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16. Abstract

This technical paper is a compilation of seven related studies of information transfer problems. The first describes the dimensions of the problem in the aviation system, based on screening of a sample of 12,373 ASRS reports. Two studies discuss communication problems within and among air traffic control work stations. Two papers explore air-ground communication problems under normal and emergency conditions. A report of communication patterns and problems within the cockpit presents experimental and anecdotal data to show the relationship between communications and flightcrew performance. A final paper summarizes the findings of these studies, discusses the implications for safety, and offers conclusions.

It is concluded that both human attributes (distraction, forgetting, failure to monitor, nonstandard procedures and phraseology, and complacency) and system factors (nonavailability of traffic information, degraded information, ambiguous procedures, environmental factors, high workload, and, less commonly, equipment failure) contribute to information transfer deficiencies. Various facets of the air traffic controller's role are discussed in the context of the enabling factors found in these studies. The role of the pilot is considered, especially when flying under visual flight rules, who could do more to enhance information transfer within the system. Automation also appears to be a factor in information transfer in that automated information systems may lead to delayed decisionmaking. Behavioral impediments to information transfer are discussed. Several ways of enhancing information transfer are presented.

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INFORMATION TRANSFER PROBLEMS IN THE AVIATION SYSTEM

SUMMARY

Problems in the transfer of information within the aviation system were noted in over 70% of 28,000 reports submitted by pilots and air traffic controllers to the NASA Aviation Safety Reporting System (ASRS) during a five-year period 1976-1981. These problems are related primarily to voice communications, although many deficiencies in visual information transfer have also been described.

Much of the information on which the safety and efficiency of the aviation system depends is highly dynamic. Without current, unambiguous information, neither pilots nor controllers can make appropriate decisions in support of their respective missions. Information transfer deficiencies, therefore, have obvious safety implications.

This technical report is a compilation of seven related studies of information transfer problems. The first describes the dimensions of the problem in the aviation system, based on screening of a sample of 12,373 ASRS reports. Two studies discuss communication problems within and among air traffic control work stations. Two papers explore air-ground communication problems under normal and emergency conditions. A report of communication patterns and problems within the cockpit presents experimental and anecdotal data to show the relationship between communications and flightcrew performance. A final paper summarizes the findings of these studies, discusses the implications for safety, and offers conclusions.

It is concluded that both human attributes (distraction, forgetting, failure to monitor, nonstandard procedures and phraseology, and complacency) and system factors (nonavailability of traffic information, degraded information, ambiguous procedures, environmental factors, high workload, and, less commonly, equipment failure) contribute to information transfer deficiencies. The air traffic controller plays a pivotal role in information transfer within the aviation system; various facets of this role are discussed in the context of the enabling factors found in these studies. The role of the pilot is considered; the study suggests that pilots, especially when flying under visual flight rules, could do more to enhance information transfer within the system. Automation also appears to be a factor in information transfer in that automated information systems may lead to delayed decisionmaking. Behavioral impediments to information transfer are discussed. Several ways of enhancing information transfer are presented.

INTRODUCTION

The NASA Aviation Safety Reporting System (ASRS) was implemented in April 1976, under the terms of a Memorandum of Agreement between the National Aeronautics and Space Administration (NASA) and the Federal Aviation Administration (FAA). During the ensuing 5 years, over 28,000 reports were voluntarily submitted by pilots, air traffic controllers, and others who work within the U.S. national aviation system.

Throughout this period, skilled aviation professionals have scrutinized incoming reports for evidence of deficiencies or discrepancies in the system, and for human behavioral problems that may negatively affect the system's safety and efficiency. From the early months, it has been clear that deficiencies in the handling of information are frequent concomitants of the occurrences reported to ASRS. As a result, research performed on this large data base has tended to focus on problems in the management and handling of information. This technical report deals with information transfer as a generic problem; it examines information transfer problems in several settings.

Close examination of ASRS reports led to the finding that information transfer problems, as we have come to call them, did not ordinarily result from an unavailability of information nor because the information was incorrect at its source (although there are certain exceptions to this generalization). Instead, the most common findings showed that information was not transferred because (1) the person who had the information did not think it necessary to transfer it or (2) that the information was transferred, but inaccurately. A host of other problems was noted, but less frequently. The distribution of information transfer problems in a large subset of aviation safety reports is discussed in chapter 1.

The air traffic control system may be thought of as an information management system in which nearly all the information changes rapidly over short periods of time. The ATC system contains many information transfer nodes or interfaces, but the tactical management of air traffic depends almost entirely on the timely transfer of information among controllers and between controllers and pilots. Among controllers, two interfaces appear to be associated with significant potential information transfer problems: problems associated with the transfer of information between a controller responsible for a sector and another controller who is about to relieve him (discussed in ch. 2) and problems associated with the transfer of information between sectors – the coordination of air traffic (examined in ch. 3 in the context of the often severe operational problems occurring therein).

The exchange of information between controllers and pilots is presently carried out entirely by means of radiotelephone. Voice messages carry virtually all clearance, advisory, and warning information from ground to air, and provide the medium by which pilots normally respond to such information. Many psychological studies over the years have examined the types of problems involved in the oral transfer of information; chapter 4 examines the communication problems reported to ASRS.

The management of information within the cockpit of modern complex aircraft is as important to the safe and efficient conduct of flight operations as is the management of information on the ground. The competent aircraft commander in today's environment must collate and process a great deal of information from aircraft instruments, from manuals and charts, from other flightcrews, and from the ground. This task is not always a simple one, particularly when some of the information received is contradictory, ambiguous, or otherwise misleading. The information interfaces among cockpit crewmembers are examined in chapter 5.

Chapter 6 contains the results of a study performed to determine whether information is efficiently transferred in situations in which the system is not performing normally. It has long been known that people function differently in emergencies than under other circumstances. Narrowing or channeling of attention occurs under such circumstances; peripheral information may easily be missed. Subjective time compression is frequently observed, and essential functions may be neglected. Although aviators and air traffic controllers are trained to cope effectively with emergencies, information transfer during such emergencies is often a secondary task. It was thought that information transfer failures in such circumstances could compound the original problem, whereas under less trying circumstances, the problem might arise from a deficiency in information management. This proposition was examined as part of a larger effort to study behavior in emergency situations.

The final chapter represents an attempt to draw generalizations from the data studied in the course of these six research tasks. It summarizes the conclusions drawn in the course of the studies and suggests possible approaches to the problems identified.

Each of the chapters of the report presents the conclusions of its author and should be read as an individual research effort. The conclusions presented are also the opinions of the authors and do not represent an official position of NASA, Battelle's Columbus Division, or the FAA.

The editors acknowledge with gratitude the insights of ASRS staff members that led to this series of studies. They are most grateful to Dr. Earl L. Wiener and Dr. Alan B. Chambers for their thoughtful and critical reviews of the final document.

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ABBREVIATIONS AND ACRONYMS

A/C	Aircraft
ACR	Air carrier aircraft
AIM	Airman's Information Manual
AR	Approach radar controller position
ARTCC	Air Route Traffic Control Center
ASDE	Airport surface detection equipment (radar)
ASR	Airport surveillance radar
ASRS	NASA Aviation Safety Reporting System
ATC	Air traffic control
ATIS	Automated terminal information service
B747	Boeing 747 widebody transport aircraft
BFF	Scottsbluff, Nebraska
BOR	Briefing of relief
BOS	Boston, Massachusetts
BRITE	Bright radar indicator (control) tower equipment
CRT	Cathode ray tube or scope
DAB	Daytona Beach, Florida
DCA	Washington National Airport, Washington, D.C.
DEN	Denver, Colorado
DME	Distance measuring equipment (airborne)
DR	Departure radar control position
E	East
FAA	Federal Aviation Administration

FAM	Farmington, Missouri
FE,F/E	Flight engineer
FL	Flight level (standard altitude in hundreds of feet)
F/O	First officer or copilot
F4	MacDonnell-Douglas fighter-bomber
GA	General aviation
IAD	Dulles International Airport, Washington, D.C.
ICT	Wichita, Kansas
IFR	Instrument flight rules
ILS	Instrument landing system navigation facility
IMC	Instrument meteorological conditions
J	Jet airway (with identifying number)
JFK	J. F. Kennedy International Airport, New York
L	Left one of a pair of parallel runways
LAX	Los Angeles, California
LGA	LaGuardia Airport, New York
LHR	London Heathrow Airport, England
LIT	Little Rock, Arkansas
LTSS	Less than standard separation
Mayday	Internationally recognized distress call or message
MIA	Miami, Florida
Mode A	Airborne radar beacon transponder without altitude reporting
Mode C	Airborne radar beacon transponder with altitude reporting
MSL	(Altitude with respect to) mean sea level

N	North
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NE	Northeast
NM	Nautical miles
NMAC	Near midair collision
NTSB	National Transportation Safety Board
NW	Northwest
ONL	O'Neill, Nebraska
ORL	Orlando, Florida
R	Right one of a pair of parallel runways
RAPCON	Radar approach control facility (military)
RVR	Runway visual range
S	South
SE	Southeast
SFO	San Francisco, California
SID	Standard instrument departure route
SMA	Small aircraft (less than 5,000 lb gross weight)
SMT	Small transport (5,000-12,500 lb gross weight)
Stage III	Radar control and separation services in terminal area
SW	Southwest
TACAN	Tactical air navigational aid (navigation facility)
TRACON	Terminal radar approach control facility
U.S.	United States

UHF	Ultra-high-frequency (radio communications unit)
V	Victor airway (with identifying number)
VFR	Visual flight rules
VHF	Very-high-frequency (radio communications unit)
VMC	Visual meteorological conditions
VOR	Visual omnirange navigation facility
W	West
WX	Weather
XXX	Code letters used to avoid identifying a location or navigation facility
XYZ	Code letters used to avoid identifying a location or navigation facility

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1. DIMENSIONS OF THE INFORMATION TRANSFER PROBLEM

Charles E. Billings and William D. Reynard

INTRODUCTION

This report describes a class of problems that in one form or another is involved in the vast majority of the occurrences reported to ASRS. Over 70% of reports contain evidence of human error, either in the air or on the ground. An even larger fraction, however, contain evidence of a problem in the transfer of information within the aviation system. Several facets of the information transfer problem have been examined in previous ASRS reports (refs. 1-3). Others are addressed in this compilation. This chapter presents a general analysis of the problem and examines the implications of some proposed solutions.

INFORMATION TRANSFER IN AVIATION

There are presently two primary methods of transferring information in the aviation system. Relatively static information is stored in the form of books, manuals, and charts. Some relatively dynamic information, such as weather charts, is also stored in hard copy. The transfer mechanism for this information is, of course, the visual perceptual channel.

Dynamic information concerning aircraft status is portrayed in analog or digital form on electromechanical devices (instruments) in the cockpit. Information concerning aircraft identity, location, speed, and intentions is displayed in alphanumeric and symbolic form on cathode ray tubes in ATC facilities. Again, the information transfer mechanism is the visual perceptual channel.

Information about weather and other aircraft in the immediate area, under visual meteorological conditions, is also received by the aircrew by means of the visual perceptual channel.

Highly dynamic information (clearances, traffic avoidance data, changes in weather, notification of unplanned changes in status) is at present transferred almost entirely by means of simplex radiotelephone. It is transmitted by voice and received through the aural perceptual channel.

Other information concerning terminal-area weather and related information is also transmitted by voice communication channels. Nonverbal aural information transfer includes Morse code identifiers and alerting and warning sounds.

APPROACH

Each incoming report was screened by experienced aviation professionals to determine whether, in their view, an information transfer problem was present. If their finding was positive, they provided information in four coded fields to characterize the problem. These fields formed the basis for the data summaries presented in this report. The instructions are summarized and the data fields discussed briefly here.

1. Instructions: Analysts were instructed to complete a set of data fields for each information transfer event deemed significant to the occurrence or situation described in a report. Significance, in this context, was to be based on the contribution of an information transfer event (or its absence) to the unsafe occurrence or situation. Thus, significance has the negative connotation of "fault": it conveys that a message or information transfer event had something wrong with it.

2. Message origin: In this field, the analyst indicated whether the message originated with a controller, a pilot, or some other person or device. When information believed to be pertinent was not transferred, the analyst indicated by whom such information should have been provided.

3. Message type: The analyst indicated whether the information to be transferred was a clearance, coordination message, request, warning, other control message, statement of intentions, data, advisory, or confirmation, or other type of instruction.

4. Message problem: Here the analyst expressed his view of the nature of the information transfer problem (see below). Messages could be categorized as absent, incomplete, inaccurate due to phonetic similarity, transposition or other cause, false, ambiguous, untimely, garbled in transmission or presentation, not transmitted because of equipment or device failure, or not received because of a failure to monitor by the intended recipient.

5. Message medium: Here the medium used, or that would have been used, to convey the information was indicated. Available choices included publication, radio, interphone, video, tape recording, chart or similar graphic, telephone, direct voice, or visual (instrument, etc.).

It will be noted that analysts were to decide whether a failure to transfer information contributed to an unsafe occurrence. This, of necessity, involved a judgment by the analyst, and the data are heavily influenced by this judgment, as will be seen.

The coded data from a sample of 12,373 consecutive reports received between May 1, 1978 and July 31, 1980 were used in this study.

RESULTS

Grayson (ref. 4) in a study of air-ground communications, found evidence of an information transfer problem of some type (aural or visual) in over 70% of ASRS reports received between May 1978 and August 1979. The data have been rescreened based on intake since that date. The classification of the problems found by ASRS analysts in these reports is shown in table 1.1.

These data illustrate each of the generic problems within the information transfer process. A common problem was failure to initiate the information transfer process. It is necessary both that the information exist (and it almost always does exist) and that it be made available to those who need it. In a larger number of cases, an attempt was made to transfer information. The common failure points in the transfer chain were inaccuracies in the transmitted message, and failures to transmit the message at the right time. Many of the latter failures involved the issuance of advisory messages concerning other air traffic.

In a substantial fraction of these reports, a message was not heard, or if heard it was misunderstood or misinterpreted. The reports indicate that expectation plays a major role in this facet of the problem. Misunderstandings often occur because the recipient of the message, usually a pilot, hears what he expects to hear based on familiarity with the "usual" way of doing things. This error is then compounded when the originator of the message, usually a controller, hears what *he* expects to hear: the clearance read back as he gave it. If a message is not received, it will not be acknowledged, and it will usually be transmitted again. If a misunderstood message is acknowledged as correct, everyone thereafter is operating on wrong presumptions.

TABLE 1.1.– INFORMATION TRANSFER PROBLEMS

Nature of problem	Number of citations	Percent of citations
Message not originated	4,039	37
Message inaccurate, incomplete, ambiguous, garbled	3,959	37
Message correct but untimely	1,356	13
Message not received or misunderstood	1,165	11
Message not transferred due to equipment failure	296	3
	10,815[a]	100%

[a]10,815 citations in 9,046 of 12,373 ASRS reports, May 1978-July 1980; 73.3% of reports contained such a citation.

It is noteworthy that few of these information transfer failures (less than 3%) involved an equipment failure. The rest involved human errors, or the inability of the human to accomplish all of the tasks involved in information transfer in timely fashion, or a decision by a human that information transfer was not necessary.

Does visual information transfer work better? The data would suggest that it does, though hundreds of reports involve problems with charts and manuals, the reading and setting of aircraft instruments, the placement, format, and presentation of information on ATC radarscopes, and traffic not sighted. Table 1.2 shows the distribution of problems between aural and visual media in all citations in which the appropriate field was coded.

TABLE 1.2.– MEDIA INVOLVED IN INFORMATION TRANSFER PROBLEMS

Message medium	Number of citations	Percent of citations
Aural information transfer		
Radio	6,834	
Interphone	855	
Voice	450	
Telephone	438	
Tape recording	19	
	8,596	85
Visual information transfer		
Video/CRT	587	
Instruments, lights, etc.	416	
Publications	309	
Charts	203	
	1,515	15
	10,111	100

Remarkably little of the enormous amount of information in manuals and charts is wrong. The problem with printed data is usually that it is difficult to find, or to read, or to interpret, especially under poor viewing conditions, in turbulence, or while under stress or high workload. For example, late changes in approach clearance, usually involving a change in landing runway, place the pilot in an unexpected high workload situation and make it necessary to find, scrutinize, and memorize new data very rapidly.

Among reports from controllers are many concerned with errors associated with overlying data blocks, tag drops or swaps, and related problems. Radar often fails to portray primary targets; the presence and positions of these aircraft thus comprise information not available to the controller. Tower controllers report problems in sighting traffic visually at airports and difficulties in estimating relative positions of several aircraft.

Finally, there are many reports from pilots of conflicts and near midair collisions with traffic not sighted early enough to permit timely corrective action. Workload is clearly a factor in traffic detection in terminal areas, where these conflicts are most often reported. These failures may involve a verbal information transfer problem, a visual perception problem, or both.

TABLE 1.3.– FAILURE TO RECEIVE INFORMATION CORRECTLY

Failure to receive or monitor a radio message	1096 of 5002 citations (22%)
Failure to receive visual information	177 of 910 citations (19%)

Table 1.1 indicates that although the bulk of information transfer failures can be traced to the sender of the message rather than to the receiver, failures to receive the information correctly accounted for 11% of the citations. Table 1.3 summarizes an examination of failures to receive information that was available.

In approximately one-fifth of the cases in which there was a transfer problem with information that was made available, it occurred at the receiving end of the transfer link.

DISCUSSION

These data make it quite apparent that verbal communication is an imperfect method of information transfer. For that reason, much attention has been given to alternative means of transferring the information that is now communicated almost exclusively by voice.

Digital data link, making use of augmented discrete address beacon systems, or transponders, is entirely feasible using today's technology and is under test at this time. Information would be presented on cathode ray tubes in the cockpit, either in alphanumeric or graphic form. The messages could be composed either manually by controllers or automatically by ATC computers.

Attention has also been directed to the uplink of digital data regarding pertinent traffic and to the graphic display of traffic information within the cockpit. This is not proposed as a means of collision avoidance per se, but rather as a way of putting the flightcrew "in the big picture" regarding the control of their aircraft by ATC. It is thought that with such information, pilots might well be able to assume the responsibility for spacing and perhaps other functions now performed by air traffic control. It is also believed that such information would permit pilots to detect errors made by controllers, something they cannot do now because they often lack the necessary information.

Collision avoidance would be provided by another set of devices, either on the ground or in the aircraft; collision avoidance and conflict resolution information would also be presented visually.

There is no doubt that these devices, if implemented, could handle a considerable amount of information now transferred aurally. Many of the problems now observed would be substantially alleviated. One of the most serious – in which a pilot acts on a clearance meant for someone else – might be eliminated if clearances were seen only by the flightcrew for which they were intended. What new problems might be created, however, by these solutions of the present problem?

Visual perception of data is by no means free of errors, as evidenced by table 1.3. Both at the perceptual and cognitive levels, numbers are transposed or dropped; expectation can modify perception of the printed word as it does auditory information. Careful design of graphic displays can help to minimize errors in the interpretation of the information presented, but such errors will continue to occur. Visual presentation of data, however, is less transient than auditory presentation. The data can thus be reread by a recipient.

More important is the question of visual channel capacity. ASRS reports indicate that there are, in the present aviation system, situations in which pilots find themselves fully occupied or overloaded by tasks with a large visual perception component (ref. 5). These situations often involve descents at high speed into busy terminal areas, using complex procedures . Under these conditions, which require a very close attention to visual displays within the cockpit (especially if there is weather requiring concurrent attention to the radarscope), visual scanning for other aircraft is markedly reduced.

The effect of adding additional displays, some of which require not merely a casual scan, but careful attention, may well result in overloading the visual channel unless a way can be found to relieve the pilots of certain of their present visual tasks. The resolution of this problem is central to the mitigation of the information transfer problem in aviation operations.

CONCLUSIONS

Based on reports to ASRS, it is concluded that information transfer problems are responsible for many potentially serious human errors in aviation operations. Voice communications, in particular, are a pervasive problem. Technological solutions exist for many problems related to information transfer. These solutions, however, may give rise to serious new problems unless they are implemented with an understanding of the capabilities and limitations of the humans who operate the aviation system.

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2. INFORMATION TRANSFER IN THE SURFACE COMPONENT OF THE SYSTEM: PROBLEMS ASSOCIATED WITH BRIEFING OF RELIEF CONTROLLERS

Ralph L. Grayson

INTRODUCTION

A substantial majority of occurrence reports submitted to the NASA Aviation Safety Reporting System by pilots and air traffic controllers contain evidence of problems in the transfer of information among the participants in the national aviation system. Although failures of information transfer between ground and aircraft are most common, there are also many failures within the cockpit and within the ATC system. Because such failures are often the precursors of other failures, it is important to gain an understanding of what they are and how they occur.

The briefing of a relieving controller by the controller being relieved is a pure information transfer exercise. There is always the possibility that necessary information will not be transferred and thus there is a potential for later failures of separation. Since the mode of briefing is invariably oral, the process is subject to the many sources of error inherent in oral communications. The ASRS has received a small but steady flow of reports concerning problems associated with briefing of relieving controllers. This discussion summarizes an analysis of such reports; the analysis was undertaken with the intent of shedding light on the nature of the errors involved and their sources.

OBJECTIVE

The objective of this study was to characterize the types of human errors reported in connection with briefing of relief in air traffic control operations, and to examine the factors associated with these errors.

APPROACH

ASRS reports associated with briefing of relief (BOR) were counted to evaluate temporal trends in their submission. A sample of 52 occurrences was chosen for detailed study. These reports were examined and categorized as to reporter, errors committed, and factors associated with the errors. An examination of the resulting array of data produced some thoughts about ways of reducing the rate of errors.

