

AIRCRAFT ACCIDENT REPORT

**PAN AMERICAN WORLD AIRWAYS
BOEING 747, N 737 PA**

**KLM ROYAL DUTCH AIRLINES
BOEING 747, PH-BUF**

**TENERIFE, CANARY ISLANDS
MARCH 27, 1977**

**AIR LINE PILOTS ASSOCIATION
ENGINEERING AND AIR SAFETY
WASHINGTON, D.C.**

HUMAN FACTORS REPORT

on the

TENERIFE ACCIDENT

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PREFACE

The following report on the human factors in the Tenerife accident, between KLM 4805 and Pan Am Clipper 1736, on March 27, 1977, contains the views of the Air Line Pilots Association of the United States. It is not intended to express an official view or opinion of the accident, as that task has previously been fulfilled by the Spanish Government pursuant to Article 26 of the Chicago Convention and Annex 13 of International Civil Aviation Organization governing the investigation of aircraft accidents in international air transportation.

The circumstances and details of the accident as presented in this report are believed to be as factual as possible. It must be remembered, however, that the report is a reconstruction of the event based on the best available information, some of which may be subject to other interpretation. There is, necessarily, conjecture contained in portions of the report, which the Air Line Pilots Association feels is supported by the evidence.

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I. INTRODUCTION

A. History of the Event

At 0742 GMT (0242 EST) on March 27, 1977, Pan American Flight 1736 took off from John F. Kennedy Airport, New York, for Las Palmas in the Canary Islands. The charter flight, a Boeing 747-100, carried 373 passengers, and had originated earlier at Los Angeles, California. The crew of sixteen, headed by Captain Victor F. Grubbs, had boarded the flight at New York.

One hour and eighteen minutes later, at 0900 GMT, KLM Flight 4805 took off from Schiphol Airport, Amsterdam, also destined for Las Palmas. KLM 4805 was also a Boeing 747 and also a charter flight with 234 passengers and a crew of fourteen under Captain Jacob L. Veldhuyzen van Zanten.

While the two aircraft were en route to Las Palmas, a terrorist's bomb exploded at 1230 GMT in the passenger terminal at that airport. Because of this incident, and a warning of the existence of another bomb at Las Palmas, the airport was closed. Many aircraft destined for Las Palmas were diverted to the Los Rodeos airport at Tenerife; among them were Pan Am Clipper 1736 and KLM 4805. The Dutch airplane landed at 1338 GMT, while the Clipper arrived at 1415 GMT. Local Time at Tenerife was the same as GMT. Due to congestion on the ramp area caused by the Las Palmas diversions, both 747s were parked in the holding area for Runway 12, with KLM closest to the runway. (See Appendix One.)

At about 1430, the Las Palmas airport was opened and aircraft at Tenerife began departing for that island. Clipper 1736 was, however, unable to depart, since KLM 4805 was interposed between their position and the entrance to the runway. The KLM captain had made a recent decision to take on fuel to expedite their transit at Las Palmas. This process prevented their immediate departure and further delayed Pan Am.

After their fueling was completed, KLM 4805 called for start clearance at about 1651 and Clipper 1736 requested start clearance some 20 seconds later. At about 1658, KLM 4805 was cleared onto the runway and, after some initial confusion with regard to taxi route, received an amended clearance to backtrack to the end of the runway. Clipper 1736 also was cleared to enter the runway some four minutes later, again with some confusion as to the taxiway to be used to leave the runway. Visibility at this time was variable, from good to very poor.

KLM 4805 completed its 180 degree turn at the end of Runway 12 and lined up for takeoff on Runway 30. ATC clearance was requested at about 1706. While the KLM aircraft was receiving its ATC clearance, the Clipper was passing its assigned runway exit point in a thick cloud with very low visibility.

While KLM 4805 was reading back its ATC clearance, the aircraft began its takeoff acceleration, entering the thick cloud some 400 meters (1300 feet) into the takeoff roll.

At 1706:4903 GMT, some five seconds after V_1 , KLM 4805 collided with Clipper 1736 as the latter aircraft was turning to clear the runway. There were no eyewitnesses to the collision.

B. Purpose of this Study

The purpose of this study is to attempt to determine why this accident happened. What happened is fairly straightforward and is the subject of an official report, published by the Spanish Government and released in October 1978.

As a result of its analysis of all available data regarding this accident, the Study Group has identified what it believes to be the significant human aspects and system aspects which led, step by step, toward tragic human error, and then neutralized the opportunities for reversal of the final outcome.

It is not our purpose to fix blame or to determine probable cause, but to learn from this event and to make recommendations which may help to prevent similar catastrophic accidents in the future.

C. Scope of this Report

This report has been prepared by a study group assigned by the President of the Air Line Pilots Association to investigate the human factors behind aviation's most catastrophic accident. The investigation has spanned eighteen months and three countries.

The credentials of the study group include considerable experience in the following areas: pilot in command in international commercial aviation; aviation safety work; and human factors training and application. All members are pilots.

The study group notes with approval that the official report of the Spanish Government has, itself, included a section on human factors involved in this accident. We feel that this is an excellent beginning toward a better understanding of the causal factors of aviation accidents, an idea whose time has finally come. While in general agreement with the human factors analysis of the official report, the study group seeks, herein, to expand and deepen the scope of the human factors investigation.

Information contained and discussed in this report results from data and interviews obtained at the accident site, analysis of the transcript of air traffic control communications, analysis of both cockpit voice recorders and flight data recorders, and interviews with the Pan American captain and friends and colleagues of the KLM crew.

It is recognized that some data we would like to have are either missing or incomplete. Two of the three members used their spare time between flights to conduct the study. Time and travel constraints and the inaccessibility of some principals and some recorded information somewhat limited our investigation. Nevertheless, it is believed that enough data have been analyzed to form valid hypotheses. Missing information is noted in the body of the report.

II. BACKGROUND

Under BACKGROUND we have tried to recreate, for the reader, the conditions existing at the time of the accident. To do this we have compiled, as far as possible, the pertinent historical data of the individuals involved, both long and short term. We have called these data "Human Aspects." In addition, we have compiled the additional factors external to the personalities themselves and which may have had some effect on the course of events. We have called these "system aspects." It is recognized that the lines are sometimes blurred between these two categories, and that some interplay does exist. We believe, however, that this is the clearest way of "setting the stage" for the analyses to come.

A. Human Aspects

1. KLM Crew

KLM Captain - The captain, Jacob Louis Veldhuyzen van Zanten, was 50 years old (date of birth February 5, 1927) and had a total of 11,700 flight hours. His flight time on the B-747 was 1545 hours. This was an average of approximately 250 hours per year since he checked out on the aircraft in 1971. He was head of the Flight Training Department of KLM, and a training captain, so some of this time was built up on training flights, which tend to be of shorter duration and have fewer operational problems than regular line flights. In addition to being a flight instructor on the B-747, he had previously been an instructor on the DC-9.

The breakdown of the captain's flying time for the last six years shows that he spent the majority of his time conducting training (1545 hours on the 747 since January, 1971). It is also of significance that it was this captain who gave the copilot his 747 qualification check some two months earlier.

The captain was in good health at the time of this accident. His hearing and vision were both normal for someone of his age and he did not wear glasses. The Company doctor knew of no current medical problems with the captain. His most recent airman's medical examination was on December 2, 1976 with no waivers.

The captain reported for duty for this trip at 0745 GMT (0845 local time). He had been on duty for 9 hours and 21 minutes at the time of the accident.

The amount of rest he received during the previous night is not known. His previous night's activities and food consumption are not known.

KLM First Officer - The first officer, Klass Meurs, was 32 years old (date of birth February 14, 1945) and had a total of 9,200 flight hours. He had logged 95 hours in the B-747 since his base check and type qualification check by Captain van Zanten on January 17, 1977.

The first officer's most recent airman's medical examination was taken on December 2, 1976. He reported for duty at the same time as the captain. His previous night's activities, meal consumption and sleep are not known. It is not known what he actually ate or drank during the day of the accident.

KLM Flight Engineer - The flight engineer, Willem Schreuder, was 48 years old (date of birth August 30, 1928) and had a total of 15,210 flight hours. He had been on the B-747 for about one year and had accumulated 540 hours on the aircraft. He was also a private pilot and was a member of the flight engineers' aero club.

A friend of his has stated that the flight engineer was not in favor of integrating the functions of that position with those of the pilot crewmembers such as communications, navigation, and general monitoring of the operation of the flight. He is said to have felt that flight engineering should consist of specialized emphasis on powerplant and systems analysis and maintenance considerations. He is described as having "a very positive personality" and showed no reticence in expressing his opinions. This trait was shown at Tenerife, as we shall show later.

Mr. Schreuder was a principle founder of, and first President of, the European Flight Engineer's Organization, a post he still held on the day of the accident.

The flight engineer's most recent airman's medical examination was taken on August 16, 1976. He reported for duty at the same time as the captain. His previous night's activities, meal consumption and sleep are not known. It is not known what he actually ate or drank during the day of the accident.

2. Pan Am Crew

Pan Am Captain - The captain on the Pan Am aircraft, Victor Grubbs, was 56 years old (date of birth May 18, 1920). He had 21,043 hours total flying time and 564 hours on the B-747 aircraft. His last medical examination had been on March 23, 1977, and his most recent proficiency check was on November 15, 1976.

He had a nap the afternoon or evening prior to the flight and ate a normal dinner after awakening. He reported at the airport about 00:45 local (0545 GMT). The accident occurred at 1706 GMT, 11 hours 21 minutes later. Their scheduled takeoff time from

New York was 01:45 local; but because of a late arrival of the aircraft from its origin in Los Angeles, the actual takeoff time was one hour late, 02:45 local.

He had a snack during the delay in New York, but he did not recall eating during the flight or while they were on the ground at Tenerife.

Pan Am First Officer - The first officer on the Pan Am aircraft, Robert Bragg, was 39 years old (date of birth September 14, 1937). He had 10,800 hours total flying time and 2,796 hours on the B-747 aircraft. His last medical examination had been on January 13, 1977, and his most recent proficiency check was on January 17, 1977. He was a very senior and experienced first officer at the time of this accident.

The first officer's previous night's activities, meal consumption and sleep are not known. It is not known what he actually ate or drank the day of the accident.

Pan Am Flight Engineer - The flight engineer on the Pan Am aircraft, George Warns, was 46 years old (date of birth December 12, 1930). He had 15,210 hours total flying time and 559 hours on the B-747 aircraft. His last medical examination had been on June 25, 1976.

The flight engineer's previous night's activities, meal consumption and sleep are not known. It is not known what he actually ate or drank on the day of the accident.

3. Air Traffic Controllers

At the time of the accident, air traffic control was provided by a ground controller and an approach controller, co-located in the control tower. A third controller was occasionally present to provide relief or perform errands. The ATC workload at Tenerife on this particular day was unusually heavy because of the number of aircraft that had to divert there after the bomb explosion at Las Palmas. The tower controller position was not manned because of a lack of personnel but the tower control frequency (118.7 MHz) was used by both the approach controller and ground controller (see German incident report in Appendix Three). The Pan Am aircraft was cleared onto the runway by the ground controller while the KLM aircraft was cleared onto the runway by the approach controller. Their clearances were given on different frequencies. The accent of the ground controller made it very difficult for the Pan Am crew to understand their taxi clearance. This confusion was not cleared up until they talked with the approach controller and verified their taxi instructions. Both controllers came on duty at approximately 10:00 a.m. local time. We do not have information on their rest or what food they had eaten. Although both controllers were interviewed after the accident, the information contained in this report is drawn mainly from the cockpit voice recorders of both aircraft and a transcript of the ATC approach control frequency (119.7).

B. System Aspects

1. Time Factors

One of the strong concerns for the KLM crew, as they sat on the ramp at Tenerife, was related to the duty time they had available. The regulations concerning duty time were complex and crews were instructed to ask for help interpreting them. They were personally and legally responsible for abiding by the maximum flight and duty time regulations and their conversation expressed great concern about being able to return to Amsterdam that evening while remaining within the regulations.

