the controller's message. In 2 of these, the pilot mistook someone else's clearance for his own. In two other cases, the pilot heard the wrong runway number, and in another case he lost that part of the message that contained the "hold short" instruction.

5.3.2 Controller Errors

A breakdown of controller errors as extracted from the reports is shown in Figure 5-4. In addition to the 79 cases definitely assignable to the controller, there were 24 cases in which it was not certain whether the error should be attributed to the controller, the pilot or the airport. (See boxes at upper left and upper right of the Figure).

Of the 79 cases attributable to the controller, 7 were classified as errors in the instruction itself and 5 as due to faulty coordination between the ground controller (GC) and the local controller (LC). However, the overwhelming majority of cases (65) were classified as arising from conflicting clearances. The percentage breakdown at this first level is shown in Figure 5-5.

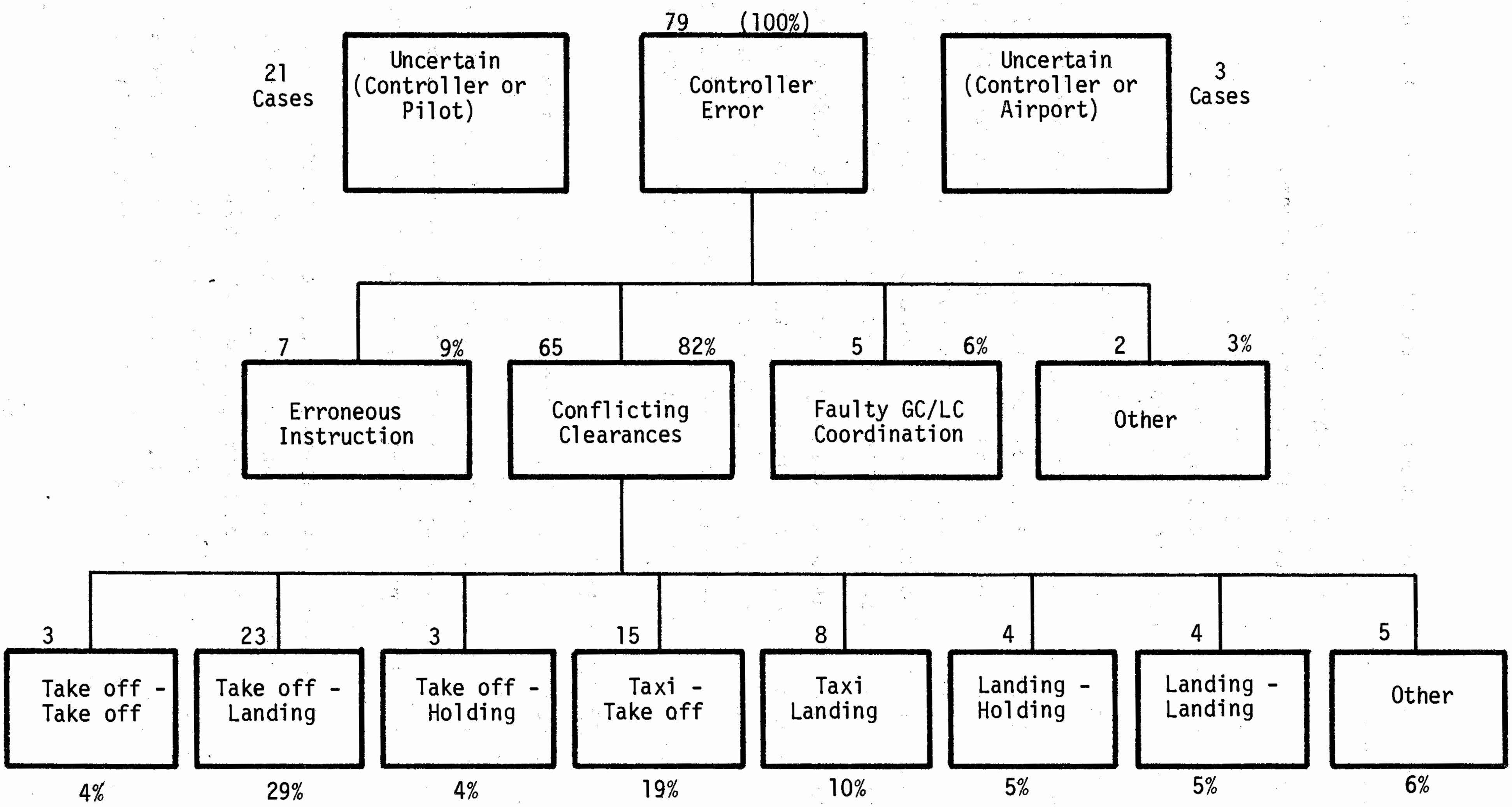