For purposes of this study, a BOR problem was considered to be a failure to transfer information completely and accurately from an air traffic controller operating a position to another controller who was to assume subsequent responsibility for the operation of that position.

RESULTS

Figure 2.1 shows the monthly receipts of ASRS reports since July 1976 that were associated with briefing of relief. There was a gradual decrease in reports until October 1978, which is the only month during which no reports were received. Since that time there has been a slight trend toward a greater number of reports, but this did not prove to be statistically significant. The increase may be attributable to changes made in 1979 in the waiver of disciplinary action provided by FAA to reporters to ASRS, which had the effect of fostering multiple reporting of the same occurrence.

TABLE 2.1.– REPORT SOURCES; HUMAN ERRORS IN BOR REPORTS

Originator of report	Error committed by			
	Relieved controller	Relieving controller	Other person	Total
Relieved controller	18	2	1	21
Relieving controller	13	6	4	23
Other person	5	1	2	8
Total	36	9	7	52

The source of each of the reports was determined. Each report was categorized on the basis of who committed the described error. The results of these categorizations are in table 2.1.

Responsibility for the accuracy of a relief briefing is clearly that of the person providing the briefing (here, the relieved controller). It is not surprising, therefore, that most BOR problems were enabled by the relieved controller. The purpose here is not to place blame, but to isolate the factors that caused the BOR to be inadequate.

The BOR problems were next classified according to the information transfer problems reported. The results are shown in table 2.2.

Factors thought to be important in BOR problems were evaluated; they are summarized in table 2.3. More than one factor was assigned to certain reports.

TABLE 2.2– CLASSIFICATION OF BOR DEFECTS

Category	Number of occurrences
Absent briefing	5
Incomplete briefing	21
Inaccurate briefing	26
Total occurrences	52

TABLE 2.3.– FACTORS ASSOCIATED WITH BOR OCCURRENCES

Factor	Number of occurrences
Nonrecall of pertinent information	14
Failure of technique	11
Failure of perception	8
Complacency	5
Distraction	4
Message ambiguity	2
Workload	2
Inattention	2
Misidentification of aircraft	2
Other factors	7

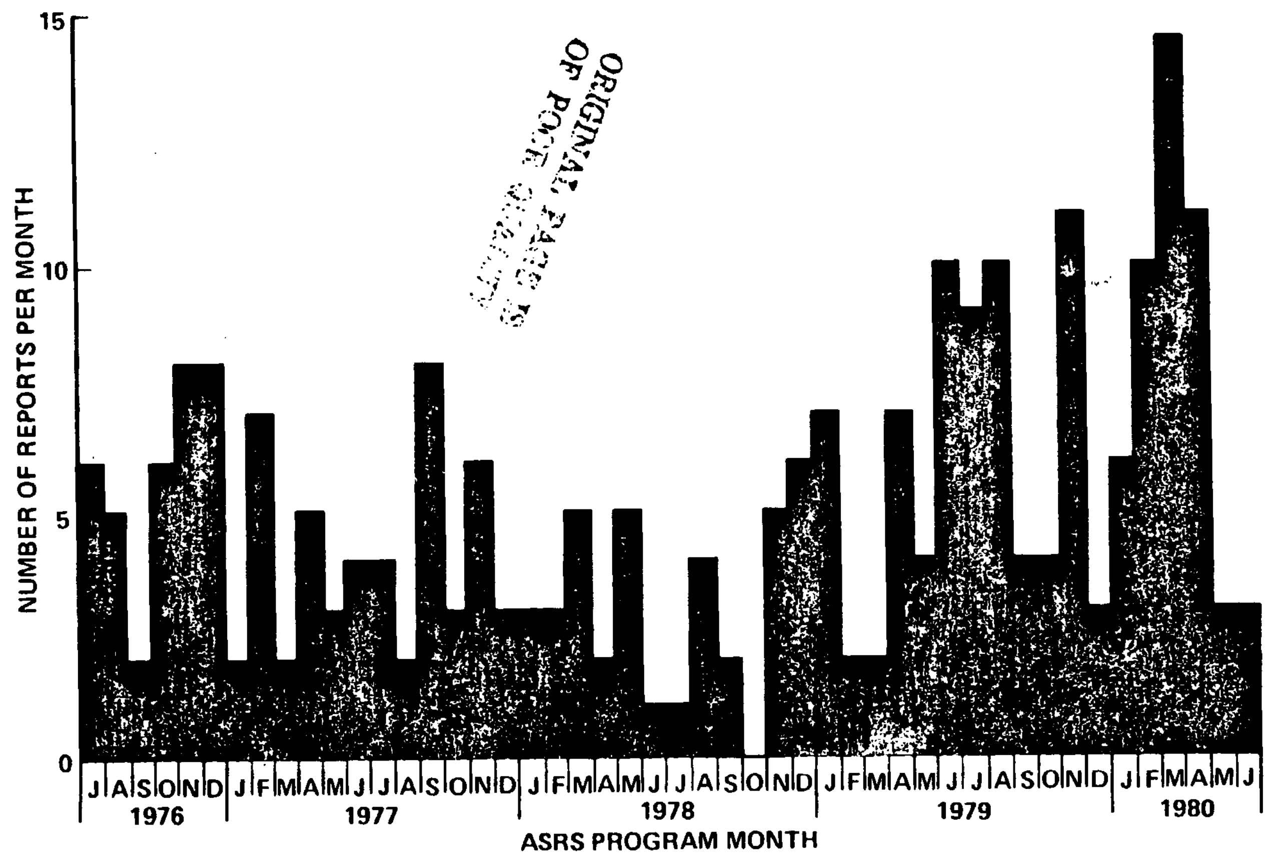

Figure 2.1.– Monthly receipts of ASRS reports associated with briefing of relief.

These factors, alone and in combination, were then studied further with the hope of identifying the root causes of the occurrences and the procedures or practices that could have prevented them.

DISCUSSION

Although the sample consisted of a relatively small number of reports, the safety significance of briefing errors is indicated by the fact that in most cases the consequences of such errors were serious. An example is the following report.

> Assuming the final position the controller released aircraft B. When B turned downwind, aircraft A departed and was immediately in conflict with B. Aircraft A took evasive action to climb above B passing over him by 600 ft. Probable contributing factor – volume of traffic resulted in an incomplete position briefing.

The following sections describe each type of error and discuss the enabling factors observed in connection with it. Also covered are a subset of occurrences associated with correct briefings and a discussion of methods for reducing the occurrence of briefing errors.

Failure to Brief Relieving Controller

The responsibility for providing a relief briefing is defined in FAA Agency Order 7110.78A, effective July 1978 and related facility orders, all of which require that a controller being relieved shall orally brief the relieving controller; the content of the oral briefing is specified. ASRS reports show no evidence of misunderstanding of this precept.

> This deviation was caused by the relieved controller failing to adequately brief his relief.

* * *

> This situation occurred, I believe, because the air traffic controller was not properly briefed on the recovery profile being used.

Yet in five cases in this sample, no relief briefing was given. In these five instances, the most frequent cause was attributed to heavy traffic workload. The relieved controller was too busy with current traffic to provide a briefing.

> Traffic built to a point where more controllers were needed. The controller who was working all positions was too busy to brief me when I attempted to take radar west and a final position.

* * *

> Supervisor came back to sector with a headset and pulled out my headset plug. I immediately asked him if he was ready for a mandatory briefing and he told me to relieve another sector and that he needed no briefing. I consider this a double standard since controllers are mandated to give a full briefing before being relieved from duty.

In the latter case, a supervisor assumed the position, stating to the relieved controller that he needed no formal briefing since he was already familiar with the traffic situation. Although this may well have been true, he might still have been unaware of other pertinent information that could have been transferred in a formal, checklisted briefing.

Incomplete or Inaccurate Briefings

Twenty-one occurrences involved an incomplete briefing (failure to transfer relevant information). Twenty-six involved the transfer of inaccurate information. The factors in these two categories were examined.

Of the 21 incomplete briefings, 9 involved a failure to recall information. This factor was also found in 7 of 26 inaccurate briefings. Examination of these occurrences indicated that the information not recalled was available at the position in about half the cases.

> The new controller was told that aircraft A had been stopped at FL330. Tape recordings indicate that A was never recleared to FL330. When he reported in he advised climbing to FL370. The controller acknowledged but did not verify the assigned altitude. Later aircraft B requested descent clearance and the controller noticed the A and B targets merging as A was leaving FL348.

In other cases, the information was not immediately available because of incorrect recall of a clearance, failure to mark flight-progress strips during a holding operation, no transponder code or an incorrect code, and similar irregularities.

> We were requested by an inbound sector controller to move 21,000 traffic to 19,000 and asked what an aircraft at 23,000 was doing there. We were then advised that the adjacent sector was holding at 20,000 up. I was not aware of the holding stack and neither was the controller I relieved. He should have been advised of the stack by the coordinator.

* * *

> Aircraft A called stating he was on frequency at 6,000. Assuming it was his initial call-up I gave him the beacon code on the flight-progress strip. A few seconds later he acquired about 1 mile behind aircraft B. It was found in the system error investigation that (1) the relieved controller had been in contact with A and amended his clearance assigning a heading of 090°, (2) had forgotten about A at the time of relief, (3) the aircraft had not been assigned his correct code which would have resulted in auto acquisition.

Perceptual errors were uncommon in incomplete briefings but were the next most common factor in inaccurate briefings. In at least half of the six cases cited in this category, the information was correct in the full data block or the flight-progress strip, but was not read or was misread during the briefing. In one case, there was a conflict between the two sources of information and the wrong one was used.

> During the briefing of relief checklist, I was advised by the relieved controller that B was level at 7,000 due to A westbound at 8,000. The adjacent Center called and advised that the two aircraft passed within 1/4 mile at 7,000. No altitude readouts were noticed by me. I only had the information from the relieved controller.

Technique failures were cited in one-fifth of the incomplete or inaccurate briefings. In most cases, the information was available but was not utilized in the briefing. In the cases where it was not available, this was because of a previous error by the relieved controller.

> When I was briefed by the relieved controller, he did not mention anything about traffic holding at XYZ, nor was anything written about it at the sector. Approach control later asked what altitude the inbounds were out of if they were descending. Later approach control advised that the F4's were clear of XYZ. Investigation revealed that holding had been coordinated at XYZ but no written entry was made. The trainer controller also failed to mark it down and did not brief his relief.

* * *

> A was descending to 8,000. The aircraft track, data block, and flight plan were accidentally removed from the radarscope and computer as A left 28,300. One minute later I was relieved and briefed my replacement on all of the aircraft represented by data blocks. I did not realize A had been removed. SMT B had cancelled IFR and the incorrect computer identification number was used.

A few of these occurrences involved system factors. In one case of nonrecall, the flight-progress strip had not been delivered to the position and the aircraft tag had dropped from the radarscope; in a second the aircraft was on the wrong beacon code. In a third case, a controller was being relieved after only 3 min on the sector. Several other human factors were implicated in the reports, however. Distractions were cited in four instances, workload in two. Complacency or inattention were thought to be factors in seven occurrences.

> While briefing my relief, I was interrupted by Center several times on the handoff lines. Due to the interruptions (I felt) I overlooked a point-out for sequence that I had previously given another controller. My reliever assumed the position and overtook the sequenced aircraft with another faster aircraft. Computer tapes indicated that I had taken the handoff via computer and rogered the aircraft checking in on frequency.

* * *

> The radio button was off when aircraft A said he did not want a visual to runway 32. I was being relieved by another controller. The two aircraft got extremely

close over the outer marker. Probable cause: either lazy relief procedures or radio problems.

Errors by Relieving Controller

In nine occurrences, an error was committed by the relieving controller. These reports were examined to determine the error patterns.

In one case, the relieving approach controller assumed that an observed target was an arriving aircraft that had previously been transferred to tower frequency. He then vectored a subsequent arriving aircraft to within 200 ft of the preceding arrival aircraft.

> Why did it occur? Poor radar due to weather, weather conditions, misidentified target, poor cooperation among controllers, all positions not being alert to the situation.

In two instances, failure to recall pertinent information during the briefing resulted in a hazardous incident.

> We were cleared to tower frequency just prior to the outer marker and made another request for clearance for an approach. No reply, went to tower frequency and were cleared to land. Requested approval for approach which was granted. Started high rate of descent, broke out at 800 ft at middle marker too high and too fast. Cleared back to Approach Control. Controller apologized for the mixup, claimed he had just relieved another controller and was told we had been cleared for the approach.

* * *

> When I relieved the previous controller, I was told that aircraft A was released to Sector 23 and on to Sector 35. Sector 35 called and asked the status of A. At the time I did not recall what it was. I later learned that A was in Sector 35 airspace and no handoff had been made.

In one instance, the relieving controller assumed that a VFR aircraft receiving Stage III radar service would be assigned 6,500 instead of 7,000 which had been assigned by the previous controller.

> Position relief had occurred just prior to the incident. Possible cause: problems in briefing of relief. Better briefing would lead to a better awareness of the situation by the relieving controller.

A controller moved to a handoff position to assist a controller who had become very busy. The coordinator pointed out an aircraft stating "This aircraft is for an ASR," which was heard as "This aircraft is VFR."

> I believe that I was not properly briefed and that the radar controller and the coordinator were not communicating properly.

In a similar case the relieving controller received a message correctly but misinterpreted its meaning.

> The relieved controller advised me that aircraft A was "going over the top" of aircraft B. I believed this to mean an approach to a 360° overhead. Failure to understand or my assumption that A was an overhead approach contributed to this incident as well as failure to inform or make certain that the relieving controller understood the situation.

Thus a variety of human error factors can be present when the relieving controller makes an error in the period immediately following position relief.

Control Errors Associated with Relief Briefings

Several reports related to errors that occurred in association with relief briefings that were not in themselves faulty. Errors or oversights by the relieved controller prior to the briefing can result in a reportable incident after the relieving controller has assumed the operation of a control position; other control errors occur shortly after the transfer of responsibility for the position. Both relieving and relieved controllers reported errors in control during the conduct of the briefing.

> Evasive action should have been taken but it was too late when finally noticed by the controller. He forgot to turn A in on the localizer while he was briefing another controller who was relieving him.

It is noteworthy that a relief briefing is itself a distraction, albeit a necessary one, involving increased workload for the controller providing it. Though the relieving controller may receive a complete and accurate briefing, it also appears that it commonly takes him a few minutes to become fully comfortable with the traffic situation. During these periods, mistakes can occur if controllers are not especially alert to them.

REDUCTION OF ERRORS IN BRIEFING OF RELIEF

It is self-evident that controllers should and do strive to prevent errors in relief briefings, and the FAA has stressed the importance of this. Certain lessons in the reports studied here may further assist in reducing these errors.

The three most common factors in these occurrences were nonrecall (failure to remember pertinent information), perceptual errors (failure to perceive or notice pertinent information), and technique errors (failure to transfer pertinent information). The fact that pertinent information may not be immediately available at the time control is transferred points up the importance of written notes to assist the recall process. "Scratch-pad" notations can be helpful to the briefing controller and more helpful to his relief during his initial minutes on the position. Standardization of procedures and phraseology in the conduct of briefings can reduce ambiguity and the likelihood of misinterpretation of the information being transferred.

In cases in which traffic workload tended to prevent or inhibit the briefing process, the basic problem was that the briefer had to retain his grasp of the changing traffic situation and maintain radio communications while delivering the briefing. This is especially difficult because most controllers are conditioned, properly, to respond to any radio or telephone call as a first priority matter. However, when the volume is such that the briefing is being delayed, this priority can in some cases be modified judiciously. If no emergency is in progress, most routine radio contacts can be delayed briefly without causing problems, or a second specialist can monitor the frequency, accumulating calls on standby while the briefing proceeds. If this or similar techniques cannot be used, then a better technique would be to delay relief temporarily, allowing the relieving controller to monitor the situation until a formal briefing opportunity presents itself. Considerable information can be transferred within a few seconds given the undivided attention of a reliever who has monitored for a while. In any case, every effort should be made to conduct a formal briefing – especially under heavy traffic conditions where there is the least margin for error.

ASRS reports indicate a presumption by reporters that the relieved controller is solely responsible for the completeness and accuracy of the information contained in the oral briefing.

> I relieved the radar controller and received a briefing on three jets landing in the XYZ terminal area. Nothing was said in the briefing about aircraft A at 12,000 with no transponder. The jets had received clearance to 11,000, 9,000, and 7,000 from the previous controller. I assumed the position and continued vectoring the jets in trail and failed to notice the strip at the very bottom of the board on aircraft A at 12,000.

This indicates a strict interpretation of the language of FAA agency order 7110.78A. It is obvious that the relieved controller must bear responsibility for any information that is known only to him. However, much of the data transferred during the briefing can be verified by a thorough check of the radar display, contents of full and limited data blocks where available, and flight-progress strips, which are nearly always posted and available concurrently with radar information. Corroboration of the data supplied by the relieved controller using all available sources might improve the quality of the briefing process if this were made a direct responsibility of the relieving controller.

This is also important because the relieved controller may well be tired after handling heavy traffic, or bored after a long period of low activity. The relieving controller should be alert to possible errors or omissions in the information being given him. Though the responsibility for the briefing remains with the relieved controller, his counterpart can be of substantial help to him in discharging it.

SUMMARY

Failures in the briefing of relieving controllers, as observed in ASRS reports, appear to be a continuing problem, though one that has been alleviated to an extent by various efforts over the past 3 years. Failure to recall information is an important enabling factor; failure to check the information and to transfer it when available are also major factors. The elements of such failures are always present in this critical task; relieving controllers can be of appreciable assistance in minimizing errors in the information transfer process.

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3. INFORMATION TRANSFER IN THE SURFACE COMPONENT OF THE SYSTEM: COORDINATION PROBLEMS IN AIR TRAFFIC CONTROL

Ralph L. Grayson

Do not allow an aircraft under your control to enter airspace delegated to another controller without first completing coordination. – *Air Traffic Control Handbook 7110.65B.*

INTRODUCTION

Coordination is a term used widely in the air traffic control (ATC) system to describe control activities that affect aircraft traversing jurisdictional boundaries of airspace. It is usually used in reference to the transfer of information between air traffic controllers who control separate segments of airspace through which controlled aircraft are or will be passing. This information transfer process is used by the controllers in developing and executing operational plans for controlling the traffic through their respective airspace segments. Although this coordination is primarily an operational process, it comprises a significant information transfer element; as a result, a discussion here of its pertinent issues and problems is most appropriate.

Coordination is the most pervasive, and perhaps the most complex, aspect of the U.S. ATC system. It is widely recognized as a controller function that is particularly vulnerable to human error. Furthermore, a coordination failure usually results in the loss of standard separation distance between aircraft. The Aviation Safety Reporting System (ASRS) data base contains many items describing occurrences involving coordination failures. This report presents the results of a study of that segment of ASRS data and the conclusions arising from it.

OBJECTIVE

The objectives of this study were (1) to identify the air traffic control coordination problems that were reported to ASRS, (2) to classify them, (3) to determine the circumstances that appear to encourage coordination failures, (4) to examine the human and system factors involved, and (5) to consider possible means of reducing the rate of such failures.

ATC COORDINATION

As is implied by the general definition above, an ATC coordination transaction is a communication between controllers (not necessarily verbal) the purpose of which is to arrive at and execute a plan for handling aircraft as they pass from the jurisdiction of one controller to that of another. Coordination is, in effect, a contractual agreement between two controllers arrived at by negotiation and binding them to perform in accordance with that agreement once it is made. The process involves the following steps, all of which are composed substantially of information transfer actions.

1. Communication by one controller to another of a request for coordination.

2. Responsive message of concurrence or nonconcurrence by the controller receiving the request; nonconcurrence will result in a discussion of alternative action.

3. Agreement on a plan of action and who is to execute it.

4. Execution of the plan.

For the purposes of this study these four steps are referred to as initiation (step 1); agreement (steps 2 and 3); and execution (step 4).

Each of these steps has to be taken with due consideration for time available to complete the entire process. Allowance must be made for communications with other controllers or flightcrews and their responses. Furthermore, each step must be completed in a timely manner with an appropriate time buffer for unforeseen contingencies such as delay in establishing radio contact. The best plans are to no avail if the enabling clearances cannot be implemented in sufficient time to preclude loss of separation.

Coordination is frequently classified as "interfacility" or "intrafacility" to indicate the number of facilities involved. This distinction has not been used in this study because the errors that result in coordination failures appear to be present in roughly equal numbers, regardless of the physical locations of the controllers.

Several different media are used for transferring coordination information. For example, most interfacility coordination is done by telephone. Also, large sectorized facilities (centers, large TRACONs) use the telephone for communication between different positions within the facility – intrafacility coordination. Among smaller facilities, and also within multisector facilities where the working positions are close together, less formal means often are employed – direct voice, informal or abbreviated messages, hand signals, and others.

Prior knowledge of an aircraft entering a sector is essential to the planning of coordination. This is normally provided by transmitting flight plan information to affected control sectors by printing out flight-progress strips before the aircraft enters the control sector. A second procedure requires either a radar handoff in areas of radar coverage or prior verbal coordination before an aircraft enters airspace controlled by another controller. The following is from the Air Traffic Controllers Handbook, 7110.65A:

> Inter- and intra-facility radar handoffs shall be accomplished in all areas of radar surveillance. The transferring controller shall complete a radar handoff or obtain receiving controller approval before the flight enters the receiving controller's airspace.

Routine transfer of flight data is communicated almost entirely by automated equipment. Flight plans are entered into computers at the en route centers where they are stored until they become timely; flight-progress strips are then routed to terminal facilities and appropriate center sectors. Radar handoffs are automatically initiated by most en route center computer systems. This precludes oversight by the transferring controller and normally results in handoff to the correct sector.