They had an HF conversation with KLM headquarters in regard to their duty time situation. The message they received indicated that departure from Las Palmas as late as 1900 GMT would be possible but a message confirming this would be waiting for them when they got to Las Palmas.

As the KLM crew prepared to leave Tenerife, they knew that there would be a time slot for leaving Las Palmas, but were not sure what it would be. In order to allow minimum ground time at Las Palmas, the captain decided to take on enough fuel at Tenerife to fly back to Amsterdam.

At Las Palmas the only ground time they were expecting would be the time required to exchange passengers and handle catering requirements, which would probably take 15-20 minutes. The group of passengers waiting at Las Palmas had been at the terminal for about six hours. If they could not depart Las Palmas, it would be very difficult to find lodging for all the passengers for one night.

The KLM station manager at Las Palmas was very efficient and could be counted on to expedite matters.

An additional factor that could delay departure from Las Palmas would be a delay in receiving ATC clearance. Clearance could be delayed because of coordination problems among the various centers (Canaries, Casablanca, Spain, France, Belgium, and Amsterdam) or for various other reasons.

In any event, their departure time from Las Palmas, if in fact they could depart, was in doubt.

2. Technical Malfunction

The KLM aircraft had a slow hydraulic fluid leak that had been on the aircraft for several days. The only thing they were able to do with it at that time was to check it at each stop and replenish the fluid as necessary. They thought the leak came from a turbo relief valve not properly seating in the hydraulic system. It was a very slow leak in system number two. They put in 35 liters of hydraulic fluid at Tenerife.

3. Weather Conditions

The cloud conditions at Tenerife are usually very different from those at most airports throughout the world. The airport is 2073 feet above sea level. Clouds that are 2000 feet above ground level on the sea coast, just a few miles away, are on the ground at Tenerife and exhibit very different characteristics from normal fog patterns.

In addition to the unusual cloud conditions, local high terrain around Tenerife causes a venturi effect at the airport, so that the local condition of increased wind speed and decreased pressure can result in increased cloud density.

From the pilot's standpoint, this causes greatly variable visibilities, as clouds blow by, with non-homogeneous cloud densities from cloud to cloud. Visibility may vary from quite good at one moment to below minimums the next. The conditions cause extreme difficulty for pilots in determining proper visibilities for takeoff or landing.

The collision took place in a cloud of very high density, which accounts for the fact that there were no eyewitnesses. The first indication to the tower controllers that something was amiss was the sound of two explosions a few seconds apart.

4. Political Unrest

The situation that prevailed at Tenerife the day of the accident was one of uncertainty. A terrorist organization had set off a bomb at the Las Palmas airport which initially caused the diversion of many flights to Tenerife. Although the bombing did not directly affect pilot or controller pre-accident behavior, there was some degree of concern as evidenced by comments on the KLM CVR and the Pan Am CVR.

The tower controllers were sensitive to the political situation. This is clear in their initial reaction to the sound of the explosions. In a later interview they stated that their first thought was that the fuel tank near the tower may have been blown up.

5. Airport Facilities

The Tenerife airport was never designed to accommodate the large number of aircraft that were diverted there the day of the accident. As a result of parking congestion on the ramp, it was necessary for the controllers to devise an ad-hoc taxi routing for the two jumbos which involved both being on the active runway at the same time. The controllers were required to provide aircraft separation under very poor visibility conditions without the aid of ground radar. The tower building was being

refurbished and reequipped. Since RVR measurement equipment was not available, the controllers were not able to provide accurate visibility information to the KLM or Pan Am pilots. In addition, the runway centerline lights were out of service.

6. Language on the Radio

The controllers' normal language was Spanish; the KLM crew's was Dutch; and the Pan American crew's was English. Although ATC instructions were given over the radio in English, information transfer may have been adversely affected due to accent and terminology used by each party transmitting on the approach control frequency. (Refer also to "Crew Management Factors", "The Ambiguous Words" and "Summary", all contained within the Analysis Section.)

III. FACTUAL NARRATIVE

When both the KLM and the Pan Am aircraft arrived at Tenerife, the weather was sunny. About 1600 local, some low clouds started moving across the field. The density of the clouds, when they moved in, varied from dark to light and they were moving at the windspeed, which was about 12 to 15 knots.

In the KLM aircraft there was some discussion about being fogged in at Tenerife, but most of the concern seemed to be directed toward duty time considerations.

In the Pan Am aircraft the APU was running all the time and it was comfortable in the cockpit. Passengers were permitted to visit the cockpit in small groups while the flight crew answered questions about the airplane and the flight. The crew appeared to be alert, although evidence of some fatigue was apparent in the Captain's remark that he was ready to "hit the sack." Both aircraft were aligned in approximately the same direction. The KLM aircraft blocked Pan Am's path to the runway and was apparently all that kept the Pan Am aircraft from leaving Tenerife. The space available for taxi was measured by the Pan Am first officer and flight engineer but there was not enough room to get around KLM. The KLM aircraft was refueling at this time.

The KLM crew appeared friendly and relaxed during their wait on the ground at Tenerife. Prior to starting engines, their conversation touched on a number of subjects. The CVR transcript does indicate they were concerned about their present situation. They discussed the time required to get back to Amsterdam and how this affected their duty day. There was some indication they were thinking about their families, who, they felt, may become fearful upon hearing of the bomb blast at Las Palmas airport.

The captain mentioned the evening news broadcast to which his wife normally listened.

The crew got their papers on board from the Tenerife handling agent about 1645, after refueling had been completed. At about 1651, KLM called for start clearance. This resulted in a comment from the Pan Am cockpit: "Aha, he's ready!" Clipper 1736 requested their own start clearance as the KLM was starting engines. They were asked to stand by while instructions were given to Sunjet 282. The Pan Am crew began the pre-start checklist while passengers left the cockpit.

The KLM captain, with his comment "easy, easy, easy, give the man a fair chance", appeared to be the moderating pace within the cockpit. However, two minutes later he called ground control for start clearance, a function that is normally performed by the first officer. He made this call before the pre-start portion of the checklist was complete.

KLM was cleared to taxi and hold short of Runway 12. When they changed to approach control frequency, they asked to backtrack on Runway 12 so

they could take off on Runway 30. The approach controller cleared KLM to taxi on the runway but to exit at the third taxiway on the left and proceed to the holding position for Runway 30. KLM read this back as exiting by the first taxiway. The approach controller then amended his clearance, directing them to taxi straight down the runway and make a backtrack.

This was acknowledged by the first officer. About a minute later, as they were taxiing down the runway, the captain asked the approach controller if they were to turn left at Taxiway C-1. The controller again directed them to taxi straight down the runway, which they then did. A short time after this, as they were approaching Taxiway C-4, the captain asked the first officer if he was to turn off there. The first officer answered no, that they had been cleared to backtrack.

In the meantime, the Pan Am aircraft had started engines and was ready to taxi. They were initially cleared to hold short of the runway and then received clearance to taxi down the runway behind the KLM aircraft. The ground controller directed them to leave the runway at the third taxiway on their left. There was a great deal of difficulty and confusion understanding these instructions within the Pan Am cockpit because of the heavy Spanish accent of the controller as he spoke English. The captain expressed the desire to hold short of the runway and wait for the KLM aircraft to take off. The tower never received this information. When they changed to approach control, their instructions were repeated and the Pan Am aircraft taxied onto the runway.

There was still some confusion as to whether they were to leave the runway at the first or the third intersection on their left.

As the Pan Am aircraft taxied to the runway, the visibility was about 500 meters and the runway centerline lights were out. The visibility decreased shortly after they turned onto the runway and was estimated by witnesses to be less than 100 meters. Their taxi speed on the runway was about 9-10 knots.

When the approach controller asked the KLM aircraft for their position on the runway, the first officer replied that he thought they had just passed Charlie four. The controller acknowledged this position report and asked them to make a 180 degree turn at the end of the runway and to call him when they were ready to receive their ATC clearance.

A few seconds after the KLM first officer's conversation, the captain asked if the runway centerline lights were available. The KLM windshield wipers had been on for over two minutes at this point indicating the probable presence of heavy moisture with the resulting reduced visibility.

Shortly after this request, the Pan Am first officer again called to confirm that they were to turn off the runway at the third taxiway. From the CVR transcript, this appeared to be before they had passed any taxiways and it seemed finally to clear up their confusion.

During this discussion between the Pan Am aircraft and the approach controller, the windshield wipers in the KLM aircraft were turned off, as the cloud in which they had been taxiing blew past them and out into the approach course, leaving them in good visibility.

The Pan Am Crew studied the airport layout chart prior to entering the runway but did not recall referring to it while taxiing. Before they arrived at the first taxiway, they felt certain where they were to go. As they taxied down the runway, they counted taxiways as they passed them.

They are heard, on the CVR, to call out "there's one" and "that's two", but there is no mention of passing a third taxiway.

The KLM aircraft completed its 180 degree turn in relatively clear weather and lined up on Runway 30. The next cloud was some 900 meters (3000 feet) down the runway moving toward the aircraft at about 12 knots (six meters per second). The captain started to advance the throttles, but was reminded by the first officer that they did not yet have their ATC clearance. The captain then retarded the throttles and directed the first officer to call for the ATC clearance.

At about 1706, KLM 4805 was given the following ATC clearance: "KLM eight seven zero five you are cleared to the Papa beacon, climb to and maintain flight level niner zero. Right turn after takeoff, proceed with heading zero four zero until intercepting the three two five radial from Las Palmas VOR."

Toward the end of this transmission of the ATC clearance, the CVR showed that the captain made the exclamation: "Ja!" (yes). Some five seconds later, while the first officer was still reading back the ATC clearance, the captain said "We go---check thrust" followed by the sounds of engine spin up.

The CVR showed that the last portion of the first officer's readback became noticeably hurried and less clear. He ended his readback with the words, "We are now - uh - takin' off" or "We are now at takeoff."

The controller then said, "Okay (pause) stand by for takeoff, I will call you." On the KLM CVR, the portion of this transmission following the word "okay" is overlaid by a high pitched squeal, and the tone of the controller's voice is somewhat distorted, though understandable.

In Clipper 1736, upon hearing the KLM first officer advise that they were "taking off" or "at takeoff," and the controller's "okay" and pause, the Pan Am first officer transmitted: "and we're still taxiing down the runway - the Clipper one seven three six." It was this transmission that caused the squeal and the distortion in the KLM cockpit of the controller's transmission directing them to stand by for takeoff. The Pan Am transmission was itself almost totally blocked by the controller's transmission to KLM. Only the words "clipper one seven three six" were heard in the tower. The controller then said: "Papa Alpha one seven

three six, report runway clear," to which the clipper replied: "okay, we'll report when we're clear." During these transmissions KLM 4805 continued to accelerate on its takeoff run.

Aboard the KLM aircraft, the flight engineer asked, "Is he not clear then?" The Captain said, "What did you say?" The flight engineer: "Is he not clear, that Pan American?" To this, both captain and first officer responded with a positive and almost simultaneous, "Yes." About seven seconds later, the first officer called, "V one."

On the Pan Am aircraft they commented on the apparent hurry of the KLM captain. Shortly thereafter, they saw the lights of KLM 4805. The realization came suddenly that the other airplane was accelerating toward them. The first officer exclaimed, "Get off, get off, get off." The Pan Am CVR records the sound of the takeoff warning horn as the captain pushed the throttles to the forward stop.

On hearing "V one", the KLM captain eased back the control column to lighten the nose wheel. Three seconds later the Dutch crew saw directly in front of them, the shape of Clipper 1736 turning to KLM's right in its attempt to clear the runway. The captain pulled the control column all the way aft. KLM 4805 pitched up, striking its aft fuselage on the runway and leaving a 20 meter long streak of metal embedded in the surface of the runway. The KLM 747 broke ground just before its impact with Clipper 1736 at a point 1300 meters down the runway and near the intersection of taxiway charlie four.