FIGURE 5-4. CLASSIFICATION OF CONTROLLER ERRORS

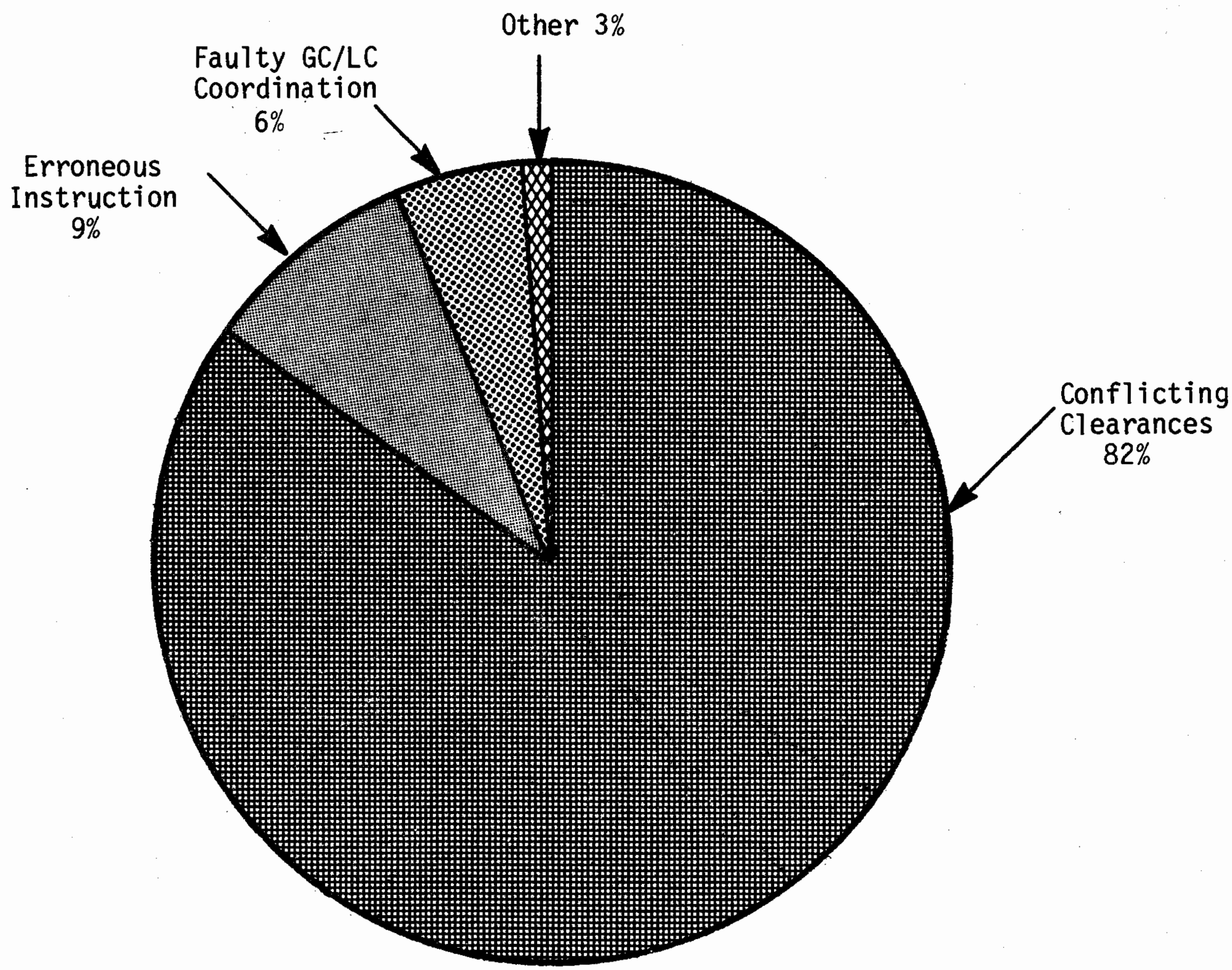

FIGURE 5-5. MAJOR CONTROLLER ERRORS (79 CASES)

Each of these categories is analyzed further in the following sections.

1. Erroneous or Incomplete Instruction

The 7 cases grouped under this heading illustrate several features of an erroneous instruction. The 3 incomplete instructions all lacked the same information: what the pilot should do after landing and turning off the runway. Generally, LC failed to tell the pilot how far or where to go or where he should hold, after the turn-off. In these 3 instances:

- o LC cleared pilot to land on 25L but failed to warn him to hold short at 25R after turning off. 25R was active at the time.
- o Tower instructed pilot to exit at the high speed turnoff, but failed to warn him of traffic after that point.
- o Pilot cleared to land, turn off at taxiway Romeo, and contact GC. However, the aircraft crossed an active runway soon after turning off at Romeo and before contacting GC.