Routine transfer of flight data and radar handoffs prior to transfer of control appear to present few problems. However, if the originally planned flight must be changed in order to maintain standard separation as an aircraft passes from one sector to another, some type of specialized communication is necessary between the controllers involved. Most coordination failures reported to ASRS concern such complex operations and this study concentrated on them.

APPROACH

The first step in the approach was to retrieve a representative sample of ASRS reports involving coordination failures. The initial search yielded 1,801 reports out of a total of 9,795 received during the period from May 1978 through February 1980. A subset of 200 reports of unique occurrences was generated by selection and screening every ninth report from the original sample; these would be evenly distributed in time throughout the initial data set. Since the study was directed to controller-enabled ATC coordination failures, any report in the initial selection that described a flightcrew-enabled failure was replaced with a report on a controller-enabled problem received by ASRS at about the same time. This procedure provided an overview of the time period of the data base in addition to ensuring that the sample group consisted of valid, controller-enabled coordination failures.

Reports were first classified according to the phase of coordination – initiation, agreement, or execution – in which the failure occurred. The initiation phase citations consisted of those instances in which no effort had been made to begin coordination or in which the process was interrupted before a request was communicated to the appropriate controller. The agreement phase was chosen when initiation had occurred, but no agreement had been reached. The third phase, execution, was chosen if an agreement had been reached but the controllers responsible for carrying out the plan failed to do so. Errors in execution included failure to implement the agreement or doing it in such a way that loss (or potential loss) of standard separation resulted.

Further examination revealed the mode of failure that occurred in each case. If appropriate communications were not made or action was not taken, the failure was considered to be of the "absent" type. If some communication or action had begun but was not completed, it was labeled "incomplete." If the information used in decisionmaking was incorrect, or if implementation was incorrect, even though the agreement was understood, the failure was labeled "inaccurate."

Assessment of human factors – errors and the predisposing conditions for those errors – followed where these were discernible in the reports. These classifications were based on an inductive evaluation of the factors stated or strongly implied by the reporter. In some cases, however, the nature of the error could not be inferred from the reporter's description of the occurrence; this was more often true of the predisposing conditions for errors.

Finally, consideration was given to possible ways of reducing the probability of coordination failures; in doing so, only present system capabilities were considered.

RESULTS

The results of the analysis of the 200-report sample were distributions of (1) the outcomes of the coordination failures reported and (2) the human factors (types of errors, predisposing conditions, and environmental factors) related to the failures. In the analysis, the coordination process was viewed as the combination of decisions, communications, and actions depicted schematically in figure 3.1. The three elements of coordination – initiation, agreement, and execution – are shown as occurring in logical sequence. Success in meeting each main requirement of each element leads to a successful coordination action whereas failure at any point causes the coordination attempt to fail. The diagram further depicts the usual consequences of the coordination failure as observed in ASRS reports.

In the discussions to follow, the first topic covered is the outcome of coordination failures. This is followed by an examination of the modes of failure observed in the study set of reports. The human factors associated with the failures are discussed next, followed by a consideration of various means of reducing the number of coordination failures.

Outcomes of Coordination Failures

Each of the coordination failures produced, as its direct outcome, a condition wherein an aircraft that was involved in the coordination action was caused to proceed along a flightpath leading to a potential or actual loss of standard separation. Altitude anomalies predominated; the next most frequently reported anomaly was lateral displacement from the correct flightpath. In a few cases an incorrect speed resulted. As indicated in figure 1, when other traffic was involved, these flightpath anomalies frequently led to loss of standard separation. In the data set studied there were 134 such occurrences, ranging in severity from nonhazardous conflicts to high-risk situations in which midair collisions were narrowly avoided. The severity appeared to be largely a matter of chance not correlated with the kind or cause of the coordination failure involved.

Coordination Failures

Reports were examined as to the phase of coordination during which the failure occurred (initiation, agreement, or execution); these sets were then further subdivided by failure mode. There were three kinds of failure among the reported occurrences.

1. Incomplete: A phase of coordination was considered incomplete if the first communications for it had begun but not proceeded to a logical end. This could range from a telephone call not answered in a timely manner to a failure to carry out all items of an agreed plan of action.

2. Inaccurate: A phase of coordination was considered to have been performed inaccurately if the plan agreed to was based on incorrect information or if an error was made in executing the plan.

3. Absent: A phase of coordination was considered to have been absent if there was a failure to initiate coordination, failure to reach an agreement after initiation, or failure to execute the plan agreed upon.

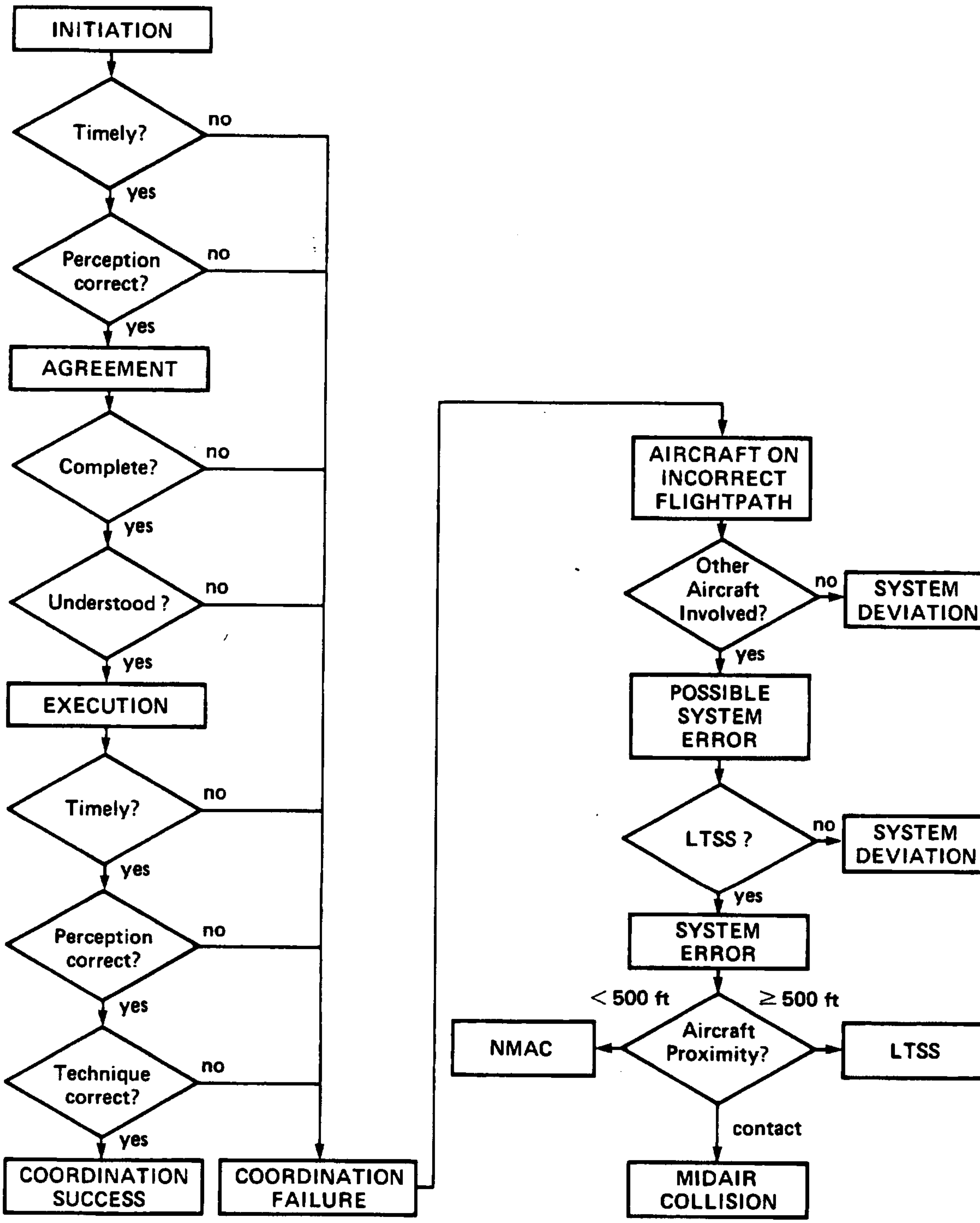

Figure 3.1.– Process of ATC coordination.

TABLE 3.1.– FAILURE MODES CLASSIFIED BY PHASE OF COORDINATION

Failure mode	Phase			Total
	Initiation	Agreement	Execution	
Incomplete	5	10	1	16
Inaccurate	2	16	40	58
Absent	121	2	3	126
Total	128	28	44	200

Table 3.1 shows the results of the failure-mode analysis. The most notable finding is the indication that in 122 reported occurrences controllers did not begin coordination, even when there was an operational need for it or when a directive in force required it. These data leave little doubt about where the main problem with ATC coordination lies. However, the data also indicate significant difficulty with the next most frequently cited failure mode – errors in executing agreed-upon coordination plans – and the third most common failure was in agreement (incomplete or inaccurate).

The data in table 3.1 also suggest that failures occur more often when action is incumbent on individual controllers, as in the initiation and execution phases. The fewest failures occurred during the agreement phase where, by definition, a dialogue is being conducted – two controllers are exchanging information to arrive at an agreement.

Human Factors

The human factors observed in the reported occurrences consist of six kinds of errors and nine kinds of conditions that were related to the errors and seem to have predisposed their commissions. Table 3.2 lists and defines these human factors.

Each report was classified according to the enabling error and its predisposing condition. In some of the reports there was no indication of what the error was; in others the nature of the predisposing condition leading to the error could not be discerned. However, most of the reports contain the reporter's statement about the cause of an occurrence or a factual description of concurrent events and traffic that makes it possible to determine a probable cause.

Coordination errors– Table 3.3 shows the distribution of the types of coordination errors that were found in the study data set; the errors are listed by failure modes. (The errors discussed below are defined in table 3.2.)

Failures of perception, the most frequently occurring errors, resulted in instances in which a controller based his plans or actions on inaccurate or incomplete information. In coordinating a planned action, the controller may have failed to take into account pertinent traffic that was not observed or otherwise made known to him, or the execution of a workable plan may have been inaccurate for similar reasons.

In the following example, the reporting controller agreed to separate aircraft in another controller's airspace without a complete understanding of the relative flightpaths of the aircraft involved. Oral inquiry to the initiating controller resulted in further inaccuracy in the position of an aircraft as perceived by the controller. The end result was a coordination failure due to inaccurate execution.

TABLE 3.2.– HUMAN FACTORS ASSOCIATED WITH COORDINATION FAILURES

Human errors	
Nonrecall	Failure to retain information received that bears on present or future traffic situation
Technique error	Use of unauthorized or incorrectly chosen procedures in the formulation or execution of a coordination plan
Perceptual error	Use of incorrect or incomplete data received from an external source, sensory acquisition, or analysis as a basis for decisionmaking
Failure to monitor	Failure to check sources of information in a routine and timely manner
Message inaccuracy	Contents of a message interpreted differently from originator's intent
Misidentification	Location or other pertinent data applicable to one aircraft utilized for another aircraft
Predisposing factors	
Distraction	An influence or activity that diverts an individual's attention from his normal responsibility
Excess workload	Traffic situation and surrounding circumstances such that the capacity of available human and system resources to respond to requirements is insufficient
Experience/training level	Inadequate individual experience or level of training is a factor in the choice of an inappropriate action or in the improper execution of an appropriate action
Complacency	Self-satisfaction which may result in impaired vigilance based on an unjustified assumption of a satisfactory system state
Airspace configuration	Boundaries of controllers' designated jurisdictional airspace so designed that they contribute to excessive coordination requirements or to failure in the conduct of coordination
Procedural problem	A coordination or separation procedure that induces controller error because of complexity, cumbersomeness, or unfamiliarity due to infrequent usage
Automation mind-set	Controllers unfamiliarity with procedures used under system-degraded conditions when automation features normally in use are unavailable because of equipment or software failures
Equipment failure	Conditions resulting from hardware failures that have an adverse effect on information available or on communications facilities
Interpersonal relationship	A personality conflict between individuals involved in the coordination process

TABLE 3.3.–HUMAN FACTORS ASSOCIATED WITH ATC COORDINATION FAILURES

	ATC coordination failure									Total
	Initiation phase			Agreement phase			Execution phase			
	Incomplete	Inaccurate	Absent	Incomplete	Inaccurate	Absent	Incomplete	Inaccurate	Absent	
Perceptual error	3	1	35	4	8	---	---	14	1	66
Technique error	---	---	38	2	---	1	1	15	---	57
Nonrecall	---	---	11	1	1	1	---	3	1	18
Message failure	---	1	3	2	4	---	---	2	---	12
Failure to monitor	---	---	2	---	1	---	---	2	---	5
Misidentification	---	---	1	---	---	---	---	---	---	1
Unknown	2	---	31	1	2	---	---	4	1	41
Total	5	2	121	10	16	2	1	40	3	200

> We approved aircraft B to climb to 10,000 after adjacent sector released the airspace to us without mentioning they had 9,000 traffic, aircraft A, about 23SE. They did force a data block to our scope. A few minutes later the location of B was asked of Approach Control since he still was not on the scope. Aircraft A was still about 15SE. Approach advised that B was 3W of the VOR. We were not concerned since B was a jet and would easily be gone before A was too close. Moments later a limited data block was observed 4–5 S of the VOR. Not being sure who it was, I called Approach to stop B at 8,000 until radar separation could be assured. Approach advised A was in radar contact and requested altitude to climb to when they were clear. 10,000 was approved reference A. The targets were observed to merge then auto acquisition occurred on the center discrete code. Aircraft A saw B and asked what the traffic was that climbed through him.

Failures of technique, the next most frequently cited error, resulted from a controller's choice of procedural steps or applications that failed to establish or maintain standard separation. The individual actions may have been the everyday tools used by the controller, but their use was inappropriate, untimely, or ineffective. In all these instances, the controller expected that separation would result even though he had not provided positive control measures that would have ensured the maintenance of minimum separation standards.

One example is allowing or requiring controllers to separate aircraft that are in the jurisdictional airspace assigned to another controller with no definite, mutually agreed upon plan for maintaining separation. In this ASRS report the reporting controller handed off an arriving aircraft to approach control at an altitude above other en route traffic which was pointed out to the approach controller. Later, another aircraft became a factor and, again, a point-out rather than full-scale coordination was used to advise approach control of the new factor.

> Aircraft A was cleared by Washington Center from Swann to Patch with proper coordination for a hi-TACAN penetration. Washington handed A off to N.Y. Center sector 17/18 then handed off A to Dover Approach at 150 requesting two turns in the holding pattern. On handoff aircraft B was pointed out to Dover as traffic for A. At that time I gave Dover control, for A's descent, reference B. Minutes later, Dover called me requesting control from 15,000 to 14,000 on A. I then gave Dover control to 14,000 in the holding pattern and his control for the penetration of A again reference B. As A began his last turn in the pattern swing, an aircraft C became traffic for A. At this time I called Dover and pointed out C as additional traffic for A. I also asked the controller if he was still watching B. He acknowledged. When A hit the penetration fix both B and C were traffic factors. Again I called Dover and asked if he was separating A from the observed traffic. He said yes. My radar display showed less than minimum separation. C did not see any traffic. B saw A.

Although this procedure is not specifically prohibited, its choice in this case can be judged an inappropriate one since it required the approach controller to monitor two aircraft that were neither under his control nor in communication with him and to separate three aircraft in airspace under the jurisdiction of another controller. If the reporting controller had retained control of the arriving aircraft until it was positively separated from other traffic under his control, the handoff would probably have been routine and the incident might not have occurred.

Technique errors affected the initiation phase of coordination primarily through controller's substitution of some other traffic control method for normal coordination. It also affected the execution phase in much the same way.

There were 18 reports in which controller *failure to recall* a previously known coordination factor was cited as the enabling human error. The forgotten factors ranged from the presence of an aircraft to steps in executing a plan. In the following example a local controller forgot that an aircraft under his control, cleared for a touch-and-go landing, was IFR; as a consequence, there was an error in executing a routine coordination plan.

> Aircraft A was on a localizer 27 approach to satellite airport with a missed approach left turn to 160°, climb to 3,000 ft. Tower had other departures and called saying that B would be ahead of A. Shortly thereafter, Tower called to ask if we (Approach Control) had A in radar contact. B was radar-identified and told of traffic less than 1 mile. Aircraft A tagged on the traffic. Approach Control turned the airplanes to avoid each other. When A made the touch-and-go, Tower forgot he was IFR and launched aircraft B.

Although this is an example of a coordination failure in the execution phase, the failures most frequently caused by nonrecall errors are in failing to initiate coordination when controllers simply forget about traffic that is present and in need of coordination action.

A *message inaccuracy error* resulted when the recipient of a message either heard incorrectly or misinterpreted the contents of the transmitted message. These failures ranged from severe garbling to use of nonstandard or unusual phraseology. The expectation factor was also prominent in several cases in which the recipient of the message heard what was expected or wanted rather than what was actually transmitted.

Misinterpretation of a request may result in approval which can lead to hazardous occurrences as in this example.

> Ground controller requested to taxi aircraft A across runway 36 at taxiway Foxtrot (intersection of runways 36 and 3) en route to runway 33. Local controller then cleared aircraft B for takeoff on runway 3. The local controller only heard the word "across" and misunderstood what the ground controller had said. Aircraft B was forced to lift off sooner than usual and flew over the tail portion of taxiing aircraft A.

The *remaining errors* were few in number and widely distributed. For example, one error in aircraft identification was reported. It appears that widespread use of discrete beacon codes and alphanumerics on the controller radar displays has been effective in providing positive identification of individual aircraft. Further, the National Beacon Code allocation plan virtually ensures that all aircraft within the jurisdiction of one automated facility will be assigned a unique transponder code. Positive identification can then be maintained as aircraft traverse ATC jurisdictional boundaries.

Only five instances were reported in which failure to monitor led to a coordination failure. This suggests that maintenance of aircraft identity by the automated system requires less detailed monitoring by the controller. He can resume scanning the display after a diversion or distraction and there is no necessity to correlate radar targets with the aircraft identification.

Some radar approach-control facilities are not yet equipped with alphanumeric displays. Others are provided only limited information by the automated system. Failure to monitor under these conditions can result in coordination errors without regard to the available display, as shown in the following example.

> Both aircraft were on practice instrument approaches to the same runway on opposite direction courses. One was in contact with tower, the other with Approach Control. They were turned into each other after missed approach. Local procedures are adequate and clear. This incident occurred because of human inattention and concentration on the situation.

Predisposing conditions– The study data set was analyzed to determine if a condition was alleged which may have predisposed or contributed to the enabling error by the individual involved.

In 137 instances no determination could be made from the information contained in the report. If a reasonable inference could be made from the described circumstances, or if the reporter said specifically that a predisposing factor was present, an appropriate count was taken. Particularly in reports that involved two or more controllers, more than one predisposing condition may have been present.

TABLE 3.4.– PREDISPOSING CONDITIONS

Excessive workload	19
Distraction	18
Experience/training level	17
Complacency	8
Airspace configuration	8
Procedural problem	8
Automation mind-set	8
Equipment failure	6
Interpersonal relationship	1
Total	93

Table 3.4 presents the distribution of predisposing conditions that could be ascertained from the study group of reports. The relative frequencies of distraction, workload, and complacency are consistent with subjective impressions of ASRS researchers about the distribution of these predisposing factors throughout the entire ASRS data base. In this case more than one condition could be associated with a single report (93 citations in 63 reports).

All of the *excessive workload* citations in table 3.4 were based either on the amount of traffic in a sector or on the existence of a contingency operation of some sort, such as traffic that had to divert around a thunderstorm. In this example an arrival controller made a technique error while dealing with the workload brought on by heavy arrival traffic.

> I was departure controller climbing aircraft A to 10,000. Aircraft A had just leveled when I noticed an arrival tag on a heading that would violate my airspace. I quick-looked and arrival aircraft B was crossing in front of my departure. I issued traffic, eleven o'clock, 1 mile out of 10,200. Aircraft A said "We're looking at him." The arrival function was overloaded and the inbound traffic was being vectored all over the sky. The arrival controller was working three fixes and flow control was ineffective.

The *distractions* consisted of extraneous communications within the facility or diverted attention connected with combining or, more often, de-combining positions. In the latter circumstance there were several complaints about interference on the part of supervisors attempting to assist in complex situations. The following is an example.

> Developmental controller, monitored by supervisory personnel, allowed two aircraft to come within 1 mile or less of one another at the same altitude in IFR conditions. Supervisor took control of frequency to S-turn aircraft A on final approach for spacing. He became so preoccupied with vectors that he overlooked overflight aircraft B and aircraft C on final approach converging at 6,000 ft. Developmental tried to cut in to ensure descent of aircraft C but was unable to obtain the frequency and also tried to tell supervisor to no avail. Developmental tried to alert monitor controller who was not aware until aircraft had passed.

There were 17 reports about the *experience or training level* of one of the participants being a factor; the reported occurrences ranged from failure to recognize the need for coordination to system errors. In some cases, the reporter alleged that supervision of a trainee developmental controller diverted his attention from either initiation or execution of the coordination plan. In others, a relatively inexperienced controller working without direct supervision committed an error in the execution of the plan. This report is illustrative.

> A handoff from Departure Control was taken by Sector 1. They were unable to climb the aircraft immediately so they called Sector 2 with a point-out (should have been a direct handoff at that altitude). I heard the D2 controller say "radar contact, my control." The aircraft was rapidly approaching an approach control boundary. We then observed the aircraft's Mode C altitude climbing into aircraft A at 6,000. I believe the error was caused by a lack of communication and low experience level among the Sector 1 and 2 controllers, both developmentals. Most controllers with more experience would have specified the altitude they wanted the aircraft climbed to before accepting a handoff or point-out. I would guess the average experience level in that area is less than 5 years.