The Clipper's aft fuselage and right wing area were destroyed by the impact as fire broke out immediately. The KLM aircraft with its main gear sheared off, sank back to the runway some 150 meters farther on, initially sliding straight ahead near the runway centerline. As it slid to a stop, the fuselage slowly deviated toward the right hand edge of the runway and rotated clockwise. Evidence indicates that the fire on KLM was immediate and extensive.

IV. ANALYSIS

The sequence of events in this accident can be divided into two phases. The first consists of those events that occur prior to the start of the takeoff acceleration. This section then deals with the possible reasons that the Dutch crew thought they were cleared for takeoff. The second phase consists of the events following the start of takeoff and deals with the possible reasons that three opportunities to arrest the takeoff were missed.

A. Before Start of Takeoff

1. Stress Factors - KLM Crew

The primary cause of stress on the KLM crew was the uncertainty caused by legal limits on their duty time and the potential effects on the completion of their flight. Family concerns, the extremely variable weather and a hydraulic leak also contributed to the stress level.

In December 1976, the Work and Rest Regulations for Flight Crews were changed by the Dutch Government. As a direct result of this change, computation of work and rest time became rather difficult and the captain no longer had any discretion in extending duty time. The crew was legally responsible for abiding by the maximum limits of the regulations, and conversations on the CVR indicate that they were concerned about being able to return to Amsterdam that evening while still remaining within the limits prescribed by the regulations. They discussed the possibility of fines, imprisonment or loss of licenses, should the time limits be exceeded. The possibility of ATC delays and labor-related problems with controllers in Spain and France were also discussed.

Additional stress may have been imposed by the threat of chaotic conditions that would result if the flight were terminated short of Amsterdam. Hotel rooms were severely limited in Tenerife and Las Palmas. Should the flight remain in either of those resorts, the logistic problem would be immense and the expense of providing food and accommodation for more than two hundred unexpected people would be very high. In addition, the protracted delay of the aircraft could be expected to cause further delays and aircraft scheduling problems throughout the KLM system. A regular line pilot may have dismissed these concerns as "part of the job". A pilot who is also a company official could, however, have felt his responsibility in these matters more keenly.

They talked about the bomb explosion at Las Palmas and wondered what effect news of it would have in Amsterdam. The captain mentioned the evening news broadcast to which his wife normally listened, and said: "At home they must be upset."

The CVR indicates that some concern was expressed about the weather and its effect in their impending takeoff. Prior to start the captain said: "Hurry, or else it will close again completely."

As mentioned previously, the minor hydraulic leak had to await repair at Amsterdam.

After 9 hours and 21 minutes on duty, the onset of some degree of fatigue cannot be ruled out.

2. Stress Factors - Pan Am Crew

Stress on the Pan Am crew was caused by the long delay in their flight imposed by the Spanish authorities and extended by the decision of KLM to refuel. Some fatigue was in evidence, caused by a delayed, late night departure, their long duty time and a time zone change of five hours.

On arrival at Tenerife, the Pan Am captain had requested to hold at altitude since they had adequate fuel. The Spanish controllers refused this request and ordered them to land.

When Las Palmas was reopened at 1430 GMT, after the bomb explosion, Pan Am called the tower requesting clearance to start engines. They were advised there was no ATC delay but that they may not be able to taxi because of the KLM 747 parked between them and the runway. This was confirmed by a measurement made by the first officer and flight engineer.

The Pan Am CVR contains several comments, concerning the fact that they were being delayed because the KLM aircraft was suddenly taking on fuel. As the captain comments at about 1637, "...We thought we would be gone an hour ago uh but all of a sudden he's got two big truck loads of gas...he said in a half hour he'd be gone and we're going to be right behind him." The Pan Am crew was ready to leave Tenerife and they were a little irritated at the delay caused by the KLM aircraft.

While they had been waiting on the ground, the weather was slowly deteriorating. In response to a passenger's question, the captain commented at 1652:52 that there was fog outside. This was in marked contrast to the clear weather they had when they landed.

The captain made one comment at 1646:31 about being "ready for the sack." They had taken off from New York that morning at 0742 GMT after arriving at the airport about 0542 GMT. They had been on duty for just over 11 hours when they started engines at about 1655 GMT.

3. Stress Factors - Air Traffic Controllers

On the day of the accident the controllers at Tenerife were working under the effect of stress caused by a series of special circumstances: The bomb explosion at Las Palmas and a possible bomb scare at Tenerife Airport; an unusual amount of traffic produced by the diversion of aircraft from Las Palmas added to the normal aircraft operations; the buildup of fatigue due to the combination of the above conditions and several hours on duty; some confusion caused by the operation of three different frequencies by two controllers.

The approach controller appeared to be hesitant when giving taxi instructions to the KLM aircraft when it came up on his frequency. After initially telling KLM to "...taxi into the runway and leave the runway (third) to your left," he changed it to "...taxi straight ahead for the runway and make a backtrack." This introduced an element of confusion in the KLM cockpit that was somewhat cleared up after the captain asked if they were supposed to turn left at taxiway Charlie one. The controller then told them to taxi to the end of the runway and make a backtrack.

There were several occasions where the controller paused in the middle of a transmission as if to gather his thoughts. This tendency, as we will see later, was most significant when he acknowledged the KLM clearance readback with "Okay--stand by for takeoff, I will call you." Also, on several occasions later in the transcript, the approach controller misidentified KLM 4805 as KLM 8705. Another call sign change, applied to Pan Am only once, was very crucial. The results of these small errors will be explored under "Filter Effect."

Since this tower, like most towers, was not equipped with an area microphone and recorder, a complete and objective study of events therein was not possible.

4. The Training Syndrome

"Training Syndrome" is an expression used by the study group to describe a condition where an individual who is heavily committed to training others may be susceptible to a blurring of the lines of distinction between the training environment (the "unreal" world) and line operation (the "real" world). The KLM captain's background centered on the world of air carrier training. It is, therefore, important to review the differences between that environment and the one in which he found himself at Tenerife.

The task of a training instructor is to compress the maximum amount of training into the available simulator or airplane time. In order to accomplish this, he may delete normally realistic ATC procedures and delays when training and checking a crew.

There are no ATC constraints in the simulator and only minimal constraints to operation of the training aircraft. In the simulator, the instructor acts as the controller, always responding affirmatively to the trainee pilot's requests for expedited handling during emergencies. The instructor generally issues ATC and takeoff clearance to the crew just prior to the final items of the pre-takeoff checklist. There is never a need for the crew to hold the simulator in position awaiting takeoff clearance.

The training instructor must train and check to specific training manual standards according to guidelines set down by the Chief of Training. As a result a successful check ride depends on the successful accomplishment of a series of specific and highly standardized tasks which, once accomplished, are checked off and forgotten. An instructor frequently follows the same scenario each time in checking details. Instead, a line flight in the real world is a continuous exercise of judgment and experience, rather than an assemblage of individual tasks.

An instructor has difficulty in maintaining proficiency in other than training maneuvers. He does not always get as much line flying as desired and is not as exposed to the everyday flexible decision making process that is so much a part of line flying. It is significant that the KLM captain had not flown the line in the past 12 weeks. Over the past six years, he had flown only an average of 21 hours per month on the B-747.

5. Crew Management Factors

Evidence from both CVRs indicates a different style of crew management in each cockpit. Since the final responsibility for safety of flight rests with the captain, it is critical that capability for a two-way exchange of information be maintained at all times between the captain and his crew.

The KLM cockpit crew behavioral profile centered around a captain who gave the appearance to the rest of the crew that all factors had been considered and a safe takeoff was ensured. Such a posture was undoubtedly enhanced by the captain's position in the company as Head of the Flight Training Department. Whenever upper management captains fly line trips, there is a natural subtle tension in the cockpit atmosphere that is not found between regular line crewmembers.

As the KLM aircraft was taxiing down the runway, the pacing and mood of the captain appeared to change as they passed Taxiway C-1. It may be at this point that the captain was beginning to be loaded up with the problems that had to be solved before they could take off. Witness statements from people who dealt with the KLM crew before taxiing indicate the captain was kind, easy to talk to, and self assured. What may have occurred here is an evolution of this captain's mood as he started to concentrate to

a greater degree on those considerations necessary for getting airborne and on the way, back to Las Palmas and Amsterdam. A short time after this, as they were approaching Taxiway C-4, the captain asked the copilot if he was to turn off there. This is one of the first indications that the captain had prioritized the communications with the controller behind other items of concern.

The KLM first officer was relatively young and new in his position and appeared to be mainly concerned with completing his tasks so as not to delay the captain's timing of the takeoff. He only made two comments in order to try to influence the captain's takeoff decision. When the captain first began pushing up the thrust levers, he said, "Wait a minute, we do not have an ATC clearance." The captain, rather than admitting to an oversight, closed the thrust levers and responded by saying, "No, I know that, go ahead ask." The second occurrence was at the end of the ATC clearance readback. The KLM first officer observed that the captain had commenced the takeoff and finished the ATC clearance readback by stating, "We are, uh, taking off" or "We are at takeoff" over the radio. After many hours of replaying the tapes, it is difficult to be sure what statement the first officer made. For this reason, we assume that neither the approach controller nor the Pan Am crew were positive about what was said. The Study Group believes that this ambiguous statement by the first officer was an indication that he was surprised by the KLM captain's actions in commencing the takeoff. We believe the first officer thought something was wrong with the takeoff decision by the captain, and tried to alert everyone on frequency that they were commencing takeoff. The KLM captain did not comment on his first officer's radio transmission but rather became immediately involved in setting takeoff power and tracking the runway centerline.

The Pan Am cockpit exhibited a very different crew coordination picture from that of KLM. Both pilots were experienced on the 747, the first officer having been on the aircraft somewhat longer than the captain. The captain has been described as easygoing and friendly, while the first officer has a confident and positive personality.

When Pan Am was waiting to taxi onto the runway, the captain commented twice to the first officer that he would prefer to remain clear of the runway. In the first case, the first officer was in the midst of a transmission to the ground controller. The second comment was made while the first officer was ending a response to the ground controller and changing frequencies. In the 22 seconds surrounding the captain's comments, there were four communications transmissions (incoming and outgoing) and 1 frequency change. Because of this, the first officer does not recall hearing the captain state his preference to remain clear of the runway.

When contact was established with the approach controller he confirmed the instructions to taxi onto the runway and the captain complied without pursuing the issue further. The captain could have made his request directly to the controller, but did not. The Study Group notes that, in international aviation, where communications difficulties and language problems are often the norm, a pilot will often comply with an instruction that may not be his precise choice but is understood by both parties rather than risk confusing the issue by pressing a request for change. The captain stated during an interview after the accident that this was one of his considerations at the time.

6. The Third Left

A look at the airport diagram (appendix 1) shows that the "third taxiway to the left", which Clipper 1736 was instructed to use, is C-3. The Pan Am airport chart did not designate the taxiways by number, nor were they necessary, since the taxiways at Tenerife were not identified by signs or other markings.