The tendency is strong for both LC and the pilot to concentrate on landing and turn-off, and to relegate clearance after turn-off to GC. About a dozen cases were found to illustrate the hazards inherent in this phase of operation.

Ambiguity in instructions occurred because of non-standard phraseology: "round the corner of the runway and don't plan on stopping", or because of deceptively simple phraseology: "taxi to the gates", which by implication clears the aircraft across an active runway.

The final two cases of erroneous instructions could not have been avoided even with the most meticulous phraseology. In one case both the supervisor and a trainee transmitted a runway number that, upon reflection, they realized was not the one intended. In the other case the controller mis-identified the aircraft as being airborne, and issued a series of vectors which the pilot interpreted as taxi instructions.

2. Faulty GC/LC Coordination

In 5 cases the error was attributed to faulty communication between ground and local control. All were similar in that GC (or, in one case, LC) taxied an aircraft onto an active runway without concurrence of the LC (or GC). It may be significant that two of the 5 incidents involved a trainee in the GC position.

3. Conflicting Clearances

Sixty five of the 79 controller errors were classified as conflicting clearances. They are distinguished from cases of "erroneous instruction" in that they involve two instructions or clearances which, taken individually, are not erroneous, but which, taken together, caused a conflict or violation of separation regulations. In general, the available reports of conflicting clearances contain limited detail and hence are only partly informative as to underlying causes. Nevertheless, the large number of cases made it advisable to analyze this group further.

Since the conflicting separations in these cases varied from a mile or more to several feet, a judgement had to be made in each case as to whether the clearances were in direct, immediate conflict at the time of issuance or whether they were normally nonconflicting instructions that resulted in a reduction of separation below specified minimums. The classification, although sometimes subjective, nevertheless gave a rough measure of the seriousness of the situation at the time the clearances were issued.

The 65 cases were also analyzed by the phase of flight of the two aircraft involved,* according to the scheme given in Appendix A. The breakdown is shown in the bottom row of Figure 5-4. The results were then further tabulated by extent of conflict (i.e., direct conflict vs substandard separation), as shown in Table 5-4.

*In two cases one of the 'aircraft' was an airport vehicle.

TABLE 5-4. ANALYSIS OF CONFLICTING CLEARANCES
(65 Cases)

Phases of Operation	Number of Cases in Each Category: Directly Conflicting Clearances	Eventually Conflicting Clearances*	Total
Takeoff/Landing			
Takeoff-Takeoff	2	1	3
Takeoff-Landing	8	15	23
Landing-Landing	2	2	4
Landing-T and G**	1	2	3
	13	20	33
Taxi/Other			
Taxi-Takeoff	14	1	15
Taxi-Landing	6	2	8
Taxi-Taxi	1	0	1
	21	3	24
Hold/Other			
Hold-Takeoff	3	0	3
Hold-Landing	3	1	4
Hold-T and G**	1	0	1
	7	1	8
All Phases	41	24	65

*Clearances that lead to sub-standard separation.
**Touch-and-Go or low flyby.

Several features of Table 5-4 are worth noting:

(a) As many conflicting clearances occurred with both aircraft in Takeoff/Landing phases as with one aircraft on the ground (Taxi or Hold Phases). (33 vs 32)

(b) Most of the conflicting clearances delivered when both aircraft were in takeoff or landing phases resulted in reduced separation rather than direct conflict. (20 vs 13).

(c) Most clearance conflicts with one aircraft in a taxi or hold phase were direct conflicts (28 vs 4).

(d) The largest single category of direct conflicts is the "Taxi-Takeoff" combination. (14).

One conclusion to be drawn from the above observation is that about one-third of the 65 cases (20) are runway transgressions only in the technical sense; they are more accurately described as violations of landing and takeoff separation standards. An additional 20 percent (13 out of 65) also involved takeoffs and landings but represent more direct clearance conflicts.

The remaining 32 cases (50 percent) are runway intrusions. They involve an aircraft taxiing or holding on or near an active runway. Of these cases, the intrusion of a taxiing aircraft on to a runway that is being used for takeoff is far more frequent (15 cases) than any other type of intrusion. It should be noted that not only are directly conflicting clearances the dominant source of error in the 32 cases of runway intrusion listed in Table 5-4, but they also constitute over 60 percent of the cases of runway intrusion found among all 79 cases that were identified as controller error.