In those cases in which controllers made errors ascribed to *complacency*, the controllers received information that should have caused them to recognize the traffic situation and then to take appropriate action; however, in these instances the controllers did not so react. In the following example, the controller assumed that the second aircraft was operating VFR since he had no inbound IFR flight plan. In addition, the local weather should have indicated that VFR flight could not be conducted at 6,000 ft.

> Aircraft A inbound descending to 6,000 ft 20 miles north of XYZ cleared for a VOR approach. Aircraft B reported 10 south of XYZ in foreign airspace at 6,000 descending. At this time it was not known that B was IFR. B crossed over the VOR at the same time as A in IFR conditions. Both aircraft landed without seeing each other. After both aircraft were on the ground, Center called with inbound on aircraft B stating that the telephone was out of service for normal communications from the foreign approach control facility.

Airspace configuration was indicated in eight reports of coordination failure in which aircraft were under the jurisdiction of different controllers but operating in proximity. This situation can occur along any jurisdictional boundary and it is particularly notable where two busy airports are located in the same vicinity. This report is an example.

> AR2 had four IFR inbound aircraft, three from the north and east of airport and SMA A from the south. He decided to vector SMA A to the west for right downwind to runway 13R. AR1 was using 13L for VFR arrivals. During coordination with the adjacent approach control it was understood that they had a departure to go on their runway 13L, so aircraft A would have to be kept close in to the airport. Actually, the departure from the adjacent airport was using runway 17L but reporter missed this information. Result was aircraft A passed opposite direction traffic with 1-1/2 miles separation.
>
> Reporter suggests that the adjacent approach control should control all IFR and Stage III arrivals since they have more sophisticated radar equipment and to reduce coordination requirements.

In the study group eight reports indicated that a *procedural problem* was a factor. In this example the controller complains of consistent noncompliance with the procedure set forth in the interfacility letter of agreement.

> SMA A being vectored to intercept bridge for right traffic entry from the west. I observed traffic inbound from the south for the bridge. Aircraft A was radar contact and came on frequency 2 miles west of the bridge heading north for airport. This is a violation of the Letter of Agreement which requires all aircraft to be vectored over the bridge unless otherwise coordinated. Such failures often result in potential conflicts with traffic already in the areas.

Automation mind-set is characteristic of some controllers in automated facilities who have little or no experience in a nonautomated work environment. Reliance on full system capabilities at all times becomes the standard or normal operation. If the system is degraded for any reason, either hardware or software, some controllers lack confidence in their ability to perform adequately with less than the complete system. For example, some controllers have asked to be relieved because they felt incapable of using the broadband radar system.

This condition appears to heighten the probability of error, both because of actual skill limitations and because of lack of confidence on the part of the controller.

Eight reports in the study group cited this problem as a factor in a coordination failure.

Equipment problems for which no redundancy is provided can increase the requirement for coordination to replace those functions that are normally supported by system equipment. Substitute communication equipment – required for communication between controllers and between pilots and controllers – may be unfamiliar to the users or unwieldy and time consuming. Reversion to broadband radar from computerized displays or to a nonradar environment may sharply reduce the capacity of the controller in terms of traffic volume.

Increased coordination requirements almost inevitably result from loss of major system components, and these additional requirements increase both the probability of error and deviations from normal operating procedures.

Interpersonal relationships characterized by personal conflict between the participants attempting coordination were cited in only one report. If an individual fails to cooperate in any phase of coordination, there can be a failure resulting in hazardous consequences. Failure to respond to a request, failure to agree to an otherwise workable plan, or failure to execute due to personality clashes between participants, or even to delay any step of the process can create a climate for failure of coordination.

DISCUSSION

The foregoing examination of coordination failures showed they tend to be caused by human errors of a complex and subtle kind. A more detailed look at these errors and the role management plays in controlling the conditions that are associated with them can suggest some approaches to reducing the frequency of their occurrence.

Coordination Errors

Table 3.1 shows that the most frequently reported coordination failures are "absent initiation" and "inaccurate execution." Further, table 3.3 shows that these two failure modes are triggered almost equally by errors in technique and perception on the part of the controllers participating in the coordination transactions. Of the two kinds of errors, mistakes in choice of technique may be the more insidious because the controller is frequently led into the position of not beginning the coordination process in time or executing it incorrectly because he is busy applying some different, ad hoc, method of separation to the traffic for which he is responsible.

Errors in coordination technique– Several reports of coordination failure portray controllers using techniques that appear to have been shortcuts or abbreviations of the full coordination procedure. Usually such reports cited factors such as workload or inadequate staffing in conjunction with these events. The reports indicate that the possibility of controller error is greater when shortcuts are used in situations where full coordination would exercise more positive control of the aircraft involved – especially when the abbreviated technique is not specifically authorized by directives providing a common understanding to all parties.

The techniques discussed are point-outs, quick-looking adjacent sectors, use of visual signals in intrafacility coordination situations, and approvals subject to other traffic. None of these procedures is illegal; they are not even marked departures from routine operating practices in many kinds of separation situations. However, in the specific kinds of situations covered here it is simply the case that – as events turned out – the use of normal coordination would almost certainly have been more successful in avoiding loss of separation.

Many reports indicate that coordination, such as it was, consisted of a *point-out* only or a statement to "miss A" or a similar abbreviated message. The reporter quoted below states succinctly the problem associated with this technique error.

> Point-out procedure was used. However, I do not believe good judgment was used – should have been handed off. Point-outs are taking the place of handoffs resulting in more system errors.

The following two reports depict results of technique substitutions in situations where normal coordination might have prevented serious conflicts.

> Two aircraft were at the same altitude when military A reported a near midair. He said he needed to climb to miss GA B. Poor coordination was the cause of the problem. Some coordination is done by pointing out traffic to another controller. The other controller could be talking to someone on land-line giving approval which is interpreted as approval for the point-out.

* * *

> Aircraft A was landing in my sector. After accepting handoff from the adjacent Approach Control, I asked my data man to request control. He advised I had control but to miss aircraft B over the VOR southbound. I delayed turning A until I was sure they would be clear of one another. I turned A to heading 340 and observed traffic at eleven o'clock 2 miles southbound readout 3,000 ft. Aircraft A advised he had the traffic and the type was that of aircraft B.

Most of the point-out reports were similar to the foregoing. Acceptance of a point-out meant that relevant traffic was observed but not under coordinated control and, in many instances, its intentions were unknown. In situations where coordination is needed, the point-out technique can work reliably only where there is a framework of facility directives that defines coordinated operations utilizing point-outs.

Other reports of coordination failures caused by technique errors contained the characteristic line "approved – traffic is A, B, and C." The almost inevitable result of this procedure – conditional approvals subject to separation from other traffic – where no attempt is made to construct an agreed upon course of action, is that one controller handles traffic in another controller's assigned airspace. The following is an extreme example of this kind of situation that was further complicated by a position relief at a critical moment.

> Controller 1 takes Center handoff on aircraft B descending to 7,000. Controller 2 radar-vectored SE bound departure A to 6,000 and made handoff to Center. Center issues climb to 11,000 with respect to B. Controller 2 clears A to 11,000 report leaving 8,000. B calls descending to 7,000 leaving 15,000. Controller 2 descends B to 3,000. Relief controller 3 assumes position. Aircraft A reports leaving 9,000. Controller 3 switches A to Center frequency. Controller 3 checks strip showing 70/30 with no indication that clearance is to 7,000. He now learns that B is descending and still above 7,000. Controller 3 asked B his altitude, reply was 13,800. At this time A and B were less than 5 miles apart converging. Controller 3 called Center to

> coordinate altitudes for both aircraft. Center advised they would stop A at 11,000 and to stop B at 12,000. Pilot of B advised he was already of that altitude. Targets merged.

Intrafacility coordination is sometimes accomplished by means of *visual signals* between controllers. Although no official recognition exists for such procedures, they may be used during periods of high activity. Problems related to the accurate understanding of such signals are similar to some of those encountered in voice communications. Since there are no standardized visual signals, they are the product of improvisation by the controllers. The meaning of the signals may be apparent when the signal is simply to climb or to descend, but efforts to convey detailed data, such as heading or altitude assignments or to provide more than approval of a request as perceived by the controller being queried, can lead to misunderstanding. Misinterpretation of the intended message results in actions leading to a possible hazardous incident.

Another substitute for verbal coordination is the *look-and-go* concept used in some facilities. This is the reverse of the point-out case. A controller quick-looks the airspace being controlled by another, and if he observes no traffic pertinent to his plan, he clears the aircraft he is controlling into the adjacent airspace. This procedure can work effectively provided all pertinent data are available on the display. Both incidents and serious accidents have resulted because either the displayed information was incomplete or because the controller failed to observe and perceive correctly the traffic situation in airspace not under his direct control. This ASRS report describes such an incident.

> Departure control was being operated by a controller who uses "look-and-go" procedures. As A asked to start descent I approved this and noticed a target with an altitude readout of 3,500 at twelve o'clock, 1 mile. A military departure was climbing alongside and through the altitude of my aircraft. This incident could have been prevented by Departure Control inquiring if I had any aircraft in that area and asking permission to enter my airspace rather than the "look-and-go" operation that is used by some people.

Two accidents exemplify the pitfalls of using the "look-and-go" technique. The first, described in a National Transportation Safety Board accident report (ref. 1), involved a landing cargo wide-body and a taxiing passenger air carrier that nearly collided after the air carrier had been cleared to cross an active runway. The wide-body suffered major damage when it departed the runway to avoid collision.

In this case a facility directive authorized the ground controller to exercise his judgment without conducting coordination with the local controller, provided he observed his radar displays of the BRITE and the Airport Surface Detection Equipment (ASDE) for appropriate traffic information. The report indicates that the spacing between the two arrivals was only 2 miles and that the standard was 4 miles. The ground controller apparently failed to perceive the radar target of the wide-body (the second arrival) and assumed that the next arriving aircraft was one displaying a full data block still well out. Since the local controller did not advise the ground controller of the less-than-standard spacing, there was a diminished opportunity for the error to be detected. This is a special case of look-and-go, done in full accord with directives then in force, but it still illustrates strikingly the lack of redundancy that exists when the look-and-go concept is in use instead of full-scale coordination.

The second accident (ref. 2) demonstrates how primary radar targets present a particular pitfall in use of the look-and-go concept. Display of primary radar data may be intermittent or may provide only weak returns at the time of the quick look. Local procedures normally require that coordination be effected when an aircraft that is not equipped with a transponder is involved. If coordination is not accomplished, or if a controller fails to recall after coordination, an incident or an accident may result. In this case, a midair collision occurred in which six lives were lost. A breakdown in coordination was involved when look-and-go procedures were in use and one of the aircraft was not equipped with a transponder. The following exerpts were contained in the report.

> While the facility operating procedures were adequate, it was imperative that specific procedures be adhered to.
>
> When the coordination procedures broke down, there was no redundancy to provide an additional safeguard for aircraft.
>
> Visual coordination was an inadequate form of coordination . . . . In reality, no coordination took place.

Perception errors– The second major class of coordination errors consisted of failures of controller perception. In most cases, the controller failed to observe a potential conflict early enough to take appropriate action. In other instances, the implementation of the coordination plan resulted in conflicts with traffic that was not a part of the coordination agreement. Less frequently, the flight-path projection of the coordinated traffic was improperly perceived.

> I accepted a handoff on B believing he would be stopped at 2,000. A minute later B reported level at 3,000 only 1 to 1-1/2 miles from A.

Only rarely could it be inferred from the context of the reports that controllers made these perceptual errors because they were incompetent to read or interpret the information coming to them from displays and from radio communications. The most often cited or implied preconditioning factor was distraction of various kinds. Controller attention was most often drawn from coordination tasks by the need to respond to incoming communications from other aircraft or from controllers not involved in the coordination action. This may reflect a possibility that controllers are conditioned by training and experience to treat such responses as first priority. Another source of distraction was a variety of events – all quite routine – occurring within the ATC facility: relieving of positions, decombining positions, supervisory intervention intended to provide assistance, and (often mentioned) the provision of the on-the-job training.

> I was conducting a check ride on a controller. Traffic was moderate to heavy. At a critical time my attention was diverted by another controller who was very insistent on talking to me about a situation earlier in the shift. During this time I felt certain that the controller had coordinated to go through another controller's airspace. He in fact had not.

The Management Role in Coordination

The crucial role played by ATC management in the coordination process manifested itself in many of the coordination failure reports. The procedures to be used are defined in facility directives and in letters of agreement that management prepares. These are, of course, compromises because they must best serve all the users yet be compatible with aviation system capabilities. In developing such procedures, management subdivides and delegates controlled airspace in such a way that the need for control transfer is minimized, thereby easing the coordination workload as much as possible. Finally, management controls, to a large extent, the immediate working environment in each facility and so has much to do with determining the amount of distraction the controllers must deal with. Thus management's role is directly involved with all the sources of error noted in the coordination failure reports.

Airspace subdivision– Airspace configuration is tailored to provide a smooth flow of traffic with minimal coordination. One design consideration is that controller workload may be less with a large segment of airspace containing a relatively large number of aircraft to be worked than with a smaller segment that requires additional coordination. Each subdivision of airspace creates a requirement for additional coordination which may result in an overall increase in workload. The distraction effect of the added coordination requirement may increase the probability of a hazardous incident.

> Airspace above our sector belongs to another Approach Control from 8,000 to 15,000. B appeared to be in level flight at 7,000 when he should have been at 6,000. B then continued on into the adjacent approach control airspace. This incident resulted from B's penetration of my airspace at the wrong altitude for direction without my knowledge. My sector only has 7,000. It is extremely complex and there is no room for error. Too much shelving, too little airspace to maneuver.

Establishment of coordination procedures– ATC management establishes all coordination procedures. Higher management, regional and Washington headquarters, usually direct general policy, which is implemented by local directives that prescribe the day-to-day procedures for controllers. For example, agency policy provides for mandatory radar handoffs between controllers if radar coverage exists. The time, location, and to whom a handoff will be made will be established by facility management in the form of facility directives, or by interfacility management in the form of a letter of agreement if more than one facility is involved.

Occasionally ASRS reports indicate that procedures were designed without taking into account some contingency of traffic configuration. Such reports are concerned most often with allegedly flawed letters of agreement. Although they sometimes reveal the existence of interfacility prejudices held by controllers, they also can indicate real hazards in which a faulty procedure creates conditions that lead to perceptual or technique errors.

Distraction-free environment– It is clearly a responsibility of ATC management to provide working environments that are as free of distractions as possible. The topic has been discussed and exemplified earlier in this report. That distraction is an important precursor of human error in the cockpit was shown by Monan (ref. 3); it is obviously an important factor in air traffic control as well.

Reduction of Coordination Errors

The coordination errors that seem to be most readily correctable by design or procedural changes are those that lead to a controller's failure to act in a timely manner, either because he requires an additional stimulus to act at the right time or better memory aids than are now available to enable him to keep abreast of a complex and changing traffic situation. There appear to be two feasible approaches to this: more extensive use of existing automation capabilities and further development of controller memory aids.

Automation capabilities– If controllers who are busy with routine matters were to receive reminders about a coordination action when time is becoming critical, their failure rates might be substantially reduced. The present automated systems already have well-developed capability for doing this but it appears from ASRS reports that some facilities are not equipped or are not using available capabilities to the full. The following is a problem that arose at the Boston Center when a manual handoff was used.

> ARTCC initiated a radar handoff after aircraft A was 1 mile inside approach control airspace. Conclusion – the ARTCC radar controller failed to handoff A prior to the aircraft entering rapcon delegated airspace.

Automatic handoff, automatic acquisition, and automatic conflict alert provide reminders to controllers at different points in the coordination process. The procedures are available, and their full utilization at all ATC facilities would directly reduce the probability of coordination failures.

The use of *automatic handoffs* by en route facilities would alert controllers when controlled aircraft are about to penetrate their airspace. The alert signal is so timed that there is usually sufficient time for remedial action if the handoff controller has not perceived the need for initiating coordination. Terminal facilities benefit from the use of the automatic handoff by Centers, even though they may not have the capability themselves. However, routine acceptance of handoffs by receiving controllers without analysis of depicted data will defeat the effectiveness of the alert provided.

Automatic acquisition allows the system to establish a track and display a data block on aircraft entering radar coverage in accordance with desired parameters. All automated facilities have this capability. An alert can be provided to the controller when a handoff cannot be made or is overlooked by the transferring controller. This feature is useful when aircraft depart an area with no radar coverage and later enter one with radar coverage. It also allows en route controllers to see departing aircraft prior to exiting terminal airspace, provided they are within en route radar coverage.

There is general agreement that the *conflict alert* system has been effective in reducing system errors, although its primary purpose was to prevent midair collisions. If a controller receives a 2-min warning of impending loss of separation, he can (in most cases) maintain separation by prompt response to the alert. In some cases, no advance warning can be provided. For example, a change of course can result in an immediate loss of separation which could not have been predicted. In those cases, the loss of separation has occurred when the conflict alert is issued.

Since ATC radar data is analyzed on a continuous basis, it would be possible to provide an earlier alert to the controller of a potential conflict. In most cases, verbal coordination is initiated in order to resolve such a conflict. An earlier signal that a conflict was likely to occur might decrease the number of cases in which action to coordinate was not initiated, the most common failure in this sample. False alerts could be minimized by providing discrete sector parameters set equal to the conflict alert parameter, if desired, or to any appropriate time value.

Neither this proposal nor the conflict alert system is infallible; the function is only as good as the data available. Use of Mode-C altitude data as the primary source of altitude information for conflict prediction would result in improvement and would reduce the likelihood of the system being defeated by human error.

Memory aids– Many controllers use scratch pads or grease pencil notations to help them remember important data. Flight-strip notations can be effective reminders of further actions that may be required. If used more extensively, these and similar devices might help to reduce the number of recall failures. Because total reliance on recall appears to be a predisposing condition to failure, as heretofore discussed, any measure that can assist in minimizing this factor would be useful.

Operational technique– The need for providing positive control to the maximum extent in the procedures of the controllers would seem to be self-evident. Reliance on radar separation as the only tool available is suggested in several ASRS reports. An example is use of vectoring when altitude separation can and should be provided. In airspace designated "positive control area," controllers often do not exercise positive control. Unrestricted climb or descent clearances are issued through other traffic, with the controller anticipating that radar separation can be applied as a last resort. An impending conflict is observed and there is a hurried effort to coordinate a change. Sometimes, the time expires before anything can be accomplished, as shown by several examples in this study report.

Letters of agreement and facility directives often provide for such procedures as route separation of transitioning aircraft and standard instrument departure routes (SIDS), but the controller can avoid many worrisome incidents by adopting the position that he will provide positive control to the maximum extent achievable, avoiding "betting on the come," by utilizing all of the tools available in the most effective and professional manner.

CONCLUSIONS

Coordination failures occur throughout the air traffic control system. The most frequently reported failure is failure to initiate action to establish coordination; the second most frequently reported is failure to execute the agreed plan. The causes of failure appear to be similar in both types of errors. The remaining failure modes are reported less frequently; they consist of misunderstanding the transferred data or the plan agreed upon, or the data used to develop the plan are incorrect.

Perceptual and technique errors appear throughout reports of coordination failure. Memory aids and reminders can be used to reduce the likelihood of oversight or failure to execute a previously developed plan. Maximum utilization of automation capabilities, where they are available, could reduce the need for oral coordination and, consequently, reduce the probability of error.

Errors in coordination often result in hazardous incidents, and they continue to be reported to ASRS in substantial numbers.

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4. INFORMATION TRANSFER BETWEEN AIR TRAFFIC CONTROL AND AIRCRAFT: COMMUNICATION PROBLEMS IN FLIGHT OPERATIONS

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INTRODUCTION

This study of problems in communications between flightcrew and air traffic controllers was prepared as a part of an analysis of information transfer problems in the national aviation system. It is adapted from reference 1, an earlier study (by the senior author) of possible effects of the Discrete Address Beacon System (DABS) Data Link on the information transfer problems reported to the NASA Aviation Safety Reporting System (ASRS); the work reported in reference 1 was performed at the request of Systems Research and Development Service, FAA.

The purpose of this report is to discuss problems in oral communication between pilots and controllers. The investigation consisted of review and analysis of pertinent information in the ASRS data base.

APPROACH

A search was conducted of 6,527 reports submitted to ASRS between May 1, 1978 and August 31, 1979. The search technique identified and retrieved reports concerning:

1. Problems in voice communications between flightcrew and ATC

2. Problems in conveying information in ATIS broadcasts (as specified in the AIM and FAA ATC Handbook 7110.65A)

3. Problems with information concerning wind shear and minimum safe altitude

In this group of reports, 5,402 information transfer problems fitting one of these criteria were identified (some reports contained more than one information transfer citation).

The research team studied selected report narratives to establish the generic types of communications problems present. A categorization of these types was developed along lines already in use in classifying ASRS reports. Ten such categories emerged:

1. Misinterpretable – phonetic similarity

2. Inaccurate – transposition

3. Other inaccuracies in content

4. Incomplete content

5. Ambiguous phraseology

6. Untimely transmission

7. Garbled phraseology

8. Absent – not sent

9. Absent – equipment failure

10. Recipient not monitoring

The retrieved reports were grouped according to these categories. The groupings were then further subdivided according to the operational regimes in which the reported incidents occurred (i.e., terminal operations, en route operations, and various special operations). Selections of these reports were reviewed to determine unique characteristics and common features.

RESULTS AND DISCUSSION

The initial pass over the data base, the first step of the search, produced a finding considered significant to the central issue of this study: 70% of the reports to ASRS involve some type of oral communication problem related to the operation of an aircraft. The nature of the problems reported varied widely, ranging from failure to originate an appropriate message to failure of the intended receiver to comprehend and confirm the message accurately.