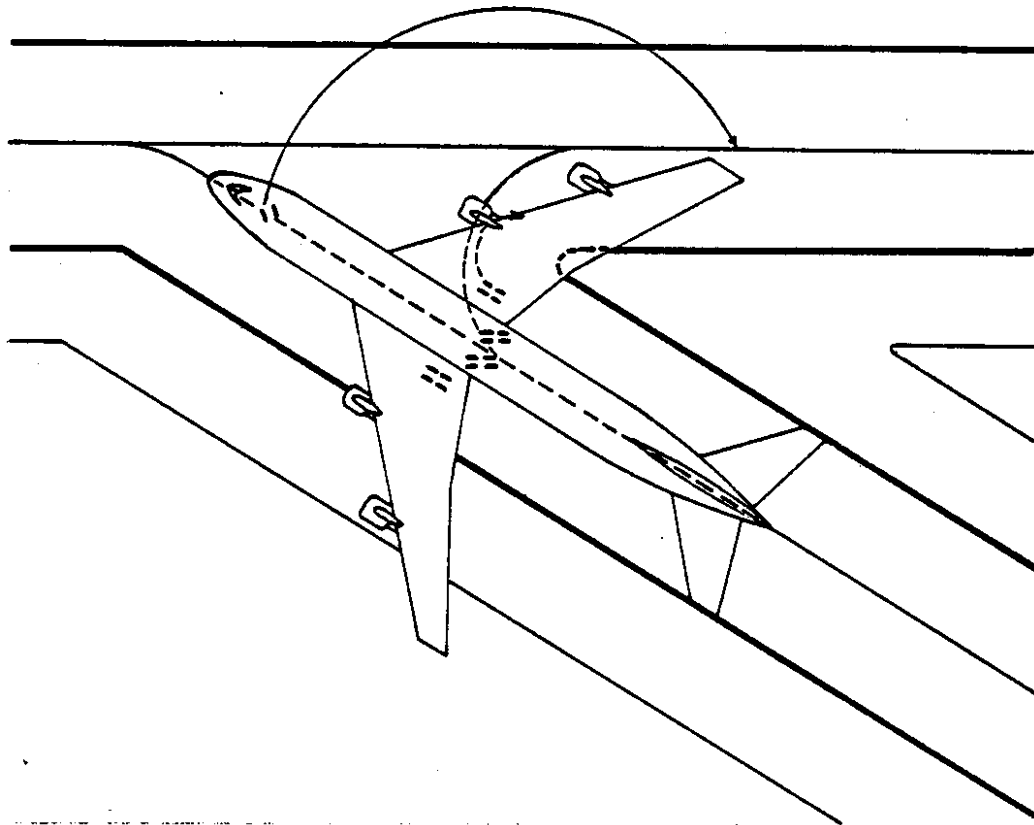
This taxiway is 73.8 feet wide and has stabilized non load-bearing shoulders. To transition to C-3 and then resume direction on the parallel taxiway would have required a 148 degree left turn, followed by a second 148 degree right turn onto the parallel taxiway. That taxiway is also 73.8 feet wide.

The turning radius charts made available by the aircraft manufacturer show that it takes a minimum pavement width of 142 feet to make a 180 degree turn with the B-747. The amount of space required to turn 148 degrees is not specified. The Pan Am crew, on reviewing the airport chart, felt that it might be possible to negotiate the first reverse turn using the extra space provided by the 150 foot wide runway, but did not believe it possible that another 148 degree turn would be made from one narrow taxiway to another.

The study group has determined, using a scale drawing, that this turn is a practical impossibility. With the aircraft starting on the centerline of Charlie 3, in the normal taxiing position, a minimum radius right-hand turn of 148 degrees would inevitably result in either the nose wheels or the right wing gear leaving the load bearing surface. Further, if a B-747 pilot were to follow the taxi guidelines, he would undershoot the corner by a very large distance. (See illustration next page.)

Thus, the Pan Am crew was convinced that the controller must have meant them to leave by C-4, an exit involving a left turn of only 35 degrees or so. Reinforcing this conclusion was the fact that, having seen other B-747 aircraft at Tenerife, they believed that the controller must have been familiar with its critical geometry. Once having reached that conclusion, and considering the previous confusion regarding their route, they believed it better to proceed with their plan, rather than further question the controller.

The Transition From Charlie Three



It was mentioned earlier, that the Pan Am crew counted taxiways as they passed them, but a third is not mentioned. Yet they had almost reached the fourth taxiway when the collision occurred. The study group has calculated that Clipper 1736 was passing the third left at the time the ATC clearance was being delivered to KLM 4805. In the Pan Am cockpit, someone started to speak, then stopped when KLM asked for their clearance. As the controller delivered the clearance to KLM, the Pan Am crew was silent.

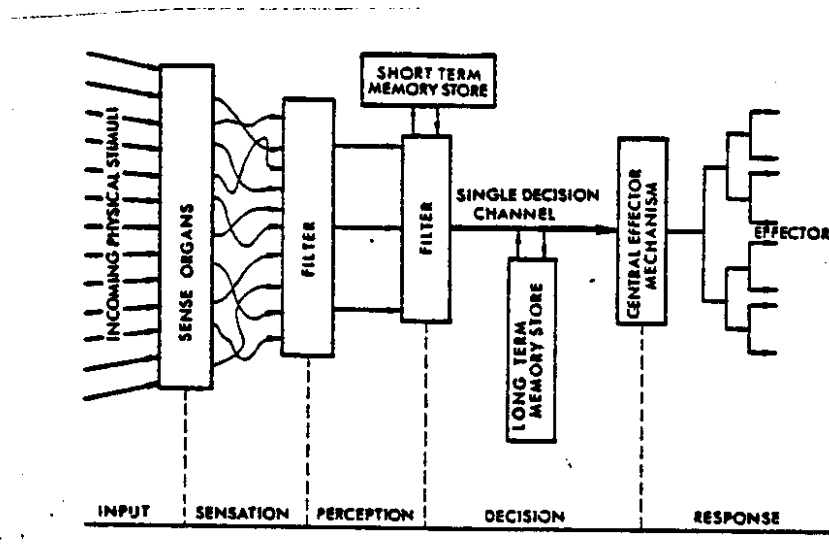
Since they were unfamiliar with Tenerife Airport, and since they knew they could expect the same departure as that given KLM, the Pan Am crew was probably concentrating deeply on the clearance being given. The silence and the Pan Am captain's almost verbatim recollection of the clearance attest to this. This concentration on the aural channel rather than the visual channel, along with the very low visibility may have prevented their seeing taxiway C-3 as they passed.

B. After Start of Takeoff

1. Filter Effect

"Filter effect" is an expression which the Study Group uses to describe a phenomenon which, we believe, had a significant adverse effect on the events which led to the Tenerife accident.

We define "filter effect" as the peculiar manner in which an individual screens and rejects or admits to the brain incoming physical stimuli. The following diagram models the human information processing system--including the filtering--that occurs between sensation, perception, and decision. In order to make a decision one must first perceive; and it is clear that something which is heard (sensation) may not be perceived or acted upon.



Courtesy: Ronald Hurst, Pilot Error

One of the primary limitations of the human information-processing system is the initial relevance placed on an incoming message. To determine the admissibility of information, the filter uses a complex system of stimuli, or keys, which have been registered from both long-term and short-term experience. Thus a pilot can listen to a busy radio frequency but may only perceive those messages preceded by his company name and trip number.

Another characteristic of the "filter effect" is its variability. The "fineness," which determines the amount of information

allowed to pass, is a function of the attention required from an individual in the performance of a separate and simultaneous task. Thus if the pilot's workload is high, such as that encountered during initial takeoff roll, the filter may be closed, or nearly closed, admitting nothing but the most urgent messages. On the other hand, if the attention demand of the flying task is not great, the filter may be open, allowing the brain to process a variety of information.

The Study Group is convinced that the "filter effect" was operative in neutralizing three important opportunities to arrest the chain of events that led to this accident.

The first opportunity occurred early in the takeoff roll when the controller advised KLM, "Okay----stand by for takeoff, I will call you." We believe that nothing after the word "okay" passed the filters of the Dutch crew, thus they believed the controller's transmission approved their announced action in taking off. The reason for this is that the second part of that transmission was overlaid by a loud squeal caused when the Pan Am first officer transmitted that they were still on the runway. The controller's transmission could still be understood in the KLM cockpit if one were listening closely but the radio interference caused a change in the timbre of the controller's voice and made it sound as if another station were broadcasting. Thus, an important key, the familiarity of the voice controlling them, was lost, and the message did not pass the filter.

The second opportunity came within seconds of the first when the controller asked Pan Am to report clear of the runway and the Pan Am first officer responded. The two transmissions were as follows: APP: "Roger Papa Alpha one seven three six report the runway clear." Pan Am: "Okay we'll report when we're clear." It was a tragic coincidence that for the first and only time that day the controller used the call sign "Papa Alpha" instead of the familiar "Clipper," the "key" registered on their filters by the short-term experience of the Dutch crew. So the second key was lost, the second message escaped perception and another opportunity to avoid disaster was missed.

The third opportunity occurred when the KLM flight engineer asked if Pan Am was clear of the runway. This was asked in a tentative, unsure manner and was curtly dismissed by both pilots. It is to be noted that, at this time, the aircraft was just entering the thick cloud bank, now 400 meters down the runway. Both pilots were contending with heavy demands on their attention as the visibility rapidly worsened. The flight engineer, to the contrary, had completed the heaviest part of his workload and was now reverting to an instrument monitoring role. His filter was probably a little more open than those of the pilots. It is our opinion that the flight engineer, like the pilots, did not perceive the message from the controller to Pan Am asking them to report the runway clear. (Because of the use of the address "Papa Alpha.") However, he probably perceived the response from the Pan Am first officer due to the "key" of the familiar voice,

which had been heard several times earlier that day. If that was the case, he would have heard only, "Okay, we'll report when we're clear." Clear of what? The flight engineer was unsure. Thus his question to the captain lacked the force of conviction and he was easily dissuaded. The final opportunity to avoid disaster was lost.

2. The Ambiguous Words

During the weeks following the accident, many experienced people listened repeatedly to the last few words of the readback of KLM's ATC clearance. These words were on three different tapes; different speakers, different filters, and different tape speeds were used. In spite of all this, investigators are about evenly divided as to what was said.

The words are either "We are now at takeoff" or "We are now uh takin' off." The inability to determine what the words are is due to the fact that the words are hurried and the voice tremulous, signs of the acute stress the KLM first officer must have felt as he noted the takeoff had begun. That these words were also ambiguous to the other parties listening at Tenerife that day is evident, and the ambiguity was significant to the outcome.

The controller thought that KLM meant that he was at takeoff position. He started to acknowledge the readback with an "Okay," then paused, as though not totally sure. During the pause he probably made the decision to cover either eventuality with "Stand by for takeoff."

Upon releasing his microphone button, the controller heard the words "Clipper 1736." At that time he must have weighed the relative importance of receiving an acknowledgement from KLM or responding to Pan Am. Since one's first impression is the strongest, he probably felt sure that KLM had simply reported reaching the takeoff position and that, in any event, he had covered the situation, so he chose to call Pan Am.

The word (or letters) "OK" can be ambiguous also; to the controller it was either a word of acknowledgement or a delaying term to allow a moment to think. It can also mean a host of other things, such as a state of well-being, a checkoff of a task accomplished, or a statement of approval. It could have had the latter meaning for the KLM crew.

C. Summary

The KLM captain assumed that he had received takeoff clearance due to development under stress of a false hypothesis that the runway was clear. Development of this false hypothesis was probably caused by both long-term and short-term factors.

The long-term factor which contributed most to the development of the false hypothesis was his behavioral conditioning as a result of nearly constant exposure to the training environment. This is discussed under "Training Syndrome" in our analysis.

A number of short-term factors contributed to the development of the false hypothesis. They include:

1. Inadequate visual information caused by low visibility. Due to the unusual and variable weather conditions associated with Tenerife, the entire runway environment was not visible to the KLM captain.
2. Misleading aural information. As KLM was nearing the end of the runway, the following conversations took place: Pan Am: "Would you confirm that you want the Clipper one seven three six to turn left at the third intersection?" APP: "The third one sir, one, two, three, third, third one." Pan Am: "Very good, thank you." It is significant that there was silence in the KLM cockpit at this time, indicating that they were listening. These discussions could have led the KLM captain to believe that Pan Am was looking at C-3 taxiway and wanted one additional confirmation before using it. Once Pan Am appeared to comply with the very definite "one, two, three, third" clearance given by the controller, the KLM captain may have assumed the Pan Am aircraft was initiating a turn off the active runway.
3. Reinforcement. From the radio conversations between the KLM first officer and the controller, the captain could have inferred that the only remaining obstacle, once the 180 degree turn was made, was receipt of the ATC clearance. After the turn, the captain started to push up the thrust levers and was reminded by the first officer that they did not have an ATC Clearance. The first officer then told the controller they were ready for takeoff and were waiting for their ATC Clearance. This implied request for two clearances in a single transmission could have fixed the false hypothesis that any positive response would satisfy both requests.