5.3.3 Errors and Factors in Runway Intrusions

The above analysis of controller errors suggests that a clearer conclusion may be reached by considering only the runway intrusions defined in Table 5-5. To this end all 166 runway transgressions (Figure 5-1) were screened for those instances in which one or more of the aircraft were in the Taxi or Hold phase of flight,

TABLE 5-5. TERMINOLOGY EMPLOYED FOR AIRPORT TRANSGRESSIONS

AIRPORT TRANSGRESSIONS:	Improper movements of one or more vehicles on or immediately above the surface of an FAA-towered airport.
RUNWAY TRANSGRESSIONS:	Airport transgressions on or immediately above an active runway (a subset of airport transgressions).
RUNWAY INTRUSIONS:	Runway Transgressions involving at least one aircraft in the Taxi or Hold phase of flight (a subset of runway transgressions).

Note: Both accidents and incidents are included in these definitions.

including take-off entry and hold, and landing exit. Altogether 110 such cases were found. The errors and factors ascribed to these 110 cases were then tabulated in 4 groups: Pilot, Controller, Airport and Other. Table 5-6 shows the number of citations for each error or factor and the percent of times that it appears among all the factors in its group.

The percentage breakdown described above is illustrated in Figure 5-6, which is an overview of the runway intrusion problem as extracted from the reports. In the group of errors and factors attributable to pilots, the three that appear with the highest frequency include 72 percent of all pilot citations. In order of decreasing frequency, they are:

(1) Proceeded without a clearance 35%

(2) Lost and/or disoriented 20%

(3) Failed to follow a controller's instruction. 17%

In the group of errors and factors attributable to controllers, 85 percent of all cases appear in the four most frequent citations. In order of decreasing frequency, they are:

(1) Issued directly conflicting clearances 46%

(2) Faulty GC/LC coordination 14%

(3) Issued erroneous instructions 13%

(4) Maintained insufficient separation. 12%

Airport congestion is the least common factor in its group, while the presence of airport vehicles on the runways is the most common with 43 percent of the citations. It must be emphasized that the table and chart containing these results provide information only on the identifiable sources of error. In general, they cannot be used to assign causes, which are not identified in most reports.

It is possible to compare the breakdown of errors and factors related to runway intrusions (Figure 5-6) with those related to

TABLE 5-6. ANALYSIS OF ERRORS AND FACTORS IN RUNWAY INTRUSIONS (110 Cases)

Group[1]	Error or Factor	Number of Citations	Percent of Citations in Group
PILOT			
P1	Proceeded without clearance	19	35
P2	Failed to see and avoid	7	13
P3	Failed to display proper lights	1	2
P5	Lost/disoriented	11	20
P6	Failed to understand message	7	13
P7	Failed to follow instructions	10	17
		55	100
CONTROLLER			
C1	Directly conflicting clearances	32	46
C2	Insufficient separation	8	12
C3	Cleared to obstructed runway	3	4
C5	Provided inadequate information	2	3
C6	Erroneous instruction	9	13
C7	Faulty GC/LC coordination	10	14
C8	Failed to track aircraft	4	6
C9	Poor supervision	1	2
		69	100
AIRPORT			
A1	Airport congestion	2	9
A2	Airport vehicles	9	43
A3	Controller's view obstructed	5	24
A4	Airport signs, markings, lights	5	24
		21	100
OTHER			
E3	Radar reception failed	1	3
E4	Communication congestion	7	18
W	Weather; restricted visibility	6	16
X	Pilot/Controller misunderstanding	6	16
U	Uncertain	18	47
		38	100