These communications problems were subdivided into the 10 generic types listed previously. Before taking up these assessments, however, two aspects of communication difficulties require consideration: the expectation factor and the problem of conveying traffic avoidance information effectively.

The Expectation Factor

ASRS reports indicate that many instances of misunderstanding can be attributed to the expectation factor; that is, the recipient (or listener) perceives that he heard what he expected to hear in the message transmitted. Pilots and controllers alike tend to hear what they expect to hear. Deviations from routine are not noted and the read-back is heard as the transmitted message, whether correct or incorrect.

> Aircraft A was in a block altitude of 12,000–14,000 ft. The instructor pilot and the student both thought the controller told them to turn left to a heading of 010° and descend to and maintain 10,000 ft. At 10,700 ft the controller requested aircraft A's altitude. The crew responded 10,700 ft. The controller stated the aircraft had been cleared to 12,000 ft, not 10,000 ft. There are two contributing causes for this

occurrence: 99% of all clearances from that area are to descend to and maintain 10,000 ft, and as the instructor I was conditioned to descend to 10,000 by many previous flights. The controller may have said 12,000 ft but I was programmed for 10,000 ft.

Conveying Traffic Avoidance Information Effectively

ASRS reports suggest that the least satisfactory aspect of air/ground information transfer is the conveyance of traffic advisories and avoidance information. Faults of all kinds are cited, but the pervasive difficulty that appears to underlie many of these faults is the seeming inconsistency with which information about traffic is made available.

> While descending through 12,200 MSL first officer observed and called traffic at twelve o'clock level as we were turning through 300°. Turn was continued to approximately 320° and other aircraft diverged to the left on a southeast heading with clearance of approximately 1,000 ft laterally. On inquiry, ATC indicated that the only altitude readout on a target in that area was 6,700 MSL. If our aircraft had not been turning in on heading approaching VOR, a projected collision course would have resulted. Situation discussed with ATC supervisor who indicated that a "skin paint" was later picked up on other aircraft but later lost by adjacent center. Other aircraft apparently operating without transponder would be primarily cause of this incident. Contributing would be difficulty in picking up front profile visually at such closing speeds. Other aircraft made no evasive action and we assume he did not observe us.

In the present system, air traffic controllers provide traffic advisories as an "additional service," which means that workload permitting, the controller will issue advisories on traffic that he observes when he is not occupied with higher priority duties. This results in pilots failing to receive traffic advisories on aircraft that are not readily seen on radar – especially those that are not transponder-equipped. In addition, it is during periods of high traffic that the workload of the controller is likely to preclude issuing traffic advisories – precisely when the need is the greatest.

Generic Types of Problems in Oral Communications

Thousands of ASRS reports cite the difficulties in the exchange of information through the use of oral communications. Some reports concern transfer of information between ground facilities or personnel within such facilities. The greater number of reports concern air/ground communications and a very small number concern air communications alone.

Air/ground communications are conducted by voice radio as they have been for about 50 years. During that time technical advances have improved the quality of voice transmissions and mitigated atmospheric or induced electronic interference. Remaining technical problems include blocked transmissions, line-of-sight limitations, and hardware failures that remain undiscovered until the next occasion for a communication arises. However, the retrieved ASRS reports concerning problems in air/ground communications indicate convincingly that most of such communications problems involve human error.

Misinterpretable – phonetic similarity– The "phonetic similarity" category was assigned when similar-sounding names or numerics appeared to lead to confusion either in meaning or in identity of the intended recipient, thus causing an information transfer failure. A total of 71 reports were classified in this category. The following narrative is typical.

> We were cleared into position on runway 32L for an intersection takeoff. After a brief hold in position we received what I thought to be a takeoff clearance. I then repeated "Roger, ACR 122 cleared for takeoff, straight out departure." There was no response from the tower until we were well down the runway approaching V-1 speed. The tower controller then said rapidly, "ACR 122 that clearance was not for you, it was for ACR 142." We heard no other trip respond to the takeoff clearance but possibly we responded at the same time as ACR 142 so that tower was unaware that we had both answered and blocked each other's response.

Most reported phonetic similarity problems involved execution of clearances by someone other than the intended receiver.

Inaccurate – transposition– In the group of ASRS reports reviewed, there were 85 in which some part of the message was misunderstood because of a transmitted or recipient-perceived error in the sequence of numerals within the message. This type of error seems to occur most often when ATC gives assigned headings or distances in conjunction with changes in assigned altitudes in the same clearance. Heading 270 might be heard as a new assigned altitude. The readback then might not be perceived as incorrect (expectation factor) and an incident might result. One ASRS report illustrates this problem.

> F/O flying, Captain working radio, Center gave clearance to descend, (either) (1) to cross 10 DME east at 240 or (2) to cross 24 DME east at 10, F/O set 10,000 ft altitude and 24 DME, and started descent. Leaving 19,200 Center advised we should be at 240. Captain advised we show 10 at 24 DME, but what altitude did he want at this time, he then said maintain 180.

Other inaccuracies in content– Other reports cited inaccuracies for reasons other than phonetic similarity or transposition. There were 792 indicating a message problem of this category. Generally, they involved messages that were accurately transmitted and received, but they contained, or were based on, erroneous data (formulation errors), or, to a greater degree, they were the results of errors of judgment in the originator's decision process. This resulted in the relatively large number of reports in this category.

> Faster aircraft B was overtaking aircraft A so I issued headings that would provide lateral separation. Later aircraft A requested deviation around weather that I did not observe on radar. Thinking that a route direct to XYZ would maintain lateral separation and provide A with necessary deviation, I issued the clearance. The clearance brought A back south and since I only had 5 miles in the first place, I immediately lost separation.

Other reports in this category reflect conflicts in the interpretation of a message between the sender and receiver where there is no obvious explanation for the difference in understanding.

> Lift off runway 31 climbing to 5,000 per SID. On initial contact flight was cleared to 12,000. Subsequent transmission received and acknowledged to climb to 14,000 and maintain speed less than 250 knots until 13,000 or above. Traffic was observed at one o'clock on converging course descending. When our flight left 13,000 ft Departure Control asked our altitude and advised us to descend to 12,000 and increase speed. No member of the crew either heard or acknowledged such a message.

Incomplete content– A reported problem communication was classified as "incomplete" when the originator failed to provide all of the information necessary for the recipient to understand it properly. There were 296 reports classified in this category in the study group.

> Between LIT and FAM we were cleared for a Farmington transition to 30 left. To the best of both pilots' recollection, no statement was made by the controller to "expect a profile descent," when the clearance for a Farmington transition was given. A flight was in the Farmington area climbing to FL230. Upon hearing aircraft B talking with Center, we volunteered our altitude as being FL240 and we leveled off. I was watching B at FL230 and no evasive action was required.

In this example the requirement for profile descent was not effectively transferred, whether because of input error, failure to comprehend, or a failure of the voice radio system. These failure causes are characteristic of the reports in the "incomplete content" category.

Ambiguous phraseology– A reported problem communication was classified as ambiguous or misleading if the composition, phraseology, or presentation of the message were such that the recipient would tend to misinterpret or misunderstand the message when receiving it under normal conditions. There were 529 reports in which this kind of message problem was cited.

> We were being vectored downwind when the controller said to plan on a visual approach to runway 28. At this time we were at 6,000 to stay above departure traffic. We were assigned heading of 100 and cleared to 4,000. At this point we were south of runway 28 abeam the airport. Controller said, "The runway is nine o'clock and 3 miles, can you see the runway? We responded yes. He said, OK, turn to 360°. At this point we started our turn and (thinking we were cleared for a visual approach) began a descent. He asked our altitude at 3,400. Then he said he had not yet cleared us below 4,000 but to stay where we were. Shortly thereafter, he then cleared us for a visual and changed us to the tower.

Untimely transmission– Messages were classified as untimely if they originated too late or too early to be useful to the recipient. There were 710 reports that indicated this message problem.

> Departure clearance was left turn after takeoff to 120°, climb and maintain 7,000. We had just cleaned up and finished the climb checklist and at about 4,500 ft Departure Control gave us VFR traffic at twelve o'clock less than a mile. The Captain spotted the traffic and pointed it out to the F/O who was flying and nosed the aircraft over into level flight to go under aircraft B 50 to 100 ft and slightly behind him about 100-200 ft. Aircraft B saw us just before we passed under and behind him – he flinched just enough to slightly raise his left wing. We feel that

> radar should have had aircraft B in radar contact at the time we took off and we should have been advised of the traffic at or before takeoff.

Garbled phraseology– Messages were coded as being garbled if information content was lost or severely distorted so that the recipient was unable to understand the intended message. There were 171 such reports in the study report group.

> Departed on runway 27 with a right turn to 300°. After takeoff the heading was amended to 330° but the transmission did not come through clear to us and it was mistaken for 030°. Subsequently we learned that our read-back to the controller was not received clearly and it was assumed that we had received 330° instead of what we interpreted to be 030°. Obviously, too much assumption, probably assisted by the unusually clear weather. We later learned that our error had brought us in conflict with aircraft B that had taken off immediately in front of us. Radar had us less than a mile from aircraft B when we passed.

Absent – not sent– Problem communications were assigned to the "absent – not sent" category when there was a failure to originate or transmit a required or appropriate message. In the study sample, 1,991 reports were classified in this subset. The large number is due to a broad interpretation that an appropriate message would have broken the chain of events that resulted in a hazardous occurrence. This could consist of either a point of information or an air traffic control clearance.

> Runway 9R in use – (heading 120 and told to expect a new heading when in the air). The aircraft ahead of me was issued right turn to 240 or 270. I was left on 120. This heading aimed me toward aircraft B and I felt very uncomfortable. When Tower did not give me an immediate turn, I contacted departure radar expecting the other turn. After radar contact was established, the departure man asked me to go back to Tower and upon returning he (Tower) told me I should have expected the second turn from him. If Tower had issued "expect further clearance from him," it would have made this clear and concise.

Absent – equipment failure– Problem communications were categorized as "absent – equipment failure" when a failure caused a complete loss of the message. The study report group contained 153 of these reports. This finding suggests that the equipment in use is reliable when compared to the human error-initiated problems in message transfer that are reported to ASRS.

> Aircraft A and aircraft B were being vectored to Detroit Metro Airport by Approach Control. Aircraft C was being vectored to Willow Run airport on the same frequency. The microphone button became stuck on C. As a result the approach controller was unable to communicate with A or B and less than standard separation occurred. The two aircraft were within approximately 500 ft vertically, the pilot of B called the tower controller and advised there was a stuck mike on Approach Control. The tower controller, using the information on his radar display, attempted to descend and turn B to avoid the conflict. However, the situation had deteriorated to the point that the conflict could not be avoided. Aircraft B apparently took evasive action.

Loss of communication is an extremely frustrating experience for an air traffic controller. He is usually helpless to take action to preclude a hazardous consequence. In the above example, one pilot had the presence of mind to contact the tower after noting the approach control frequency was blocked due to the stuck mike, but it was too late to avoid loss of separation.

Recipient not monitoring– A problem communication was placed in the "recipient not monitoring" category if the recipient failed to maintain listening watch, proper lookout, or failed to read available correct information. There were 553 reports in this classification.

> A conflict occurred between aircraft A on my frequency and aircraft B on Approach Control frequency. Aircraft A was departing and B was arriving. I was not aware that the B flight was in the area and the conflict was first noted by an approach controller who must have seen what happened. An investigation followed showing that the approach controller who had handed off A to me failed to coordinate all aspects of control to me as per letter of agreement between our facilities, and I failed to catch the mistake when A came on my frequency. Poor coordination between controllers and not properly listening to the pilot's initial contact were contributing factors in this incident.

A substantial number of reports in this category described the results of traffic advisories not being issued when the reporter alleged or inferred that the traffic could and should have been seen on radar. It may be technically correct that a specific target was not seen because of inattention to the particular area in question, and, therefore, the area was not being monitored by the radar controller. It appears, however, that many pilots expect traffic advisories at all times if they have been advised that they are in radar contact.

Another case is the failure of the flightcrew or the controller to receive a message or initial broadcast or to respond to a call when time is critical. In some reported cases the controller became aware that his original plan for providing separation was not working, and he then attempted to correct the situation at the last moment. Lack of instantaneous response gave rise to the allegation that a proper listening watch was not being maintained.

Communications Problems Related to ATIS

The data base was searched for reports that concerned (1) items of information contained in the present Automated Terminal Information System (ATIS), (2) broadcast problems with ATIS, and (3) indications of both a communication message problem and at least one item of ATIS information. In addition, reports concerning wind shear and minimum safe altitude warning were identified. (ATIS items of information included in these broadcasts are specified in the Airman's Information Manual and the FAA Air Traffic Control Handbook 7110.65A.)

An interesting finding of this search was that relatively few of the message problem reports were concerned with terminal information services; only 50 such reports were retrieved. It had been expected that there would be a large number of reports of difficulty in understanding the ATIS broadcasts. A considerable number of such reports were received in early ASRS operations (1976 and early 1977), but they decreased to a smaller number during the search period of this study. This suggests that improvements have been made in response to several FAA directives aimed at poorly prepared ATIS tapes, use of excessively rapid rates of speech, and technical problems with ATIS broadcast equipment. It may also suggest that difficulty in understanding ATIS is judged by airmen to be a minor matter, one that is easily overcome by repeating the broadcast and therefore not worthy of an ASRS report. In any case, most terminal-information-related reports described problems with ATIS that had substantially more serious consequences than having to listen to a broadcast a second or third time.

The problems present in the terminal information segment of the retrieved reports were classified as follows:

1. Unintelligible transmissions

2. Obsolete approach/runway-in-use information

3. Noncurrent runway visibility readings

4. Obsolete weather information

Unintelligible transmission– Reporters have cited difficulty in receiving ATIS broadcasts because of the rate of speech and the quality of the recording.

> On a VFR flight to ICT late in October, I had to listen to the ATIS seven times to get active runway, wind, altimeter setting because of the rate the words were spoken – too fast. As a low-time pilot my workload when landing at an unfamiliar airport is higher than it should be; I check and double check everything and it is unsettling to be unable to get the information needed. Most places I've been that use ATIS – Chicago, Milwaukee, Madison, Rockford – it seems that making the tape has become a chore so it reads as fast as possible to get it over.

* * *

> ATIS is supposed to speed up and facilitate arrivals and departures at airports large enough to warrant its installation. This is a wonderful concept. However, on the times that I have been into airports that have it (Boise and Portland) the report has been so distorted as to be all but useless. There is no need for the person recording the information to speak as fast as he can. I do not believe that I should have to listen to ATIS more than three times at the most to have all the information straight. Once should be sufficient. But I have had to listen 5 minutes or more before I was able to clearly understand what it is the man is actually saying. Without exception, I have not been able to clearly understand the content of the ATIS broadcast the first time simply because the man spoke too fast and, for the lack of a better word, mumbled as he talked.

Obsolete ATIS data-approach/runway in use– A frequent complaint from reporters is a change of approach or active runway from the information contained in the ATIS broadcast received by the reporter.

> Planned approach and landing for runway 31R JFK. Prior to turning final, runway was changed to 22L and aircraft was vectored for ILS or visual approach to runway 22L. Visibility approximately 5 mi smoke and haze. Our aircraft was advised being vectored for 22L ILS approach to advise when runway in sight. Throughout the vector until turning on final we received the 13L ILS identification (IMOH). Both 22L and 31R share a common frequency 110.9. We reported this to Approach Control and were advised the ILS was operating normally on 22L. Not until we were established on visual approach for 22L did the ILS start operating normally with current identification. At this time Tower advised that 22L was now operating normally. Not serious in VFR but could be very confusing and possibly cause missed approach in IFR.

Runway visual range– Rapidly changing runway visual range (RVR) results in both frequency congestion and cockpit distraction at the most critical time in the execution of an instrument approach. Since RVR is not transmitted unless the approach is being conducted in near-minimum weather conditions, it is a critical distraction in which voice transmissions are used in the present system. In other cases the RVR appears to have been omitted or the reading was not accurate when it could have been very valuable to the pilot on approach.

> Flight making ILS approach crossing outer marker, Tower reported heavy rain at airport. Speed and rate along with localizer and glide slope all were normal throughout approach. Sighted approach lights at 400 ft and began encountering light rain at 300 ft. Runway was in sight and just at touchdown encountered a wall of hard rain and had no forward visibility. I could see by the center line that we were going off the left side of the runway. We soon felt our left main gear was in the lights or possibly off to the left side of the runway. We continued forward velocity for about 1,000 ft when we again regained forward visibility at which time the captain was able to bring the aircraft back over the runway and bring it to a stop.

Obsolete weather information– Instances were reported when ATIS transmitted obsolete weather information. (These problems are similar to those reported above.)

> Approach was made VFR – on short final encountered rain (which we thought was light because Tower had not reported any). Rain was heavier than anticipated. Normal touchdown – wind from left which was not reported blew us from runway because of hydroplaning. Aircraft came to a stop just off side of runway 7R.

In another report the wind-shear factor in addition to the obsolescence of the ATIS information proved to be a problem.

> Several aircraft reported to Tower that there was moderate to severe turbulence on final approach. Flightcrew monitored Approach Control and Departure Control frequencies while waiting for takeoff. To my knowledge arriving aircraft were not advised of "wind shear"/turbulence/airspeed excursions. After our takeoff at XX55 I checked arrival ATIS – no mention of approach difficulties – in fact information was 50 min old. Despite reported hook cloud classically displayed on radar to the SW, I advised local operations of wind problems reported on final, suggesting they

advise pilots in range and that MIA dispatch also be advised – that evening about six tornadoes hit central Georgia and there was extensive tornado damage to Forest Park. Arriving A/C seemed to be left out of the information loop.

Terminal Operations

Examination of communication problems in terminal operations concerned aircraft operating under ATC control while moving on the surface at the airport, flying within the airport traffic area, or arriving and departing the terminal area. These problems are discussed below.

Communications at airports without towers were considered to be advisory only and no detailed study was made or considered appropriate to this report.

Surface operations– In connection with surface operations, ASRS reports evidence two main types of communications problems: clearance misinterpretations leading to active runway incursions and failures to communicate taxi routes to preclude wrong turns and consequent ground conflicts.

> ATIS was received advising departures on runway 4, arrivals to runway 31. Cleared to runway 4. We switched to Tower and advised we were ready for takeoff. Tower said, "Taxi up to but hold short," which first officer acknowledged, but I thought Tower said, landing was on runway 31. As I took the runway, I looked to my left and noticed an aircraft on about a 3-mile final. The error was caught by me, the tower, and the first officer at the same instant. Tower advised I was supposed to hold short. I immediately cleared the runway well before the traffic landed. Factors which I think contributed were Tower deviating from the ATIS information and then not specifically advising us. I have become accustomed to holding in position while an aircraft lands on another runway, and we are creatures of habit and I thought I heard something I obviously didn't.

Many runway incursion problems appear to result because a flightcrew acts on a clearance, onto the runway or for takeoff, intended for another aircraft. This occurs most often because of phonetic similarity of call signs or crew predisposition – expectancy.

The taxi problem is most often related to flightcrew unfamiliarity with airport layout, repairs, and changes; communications problems tend to be secondary.

Flight operations – airport traffic area– The airport traffic area is the scene of many reported system irregularities. Prominent among these are traffic conflicts with unknown aircraft or with aircraft that are not properly in the pattern or on proper approach/departure paths; traffic conflicts due to sequencing disorders; use of wrong runways; and deviations from intended aircraft trajectory (course, speed, altitude) during approach or departure. The role of communications problems in enabling these events is highly varied but is important in each class.

Conflicts with unknown aircraft: ASRS reports describe conflicts of this type often occurring when controllers are unaware of the traffic or are too busy to issue advisories. These situations fall under the general headings of absent or untimely communications problems.

While on a heading of 270°, I was instructed to turn to a southerly heading. I checked the area off my left wing and saw aircraft B on a converging course to mine. His heading was about 300°. I advised Approach Control of the conflicting traffic and told them I needed a turn to the north to avoid traffic. It was later determined that aircraft B was not transponder-equipped and not seen by Approach Control radar. They had turned me south to avoid departing aircraft C.

Sequencing disorders: Examination of ASRS reports shows that sequencing disorders and their consequent traffic conflicts most frequently are caused by errors in a controller's planning or judgment of traffic spacing. However, communications problems enter the picture significantly; taking a sequencing control message by an aircraft other than the intended recipient is a frequent occurrence.

I was on final for runway 25. On contacting the tower 8–10 miles out I was told to reduce to approach speed as they wanted to get a departure out. We were No. 2 following a heavy aircraft B on 2-mile final. After B landed aircraft C was told to taxi into position and hold. The pilot acknowledged. Aircraft B was told to turn off at the high-speed taxiway; B stated he could not make the high-speed turnoff. About 30 sec later Tower called "C hold your position, do not take off." This was stated twice, then the controller asked C if he had started his takeoff roll and C stated that he had and that he wanted permission to make a right turn at the first taxiway. At no time did I hear the tower clear C for takeoff.

Runway assignment errors: Use of the wrong runway for landing or taking off is a frequently reported airport traffic area problem. In virtually every case the fault is a communications problem. Most of the problems involve flightcrew misinterpretations of landing or takeoff clearances – sometimes in connection with a last-minute change in the runway assignment.

Visibility restricted but VFR. Aircraft A reported 4-mile final for runway 9, aircraft B on right base for runway 12, aircraft C was in position for departure at threshold of runway 9. Aircraft D was holding midfield on taxiway E for departure on runway 9, aircraft D was instructed to turn left heading 360 and cleared for takeoff. Instead of departing runway 9, aircraft D started takeoff roll westbound on runway 27 toward aircraft C and aircraft A. He was instructed to abort and stopped on the runway.