In delivering the ATC clearance, the controller gave them a "right turn after takeoff...." This use of the word takeoff in what was strictly an ATC clearance could certainly have reinforced any assumption that a takeoff clearance had been given.

4. The last reinforcement of the erroneous takeoff decision occurred when the first officer told the controller, "We are now-uh-takin off" or "We are now at takeoff." The controller acknowledged "Okay (pause)" followed by a high-pitched squeal and a transmission from an apparently unfamiliar source.

In addition to the above, the takeoff decision was heavily influenced by both long- and short-term stress factors associated with time.

Long-term stress factors which encouraged an expedited takeoff included crew duty time limitations, worsening weather conditions, passenger anxiety and family concerns.

Short-term stress factors included both the psychological tendency to continue after completing the 180 degree turn, and the timing of the takeoff between clouds. The turn required a high degree of concentrated visual workload in relatively clear weather. After completing the turn, the captain saw that the next high density cloud was some 900 meters in front of him. He also saw that the distance was shortening very rapidly as the cloud moved toward him at about 12 knots (6 meters per second). For several reasons, the B-747 can present very difficult ground directional control problems: First, the nosewheel is relatively small and lightly loaded. Second, the moment arm from the main gear to the tail is very long, causing large turning moments in crosswind conditions. Third, thrust application is usually asymmetrical from engine to engine in the initial stages of throttle movement. These effects are compounded on a wet runway which was the condition at Tenerife. It is probable, therefore, that the Captain wished to accelerate at least to the speed for full rudder effectiveness (about 80 knots) before entering the cloud ahead.

After the takeoff decision was made and the tower apparently advised, there must have been a very strong sense of relief in the KLM cockpit. All of the day's problems and delays were behind them and the trip could continue. Since directional control absorbed most of the attention of the captain and first officer, only the flight engineer, who was monitoring the radio conversation, was less susceptible to the "filter effect."

The flight engineer probably heard Pan Am say, "Okay, we'll report when we're clear" and was not sure what that meant. Both the captain and first officer dismissed the flight engineer's somewhat hesitant query as to whether Pan Am was clear of the runway.

The first officer surely felt that the runway was clear because he believed the tower had understood his advisory that KLM was "uh takin' off." Since he had heard no instruction disapproving this action, he assumed there was no objection. The Captain had already made his decision to take off much earlier and to reassess that decision at such a critical point in the takeoff may have seemed an intolerable idea. Both reactions are typical of the "false hypothesis" theory. Therefore, to reject the takeoff based upon something the flight engineer thought he heard on the radio would have been extremely difficult for the KLM captain. He elected to override his flight engineer's concern, and continue, rather than attempt a rejected takeoff with a heavy airplane on a wet runway in poor visibility.

V. CONCLUSIONS

1. Throughout the events leading to the accident, it is evident that language difficulties, including accent and idiomatic usage, degraded information transfer.
2. The KLM captain was under great stress due to concern about the legal aspects of the Dutch duty time limits and worsening weather conditions.
3. The Pan Am captain expressed a desire to hold clear of the runway, but the controller did not receive this information.
4. Both crews had difficulty understanding taxi instructions, particularly those of the ground controller.
5. The "training syndrome" may have influenced the KLM captain's early conclusion that he was cleared to take off.
6. It was possible for the KLM captain to infer that his only limiting constraint for takeoff was lack of an ATC clearance.
7. The KLM crew, in a single transmission, implicitly asked for both the ATC and takeoff clearance, and may have inferred that a single positive response would satisfy both requests.
8. The ATC clearance delivered to the KLM crew contained the words "take off," thus reinforcing the erroneous conclusion that clearance had been given.
9. The Pan Am crew passed the third left taxiway in poor visibility while concentrating on the ATC clearance being given to KLM. They did not believe this to be their assigned exit, due to their airplane geometry.
10. The controller did not obtain an acknowledgement from KLM to his order to "stand by for takeoff."
11. Ambiguous language, conflicting transmissions, the "filter effect" and inadequate utilization of the crew concept inhibited the KLM crew's perception of three opportunities to arrest the takeoff.

VI. RECOMMENDATIONS

1. All aeronautical communications should be conducted with precise standardized terminology. Rigid standards should be applied to ensure that all personnel involved in commercial aeronautical communications are fluent in English and speak with minimal accent.
2. Instructor pilots should fly the majority of their flight time in regular line operations, so as to minimize the potential of the "Training Syndrome."
3. The words "take off" should never be used in an ATC clearance.
4. Means should be taken to avoid confusion of an ATC clearance with takeoff clearance. This may involve changing the name "ATC clearance" so that it is clearly understood to be nothing more than a description of the route to be flown.
5. Ground radar should be installed at all air carrier airports.
6. Commercial aircraft should not taxi at any airport in visibility conditions below 150 meters unless suitable taxi lighting or other visual aids and airport ground radar are operational.
7. Landing lights should be on, if practicable, whenever an aircraft is moving.
8. Strobe anti-collision lights should be installed on all air carrier aircraft, and operated whenever practicable.
9. A redundant means should be provided to confirm takeoff clearance at all airports. Note: The Study Group notes with approval the installation of a VICON (Visual Confirmation of Voice Takeoff Clearance) system at Bradley International Airport, Windsor Locks, Conn., USA. (See Appendix)
10. The roles of each cockpit member should be researched by an appropriate institution to determine optimum crewmember interaction in order to minimize the probability of human error. All cockpit crewmembers should receive initial and recurrent training on the procedures developed as a result of this research.

VII. ADDITIONAL RECOMMENDATIONS

During the course of its investigation the Study Group met, and had to deal with, certain hindrances to its ability to obtain all available information. Some ideas also surfaced that we felt should be emphasized, though not directly associated with the Tenerife accident.

Recommendations regarding these conditions are presented here:

1. Attention should be drawn to the negative effect which fear of legal consequences has on the full disclosure of all factors which may have contributed to an aviation accident or incident.
2. Attention should be drawn to the negative effect which the "Freedom of Information Act" has on the thoroughness and effectiveness of aircraft accident and incident investigation in the USA.
3. For purposes of accident/incident investigation, "area microphones" and recorders similar to those in air carrier cockpits should be installed in all air traffic control rooms and airport towers.
4. The quality of recording of intra-cockpit conversation on cockpit voice recorder tapes should be improved.
5. All existing aviation medical literature regarding flight crew nutritional requirements for optimum performance should be reviewed and findings be communicated to the flight crew community.

APPENDIX 1. TENERIFE RUNWAY AND PARKING DIAGRAM

TENERIFE AIRPORT DIAGRAM

accident between

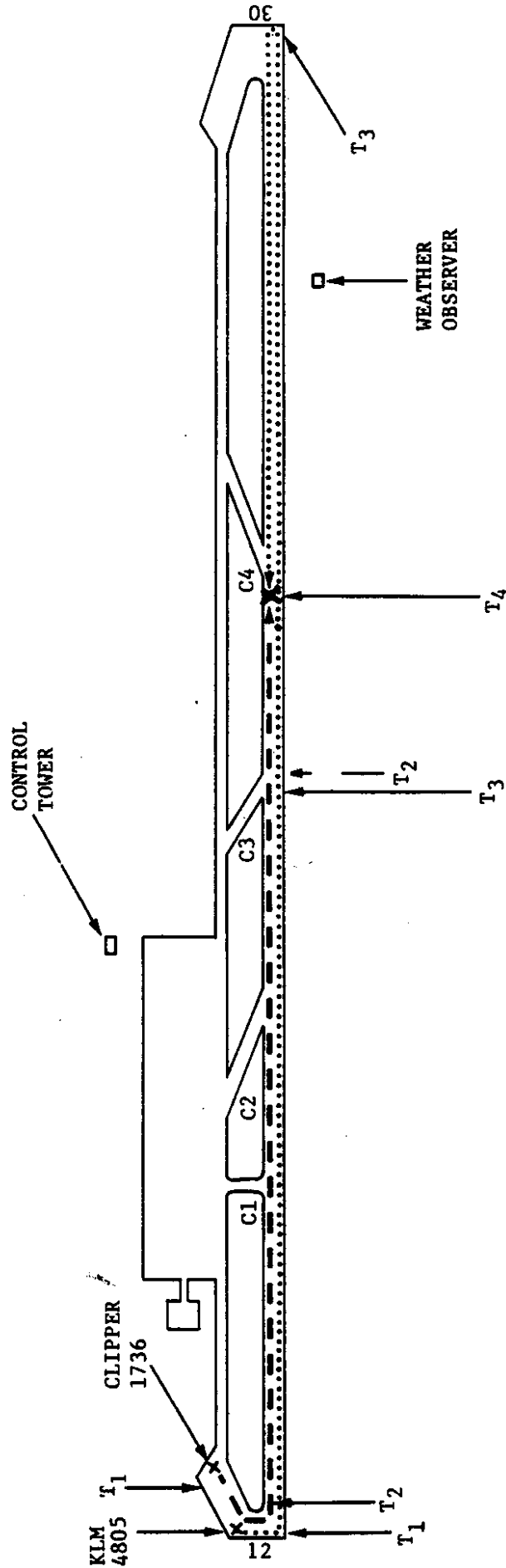
KLM 4805 and PAA 1736
March 27, 1977
Elevation: 2073 feet
Runway: 3400 x 45 meters

T₁ = 1659:10 (GMT)
Pan Am on range
KLM enters runway

T₂ = 1702:08 (GMT)
Pan Am enters runway
KLM at C3

T₃ = 1705:53 (GMT)
Pan Am passing C3
KLM receiving ATC clearance

T₄ = 1706:49 (GMT)
Impact point near C4



APPENDIX 2. KLM AND PAN AM CVR TRANSCRIPT

COCKPIT VOICE RECORDER COMMUNICATIONS

All Times are Given in Greenwich Mean Time

LEGEND

CAM Cockpit area microphone voice or sound source
RDO Radio transmission from
-1 Voice identified as Captain
-2 Voice identified as First Officer
-3 Voice identified as Flight Engineer
-? Voice unidentified
* Unintelligible word
(()) Editorial insertion
- - - Pause
APP Tenerife Approach Control 119.7 MHz.
(* Unintelligible voice transmissions in background
() Words enclosed within parentheses represent the best interpretation
of the recorded message, i.e., questionable text
UKN Unidentified source
GRD Ground 118.7 MHz
Expletive deleted

KLM COCKPIT COMMUNICATIONS

INTRA-COCKPIT

AIR-GROUND

NOTES

Time &
Source

Content

Time &
Source

Content

1702:03.3
C?

* * * lights

1701:57
PAA

Tenerife Clipper one seven
three six

1702:01.3
T

Clipper one seven three six
Tenerife.

1702:04
PAA

We were instructed to contact
you and also taxi down the run-
way is that correct?

1702:08
T

Affirmative taxi into the run-
way and leave the runway third,
third to your left. Third.

1702:17
PAA

Third to the left, okay.

1702:20.2
C1

What is this one
here?

1702:20
T

One two third left.

1702:21.5
C2

That according to
me is the one at
an angle Charly four

1702:23
S.J.

Tenerife Sun Jet two eight
two we are level one one
zero climbing

1702:26.1
C1

Do we have to get
off there?

C2

No

1702:28.9
C2

Now if you do not want
to takeoff you will block
it (the runway) for
others would not you?

C1

What did you say?

INTRA-COCKPITAIR-GROUNDNOTESTime &
SourceContentTime &
SourceContent

C2 If you don't want to
takeoff you'll
block

1702:29

T

Change now to Canarias eh
frequency one two nine point
three Sun Jet two eight two
good bye.