1 See Appendix A.

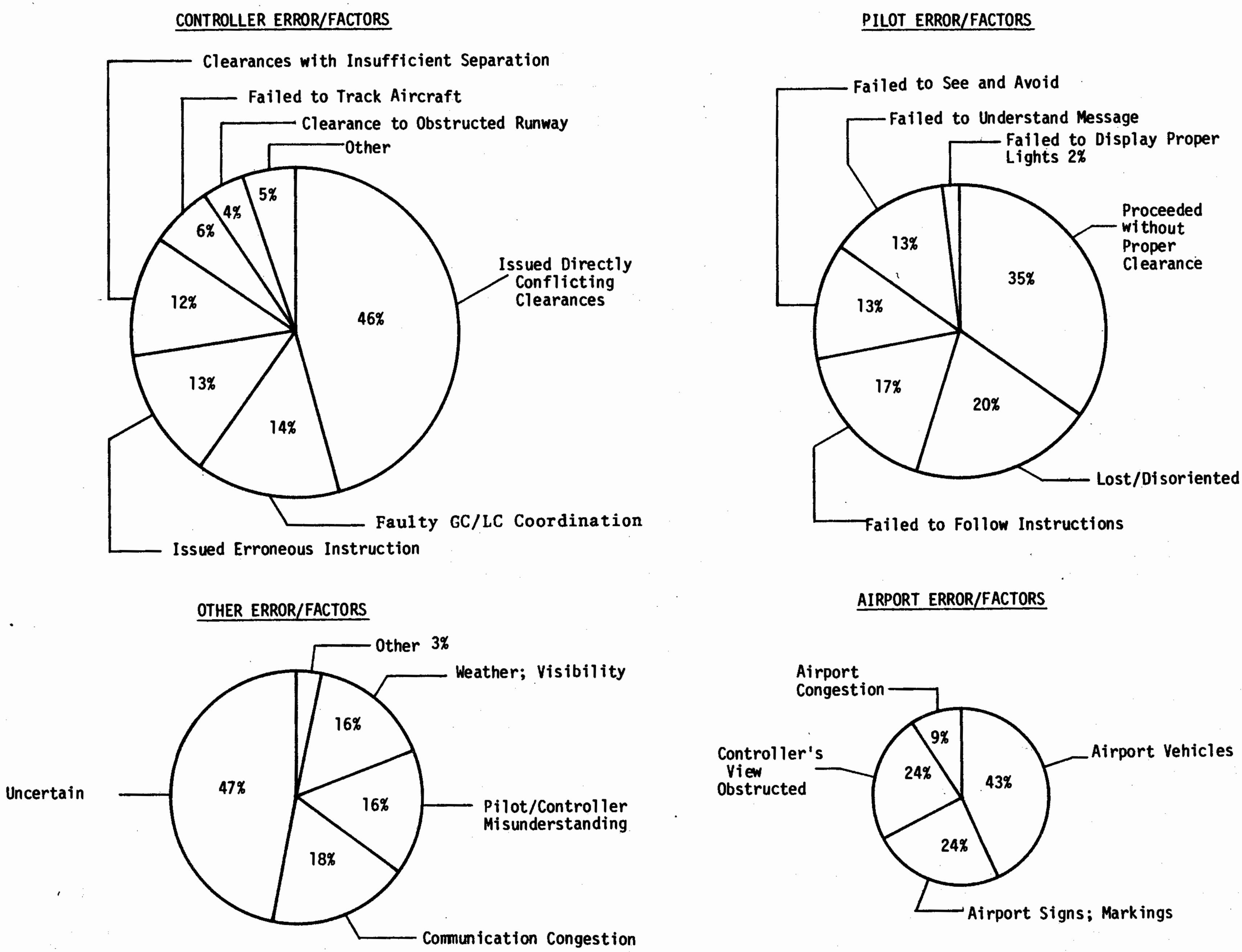

FIGURE 5-6. MAJOR ERRORS AND FACTORS IN RUNWAY INTRUSIONS (110 CASES)

all runway transgressions attributed to pilot and controller error (Figures 5-3 and 5-5). In the case of pilot errors it is seen that proceeding without clearance is less prominent in runway intrusions than in all runway transgressions (35% as opposed to 50% of the cases). Similarly, the issuance of conflicting clearances that accounts for 85 percent of controller errors in runway transgressions in general, drops to 58 percent when only intrusion cases are considered.

The reason for this shift is not difficult to find for controller errors. The excluded cases generally involve landings and takeoffs and include a large fraction of cases in which the controller issued clearances that ultimately resulted in substandard separation. The latter type of error is expected to be more common on landings and takeoffs since these operations extend over a period of time and require the controller to judge in advance whether separation will be maintained. When attention is restricted to intrusions, in which at least one aircraft is in taxi or hold, many cases of insufficient separation drop out.

The reduced prominence of "proceeding without clearance" that occurs among pilot errors when only intrusions are considered may be viewed as an increased proportion of lost/disoriented and failed to see and avoid errors among the intrusion errors. However, on the basis of the available data it seems not to be possible to fully explain this percentage shift in error sources.

6. SUMMARY OF FINDINGS

The findings of this study may be grouped under its four major headings: (1) prior studies, (2) analysis of existing data bases, (3) regional studies, and (4) comparative analysis.

6.1 PRIOR STUDIES

1. The NASA report provides an extensive description of the factors involved in airport transgressions. These factors are listed in Table 3-9. In most cases they are neither classified nor particularized in such a way as to make it possible to localize specific errors or underlying causes. For this reason the NASA study does not lend itself to the definition or evaluation of remedial actions.