The communications errors leading to these problems consist of phonetic similarities, transpositions, inaccuracies, ambiguities, garbling, and untimeliness.

Deviations from aircraft intended trajectory: ASRS reports record many instances of aircraft departing from assigned altitudes or headings during approaches or departures in airport traffic area airspace. Communications problems are an important factor in such trajectory deviation, sharing the burden of causation with poor flying technique on the part of flightcrews. Most communications problems involved misunderstood clearance; failures to issue appropriate clearances and failures to change frequencies properly also accounted for a significant number of the deviations. It is noteworthy that altitude deviations predominated in this fault category.

ATC cleared us to descend to 2,000. At 2,500 we spotted aircraft B 3/4–1 mile ahead at eleven o'clock at about 3,000. We advised ATC, controller asked our altitude, then stated he had cleared us to 4,000, and advised us to maintain visual separation from B. Then he cleared us to climb to 4,000. B passed above and behind our position.

En Route Operations

The en route operations evaluation concerned communications problems that arose when aircraft under ATC control were cruising en route or transitioning to or from the cruise condition. Many of these problems are traceable to difficulties of ATC coordination within and between control facilities. Most of the problems that were related to difficulties in air-to-ground communication were of three types: altitude deviations, failures of flightcrews to respond effectively to clearance amendments for conflict avoidance, and a variety of difficulties related to weather avoidance.

Aircraft A was cleared to cross 10 n. mi. east of XYZ at FL310, then descend to FL240 at pilot's discretion 14 n. mi. east of XYZ; A's altitude readout was FL320. At 10 n. mi. east the pilot was asked his altitude and he reported FL320. He was issued traffic ten o'clock, 8 miles, flight level 330, northeast bound. I was on a busy position alone and had conflict alert not come on, I would not have caught this in time. Pilot called on frequency and apologized for not making his restriction.

Altitude deviations– One of the types of incidents that has the greatest potential for causing serious accidents is failure that results in an aircraft being at an altitude other than that assigned by air traffic control. This is especially serious when an altitude restriction has been issued during climb or descent. Restrictions are issued because of conflicting traffic, and failure to comply will almost always result in loss of separation.

We requested descent clearance. Center asked whether it was necessary that we begin descent at that time, and I replied it was, or we would be unable to get down without circling. Center then gave us a 60° vector turn to the right to avoid conflicting traffic 2,000 ft below us. This was misunderstood by the copilot, and, as he had the conflicting traffic in sight, began descent. I had switched to monitor ATIS and did not notice he had begun descent until he had reached FL320. I asked if he had received further descent clearance. He had not and began climb back to FL330. Since we had the traffic in sight safety was not jeopardized, but it could have been in IFR flight conditions.

Clearance amendment response– Clearances are usually amended because of potential or present conflicts. A routine clearance may be issued, then a change in the traffic situation makes it necessary that the clearance be amended. Altitude assignments, heading assignments, and speed control are sometimes misunderstood by the recipient and the read-back, if given, may not be noted by the controller. Such clearances are usually time-critical and errors frequently result in loss of standard separation.

After obtaining position reports from departing aircraft A 3 n. mi. SE XYZ leveling at 5,000 and arriving aircraft B 30 n. mi. E XYZ, A was asked if he would like the

Victor airway. He asked the radial and concurred and was recleared via Victor airway to maintain 5,000 and report passing the 246 radial of XXX VOR. B was recleared via the north Victor airway to cross the 18 DME fix at or below 4,000. Aircraft A reported crossing the 246 radial and was cleared to climb to 7,000. Shortly thereafter, Center reported getting aircraft A on radar and that A and B were head-on about 8 n. mi. apart on Victor airway north. Clearance was issued to A to stop climb and B to stop descent but the aircraft sighted each other passing about 1/2 mile apart at near the same altitude.

Weather avoidance– In periods of rapidly moving frontal activity or summer thunderstorms, weather avoidance becomes a major factor in en route operations. Deviations from planned routes become commonplace and there are frequent incidents involving uncoordinated penetration of airspace assigned to another aircraft or to a different air traffic controller.

Two northbound aircraft B and C on separate jet routes at FL330 were deviating from course to circumvent thunderstorm buildups. Aircraft A was a no-radio contact aircraft in the same area and B and C were provided separation from A. B was expected to follow C but he had deviated right of course 5 to 8 n. mi. Separation from C was decreasing. Controller attempted vectors to increase separation but pilot response was slow. Therefore, controller cleared B to FL290 and heading 330. Again, pilot responded slowly but separation increased.

The Party Line Concept

A popular point of view among pilots is that there is substantial benefit in the "party line" concept, that is, that monitoring of a communication frequency can provide useful information, for example, about traffic flow and location of other traffic. Many pilots make extensive use of this practice, particularly at noncontrolled airports or at lower-activity terminals served by a control tower.

I was in aircraft A cleared through the airport traffic area at 2,500 MSL. While passing over the field, I heard the tower clear aircraft B for takeoff on 31L. He was to climb to 3,000 MSL on a 270° heading. I kept looking, but was unable to see him. The tower never did advise me he was coming. At about 6 miles west I saw him as he climbed out from under my left wing. He was traveling extremely fast and passed about 200 to 300 ft from me.

Some pilots contend that this is the usual means of acquiring a mental picture of the current traffic situation.

The beneficial use of party line is mentioned incidentally in several ASRS reports that are concerned with some other primary occurrence; this is because almost all reports concern an unsafe incident or condition. This report is an illustration.

I was descending to 1,500 MSL in aircraft A and had been told to enter left downwind for runway 05, approaching the airport from the northwest. Aircraft B had just departed runway 05 and asked for a left turnout to the northwest. The tower approved and said, "No reported traffic." Immediately, I began looking and saw him approaching me on a collision course. Evasive action was required on my part. Aircraft B passed my right wing less than a mile. I don't think he ever saw me, because the tower had told him there was no traffic NW of the airport.

Party line effectiveness must be evaluated in terms of the number of aircraft on a common frequency that are pertinent to the traffic situation. In large terminals, approach control is sectorized; local control is sometimes divided by the runways in use; ground control is split; and departing aircraft may still be in terminal airspace after being changed to center frequency. Many military aircraft are equipped with UHF only. Frequency monitoring may disclose only a fraction of the traffic that could be involved in an incident.

Errors can result from misunderstanding an overheard transmission, when a pilot may initiate an action based on his misperception of the message content. Some ASRS reports concern pilots acting on a clearance intended for another aircraft. This is an example of such an occurrence.

Aircraft A was told to taxi into position and hold on runway 35 while aircraft B was on landing rollout. Aircraft C was told to taxi into position and hold on runway 23 behind aircraft D. Aircraft B, landing on runway 33, was holding short of runway 23. When aircraft B turned off runway 33 and aircraft D rolled past the intersection of runways 23 and 33, aircraft A was told to turn right heading 090 after departure, cleared for takeoff. Aircraft C (holding on runway 23) thought the clearance was for him and started takeoff roll. Aircraft A was rolling also. The local controller did not hear aircraft C acknowledge for the takeoff clearance nor did he see aircraft C start takeoff roll until it was too late. Aircraft A and aircraft C missed by approximately 200 ft at the intersection.

Party line is also capable of making useful information available. The relative position and flightpath of other aircraft can often be ascertained when they are not in view. The intentions of the pilot may be overheard and, therefore, they may be taken into account in planning future courses of action.

But the use of simplex communications also poses the problem of misunderstanding by the intended recipient of a transmission, the problem of blocking of reception by another transmission, and the possibility of a clearance being accepted and acted upon by other than its intended recipient.

CONCLUSIONS

It is concluded that ATC-aircraft communications problems are involved in a large fraction of the occurrences reported to the ASRS. Many or most of these communications problems involve human errors on the part of the sender or receiver of the message. A small number are associated with breakdown of communications equipment, frequency saturation, and other system factors. The air-ground communications link is the cornerstone of the present system for the control of air traffic, and the problems observed in this study constitute a threat to the integrity and safety of the aviation system.

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5. INFORMATION TRANSFER WITHIN THE COCKPIT: PROBLEMS IN INTRACOCKPIT COMMUNICATIONS

H. Clayton Foushee and Karen L. Manos

INTRODUCTION

During the last few years there has been a rising concern among those in the aviation system about incidents and accidents attributable to the improper utilization of resources available to the human element in the system. This is documented by reports made to the Aviation Safety Reporting System (ASRS), over 70% of which cite human errors. According to a study by Billings and Reynard (ch. 1), the most common difficulty is a failure of the information transfer process. These information transfer problems include messages that are not originated; messages that are inaccurate, incomplete, ambiguous, or garbled; messages that are untimely; messages that are not recieved or are misunderstood; and less common, messages that are not transferred because of equipment failure. Although problems occur at all points in the information transfer system, this report deals with information transfer problems that occur within the cockpit and, more specifically, with communication patterns among cockpit crew members.

Communication patterns among cockpit crewmembers probably play a more significant role today than ever before. With the large air carriers (many employing thousands of pilots) and their complicated bidding procedures for assigning flight duties, it is possible that pilots may fly together without having met before. Thus, responsibilities that may be implicitly understood by crews that fly together frequently have to be explicitly assigned to members of a newly assembled crew.

There is a growing consensus among human factors specialists, airline training departments, and social and personality psychologists that communications patterns exert significant influences on important performance-related factors. At the very least, communication patterns are crucial determinants of information transfer, but research has shown that they are also related to such factors as group cohesion (important from a crew coordination standpoint); attitudes toward work; and complacency. An argument in the crew room prior to departure can affect the interactional patterns of the flightcrew for the rest of the day. Overbearing captains can severely inhibit information transfer from subordinate crewmembers, even in potentially dangerous situations.

In the 1979 crash of a northeastern commuter carrier aircraft, these factors appeared to have played a pivotal role. The accident report (ref. 2) characterized the cockpit situation as follows: "The captain was a company vice president with over 20,000 flight hours who was known to rarely acknowledge checklist items or other callouts from any first officer. The first officer . . . had only been with the company for 2 months. For the first year pilots are on probation, are not represented by the pilots' union, and may be terminated with or without cause . . . ." The first officer testified that the aircraft was well below the glide slope on final approach and that he made all required callouts to that effect. The evidence suggests that the captain may have been incapacitated, but the first officer could not confirm this. The end result was a crash in which the airplane impacted several miles short of the runway. The NTSB concluded that "The probability of the first officer recognizing and reacting to any possible physiologic incapacitation in the captain was remote."

As in the following report to ASRS, subordinate crewmembers can become "conditioned" into this pattern so that they react similarly, even with captains who encourage open channels of communication:

> I was the copilot on a flight from JFK to BOS. The captain was flying. Departure turned us over to Center and we were given FL210 which was our flight plan altitude. I noted we had reached FL210 and were continuing through it, but was reluctant to say anything. As we climbed through 21,300 ft, I mentioned it to the captain, but not forcefully enough, and he did not hear me. I mentioned it again and pointed to the altimeter. We were at 21,600 ft when the climb was stopped and we descended back to 21,000. As we started our descent, Center called and told us to maintain FL210. The captain said he had misread his altimeter and thought he was 1,000 ft lower than he was. I believe the main factor involved here was my reluctance to correct the captain. This captain is very "approachable" and I had no real reason to hold back. It is just a bad habit that I think a lot of copilots have of doublechecking everything before we say anything to the captain.

It is the central thesis of this paper that the patterns of communication between cockpit crewmembers determine in a large degree the response patterns of the crewmembers.

APPROACH

An opportunity for a more systematic analysis of cockpit communication patterns and performance was provided by data acquired in a NASA full-mission simulation study conducted by Ruffell Smith and associates (ref. 1). In that study, fully qualified B-747 crews flew a simulated, routine line trip segment (IAD-JFK) followed by a segment (JFK-LHR) in which a mechanical problem was introduced which necessitated an engine shutdown and diversion from the original flight plan. The simulation included all normal communications, ATC services, weather, closed runways at the diversion airport, and later, an inoperative autopilot which further increased pilot workload. As reported by Ruffell Smith, the scenarios were constructed in such a way that good crew coordination, cockpit communications, decisionmaking, and planning skills were required, but they were not complex enough to preclude an entirely safe operation given proper performance and coordination.

The study reported in reference 1 allowed the examination of flightcrew performance in a very controlled setting. Errors in performance were carefully monitored and recorded. Eighteen volunteer line crews flew the scenario, and marked variations in the behavior of the crews were observed. Ruffell Smith and his colleagues noted frequent problems in areas related to communication, decisionmaking, and crew interaction and integration. As a result, it was suggested that one of the major variables that influenced how effectively and safely a crew handled problems was the identification and utilization of the various human and material resources available to them. The presence or absence of strong leadership seemed to mediate the frequency and severity of the errors committed by the flightcrews.

We undertook a study to examine more closely what role the communication patterns of these flightcrews played in the management of resources and performance. Complete cockpit voice recordings were available for 12 of the 18 experimental runs. (Audio difficulties prohibited the inclusion of the remaining six). These 12 runs were subjected to a rigorous content-coding technique in which an attempt was made to classify each statement or phrase into one of 13 categories. Of the 13 categories, three were combined, leaving 10 usable categories. Obviously, some statements were nonclassifiable and others were inaudible because of other cockpit noises, simultaneous speech, etc., and these were not coded. The communication categories, definitions, and frequency of occurrence of each category in this sample are shown in table 5.1.

TABLE 5.1.– COMMUNICATIONS CATEGORIES OBTAINED FROM THE RUFFELL-SMITH COCKPIT VOICE RECORDINGS

Category	Definition	Number of citations	Percent of all communications[a]
Crewmember observation	Remarks made by crewmembers aimed at orienting others to some aspect of flight status (e.g., references to instruments, navigation, etc.)	2316	44
Commands	Specific assignments of responsibility, usually by the captain, in the form of declarative statements	648	12
Inquiries	Requests for information regarding some aspect of flight status, progress, etc.	1308	25
Response uncertainty	Statements indicating uncertainty or lack of information with which to respond to a command, inquiry, or observation	40	.8
Agreement	Statements indicating agreement with an observation, command, crew response, etc.	85	1.6
Acknowledgments	Recognitions of a command, inquiry, etc.	587	11
Tension release	Laughter or humorous remarks	128	2.5
Frustration or anger	Derision for an incorrect response or anger in response to some occurrence	51	1
Embarrassment	Any response apologizing for an incorrect response, etc.	26	.5
Pushes	Repetitions of already administered commands or inquiries	27	.5

[a]Total of 5,216 communications.

RESULTS AND DISCUSSION

The number of occurrences in each category was tabulated and statistically analyzed. Overall, there was a tendency for crews who did not perform as well to communicate less, suggesting that as expected, poor crew coordination tends to result in more marginal performance.

A number of interesting relationships emerged between the various categories of communications and the types of errors made in the simulation. A negative correlation[1] (r = -0.51) between crewmember observations and systems operational errors was obtained. This relationship appears quite logical. When more information regarding flight status was transferred, there were fewer errors related to system operation (e.g., mishandling of engines, hydraulic and fuel systems, misreading and missetting of instruments, and failure to use ice protection). The relationship should serve as important evidence in support of the concept of cross-checking and redundancy among the cockpit crew.

Similarly, there was a strong negative relationship (r = -0.61) between systems operational errors and acknowledgments. When crews frequently acknowledged commands, inquiries, and observations, these kinds of errors were less apparent. It would appear that acknowledgments serve an important function of validating that a certain piece of information has been transferred. These kinds of communications also serve as reinforcements to the input of other crewmembers. Frequent acknowledgments were also associated with a lower incidence of tactical decision errors (e.g., amount of fuel dumped, flap settings, and braking). Most significant, however, is the fact that acknowledgments were strongly negatively associated with total errors (r = -0.68). "Low error" groups tended to acknowledge communications more often, overall.

Commands were associated with a lower incidence of flying errors (r = -0.64) (engine handling, neglect of speed limits, altitude errors, and the lack of formal transfer of control of the aircraft between captain and first officer). Often communications of this type seem to ensure that cockpit duties are properly delegated, but it is also suggested that too many communications of this type can have negative consequences. The use of commands appears to be one of the significant variables of interpersonal style. An identical piece of information can be related to other crewmembers in one of several different ways. For instance, a communication such as, "Check the plates for the profile descent," which would constitute a command, could also be relayed, "I think we should check the plates for the profile descent," an observation; or "Why don't we check the plates for the profile descent?", an inquiry. Although it is rare that a single communication will alter or affect the cockpit atmosphere, repeated commands from the captain, for instance, might prove intimidating to subordinate crewmembers. First officers have often reported that the styles of some captains can inhibit them from offering information even in potentially dangerous situations. Although the use of command communications is both necessary and beneficial in many situations, it is possible that other types of communications give the recipients of information a greater sense of responsibility.

Also interesting was the finding of a negative relationship between agreement and total errors (r = -0.61). "Low error" crews tended to exhibit more agreement; however, it is not possible to

[1]The correlation coefficient, "r," varies from -1 to +1; it is a statistical measure of the strength of association between two variables. A high correlation coefficient, either positive or negative, indicates a considerable degree of correspondence between the variables. A coefficient near zero indicates very little relationship between the variables.

determine whether the lack of agreement in "high error" crews was caused by the errors being committed or whether this lack of agreement tended to cause certain errors.

Additionally, there was some evidence of higher rates of response uncertainty (r = 0.68), frustration/anger (r = 0.53), and embarrassment (r = 0.53) in "high error" crews, although again it is difficult to determine whether the communication patterns gave rise to the errors or vice versa.

In short, within-cockpit communications patterns seem to be significantly related to performance. The lack of appropriate communications between cockpit crewmembers is an obvious problem, but it is also apparent that the style of communication plays an important role. In an effort to obtain further documentation of problems of this nature, a search of the ASRS data base was undertaken. Eighty-eight reports were positively identifiable as instances of communications problems within the cockpit. It should be noted that the frequency of incidents reported to ASRS where within-cockpit communication problems were partially causal is probably higher. However, the narrative descriptions are sometimes not specific enough with respect to antecedent conditions to allow classification. Moreover, it appears that pilots are reluctant to report instances of interpersonal conflicts in the cockpit.

Nonetheless, many pilots did report communication problems with other crewmembers as causal factors. Of these reported within-cockpit communications difficulties, 35% cited problems with crew coordination dealing with poor understanding and division of responsibilities. Often the lack of appropriate acknowledgments and cross-checking was a factor as in the following example:

> On takeoff from Atlanta, our flight used an improper heading for climb-out . . . . During this period, immediately after liftoff and while engaged in the climb-out and weather analyzing, I said "075, the heading, right?" He (the first officer) looked at me quizzically and said what I understood as, "Yeah, OK." We continued to climb and were told to contact departure . . . they told us to turn immediately to 110 . . . then asked, "What heading were you cleared to?" I said, "Tell them 075°, that's what we read back wasn't it?" The copilot did not answer me, so I looked at him and he again had that odd look. I repeated louder, "Tell them 075 . . ." At no time were we aware of the serious problem with the other aircraft that unbeknownst to us had taken off on runway 8 . . . I believe it was solely due to poor cockpit communication . . . . I thought 075° was the correct departure heading, and to confirm it, I asked the copilot. But my question came at a time when we were very busy . . . he thought I was asking his evaluation of a direction. Coincidentally, that, to him, was a good direction and he answered in the affirmative. I took his answer as a concurrence of my question of proper takeoff heading . . . .

As in the Ruffell Smith study, the lack of appropriate acknowledgments and cross-checking is a frequently occurring problem. It was previously noted that acknowledgments probably serve the purpose of verifying that information has been transferred and that it is correct. Thus, the use of these kinds of communications is important for monitoring and cockpit crew redundancy purposes. This function is clearly illustrated by the air carrier captain who submitted this report to ASRS:

> Departed SFO on Porte One departure cleared. Misread clearance and began turn at 2500 and about 4 miles instead of at least 2500 and 6 DME miles. WX was VFR and terrain clearance was no problem. Turned left to 180° and Departure Control

requested I turn back to 280°. I did so immediately and shortly after back to 180°. Did not observe any traffic. No evasive action. Read clearance incorrectly and copilot had his head up and locked. He should have caught this if he had been monitoring this departure. Airline lacks adequate training program. Cockpit standardization is a joke.

A total lack of communication between cockpit crewmembers was cited as a factor in 12% of the reports, thus lending credence to the positive relationship between communication and good performance obtained from the Ruffell Smith data. The following typifies the potential severity of such occurrences:

I was pilot in command of airlines flight . . . Chicago to El Paso. The checklist was completed and I lined up for takeoff. (As throttles were advanced, the takeoff warning horn sounded.) Following checks . . . the warning horn sounded two more times and then stopped. My hand was in the process of transitioning back to the thrust levers with the intent of aborting the takeoff . . . . I was at 60–70 knots when the horn stopped. I elected to continue the takeoff since in my judgment all the parameters for a safe takeoff were accomplished. *What I did not know, however, was that the warning horn circuit breaker was pulled by the engineer without his advising me of such action* . . . . He preempted my actions by pulling the circuit breaker, an action I never intended to make . . . not advising the crew . . . resulted in a false impression of a safe configuration for flight.