S.J.

one two nine three, so long

1702:35.2

C1

Now then I can still
clear there at the end
I can clear it other-
wise if not eh then
(I'll have to see)

(sound of wipers)

C2

Yea

1702:47.6

C2

Here comes the end of
the runway

(Background con-
versation in
Tower Cab)

1702:49.2

C1

A couple of
lights (to go)

1702:51.3

T

KLM four eight zero five how many
taxi ways did you pass?

1702:56

RD2

I think we just passed Charly
four now.

1703:01

T

Okay at the end of the runway
make a one eighty and report
ready for ATC clearance.

1703:09

RD2

Okay sir.

1703:11.4

C2

Do they have center-
line lighting?

INTRA-COCKPITAIR-GROUNDNOTESTime &
SourceContentTime &
SourceContent

1703:18.0

C2

Would he know (it)?

1703:14

RD1

Is the center line lighting
available four eight zero five?

1703:19

T

Stand by I don't think so sir.
I don't think so stand by. I
will check. (cockpit speaker
on low volume)

1703:23

RD1

Okay.

1703:25

T

They are working on them eh
anyway will check it.

1703:28

RD1

Okay

1703:29

PAA

eh would you confirm that you
want the Clipper one seven
three six to turn left
at the third intersection? (emphasis on
third)

1703:36

T

Third one sir, one two three
third, third one. (wiper off)

1703:40

PAA

very good thank you.

1703:47

T

Clipper seven one three six
report leaving the runway

1703:48.6

C?

cough cough

1703:54.1

C1

check list verder
((1703:48.6))

1703:55

PAA

Clipper one seven three six.

1703:57.4

C2

Brake temperatures

f. eng. seat going.

INTRA-COCKPITAIR-GROUNDNOTES

<u>Time & Source</u>	<u>Content</u>	<u>Time & Source</u>	<u>Content</u>
1704:05.4 C3	All in the green		
1704:07.6 C2	Fuel system		
1704:10.1 C3	Set for takeoff		Iberia operations Sterling seven one two 2 x ((about 8 seconds after last trans- mission from Clipper))
1704:11.2 C2	E.G.T. alarm		
1704:12.7 C3	Off		
1704:37.1 C?	Hope he's gonna make it.		
1704:38.0 C1	he		
1704:39.2 C?	I hope so too		
1704:41.5 C3	Yes I understand		click ((3 x sharp)) Iberia operations Sterling seven one two do you read?
1704:48.6 C2	Turn no tires from withunder (does not scrub the tires)		
		1704:58 T	KLM eight seven zero five and Clipper one seven three six for your information the center line lighting is out of service
1705:05.8 C1	Okay		Radio transmission in the background
1705:08.7 C1	Check list		
1705:09.5 C2	Cabin warned		Sound of chime
1705:12.3 C1	Yes O.K. I will get with it.		

INTRA-COCKPITAIR-GROUNDNOTESTime &
SourceContentTime &
SourceContent

1705:16.6
C2 flaps set eh ten en?

1705:18.6
C3 eight greens

1705:19.9
C2 water injection

1705:21.1
C3 Not (no)

1705:22.1
C2 ignition

1705:23.1
C3 Is coming

1705:24.2
C2 body gear

1705:26.1
C?+C? (Ignition - flight start)

1705:27.1
C3 All on flight start

1705:28.3
C3 body gear O.K.?

1705:29.6
C1 Yes go ahead
C2 wipers

1705:30.4
C2 Wipers on?

1705:31.7
C1 Lights on are on

1705:32.5
C2 No the wipers

1705:33.4

1705:06
RD2 I copied that

1705:07
RD2 four eight zero five

((1705:24.0))
click click click
click ((1705:27.0))

Iberian operations
Sterling seven one
two ((very weak))
((simultaneously))

Sigan Llamando a
opera liones,
Adelante 2x

INTRA-COCKPITAIR-GROUNDNOTES

Time &
Source

Content

Time &
Source

Content

1705:33.4

C1 Now no I'll wait a bit

1705:35.4

C1 If I need them I'll
ask (for them)

1705:36.7

C2 body gear disarmed landing
lights on, check list
completed.

1705:41.5

C2 Wait a minute we do not
have an ATC clearance

1705:42.8

C1 No I know that, go
ahead ask

1705:44
RD2

eh the KLM four eight zero
five is now ready for takeoff and
eh we are waiting for our ATC
clearance ((1705:50.77))

1705:53
T

KLM eight seven zero five eh you are
cleared to the Papa beacon climb to
and maintain flight level niner zero
right turn after takeoff proceed with
heading zero four zero until inter-
cepting the three two five radial
from Las Palmas VOR ((1706:08.9))

1706:07.39

C1 Yes

1706:09
RD2

eh Roger Sir we are cleared to eh
the Papa beacon flight level nine
zero right turn out zero four zero
until intercepting the three two
five. We are now (eh taking off)
((1706:17.79))

1706:12.85

C1 We go ... check trust
((1706:16.11))

((1706:13.99))
Sound of eng.
starting to spin
up

INTRA-COCKPITAIR-GROUNDNOTES

Time &
Source

Content

Time &
Source

Content

NI STABLE
((1706:19.33))
"Okay" on radio
followed by squeal
((Following the
word "OK" and
before "Stand BY"
a squealing sound
starts and lasts
through the remainder
of this transmission

1706:18.19

T Okay --- squeal

1706:20.8

T. Stand by for
takeoff
I will call you -
((1706:21.79))

NOTE: squeal starts at: 1706:19.39
squeal ends at: 1706:23.19

1706:21.92

PAA *Clipper one seven
three six ((1706:23.39))

1706:25.47

T Papa Alpha one seven three
six report runway clear
((1706:28.89))

1706:29.59

PAA Okay. We'll report when
(we are) clear ((1706:31.93))

1706:32.43

C? Is he not clear
then? (Is he
not there off)

1706:31.69

T Thank you - ((1706:31.93))

1706:34.15

PAA (Yup) NOTE: Sounds like releasing
of TWR microphone key.

1706:34.10

C1 What did you say?

1706:34.7

C? Is he not clear that Pan
American (Is he there not
off that Pan American)
((1706:35.93))

1706:35.70

C1 Oh yes (well yes) ((1706:35.99))

1706:43.49

C2 V one ((1706:43.88))

1706:47.44

C1 Oh # ((1706:48.59))

NOTE: Sound of impact 1706:49.03
END OF RECORDING 1706:49.81

PAN AM COCKPIT COMMUNICATIONS

<u>INTRA-COCKPIT</u>		<u>AIR-GROUND</u>		<u>NOTES</u>
<u>Time & Source</u>	<u>Content</u>	<u>Time & Source</u>	<u>Content</u>	
1700:27.1 CAM-2	On the hour			
CAM-1	Okay there we go	1700:43.5 GRD		Clipper one seven three six cleared taxi into the runway following the seven four seven from KLM
		1700:51.1 RDO-2		Clipper one seven three six
CAM-?	* * *			
1700:54.7 CAM-?	Better lock that door			
CAM-1	He says it clear there and it's clear all around			
CAM-2	Yea, it clear all the way			
CAM-3	* * *			
CAM-2	I'd love, yea, sure would, yea, that would be very well appreciated	1701:19.5 GRD		Seven one two stand by Break clipper one seven three six leave the runway dah three one dah on to (our) left ((GRD clearance given with Spanish accent, difficult to distinguish between "our" and "your" and "first" and "third"))
1701:27.3 CAM-1	What			
CAM-3	Using runway three one			
		1701:28.6 RDO-2		I am sorry, say again please
		1701:31.6 GRD		Leave the runway the third one (your) left

INTRA-COCKPIT

AIR-GROUND

NOTES

Time &
Source

Content

Time &
Source

Content

1701:35.6

CAM-3

Leave the runway the first 'N section on the left

1701:37.7

RDO-2

Okay, ah, taxi down the runway and ah leave the runway at the first intersection on the left, is that correct? ((1701:44.4))

1701:40.6

CAM-1

* * * tell them that we are clear tell em we

1701:45.6

GRD

Negative the third one, the third one and change one one nine point seven

1701:51.1

RD-2

Okay, the first one and one nineteen seven changing ((1701:53.9))

1701:54.2

CAM-1

We can hold clear here, if he'd let us

1701:57.0

RDO-2

Tenerife the clipper one seven three six ((1702:00.2))

1702:01.8

APP

Clipper one seven three six Tenerife

1702:03.6

RDO-2

Ah we were instructed to contact you and also to taxi down the runway, is that correct? ((1702:07.4))

1702:08.4

APP

Affirmative, taxi into the runway and ah leave the runway third, third to your left, third ((background conversation in the tower))

1702:16.4

RDO-2

Third to the left okay ((1702:18.3))

1702:18.4

CAM-3

Third he said

INTRA-COCKPITAIR-GROUNDNOTESTime &
SourceContentTime &
SourceContent

CAM-? Three

1702:20.6
APP

-ird one to your left

1702:21.9

CAM-1 I think he said
first1702:23.3
282Tenerife Sunjet two eight two
we are level one one zero climbing

1702:26.4

CAM-2 I'll ask him again

CAM-? * *

1702:28.8
APPChange now to Canaries ah frequency
one two nine point three Sunjet
two eight two goodbye

1702:32.2

CAM-2 Left turn

1702:33.1

CAM-1 I don't think they have
takeoff minimums anywhere
right now

1702:39.2

CAM-1 What really happened over
there today?

1702:41.6

CAM-4 They put a bomb (in) the
terminal sir right where
the check in counters are

1702:46.6

CAM-1 Well we asked them if we could
hold and uh I guess you got the
word, we landed here **

DK282

One two nine three so long

CAM-X * * *

1702:49.8
APPKLM four eight zero five how
many taxiway ah did you pass?1702:55.6
KLI think we just passed charlie
four now1702:59.9
APPOkay --- at the end of the runway
make one eighty and report ah ready
ah for ATC clearance ((background
conversation in the tower))

INTRA-COCKPITAIR-GROUNDNOTES

Time &
Source

Content

Time &
Source

Content

1703:09.3

CAM-2 The first one is a
ninety degree turn

1703:11.0

CAM-1 Yeah, okay

1703:12.1

CAM-2 Must be the third--
I'll ask him again

1703:13.8

KL Okay sir

1703:14.2

CAM-1 Okay

1703:14.2

KL Is ah centerline lighting
available for four eight zero
five?

1703:16.6

CAM-1 We could probably
go in it's ah ---

1703:19.1

CAM-2 You gotta make a ninety
degree turn

1703:19.8

APP Standby, I don't think so sir
I don't think so standby, I
will check

1703:21.6

CAM-1 Yeah uh

1703:21.6

CAM-2 Ninety degree turn to get
around this -- this one
down here it's a forty-
five

1703:22.9

KL Okay

1703:25.0

APP They are working on them ah
anyway we'll check it

1703:29.3

RDO-2 Would you confirm that you want
the clipper one seven three six
to turn left at the third inter-
section ((1703:35.4))
((PAA: "third" drawn out and
emphasized))

INTRA-COCKPITAIR-GROUNDNOTESTime &
SourceContentTime &
SourceContent

1703:35.1

CAM-1 One two

1703:36.4

APP

The third one sir, one two
three third third one ((1703:
38.3))

1703:38.3

CAM-? One two (four)

1703:39.0

CAM-1 Good

1703:39.2

RDO-2

Very good, thank you ((1703:40.4))

1703:40.1

CAM-1 That's what we need right,
the third one

1703:42.9

CAM-3 Uno, dos, tres

1703:44.0

CAM-1 Uno, dos, tres

1703:44.9

CAM-3 Tres uh --- si'

1703:46.5

CAM-1 Right

1703:47.6

CAM-3 We'll make it yet

1703:47.6

APP

---er seven one three six
report leaving the runway

1703:49.1

CAM-2 Wing flaps?