2. The MITRE/METREK Behavioral Study attempts to describe in great detail the underlying causes of transgressions so as to facilitate the identification of appropriate remedies. Unfortunately, a complete documentation of the links connecting the behavioral patterns that were found with actual transgressions would be very difficult and has not yet been attempted.

3. The VICON study provided insight into some of the causes of transgressions by means of pilot and controller surveys, but the results are subjective and not quantifiable.

6.2 COMPARISON OF EXISTING DATA BASES

Comparison of the ASRS, NTSB and SEIS data bases disclosed great diversity among them in the distribution of occurrences by

- o conflict type
- o incident classification
- o probable fault
- o aircraft class.

The only common feature found among the three data bases was the distribution of occurrences by hub size.

6.3 REGIONAL STUDIES

Local studies of airport transgressions were conducted by personnel of the FAA Eastern, Great Lakes, and Western Regions. They found that incidents occur more frequently than they are reported. Numerous factors were cited as contributing to the occurrences , among which are:

- faulty communications due to various causes
- complex physical configuration
- intersection takeoffs
- non-standard signs
- pilot disorientation
- inadequate command of English by foreign pilots
- non-standard phraseology
- poor diction
- lack of gates
- snow obliterating markings
- missing signs
- communications loading
- limited visibility
- restricted movement routes
- unreliable ASDE
- difficulty in identifying taxiways
- too rapid speech due to traffic congestion
- anticipated actions by pilots and controllers
- lack of pilot/controller experience
- obstructions to visual communication
- breakdown in communication between local controller and ground controller
- poor ambient lighting behind control area
- small "N" numbers on aircraft.

The region studies were similar to the VICON project in that they helped to gather opinions from pilots and key airport personnel. While most of the factors brought out in the region studies are relevant, it is not possible to determine what relative importance should be attached to each.

6.4 ANALYSIS OF RUNWAY TRANSGRESSION REPORTS

A careful examination of 166 cases of runway transgressions from ASRS and NTSB reports disclosed three levels of causes: circumstantial, malfunctional, and underlying. Because the reports contain only very limited information about underlying causes the conclusions that follow were based primarily on circumstantial and malfunctional causes.

1. Runway transgression errors were found to be distributed as follows: 47 percent to controllers, 35 percent to pilots, 13 percent uncertain as to pilot or controller, 5 percent airport, equipment and other. Thus, over 95 percent of the cases were attributable to human error.

2. The greater percentage of pilot errors in the NTSB reports, compared to the ASRS reports, was traced to the greater percentage of GA involvement in the NTSB data. From this it was estimated that in GA incidents the probability of pilot error was 0.90 and the probability of controller error was close to zero. Conversely, it was found that for the air carrier and air taxi incidents the corresponding probabilities were 0.15 for pilot errors and 0.67 for controller errors.

3. The controller was found to be the source of error in about the same fraction of occurrences in both pilot reports and controller reports to the ASRS (50% to 55%). However, the pilot was identified as the source of error somewhat more often in controller reports than in pilot reports (39% to 28%). In the pilot reports the "uncertain" attribution is used in 20 percent of the occurrences, but in only 2 percent of the controller reports.

4. In 50 percent of the cases of pilot error, the aircraft proceeded without proper clearance. In the other half of the cases, the pilot was lost or disoriented (16%), failed to follow instructions (14%), failed to understand the controller message (12%), or failed to see and avoid (5%).

5. The issuance of conflicting clearances accounted for 82 percent of controller-attributed errors. The other controller

errors were erroneous instructions (9%) and faulty coordination between Ground and Local controller (6%).

6. Among the 65 cases of conflicting clearances about 41 were judged to involve immediate conflicts between vehicles, while 24 were judged to be cases of clearances that evolved into conditions of inadequate separation. In none of these cases did the report contain enough information to allow identification of specific errors or underlying causes.

7. Among the 65 cases, about one half (32 cases) were runway instrusions (at least one aircraft in the taxi or hold phase), and 28 of these 32 cases involved immediately conflicting clearances.

8. The analysis of errors and factors for runway instrusions showed that the pilots proceeding without clearance, and controllers issuing conflicting clearances were still the most prominent errors, as they were in the larger population of airport transgressions.

6.5 CONCLUDING OBSERVATIONS

Information that can be used to help solve the runway transgression problem can be obtained from two general sources: expert opinion and objective data. The role of expert opinion in formulating a solution to the runway transgression problem can be important. Knowledgeable users and operators of the Air Traffic System are in an excellent position to (a) identify the sources of transgression errors, and (b) suggest possible solutions. The NASA, MITRE/METREK and VICON reports represent attempts in this direction.