There were numerous examples in this category of cockpit crewmembers not communicating regarding errors even when they had access to the correct information. Misunderstood clearances (examples of ground-to-air communication problems) posed frequent problems; and, as in the following example, these often evolved into within-cockpit communication difficulties:

After takeoff from LGA runway 4 on a heading of 055, Departure Control cleared my flight to 12,000 ft on a heading of 340°, but which I misunderstood and thought I heard him say 240° heading. After completing the turn to 240°, he called my flight to ask my altitude and heading. My first officer returned the call with 6,000 and 240° heading. The departure controller then said we were supposed to be on a 340° heading and to turn to 340°. I started my turn to 340° and as I was rolling through 270°, he gave me a heading of 210°. I then told Departure Control I understood my heading was originally 240°, but he came right back and said he had given me 340° heading. I had misunderstood him along with my second officer, who said to me he had understood the heading was 240°. This mistake on our part was confirmed by the first officer who said he repeated back to Departure 340° and had set his heading bug on 340°. My heading bug was on 240°. *I think the contributing factor to this incident was the first officer not saying anything to me about our heading when I rolled past 340° in my turn to 240°. This lack of attention to our flight progress and his not bringing it to my attention was why the 240° heading occurred.* It is my company's procedure for required callouts; with callouts for deviations from heading, altitude, etc., when they occur at any time during any phase of flight. My first officer did not make this callout as I rolled in my turn through the 340° heading he knew we were supposed to be on and which I had misunderstood to be 240° instead of 340°.

Over 15% of the reports dealt with information which was believed by one or more crewmembers to have been transferred, but for one reason or another (e.g., interference or inadequacy of the message) was not:

> I was monitoring an autopilot single autoland approach on flight . . . to runway 22L at EWR in visual conditions when a GPWS "pull-up" warning occurred . . . the entire crew's attention was directed to confirming configuration position, speed, and sink rate, all of which were normal. I commanded, and simultaneously with the copilot, selected 50° flaps, considering that the landing flaps not selected mode was possibly the reason for what I considered to be "probably" a false warning, due to a possible failed flap position switch. The FE said something which I could not clearly grasp while the "pull-up" was sounding. As the flaps extended to 50°, the GPWS warning silenced. A normal auto landing occurred. Sounds simple and somewhat everyday – until during taxiing I was informed that the FE had "inhibited" the GPWS without being commanded to . . . . He stated he asked me if I wanted it cancelled, but I didn't reply so he assumed I did.

In a number (10%) of instances, communications between cockpit crewmembers were deficient as a result of overconfidence and complacency – assumptions that everybody understood what was taking place, when in reality they did not. In about 5% of the reports a lack of confidence in subordinate crewmembers caused captains to become overloaded by trying to do too much. This was seen in the Ruffell Smith study and is a frequent contributor to the hesitancy of subordinate crewmembers to question the actions of captains.

> On arrival at DCA landed runway 33 and made a left turn on taxiway K which leads to the gates after being cleared to the gate by Ground Control we were in a position that happens very often. We were blocking the taxiway from Page to the active runways with aircraft waiting for us to clear. There was another aircraft parked to our right and an aircraft parked to our left which was waiting to push back, and the aircraft agent was standing behind the right wing watching as we started between the two aircraft. After checking the clearance on the left wing and getting a clear signal from the agent, I leaned forward and to the right to check the clearance on the right wing. *This was done because I had a new copilot and did not trust his judgment.* As I turned back to check the left wing, the agent was giving a hold signal. At this time the left wing tip was just under the tail cone of the center engine. The indicator for the nav. light (a small piece of plexiglass that stands about 3 inches above the wing) hit the tail cone breaking the top of the plexiglass off.

Another common problem (16%) was interference with pertinent cockpit communications by extraneous conversation between crewmembers or between crewmembers and flight attendants. This often reflected a cockpit atmosphere that had become too relaxed, as in the following:

> While I was in the passenger cabin waiting to go to the bathroom (this took over 15 min because of crowded conditions and bathroom hog), the copilot failed to turn down J114 toward DEN. (We were over ONL bound for LAX). When I returned to the cockpit, we were 86 miles from BFF. About that time DEN center asked us our routing to LAX. I told him we should have been on J114 and asked for a vector to DEN. We were about 70 miles off course at the time. I have never been

> that far off course before. *The copilot was telling war stories (he was a fighter pilot in Viet Nam) to the engineer and wasn't paying any attention to his job.* I told him his behavior was inexcusable, but I'm afraid the man didn't really understand how serious this could have been. This was a BOS-LAX nonstop of about 6:05 and I usually have to leave the cockpit at least once.

Finally, several reports dealt with role and personality conflicts creating a state of affairs on the flight deck such that communications between crewmembers have completely deteriorated:

> I was the first officer on airlines flight into Chicago O'Hare. The captain was flying, we were on approach to 4R getting radar vectors and moving along at 250 knots. On our approach, Approach Control told us to slow to 180 knots. I acknowledged and waited for the captain to slow down. He did nothing, so I figured he didn't hear the clearance. So I repeated "Approach said slow to 180," and his reply was something to the effect of *"I'll do what I want." I told him at least twice more and received the same kind of answer.* Approach Control asked us why we had not slowed yet. I told them "We were doing the best job we could" and their reply was "You almost hit another aircraft." They then asked us to turn east. I told them we would rather not because of the weather and we were given present heading and maintained 3,000 ft. *The captain descended to 3,000 ft and kept going to 2,500 ft even though I told him our altitude was 3,000 ft. His comment was "You just look out the damn window."* Finally we were cleared for the approach.

In this report, the first officer was apparently providing information in accordance with his responsibilities, but the information was unheeded. One wonders what occurs in this particular captain's cockpit with a less assertive first officer.

SUMMARY

It is apparent from the data that cockpit communications patterns are related to flightcrew performance. It would be a mistake, however, to infer from these data that more communication among flightcrew members necessarily translates into better performance. The type and quality of communications are the important factors – not the absolute frequency. These observations are reinforced by a number of reports from ASRS in which it is implied that within-cockpit communications difficulties are significant factors in the information transfer problem.

REFERENCES

1. Ruffell Smith, H. P.: A Simulator Study of the Interaction of Pilot Workload with Errors, Vigilance and Decisions. NASA TM-78482, 1979.

2. Aircraft Accident Report No. AAR-80-1. National Transportation Safety Board, 1980.

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6. INFORMATION TRANSFER DURING CONTINGENCY OPERATIONS: EMERGENCY AIR-GROUND COMMUNICATIONS

Richard F. Porter

INTRODUCTION

Although radio communication is always crucial to the safe and efficient operation of the nation's aviation system, the necessity for the effective transfer of information is never more clearly obvious than when an aircraft is in distress.

The reports in the data base of the Aviation Safety Reporting System (ASRS) provide a unique resource for identifying deficiencies that have occurred in communications in actual emergencies, and for a pragmatic evaluation of the causes and consequences of information transfer dysfunctions.

This report presents the results of a study of safety-related problems that have occurred as a consequence of communications problems in emergency situations. All information was obtained from a review of pertinent reports contained in the ASRS data base.

OBJECTIVE

The objectives of this study task were: (1) to describe the safety-related problems occurring as a consequence of information transfer deficiencies that arise when air/ground communications are (or should be) used as a resource in in-flight emergency situations, and (2) to define the system factors, the human errors, and the associated causes of these problems.

SCOPE

This study is based on a search of 13,000 ASRS reports submitted between May 1, 1978 and September 17, 1980. For any particular incident to be pertinent to the study, three conditions were necessary. The qualifying elements were:

1. An emergency situation

2. An information transfer problem arising in radio communication associated with the emergency

3. An ensuing safety-related problem

To obtain a more appropriate sample of incidents, the study was not confined to formally declared emergencies. Instead, an "emergency situation" was defined as an unforeseen combination of circumstances that calls for immediate action to avoid disaster. This interpretation is based on a standard dictionary definition and is compatible with the statement in the Air Traffic Control Handbook (FAA, 7110.65A, ¶ 1550) – ". . . an emergency includes any situation which places an aircraft in danger; i.e., uncertainty, alert, being lost, or in distress."

APPROACH

The approach to the study consisted of the development and implementation of a search strategy for the extraction of pertinent cases from the ASRS data base, followed by an analysis of relevant information from those cases.

Each report in the ASRS data base contains key descriptive phrases in five fields. These are the enabling factors, associated factors, recovery factors, supplementary factors, and descriptors.

The initial screening consisted of a search for all reports that contained the word "emergency" in any phrase in any of the five fields. Of the 176 reports produced, 45 were judged to be either duplicate reports of other incidents or were otherwise deemed to be unsuitable for this study. This initial screening therefore yielded 131 discrete emergency situation reports for later analysis.

The next step was to expand the study sample by examining the 131 reports to identify other descriptive phrases with a relatively high frequency of occurrence, the hypothesis being that key words that appear to be correlated with emergencies would be likely to be useful in finding other pertinent study cases, even though the word "emergency" did not occur in a descriptor.

Table 6.1 lists the key descriptors that were selected. In addition, the vocabulary of descriptors used in the ASRS was examined to find any further descriptors that could be (intuitively) associated with emergency situations and that appear a reasonable number of times in the data base.

TABLE 6.1.– DESCRIPTORS SELECTED FOR FURTHER SEARCH

Situation	Descriptor
Low fuel	In-flight engine shutdown
Engine	In-flight engine shutdown Engine problem Aircraft engine-out performance Aircraft equipment-problem/engine Power plant problem Engine control problem Aircraft equipment-operating-problem/engine In-flight fire
Weather	IMC in VFR flight Weather in terminal area Weather forecast Weather report Weather avoidance VFR on top En route weather
Landing	Precautionary landing Return/land Off airport landing
Pressurization	Aircraft equipment-problem pressurization
Command authority	Command authority
Disorientation	Disorientation Spatial disorientation

Three additional descriptors were selected: blind broadcast, sensory illusion, and loss of aircraft control.

Excluding the 176 reports previously examined, it was found that at least one of the 26 selected descriptors appeared in 850 reports in the data base. From these, 37 were judged to satisfy our definition of an emergency situation.

Combining the 131 cases from the first search with the 37 additional cases gave a total of 168 emergency incidents.

The final phase of the data search consisted of segregating those cases that satisfied the two remaining study criteria from those that did not. Each of the 168 emergency cases was carefully examined to identify (1) any information transfer problem arising from air/ground communication (or lack of it) associated with the emergency; and (2) any safety-related problem that may have followed such an information transfer deficiency. Only those cases that exhibited both of these features were retained.

Fifty-two instances were found in which the study criteria were satisfied. The analysis of the 52 pertinent cases consisted of seeking common factors to permit the classification of all cases with regard to the nature and effect of the information transfer problem.

RESULTS

For an incident to be germane to this study, three elements were essential:

1. An emergency situation

2. An information transfer problem or dysfunction associated with the emergency situation

3. An ensuing safety-related problem

In this section, the results of the ASRS data base search are summarized with respect to all three of these elements. The intent here is to document the search results with as little interpretation as possible. The discussion and interpretation is presented in the following sections.

Emergency Situations

The selection process yielded 168 distinct cases in which an emergency situation existed. The total population of emergency cases is broken down in table 6.2 by generic type and by the operational category.

For the purposes at hand, "propulsion problem" includes any difficulty with an engine, propeller, or fuel system; "VFR pilot/weather" includes all situations in which a noninstrument-rated pilot is in instrument meteorological conditions or is in imminent danger of being forced into such conditions; "aircraft systems" includes problems with any aircraft subsystem other than the

TABLE 6.2.– TOTAL POPULATION OF EMERGENCY SITUATIONS

Emergency type	Number of cases			Total number	Percent of total
	Air carrier	Military	General aviation		
Propulsion problem	12	1	22	35	20.8
VFR pilot/weather	0	0	34	34	20.2
Aircraft systems	16	3	8	27	16.1
Low Fuel	8	6	12	26	15.5.
Severe weather avoidance	7	0	1	8	4.8
Lost	0	0	7	7	4.2
Miscellaneous	10	4	6	20	11.9
Subtotals	53	14	90	157	93.5
Unspecified	---	---	---	11	6.5
Total				168	100.0

propulsion system; and "severe weather avoidance" includes threats from thunderstorm activity or severe turbulence. The "unspecified" type of emergency is one in which the reporter describes a problem associated with an emergency condition but does not explain the nature of the emergency itself. The remaining type designations are self-explanatory.

All but 7 of the 168 emergency situation reports contained an explicit or implied reference to radio communication. Regarding the 7 that did not, it cannot be concluded that radio was not used because the nature of the problem was such that the immediate value of such communication would have been limited, and reference may have been omitted by the reporter. Typically, these cases involved off-airport landings by light aircraft operating VFR and were caused by sudden engine stoppage.

Information Transfer Problems

In 52 of the 168 emergency cases there were subsequent communications problems. These 52 cases were all pertinent to the study and constitute the total data set of the investigation.

Table 6.3 lists the number of emergencies in the final data set, using the same classifications of emergency type and operational category as were used in table 6.2.

The nature of the information transfer problem in each case is listed in table 6.4. The first column in the table gives the source, or instigator, of the problem as perceived by the reporter in each case.

Only the primary problem in each case is listed in table 6.4, but it should be noted that more than one problem is evident in some cases. For example, Case No. 2 is primarily a language problem, but is complicated by a lack of ATC coordination. To quote from the narrative:

TABLE 6.3.– NUMBER OF EMERGENCIES WITH INFORMATION TRANSFER DEFICIENCY AND SUBSEQUENT SAFETY PROBLEM

Emergency type	Number of cases			Total cases
	Air carrier	Military	General aviation	
Propulsion problem	2	1	6	9
VFR pilot/weather	0	0	4	4
Aircraft systems	2	1	5	8
Low fuel	0	4	2	6
Severe weather avoidance	1	0	1	2
Lost	0	0	6	6
Miscellaneous	1	4	1	6
Subtotals	6	10	25	41
Unspecified	---	---	---	11
Total				52

TABLE 6.4.– INFORMATION TRANSFER PROBLEM

Source	Problem	Number of cases
ATC	Lack of coordination	11
	Controller inattention (distraction by emergency)	8
	Lack of perception of emergency	7
	Faulty technique	4
	Frequency congestion	1
	Auditory interference in tower	1
Aircrew	Language difficulty	3
	Reluctance to declare	5
	Failure to use all resources	1
	Pilot communication errors	5
Other	Radio/radar limitations	3
	Equipment failure	3

While on duty as an air traffic controller at the DAB Tracon, an alarmed pilot began screaming Mayday, obviously wanting assistance on frequency 121.5. For approximately 10 min, between transmissions to other aircraft I tried to radar identify the aircraft. He had a very poor (self-admitted) understanding of the English language. His number was never found out until he landed. Due to the position of the aircraft, ORL Approach was able to assist aircraft along with myself. Neither I nor ORL Approach knew of each others' intentions which added to confusion . . . .

(Note: The case numbers referred to in this chapter are described in an appendix to the Battelle Columbus Laboratories Report (ref. 1) from which this chapter was derived. Copies of the original report are available upon request.)

Although most of the problem types given in table 6.4 are self-explanatory, the "controller inattention" and "lack of perception of emergency" may require clarification.

The "controller inattention" in all cases pertains to a problem caused by the distraction of the controller by an emergency. This type of problem appears as a communication deficiency with one or more aircraft other than the one actually involved in the emergency, whereas all other categories describe a problem between the subject aircraft itself and a ground facility. An example is described in the narrative of Case No. 23, reported by the pilot of a four-engine air-carrier aircraft:

Aircraft A was cleared to land . . . runway 1L by Tower. After touchdown, we observed a light (white) aircraft B, in position for takeoff at about midrunway. Prior to A's landing, B had been cleared into position and forgotten by tower controller due to a landing emergency situation on runway 1R . . . . Aircraft was stopped without incident.

The "lack of perception of emergency" category appears in some cases as an attitudinal problem (as viewed by the reporter), or as a simple lack of understanding of the problem by the controller. In either event, this study considers these cases as situations in which the flightcrew has apparently not been able to communicate the urgency of the situation to the controller. For whatever reason, the ground controller in these cases does not seem to share the aircrew's concerns.

An example from the narratives may clarify this categorization. From Case No. 26, reported by an air-carrier pilot on an IFR approach:

About 5 miles from the marker we were told that the 22 ILS was now in use and to turn left to 300 for vectors. We did this and were faced with a 15-mile line of thunderstorms on the radar with heavy contour. We stayed on that heading but told the approach controller that we had to deviate soon. He said other aircraft were going through the area with no problems (nobody crashed). An air carrier heavy was asked how the ride was and he said it wasn't too bad, however he would not recommend sending anybody else through that area. I . . . elected to do a 180 and get out of the area. Approach was upset to say the least . . . and from then on very uncooperative . . . . He said . . . that if I could not comply with a request to fly into a cell area there was nothing further he could do for me.

The listings of table 6.4 may seem to place an imbalance of blame on the controllers. In this regard, it must be pointed out that not only were 68% of the emergency cases handled without incident, but 12 reporters (pilots) explicitly praised the assistance received from the air traffic control system.

Ensuing Safety-Related Problems

In each of the 52 cases of table 6.4, the information transfer problem had an adverse influence on the resolution of the emergency situation or created a separate problem.

The postemergency problems created by the information transfer deficiency can be placed in two general categories: those in which the problem is essentially a continuation or worsening of the original emergency, and those representing a new and different hazard. The 52 pertinent cases are almost equally divided between those two categories, with 24 of the former and 28 of the latter. A further breakdown of the nature of the postemergency problem is given in table 6.5.

TABLE 6.5.– CLASSIFICATION OF ENSUING SAFETY-RELATED PROBLEMS

General type	Nature of problem	Number of cases
Continuation or worsening of existing emergency	Delay in landing	9
	Extension of emergency	8
	Landing without emergency equipment	5
	Unnecessary increase in workload	2
New/different hazardous situation	Traffic conflicts (NMAC/ LTSS/runway conflicts)	
	Involving emergency aircraft	4
	Not involving emergency aircraft	10
	Operation without appropriate clearance	8
	Noninstrument pilot in IMC	2
	Hazard of delay in terminating emergency state	2
	Hazard of collision with other aircraft or ground	2

DISCUSSION

In a search of over 13,000 reports in the ASRS data base, 168 emergency situations were uncovered. Of these, over two thirds were resolved with no information transfer problem in evidence.

The remaining 52 cases, which comprise the data set for this study, were categorized into 12 different types of information transfer problems and 9 distinct subsequent safety-related problems. Although any extensive quantitative breakdown of the data must be interpreted with caution because of the small number of cases, the data exhibit interesting features which are examined in this section.

Correlation of Communication Problem with Type of Emergency

Comparing the data in tables 6.2 and 6.3, it appears that some types of emergency situations rarely are associated with communication difficulties, while the opposite is true for others. Table 6.6 summarizes the frequency of occurrence by type of emergency.

TABLE 6.6.– FREQUENCY OF COMMUNICATIONS PROBLEMS

Emergency type	Number of cases	Number of information transfer problems	Percentage with information transfer problems
Propulsion problem	35	9	26
VFR pilot/weather	34	4	12
Aircraft systems	27	8	30
Low fuel	26	6	27
Severe weather avoidance	8	2	25
Lost	7	6	86
Miscellaneous	20	6	26
Unspecified	11	11	100

For five of the seven causal factors other than "unspecified," the percentage of emergency cases that produced communication problems is remarkably constant, ranging only from 25% to 30%. The remaining two causal factors, however, show a wide variation. For the "VFR pilot/weather" grouping, the frequency of occurrence is very low (4 out of 34), whereas the "lost" grouping shows six out of seven cases pertinent to the study. Both of these apparently anomalous groups are populated entirely by general aviation pilots.

Half of the six pertinent cases in the "lost" group are identified as student pilots; but two of these correctly used their radio to make known their problem and the third was handicapped by a language limitation and rather cavalier earlier treatment by a controller. Two of the other cases also mention a language problem, and in the remaining case the aircraft was not within direct range of any ground radio facility. In short, the high frequency of occurrence within this group in the study set may be coincidental and insignificant because of the small number of cases involved.

Conversely, the infrequent appearance of communications problems within the "VFR pilot/ weather" group is particularly difficult to explain. Again, as a group, these pilots appear to use their radio properly and effectively once they are enmeshed in the emergency condition. At the same time, the evidence suggests that this type of problem is handled particularly well by ATC.

Most Frequent Safety-Related Problems

From table 6.5, there are 14 instances of traffic conflicts as a consequence of emergency-related communication problems. Furthermore, 10 of these conflicts do not involve the aircraft that was the subject of the emergency. If we add to these the 8 cases of operation without appropriate clearance and the 2 instances of collision hazards brought about by ambiguous or unsafe ATC instructions, the direct or implied hazard of collision appears in 24 of the 52 cases.

The next most frequent problem is a delay in the landing of the emergency aircraft, appearing in nine cases, and the emergency was prolonged through a delay in rendering assistance in eight cases. In five cases, the subject aircraft landed without the alerting of emergency equipment.

From table 6.5, it may be inferred that the degree of success in resolving the emergency depends on whether one adopts the point of view of the emergency aircraft itself or the other airspace users. In all cases, the emergency was handled satisfactorily in that no accidents occurred. On the other hand, as pointed out above, 46% of the study cases (or 14% of all emergencies) suggest an actual or potential hazard to other aircraft in the system.

Correlation of Cause and Effect

Table 6.7 is an illustration of the apparent degree of correlation between the information transfer deficiency (along the top) and the ensuing safety-related problem (along the side). The number in each intersection is the number of cases in which the particular cause and effect have been found.

The most frequently observed cause and effect combination is seen to be a traffic conflict caused by the distraction of a controller by the emergency. Interestingly, none of the seven cases of this combination involved a traffic conflict with the emergency aircraft itself.

Other relatively frequent combinations are traffic conflicts caused by a lack of ATC coordination (see ch. 3) and delays in landing caused by the pilot's reluctance to declare an emergency condition.

Because of the relatively large number of cause-and-effect categories and the relatively small number of study cases, any further attempt to find significant correlations in table 6.7 is not justified.