1703:50.2

CAM-1 Ten, indicate ten, leading
edge lights are green

1703:54.1

CAM-? Get that

1703:55.0

RDO-2

Clipper one seven three
six ((1703:56.4))

1703:56.5

CAM-2 Yaw damp and instrument?

1703:58.6

CAM-1 Ah Bob we'll get a left one *

INTRA-COCKPITAIR-GROUNDNOTES

<u>Time & Source</u>	<u>Content</u>	<u>Time & Source</u>	<u>Content</u>
1703:59.3 CAM-2	I got a left		
1704:00.6 CAM-1	Did you?		
1704:00.9 CAM-2	And ah need a right		
1704:02.6 CAM-1	I'll give you a little *		
1704:03.8 CAM-2	Put a little aileron in this thing		
1704:05.0 CAM-1	Okay here's a left and I'll give you a right one right here		
1704:09.7 CAM-1	Okay, right turn right and left yaw		
1704:11.4 CAM-2	Left yaw checks		
1704:12.4 CAM-1	Okay here's the rudders		
1704:13.6 CAM-1	Here's two left, center, two right center		
1704:17.8 CAM-2	Checks		
1704:19.2 CAM-2	Controls		
1704:19.6 CAM-1	Haven't seen any yet!		
1704:20.3 CAM-2	I haven't either		
1704:21.7 CAM-1	They're free the indicators are checked		
1704:24.6 CAM-2	There's one		

INTRA-COCKPITAIR-GROUNDNOTES

<u>Time & Source</u>	<u>Content</u>	<u>Time & Source</u>	<u>Content</u>
1704:25.8 CAM-1	There's one		
1704:26.4 CAM-1	That's the ninety degree		
1704:28.5 CAM-?	Okay		
CAM-?	* * *		
1704:34.5 CAM-2	Weight and balance finals?		
1704:37.7 CAM	((Sounds similar to stabilizer trim)) ((1704:44.8))		
1704:37.2 CAM-1	We were gonna put that on four and a half		
1704:39.8 CAM-3	We got four and a half and we weigh five thirty four ((sound of stabilizer trim))		
1704:44.6 CAM-2	Four and a half on the right		
1704:46.8 CAM-2	Engineer's taxi check		
1704:48.4 CAM-3	Taxi check is complete		
1704:50.5 CAM-2	Takeoff and departure briefing?		
1704:52.1 CAM-1	Okay it'll be standard we gonna go straight out there till we get thirty-five hundred feet then we're gonna make that reversal and go back out to * fourteen		

INTRA-COCKPITAIR-GROUNDNOTESTime &
SourceContentTime &
SourceContent

1705:09.6
CAM-1 We got centerline markings (*only ((could be don't we)) they count the same thing as --- we need eight hundred meters if you don't have that centerline --- I read that on the back (of this) just awhile ago

1705:22.0
CAM-1 That's two

1705:23.5
CAM-3 Yeh, that's that forty-five there

1705:25.7
CAM-1 Yeh

1705:26.5
CAM-2 That's this one right here

1705:27.2
CAM-1 (Yeh) I know

1705:28.1
CAM-1 Okay

1705:28.5
CAM-3 Next one is almost a forty-five, huh yeh

1705:30.6
CAM-1 But it goes ---

1704:58.2

APP

---m eight seven zero five and clipper one seven --- three six, for your information, the centerline lighting is out of service ((APP: transmission is readable but slightly broken))

1705:05.8

KLM

I copied that

1705:07.7

RDO-2

Clipper one seven three six

INTRA-COCKPIT

AIR-GROUND

NOTES

Time &
Source

Content

Time &
Source

Content

1705:32.4

CAM-1

Yeh, but it goes ---
ahead, I think
(it's) gonna put us
on (the) taxiway

1705:35.9

CAM-3

Yeah, just a little
bit yeh

1705:39.8

CAM-?

Okay, for sure

1705:40.0

CAM-2

Maybe he, maybe he
counts these (are)
three

CAM-?

Huh

1705:44.8

CAM-?

I like this * *

1705:44.8

KLM

Uh, the KLM --- four eight zero
five is now ready for takeoff
--- uh and we're waiting for
our ATC clearance

1705:53.4

APP

KLM eight seven * zero five uh
you are cleared to the papa
beacon climb to and maintain
flight level niner zero ---
right turn after takeoff proceed
with heading zero four zero until
intercepting the three two five
radial from Las Palmas VOR
((1706:08.2))

1706:09.6

KLM

Ah roger sir we're cleared to
the papa beacon flight level
niner zero, right turn out zero
four zero until intercepting
the three two five and we're
now (at takeoff) ((1706:17.9))

1706:18.5

APP

---K ((1706:18.8))

1706:19.3

RDO-1

No uh ((1706:19.8))

INTRA-COCKPITAIR-GROUNDNOTESTime &
SourceContentTime &
SourceContent1706:32.1
CAM-1Let's get the (* ##
##) right here ---
get the ### out
of here ((chuckle))
((1706:34.6))1706:34.9
CAM-2

Yeh, he's anxious isn't he

1706:36.2
CAM-3Yeh after he held us up for
an hour and a half, that
##1706:38.4
CAM-2

Yeh, that #

1706:39.8
CAM-3

Now he's in a rush

1706:40.6
CAM-1There he is---look
at him--- ### ---
that---that ###
is coming
((1706:45.6))1706:45.9
CAM-2Get off! Get off!
Get off! ((1706:47.9))1706:48.7
CAM((Sound of takeoff warning
horn))((Sound of approaching
KLM engines))1706:20.3
RDO-2And (*) we're still taxiing down
the runway the clipper one seven
three six ((1706:23.6))1706:25.6
APPRoger pappa alpha one seven three
six report the runway clear
((1706:28.9))1706:29.6
RDO-2Okay we'll report when we're
clear ((1706:30.9))1706:32.1
APP

Thank you ((1706:32.7))

INTRA-COCKPIT

AIR-GROUND

NOTES

Time &
Source

Content

Time &
Source

Content

CAM ((Simultaneously, sound of takeoff warning horn emanating from Pan Am cockpit resulting from advancing throttles and body gear being unlocked))

1706:50.1

CAM ((Sound of impact))
((1706:50.6))

1706:50.6 END OF RECORDING

APPENDIX 3. INCIDENT REPORT

INCIDENT REPORT quoted in "Germany Cockpit INFO No. 13/77, 12/8/1978.

With a comment by Captain Sven Ruhberg (not printed).

Am 27. März 1977 wurden wir wegen einer Bombenexplosion im Flughafengebäude von LPA nach TCI umgeleitet.

Nachdem LPA wieder angeflogen werden konnte, forderten wir auf TCI-GND 121.70 start up-clearance und erhielten auch die Erlaubnis zum Anlassen. Schon zu diesem Zeitpunkt fiel uns auf, dass auch andere Flugzeuge ihre Triebwerke anliessen und in Richtung RWY 30 rollten, ohne dass auf 121.70 dafür eine Erlaubnis gegeben worden war. Auf unserem zweiten VHF COM-Gerät drehten wir die TWR-Frequenz 118.70 ein und stellten fest, dass von beiden Controllern auf beiden Frequenzen sowohl Freigaben zum Anlassen als auch Rollfreigaben erteilt wurden. Taxi-clearance erhielten wir von GND 121.70, hörten jedoch sicherheitshalber TWR 118.70 mit ab. An der RWY 30 warteten bereits zwei Flugzeuge aus dem EG-Raum und eine spanische Maschine auf Startfreigaben. Die beiden erstgenannten Maschinen waren in Funkverbindung mit TWR auf 118.70, die spanische Maschine weder auf GND 121.70 noch auf TWR 118.70 zu hören.

Alle drei Flugzeuge vor uns starteten, ohne auf einer der beiden o.g. Frequenzen eine Freigabe erhalten zu haben. Dann meldeten wir uns bei TCI GND 121.70 als "No. one for take-off". Die Antwort des Controllers: "Switch over to TCI - approach on 119.70." Auf dieser Frequenz (approach) erhielten wir dann line up- und take-off-clearance.

Fazit: An diesem Tag wurden in TCI auf drei verschiedenen Frequenzen von verschiedenen Leuten start-up, taxi- und take-off-clearances gleichzeitig gegeben. Wer immer mit zwei VHF COM-Geräten auf GND 121.70 und TWR 118.70 "listening watch" hielt, konnte keine take-off-clearance mithören, weil diese auf der approach-frequenz 119.70 gegeben wurde !!!!

TRANSLATION

On 27 March 1977 we were diverted from LPA to TCI because of a bomb explosion in the airport building.

After LPA had been opened up again, we asked for start-up clearance on 121.70 TCI-GND and also received the permission to start engines. Already at that time it was apparent to us that also other aircraft started their engines and taxied in the direction RWY 30, without having been given a clearance to do so on 121.70.

On our second VHF COM-set we tuned in the TWR-frequency 118.70 and established that by both Controllers on both frequencies were issued Clearances to Start as well as Taxi Clearances. We received taxi clearance from GND 121.70, but just to make sure we also listened to TWR 118.70. Near RWY 30 already two aircraft from the European Community area and a Spanish aircraft were waiting for take-off clearance. Both first-mentioned aircraft were in radiocommunication with TWR on 118.70, the Spanish aircraft could not be heard either on GND 121.70, or on TWR 118.70

All three aircraft took off ahead of us, without having received a clearance on one of the two above-mentioned frequencies. Then we reported ourselves with TCI GND 121.70 as "No. one for take-off". The answer of the Controller: "Switch over to TCI-approach on 119.70". On this frequency (approach) we received thereafter line up and take-off clearance.

Established On this day there were issued in TCI on three different frequencies by different persons start-up, taxi- and take-off clearances all at the same time. Who continuously with two VHF COM sets held a "listening watch" on GND 121.70 and TWR 118.70, could not listen in to any take-off clearance, because these were given on the approach-frequency 119.70!!!!

Note: TCI is Tenerife Airport.

APPENDIX 4. ADDITIONAL INCIDENT REPORTS - TAKEOFF WITHOUT CLEARANCE

TAKEOFF EXPECTANCY

This report from the British National Air Traffic Services highlights how words can subtly influence understanding when a person is predisposed to a certain course of action.-Ed.

At 1256Z, the 707 was cleared by Prestwick tower to the holding point at runway 31. This was acknowledged.

Approximately six minutes later the flight was cleared to line up on runway 31. This was also acknowledged. This instruction was repeated later along with his ATC clearance and acknowledged. A further instruction to "hold position there" was read back correctly.

At 1306Z ATC cleared him, "Flight --, after takeoff your clearance will be straight ahead not above three thousand feet until advised by Prestwick radar and the frequency will be 120.55".

This was acknowledged as "Roger straight ahead there at three thousand feet, 120.55, ROLLING".

Prestwick tower responded "Flight -- hold position" and this instruction was complied with. There was, in fact, conflicting traffic, overflying the airfield at the time. □

We were operating a delayed departure on trip 129 and elected R/W 28 because of a high gross weight. Runway 1 was also active. Taxing out on Fox-trot, we were cleared to the approach end of 28. Prior to the intersection of 1L, I asked the First Officer to "check." The Ground Controller reiterated, "cleared to cross both 'north-souths'."

As I cleared R/W 1L, I noticed the aircraft holding in position on 1R has landing lights on. It isn't unusual for an aircraft holding to be "ready" for an immediate takeoff. As I was about to enter R/W 1R, the lights looked slightly more conspicuous. This really didn't alert me to anything being amiss, since we had just checked on the crossing clearance. About that time the First Officer said, "Hey, he's moving." I immediately gunned it to expedite clearing the intersection. However, as you well know, 600,000 pounds doesn't accelerate quickly. I believe he rotated about 1,000' prior to our intersection. He passed over our tail at 50' altitude.