The role of objective data, however, is also important. The major deficiency in all work to date (including the present report) is the lack of an adequate data base that would support a quantitative evaluation of the causes of transgression errors together with proposed remedies. The work of the Atlanta Runway Crossing Committee is a case in point. Its vigorous efforts are well-balanced between the identification of the sources of error and the evaluation of solutions. The indeterminate results of their efforts, however, are very likely due to the limitation of their data to a single airport, Atlanta, both as a source of causal information and as a test bed for proposed remedies. A much larger body of data is required to establish statistically significant results.

Ideally, the data collection method should be designed in such a way as to make possible the rapid evaluation of proposed corrective measures, rather than the attribution of blame or legal responsibility. That objective is best served by a detailed account of events and actions prior, during, and immediately after the transgression. It is virtually impossible to record such information by any number of fixed-field data elements such as those used in accident reporting. In the present study a clear, accurate narrative was found to be indispensible in determining error sources and factors. Cross-checking of both pilot and controller reports with each other and with voice tapes is possible and could provide a reasonably detailed and accurate account of events. From this primary account any number of data elements may be extracted and coded. These data elements can serve the purpose of rapid screening; they would help select those narrative accounts relevant to a proposed solution. Comparing the narratives with the proposed solution could then indicate what effect the "solution" might have had on the events, and thereby, on the transgression occurrence.

A further consideration is that the notion of 'cause' is not always clear. An analysis of its possible definitions may be fruitful in the runway transgression problem. The view taken in the present study is that of a triple-level hierarchy, in which the middle level is the specific ATC functional element(s) that failed. In this view, functional elements include messages, acknowledgements, controller decision processes, and other embodiments of ATC procedures, as well as equipment.

Occasional failure of human elements in the ATC system is inevitable. A serious question then presents itself: Is system reliability improved most easily by improving the reliability of the human element, or by adding parallel elements? The question, and its answers affect the overall ATC system as well as airport surface control. The answers depend on how close to the limits of human performance the controller is presently operating in any given circumstance. The cost of redundant elements or procedures and their effect on message traffic need to be considered as well. When these 'costs' are ascertained the 'benefits' may be estimated from a case-file of transgression narratives and various solutions compared on the basis of their benefit/cost ratios. From such analysis it may be possible to determine, on a statistically significant basis, whether effective remedies lie in the direction of improved controller performance, modified procedures, redundant procedures, new equipment, or with other proposals that might arise. In the absence of such analysis and evalution, the only available courses of action appear to be either to try all reasonable suggestions or to select remedial measures on the basis of intuition, both of which might prove ineffective.

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APPENDIX A: DATA ELEMENTS AND ASSIGNED CODES

APPENDIX A: DATA ELEMENTS AND ASSIGNED CODES

I. Type of Accident or Incident

- C — Collision between two aircraft
- A — Accident involving only one aircraft
- NC — Near collision (min. separation $\leq$ 300 ft)
- NA — Near accident
- V — Violation of separation standards
- PV — Potential violation or potential accident

II. Phase of Flight or Location on Airport Surface

- TO — Take-off
  - TOA — Airborne
  - TOR — Rolling
  - TOE — Entering runway for take-off
  - TOH — Holding on runway for take-off
- LD — Landing
  - LDA — Airborne
  - LDR — Rollout
  - LDE — Exiting runway
- TX — Taxiing*
  - TXT — On taxiway or inactive runway to take-off
  - TXL — On taxiway or inactive runway from landing
  - TXR — On or across active runway
  - TXA — On apron, gate, or other area
- S — Stationary*
  - ST — On taxiway
  - SR — On runway
  - SA — On apron or other area

*Includes vehicles other than aircraft.

SE Stationary at Entrance*

- SET To taxiway
- SER To active runway
- SEA To other area

SH Holding under ATC*

- SHT On taxiway
- SHA On apron, gate or other area
- SHR On active runway
- SHER At entrance to active runway
- SHET At entrance to taxiway

III. Type of Aircraft or Other Vehicle

- GA General aviation
- AC Air carrier
- AT Air taxi
- HC Helicopter
- FA FAA aircraft
- ML Military
- VH Vehicle other than aircraft
    - 1 Passenger auto or bus
    - 2 Snow removal equipment
    - 3 Runway sweeper (not snow)
    - 4 Truck
    - 5 Tow
- PP Persons
- O Other object

IV. Errors and Other Factors

- C Controller
- T Trainee
    - 1 Two or more aircraft or vehicles cleared to same active

*Includes vehicles other than aircraft.

runway or on conflicting runways at the same time with insufficient separation

First aircraft

11 Taking off
12 Landing
13 Taxiing or driven across or onto runway
14 Holding
15 Touch-and-go
16 Flyby

One additional digit for each additional vehicle involved.