TABLE 6.7.– NUMBER OF STUDY CASES HAVING COMMON CAUSE AND EFFECT

Safety-related problem	Cause of safety-related problem											
	Lack of ATC coordination	Controller inattention (distraction by emergency)	Lack of ATC perception of emergency	Faulty controller technique	Frequency congestion	Auditory interference in tower	Language difficulty of pilot	Reluctance of pilot to declare emergency	Failure of pilot to use all resources	Pilot communication errors	Radio/radar limitations	Equipment failure
Delay in landing	2		2	1				4				
Extension of emergency	1		2				2				2	1
Landing without emergency equipment	2				1		1	1				
Unnecessary increase in workload				1		1						
Traffic conflicts	5	7		1						1		
Operation without appropriate clearance	1		3							2		2
Noninstrument pilot in IMC									1	1		
Hazard of delay in terminating emergency state										1	1	
Hazard of collision, other A/C or gound		1		1								

CONCLUSIONS

An extensive statistical correlation of cause and effect among reported information transfer problem cases cannot be made because of the relatively small number of pertinent cases and the broad variety of communication problems and ensuing hazardous situations. Nevertheless, from a review of the 168 emergency incidents in the ASRS data base, the following conclusions may be drawn:

1. The most common safety-related problem is a traffic conflict *not* involving the emergency aircraft itself. Traffic conflicts, direct or implied, are a hazard in 46% of the communication problem cases and in 14% of all emergency situations.

2. The most common information transfer problem arising from an emergency is a lack of interfacility coordination within ATC. The second leading problem is controller inattention caused by distraction resulting from an emergency.

3. Emergency situations in which noninstrument-rated pilots are trapped in instrument meteorological conditions lead to subsequent communications problems much less frequently than other emergency situations. It may be inferred that controllers, for whatever reason, are particularly sensitive and adept with regard to these emergencies.

4. There is no evidence in these data that pilots, even with minimum experience levels, are not familiar with proper emergency radio procedures.

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7. THE INFORMATION TRANSFER PROBLEM: SUMMARY AND COMMENTS

C. E. Billings and E. S. Cheaney

INTRODUCTION

The United States national aviation system is indisputably the world's most efficient and effective. It moves huge numbers of people and large volumes of cargo safely and routinely in good weather and bad. Its aircraft are the backbone of the world's civil air fleets. Despite ever-increasing pressure from environmental interests, population growth, and fuel-cost increases, the system has thus far kept pace with demand.

It may seem perverse, then, in the foregoing chapters, to have dwelt upon the system's problems rather than its achievements; to have focused on its failings rather than on its enormous success. But the system has been so successful over the last five decades precisely because of its tolerance of and its constructive attitude toward criticism, whether from within or without. It was in order to solicit critical comment that the FAA's Aviation Safety Reporting Program was established in 1975; its mission, and that of the corollary NASA Aviation Safety Reporting System, is to highlight deficiencies and discrepancies in the national aviation system. This study is offered as a constructive attempt to illuminate a problem that bears directly upon system safety.

In this concluding chapter, we broaden our focus of consideration from the specifics of the foregoing chapters to the aviation system as a whole – and the information transfer problems that are found within it. An attempt is made to characterize these problems independent of the settings in which they occur, and in so doing, to suggest possible intervention strategies for consideration by the designers, managers, and operators of the national aviation system.

SUMMARY OF FINDINGS

Information transfer problems are perceived by experienced analysts to exist in a substantial majority of all reports submitted to the Aviation Safety Reporting System. The absolute incidence of such problems cannot be deduced from these data, but during the period of study (May 1978 to July 1980), on average, over 4,800 such problems were reported per year.

Over one third of these problems involve the absence of information transfer in situations in which, in the opinion of the analysts, the transfer of the information could have prevented a potentially hazardous occurrence. In another third, information transfer took place, but it was adjudged incomplete or inaccurate, leading in many cases to incorrect actions in flying or controlling aircraft. One eighth of the reports involved information transfer that was correct but untimely (usually too late to be of assistance) in forestalling a potentially hazardous chain of events. In one tenth of the reports, the information was transferred but was not perceived or was misperceived by the intended recipients. The remainder of the reports involved equipment problems and a variety of miscellaneous specific conditions.

SUMMARY OF ENABLING FACTORS

The focus of these studies was not primarily upon whether information transfer problems exist, but upon the factors that appear to be responsible for their existence. It is not possible from retrospective data to state whether such factors cause the problem under examination, but it is possible to state with confidence that certain factors are frequently found in association with information transfer problems and that they *may be* causative. Several facets of the information transfer phenomenon were examined in an effort to find factors in common. Such common factors were, in fact, observed.

The human behavioral attributes found frequently in association with information transfer problems, in rough order of frequency, were:

1. Distraction
2. Forgetting
3. Failure to monitor
4. Nonstandard or ad hoc procedures or phraseology
5. Complacency

When present, these attributes were associated with failures at all points in the information transfer chain.

In addition to these human factors, certain system factors were also found or imputed to be associated with information transfer failures. These factors included:

1. Nonavailability of traffic information
2. Degraded information
3. Ambiguous or (rarely) absent procedural guidance
4. Environmental factors (noise, confusion)
5. High workload
6. Equipment failure

The first three of these, of course, are in themselves information transfer problems. The fourth was associated with difficulty in performing the tasks required. The fifth was associated with task demands that could not be met by the worker. The last, though present in significant numbers, was the least frequent system factor reported.

Many other factors were observed in specific contexts; they are discussed in preceding chapters. The factors listed above, however, appeared to be of general importance. Possible reasons for this are set forth in the remainder of this chapter.

IMPLICATIONS OF THE FINDINGS

Although discovery of enabling factors is helpful in understanding why information transfer problems exist, it is desirable to examine in more detail when, how, and why these factors apparently disrupt information flow. The more one knows about the dynamics of these unwanted occurrences, the more likely it is that strategies can be devised to deal with them.

The Pivotal Role of the Air Traffic Controller

Figure 7.1 is a schematic representation of the primary operational information transfer interfaces in today's aviation system. (This schema does not depict intracockpit communications, or secondary air-ground communications. The interfaces shown are those that bear directly on aircraft management in the airspace system.) Because of the central role of the air traffic controller, any study of information transfer problems must of necessity be largely a study of controller communication behavior. Can we gain any insights into such behavior from these data?

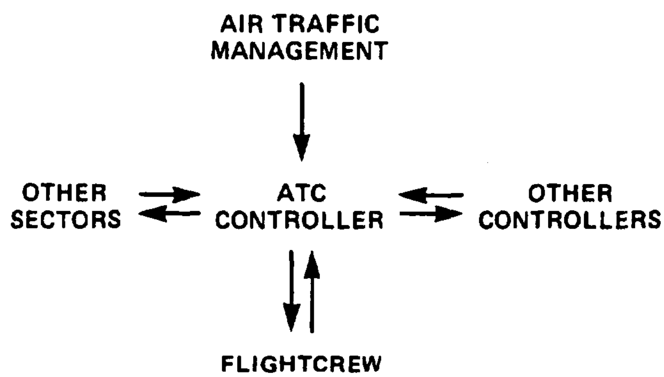

Figure 7.1.– The role of the controller in information transfer.

Many of the reports analyzed here described occurrences in which ASRS analysts believed that communications that did not take place would have averted the hazard; about the same number of reports described a variety of problems associated with information transfer transactions that did take place. The reasons for these problems may well be different but they are equally important to those who may wish to intervene effectively.

Information Transfer Problems Affecting the Controller

The data indicate that there are several kinds of information transfer failures that affect the controller's ability to perform his job and, specifically, to ensure that separation is maintained.

Failure to perceive– The controller may be unaware of an aircraft of concern because the aircraft is not shown on his radarscope (most often because it is a primary target) and the pilot has not communicated with ATC. Cunningham (ref. 1) has discussed the problem of unknown aircraft in high-density terminal airspace; in previous studies, we have pointed out some behavioral aspects of this problem (ref. 2). Local controllers may be unable to perceive an aircraft in their airport traffic area because of restricted visibility.

In both of these situations, the problem is simply that a pilot, for whatever reasons, has not drawn ATC's attention to his presence, either by use of a transponder in areas of radar coverage, or by voice communication. ASRS data make it plain that this class of information transfer failure seriously affects the functional effectiveness of the air traffic control system. It is involved in a substantial fraction of the large number of conflicts reported.

The controller may also fail to perceive a visible aircraft, or a conflict, because he is distracted by other operational or nonoperational concerns. Absent or incomplete information transfer transactions that occurred earlier (relief briefing or coordination) may fail to bring to a controller's attention an aircraft of potential concern to him. Finally, the controller may perceive an aircraft, then forget about it because it was not of concern at the time it was perceived. These human factors – distraction, failures to monitor, and forgetting – are described over and over again in reports from controllers.

Misperception– There are several factors associated with misperceptions and misunderstandings by a controller. He may quick-look an adjacent sector and fail to notice all pertinent traffic. Tag swaps, scope clutter, and other hardware or software anomalies may give him a false picture of his traffic. Transponders without altitude reporting (Mode A), inaccurate briefing or coordination messages or communications may leave him with a correct perception of an aircraft's present position but an incorrect perception of the aircraft's flightpath; this may lead him to assume the aircraft's future course of action. Expectation plays a part in the formation of these assumptions. If the aircraft thereafter heads for an incorrect runway, as an example, the controller may or may not notice the deviation.

The Controller Role in the Genesis of Information Transfer Problems

It goes without saying that the controller's decisions (and therefore his subsequent instructions) can be no better than his information. If the information is absent, inadequate, or incorrect, his decisions will be incorrect, though they may or may not cause a subsequent hazard. In many cases, however, the information reaching the controller may be correct; thereafter, he can become involved in the creation of a subsequent problem by an error. There are three types mentioned prominently in these data.

No information transfer– A substantial fraction of ASRS pilot reports of conflicts castigates a controller for not providing a timely traffic advisory. The credibility of controllers is not enhanced by the frequency with which, in response to a question from the flightcrew, they report that "It just appeared" at the six o'clock position. Many pilots realize that the provision of traffic advisories is an "additional service"; few have much sympathy for that dictum if they have just had a near midair collision. Pilots usually have no way of determining whether traffic was not announced to them because the controller did not know about it, because he was busy with another task, or because he failed to perceive the conflict.

Untimely information transfer– Many of these reports also involved traffic advisories. Again, the pilot was unable to tell whether the target had just become visible, or whether it had been visible and the controller failed to notice it. The tenor of reports from controllers suggests that the former is more often the case, though a certain proportion of reports from controllers describes situations in which they perceive a potential future conflict, defer action in order to get better (more) information, then become distracted by other more immediate tasks and forget the previously noted target. As noted in chapter 3, forgetting is also a problem with respect to coordination transactions. Other occurrences falling in this category are instructions given at operationally untimely moments, such as a revised clearance at the time of touchdown or early in rollout, or a new instruction just after liftoff.

Incomplete information transfer– It is our impression that incomplete messages are usually a result of pacing stress, less commonly a result of partially blocked transmissions. The latter failures, however, are sometimes serious, especially when they involve clearances. It must be recognized that an apparently incomplete message may result either from an omission by its originator or from incomplete perception by a receiver. The message may, or may not, be recognized by either party as incomplete.

Inaccurate information transfer– Again, misperception by either the originator or receiver of a message may be responsible for inaccuracy. Chapter 4 points out that this category of message problem either could involve a formulation error or could be a correctly formulated statement based on an inaccurate decision. The effect on the receiver is the same, but the problems may be quite different. The ASRS data indicate that there are several classes of events in the latter category. They are summarized in figure 7.2. Incorrect decisions may proceed from either correct or incorrect data; this schema characterizes only the decision process.

The various decision options for each perception (whether correct or incorrect) are indicated by the X's in each row of the figure. These can be roughly bounded by curves. The shaded area represents the realm of perceptions for which more than one decision strategy is available. One may operate extremely conservatively, near the upper curve, or one may opt for a more venturesome decision strategy, near the lower curve.

Study of the ASRS data suggests that the shaded portion of the figure contains the circumstances of many of the inaccurate decisions mentioned by controllers in aviation safety reports. If one excludes reports in which the conflict was misperceived, this part of the figure characterizes a good deal of the data.

The Role of the Pilot

The role of the pilot receiving ATC services in information management is somewhat different from that of the controller in the present aviation system. His task, except in an emergency, is to receive advisory information, accept instructions, and to act upon them. He provides an element of redundancy by reading back clearances, announcing altitude on initial callup, etc., but otherwise he provides little information unless it is asked for.

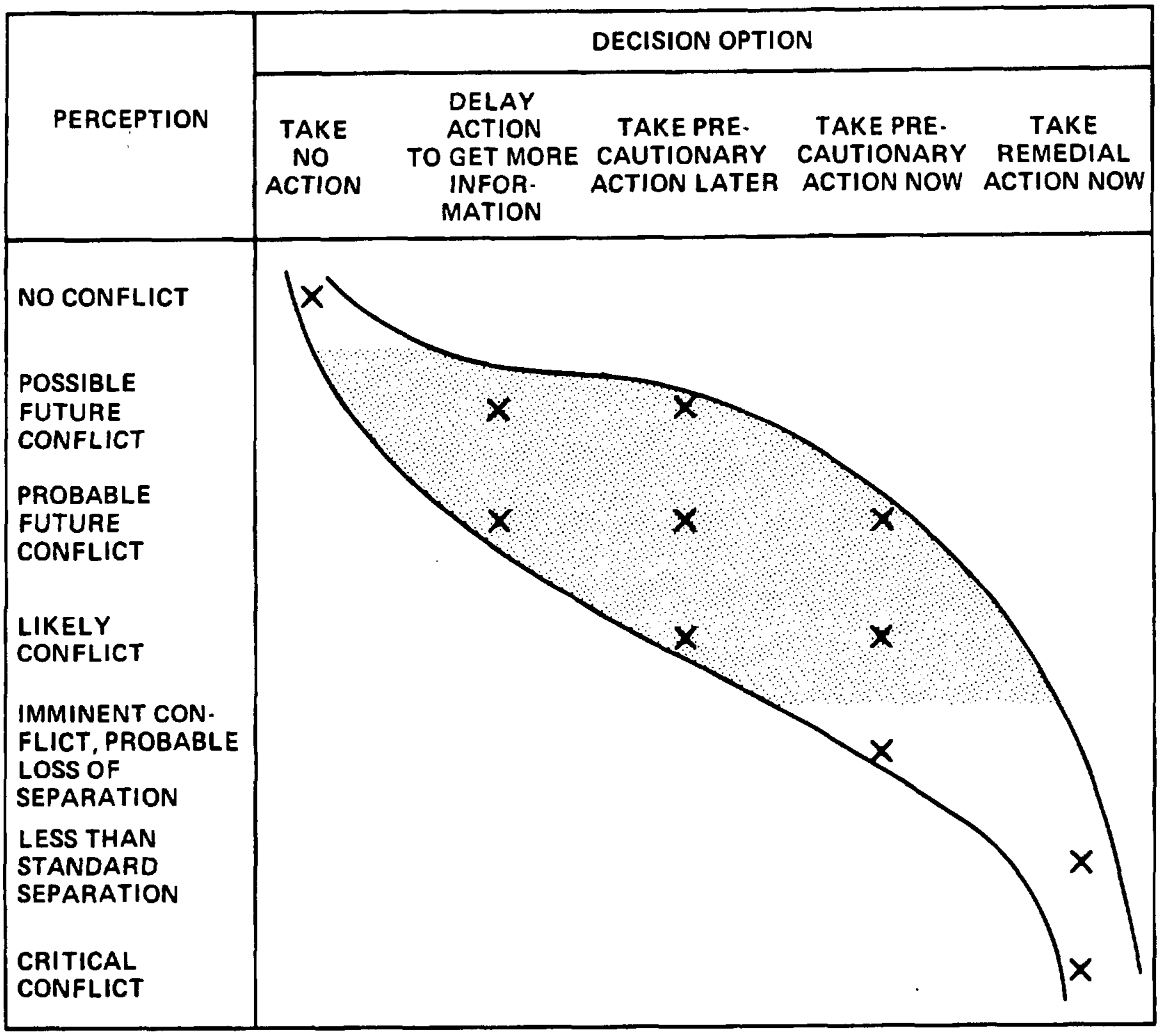

Figure 7.2.– Controller decision processes.

As was indicated above, the pilot could usefully do more, especially when flying under visual flight rules. The provision by the ATC System of separation to participating aircraft depends on ATC's knowledge of all traffic that could come into conflict with system participants. The acquisition by ATC of this information depends either on information supplied by Mode C transponders or on the same information provided orally by pilots. The provision of position, altitude, and intentions by VFR pilots (regardless of whether they intend to utilize ATC services) could do much to improve the quality of the services provided by controllers, especially in terminal areas.

Pilots often lack information with which to evaluate controller decisions and instructions. They are therefore unable to question such decisions intelligently (even if the decisions are wrong) unless the decisions are obviously inappropriate. This places a heavy burden on the controller, who in this respect is unprotected by the redundancy so carefully designed into most aspects of the aviation system. It is to the credit of controllers that they so frequently detect errors made by pilots; it is equally to the credit of pilots that they frequently detect controller errors, notwithstanding their lack of access to much information available in the ATC system.

The Role of Automation

Studies by ASRS investigators and others (ref. 3) have made it clear that automation, whether in the cockpit or in ATC, is associated with costs as well as benefits with respect to human performance. ASRS reports describe a spectrum of behaviors, from unwarranted suspicion of, to overreliance upon, automated devices.

Automation is used somewhat differently in the cockpit and in today's air traffic control system. The transfer of much of the routine information upon which the air traffic management system relies is performed automatically; most routine handoffs are likewise automatic. More recently, automatic alerting and warning systems (conflict alert, minimum safe altitude warning) have been implemented in system software. In controller reports as well as in those from pilots, one finds a broad range of views on automation, from suspicion based on warnings that seemed inappropriate (or warnings that did not occur when they were needed) to overdependence on automated functions.

The most critical reports, however, are those describing failures of the automated system to transfer or supply information. These reports suggest that at least some controllers using automated equipment have come, over time, to rely heavily upon its continued full functioning (see ch. 4). They are seriously taken aback when it fails to perform to their full expectations. We have indicated above that ASRS reports give evidence of a tendency to delay taking positive action to separate aircraft when a controller perceives that action may or may not be needed (see fig. 7.2). The particular problem with delayed decisionmaking behavior, as adduced from ASRS reports and experimental evidence (Bisseret, personal communication, 1981) is that it assumes that there will be a continuing supply of information necessary for a later decision; it also assumes that the controller will remember to return to and resolve the problem. Such behavior is clearly motivated by overreliance upon an extremely reliable system; it is nonetheless a potential point of weakness in the system.

Behavioral Impediments to Information Transfer

The study of Foushee and Manos (ch. 5) suggests that certain categories of behavior act as impediments to information flow in the cockpit. More important, their study shows that there is a significant association between information transfer and flightcrew performance. To summarize their observations, it was found that numbers of commands, acknowledgments, observations, and comments indicative of agreement were all positively associated with performance. Communications indicating uncertainty, frustration or anger, and embarrassment were negatively associated with performance.

These findings are consonant with the central thesis of this report: that inadequate information transfer is associated with errors in aviation operations. The findings are important because they also indicate that there are behaviors that interfere with information transfer, just as there are system factors (e.g., frequency saturation, high workload, and inadequately presented data) that interfere with the free flow of information.

Enhancement of Information Transfer

Many steps have been taken in recent years to enhance the flow of information in the aviation system; others, especially the implementation of data link, are planned for the near future, but it will be some time before these new developments begin to have an appreciable effect.

These and previous studies lead us to conclude that there is a real and present need for better information transfer between general aviation aircraft flying in or at the periphery of radar-controlled terminal areas and the air traffic system. We believe that the most effective way of accomplishing this information transfer is by use of Mode C transponders, although an alternative method is by voice communication between pilots and controllers. The problem with the latter method is that it does not provide the controller with a continuously visible target of adequate quality. We believe that many general aviation pilots are unaware of the degree of protection this step can provide them in terms of separation from participating traffic, and that the advantages to them of Mode C transponders have not been made sufficiently clear.

We conclude that there is a need for wider and more disciplined use of "scratch-pad" notes and other memory aids by air traffic controllers. We urge that designers of the future ATC system give thought to the desirability of incorporating memory aids into the control and display interfaces of that system.

We conclude that distraction is a serious problem that inhibits effective performance, both in the cockpit and in air traffic control. We note that FAA has introduced distraction into its general aviation flight tests, and we suggest that it might be helpful to consider ways of helping controllers deal with both operational and nonoperational (e.g., noise) distractions as well.

We conclude that failure to decide upon and relay information concerning precautionary action when potential conflicts are first noticed is one of the factors contributing to controller errors reported to ASRS. This behavior contributes to failures to ensure that proper separation is maintained. The use of memory aids can help to keep such conflicts from being forgotten, but the mental set of the controller with respect to the resolution of potential conflicts is probably equally important. We suggest that further study of decisionmaking delays may be useful in clarifying the reasons for this phenomenon.

Complacency is not widespread in reports of information transfer failures, but it can be a serious problem when it is present. We urge controllers and pilots alike to be aware of its insidious nature and of the marked decrements in perceptivity and thinking that it can cause. The system does *not* always work, and the only protection against potential disaster when it fails is alertness and forethought regarding alternative ways of accomplishing the objective.

We conclude that there is insufficient awareness of the pervasive nature of the information transfer problem in its various manifestations, and that this lack of awareness may be in part responsible for nonstandard or inadequate communications practices on the part of both controllers and pilots. We believe that wider dissemination of information concerning this problem may help to alleviate it to some extent. This report, it is hoped, may assist in resolving that most critical information transfer problem.

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