2. Two or more aircraft or other vehicles cleared to same taxiway at same time or with insufficient separation

3. Cleared to operate on runway with obstruction unknown to controller

   31 Other aircraft on runway
   32 Other vehicle on runway

4. Cleared to taxi with obstruction on taxiway unknown to controller

   41 Other aircraft on taxiway
   42 Other vehicle on taxiway

5. Failed to provide adequate information to pilot

   51 Inadequate traffic advisories
   52 Inadequate runway-in-use advisories

6. Failed to transmit instruction correctly

   61 Improper operation of communication equipment
   63 Transmitted one or more words incorrectly in message

      631 Standard phraseology
      632 Non-standard phraseology

(Errors and other Factors, cont.)

64 Transmitted erroneous, ambiguous, or incomplete message
- 641 Standard Phraseology
- 642 Non-standard phraseology

65 Garbled speech, - failed to enunciate clearly

66 Used excessive instructions; failed to use concise instruction

7. Coordination in Tower or ATC

71 GC/LC communication

72 Took over position, but failed to get properly briefed on situation

73 Tower/TCA communication

74 Distracted by other personnel

8. Lost track of aircraft; failed to locate aircraft; erroneous ID

9. Poor supervision

P Pilot

S Student pilot

1. Proceeded without clearance, when clearance was required

11 Landed without clearance

12 Took-off without clearance

13 Taxied without clearance

14 Entered active runway without clearance

2. Failed to see and avoid

21 Failed to look

22 Looked, failed to see, good visibility

23 Looked, failed to see, obstructed visibility
- 231 Weather (fog, snow, rain)
- 232 Airport structure
- 233 Vehicle

24 Looked, saw, failed to avoid

(Errors and Other Factors, Cont.)

241 No attempt to avoid, misjudged clearance
242 Attempted to avoid, failed
25 Looked, saw, avoided but came close ($\leq$ 300 ft)

3. Failed to display proper lights

4. Other improper operation of aircraft

5. Lost or disoriented

51 Lost or disoriented on airport surface
52 Landed on wrong runway

6. Failed to receive controller instruction correctly

61 Improper operation of communication equipment
62 Failure of pilot - copilot communication
63 Misunderstood one or more words in message

631 Standard phraseology
632 Non-standard phraseology

64 Misinterpreted message

641 Standard phraseology
642 Non-standard phraseology

65 Garbled message - failed to ask for clarification
66 Distracted

7. Received controller instruction correctly but failed to follow it

71 Forgot all or part of instruction; distracted
72 Followed expected instructions instead of actual instruction

8. Language difficulty

A <u>Airport</u>

1 Congestion or inadequate space

11 Ramp
12 Taxiways

(Errors and Other Factors, cont.)

- 2 Airport vehicles
  - 21 On active runway without clearance
- 3 Controller's view obstructed
  - 31 Aircraft
  - 32 Surface vehicle
  - 33 Airport structures or terrain
- 4 Signs, markings or lights
  - 41 Not present
  - 42 Not adequate
  - 43 Confusing

E Equipment

- 1. Aircraft equipment failed, poor or inadequate
  - 12 Communication equipment
  - 13 Mechanical equipment
  - 14 Electrical equipment
- 2. Airport navigation equipment failed, poor or inadequate
  - 21 Landing lights on airport runway
- 3. ATC equipment failed, poor, or inadequate
  - 31 Radar reception
- 4. Communication equipment failed, poor, or inadequate
  - 41 Excessive noise
  - 42 Excessive congestion

W Weather

- 1. Restricted visibility prevented pilot from seeing other aircraft or vehicle or object
- 2. Snow or ice obstructing RW/TW markings or signs

APPENDIX B: TABLE OF AIRPORT TRANSGRESSION ACCIDENTS FROM NTSB DATA

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YEAR	NO. OF ACCIDENTS	TYPE OF INJURY FATAL	SERIOUS	MINOR OR NONE
1964	4	0	0	82
1965	3	0	0	16
1966	5	0	0	74
1967	9	3	2	134
1968	5	0	0	105
1969	5	0	0	272
1970	7	0	1	184
1971	0	0	0	0
1972	3	10	9	125
1973	8	0	0	106
1974	14	3	0	217
1975	6	0	0	104
1976	6	0	0	28
1977	2	0	0	5
TOTALS	77	16	12	1452