We immediately communicated our extreme displeasure to Ground. In a minute or so he came back with, "It was a foul up in communication here," adding defensively that he had the "release." In another 90 seconds, he asked if I wanted to file a violation? I guess their procedures are to elicit this information. I wasn't too happy with this punitive approach and suggested we might try to learn from it. By then he was busy with the other traffic. It may have gone in one ear and out the other.

Two observations: The other pilot could have attempted to abort as we lumbered onto the runway. If so, I am certain it would have been a swerve to the right. But, by the time he reached it, our acceleration would have us on the right side of the intersection. Neither would have known the other's intention. Secondly, the incident was avoidable. If landing lights on meant starting takeoff roll, there could be no misinterpretation.

We use the rotating beacon to warn ground personnel that engines are operating. We use the position lights during daytime to indicate intention of taxi. Why can't this concept be extended to insure against a Tenerife-West? It will not increase pilot workload. In a business that prides itself on redundant back-up procedures, it fills a glaring gap. Surely there would be little opposition. As noise abatement problems increase, the use of crossing runways will also increase. And so will the potential for a Tenerife type tragedy. We can eliminate that possibility.

REPORT NARRATIVE: CREW UNINTENTIONALLY TOOK OFF WITHOUT T.O. CLEARANCE, MISUNDERSTOOD GRND CONTROL. WHILE TAXING DOWN RUNWAY GRND CONTROL DELIVERED CLEARANCE, CREW HELD CHECK LIST, CREW READ BACK CLEARANCE, CREW MISUNDERSTOOD GRND TO SAY "CLEARANCE CORRECT, CLEARED FOR T.O.", CREW RESUMED OK LIST FROM HOLDING PT., BRIEFED IN POSITION AND TOOK OFF. CREW REQUESTED "GOING TO DEPARTURE NON CLIMB. GRND CONTROL ADVISED FLIGHT HAD NOT BEEN CLEARED FOR T.O. CREW APOLOGIZED, GRND CONTROL ADVISED NO PROBLEM. FACTORS: 1) MISUNDERSTANDING 2) NO OTHER TRAFFIC, NO OTHER RADIO CONVERSATION, LACK OF "CUES" 3) HABIT PATTERNS (BEING ON RUNWAY, NO OTHER TRAFFIC) INTERRUPTED OK LIST LEAD TO MISUNDERSTANDING 4) GRND DID NOT ADVISE FLIGHT TO "CONTACT TOWER FREQ. --- WHEN READY", THIS WOULD HAVE BEEN AN ADDITIONAL CUE TO THE CREW. 5) THIS TOWER IS NOT IN OPERATION 24 HRS A DAY, SO T.O. AND LNCS. ARE NOT CONTROLLER 100% OF OUR OPERATIONS, 6) ON OCCASION HAVE BEEN CLEARED FOR T.O. BY GRND CONTROL AND (NOT NECESSARILY THIS FACILITY) CLEARED TO RAMP BY TOWER. UNFORTUNATELY, THIS POSITIVELY REINFORCES CREWS "MISUNDERSTANDING" DURING THE INCIDENT. ALTHOUGH THEY ARE UNAWARE OF IT.

REPORTER'S RECOMMENDATIONS: THIS INCIDENT POINTS TO THE FACT THAT IN ANY "SLOW" OR ROUTINE SITUATION WE HAVE TO BE EVEN MORE ALERT TO POTENTIAL PROBLEMS. MANY TIMES, PARTICULARLY IN VERY REPETITIVE SCHEDULED TYPE OPERATIONS, WE RELY TOO HEAVILY ON ESTABLISHED HABIT PATTERNS.

=====

REPORT NARRATIVE: FLITE LEFT GATE AT 0802 FOR CRIP OMA-DEN. ORIGINAL TAKE OFF ABORTED DUE TO NO. 3N GAUGE MALFUNCTION. RETURNED TO RUNWAY RUN-UP BLOCK AND ENGINE CHECKED NORMAL. TOWER WAS CALLED FOR TAKE-OFF CLEARANCE. BOTH PILOTS VERRALLY CONFIRMED TAKE-OFF CLEARANCE WAS RECEIVED. AIRCRAFT WAS TAXIED ON TO THE RUNWAY AND NORMAL TAKE-OFF COMPLETED. AFTER AIRBORNE TOWER REPLIED THAT NO TAKE-OFF CLERANCE HAD BEEN GIVEN. POSSIBLE CAUSES FOR THE INCIDENT WERE COCKPIT ACTIVITY, PA ANNOUNCEMENTS, MORE CONVERSATION THAN USUAL. A COMPANY CHECK PILOT WAS RIDING THE JUMP SEAT AT THE TIME CREATING A "DIFFERENT" COCKPIT ENVIRONMENT.

REPORTER'S RECOMMENDATIONS: - - - - -

=====

REPORT NARRATIVE: AT COMPLETION OF PREFLIGHT CHECK HOLDING SHORT OF RUNWAY TURNED TO A 45 DEG ANGLE TO FINAL APPROACH COURSE IN RUN-UP AREA AND OBSERVED SE1 ON A GO AROUND OVER NUMBER WITH NO OTHER TRAFFIC ON EITHER SIDING. CALLED TOWER AND ADVISED THAT "READY FOR TAKE OFF-STRAIGHT OUT". CLEARED FOR TAKE OFF.....START YOUR RIGHT TURN NOW". REPLIED TO TOWER." APPROXIMATELY ONE THIRD OF WAY DOWN RUNWAY HEARD "FOR TAKE OFF" REPLIEDHEARD TOWER CALL "RIGT FOUR WHISKRY" REPEATED CALL FORANSWERED "ARE YOU CALLING?" TOWER REPLIED "I DIDNOT CLEAR YOU FOR TAKE OFF ROLLING" THERE WAS ADDITIONAL TRANSMISSION - TOWER APPLIED "WHAT IS DIRECTION OF FLIGHT?" REPLIED "STRAIGHT OUT". TOWER ASKED FOR DESTINATION. REPLIED "NORTHEUND". NO EVASIVE ACTION WAS REQUIRED BY ANY AIRCRAFT. I BELIEVE THAT ON THIS VFR SUNDAY AFTERNOON WITH TOUCH AND GO TRAFFIC PLUS TRANSIT AIRCRAFT REPORTING FROM 10 TO 12 MILES OUT AND THE TAKE OFF DENSITY (WE WERE NO. 1 OF 4 AWAITING CLEARANCES AT THE TIME). THAT COMMUNICATIONS WERE MARGINAL. BOTH OF THE PILOTS ON BOARD BELIEVED THAT WE WERE CLEARED. HOWEVER THERE IS ROOM TO CONSIDER A OVER RIDE OF COMMUNICATIONS.

REPORTER'S RECOMMENDATIONS: TO HOLD DOWN LIKE OCCUPANCY SUGGEST BOTH SIDES USE COMPLETE NUMBERS FOR DEPARTING TRAFFIC INSTRUCTIONS - AFTER AGL IS SAID - PILOTS AND CONTROLLERS ARE OR SHOULD BE ON SAME SIDE.

APPENDIX 5. VISUAL CONFIRMATION OF VOICE TAKEOFF CLEARANCE

VISUAL CONFIRMATION OF VOICE
TAKEOFF CLEARANCE

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BIOGRAPHY

George A. Scott is the Acting Chief of the Training Requirements and Performance Evaluation Section, Air Traffic Control Systems Division. His career in aviation began back in 1948 with a U.S. Navy air search and rescue group stationed in Honolulu, Hawaii. In 1953, he joined the Civil Aeronautics Administration, Air Traffic Service and served as a communicator in Grand Island, Nebraska and later as an air traffic controller in the Indianapolis Air Route Traffic Control Center. Mr. Scott left the CAA in 1958, to work as Operations Chief at the Wright Air Development Flight Test Center in Dayton, Ohio. He rejoined the FAA in 1959 at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, N.J., where as a project manager, he was involved in such agency programs as: ATC System Concept and Development; Facility Establishment and Environmental Enhancements; Development of Enroute and Terminal Automation; Aviation Weather; Controller Training and productivity.

ABSTRACT

On March 27, 1977, one of the most tragic airport accidents in the history of aviation occurred on Tenerife Island, Spain, snuffing out the lives of 580 people. The probable cause of the accident was a simple verbal misunderstanding of control instructions between the pilot of the departing aircraft and the airport tower controller. This paper addresses a system wherein a stimulus in addition to voice is involved, namely a visual confirmation. Included herein are the basic system requirements, a preliminary system configuration, and a test and evaluation program dedicated to answering the following questions:

1. Does the VICON system improve safety?
2. Is the technique feasible?
3. Can VICON be integrated into the present ATC system?
4. What are the associated costs?

Testing started at NAFEC in April 1978 and it is directed at reducing the system variables to a minimum. Follow-on field testing will be completed at Bradley International Airport, Windsor Locks, Connecticut. The paper closes with a schedule that calls for completing the Bradley tests in March 1980.

BACKGROUND

In just four short years, December 1972 to December 1976, there were seven ground related aircraft collisions in the National Airspace System. Analysis of these accidents has indicated that the probable causes involved controller and pilot judgment of runway usage in takeoff, landing and runway crossing operations. At present, runway utilization generally involves a single stimulus for receiving air traffic control instructions, that of hearing a voice instruction on the aircraft radio.

In a number of the collisions mentioned above, the probable cause of the accident included a reference to, "the pilot not clarifying ATC instructions." This tends to indicate that present voice (radio) confirmation of runway usage instructions, when not clearly understood by the pilot, can lead to undesirable and unfortunately even unsafe operations. It is questionable whether additional voice confirmation of runway utilization instructions (e.g., repeating the issuance

or acknowledgment of a clearance, more detailed instruction such as runway identification, etc.) would be as effective in

* This paper is limited to only the takeoff portion.

aining the attention (and hopefully eliminating misunderstandings) of controllers and pilot as the use of a second, independent sensory stimulus to positively confirm the voice instruction.

Regardless of the weather, time of day or air traffic situation, the pilot is expected to use sight as a verification of the voice instruction to ascertain if the runway is clear of other traffic before using it. Because of factors such as weather and darkness, positive visual confirmation (Stimulus No. 2) to verify the ATC voice instruction (Stimulus No. 1) prior to proceeding down the runway, is not always possible in today's ATC system.

In order to examine the use of dual sensory stimulus there is a requirement: To determine whether or not visual confirmation of controller voice instructions as they relate to runway operations is feasible, can such confirmation be integrated into the present ATC system and will it provide an added measure of safety? In response to this requirement, the FAA's Systems Research and Development Service initiated, in April 1977, a program to develop, test and evaluate a Visual Confirmation of Voice Takeoff Clearance (VICON) system. In developing the VICON system, the following factors were considered:

1. The confirmation system shall be used as a standard procedure for all takeoffs at airports where there are operational towers, including single and multiple runway airports, and takeoffs at taxiway intersections as well as end of runway takeoffs.
2. The visual reference shall be conspicuous to pilots of all types of aircraft, other than helicopters, prior to takeoff and should have minimal impact on pilots of landing aircraft.
3. The use of the confirmation system should have minimal impact on pilot and controller procedures and on airport capacity.
4. For the controller, a means of activating and verifying the activation of the visual signal shall be collocated and should be readily accessible to the controller and separate from other lighting controls.
5. The visual signal shall be distinguishable by the pilot from other visual aids in takeoff areas including displaced threshold areas and shall meet current airport siting criteria for runway lighting systems.
6. If the takeoff visual confirmation concept proves to be operationally feasible and beneficial, it may be used as a basis for a similar visual confirmation system for runway crossings.

SYSTEM DEVELOPMENT AND TEST

As presently defined, the VICON system is basically a set of signal lights located adjacent to the runways at takeoff locations and a system control panel located in the tower cab. These two components are connected by either hardwire or radio control links. Various techniques for automatically controlling the intensity of the lights and for turning the lights "off" after manual activation by the tower controller are being tested.

To determine if a visual signal confirming a takeoff clearance is operationally acceptable and technically reliable, a two-phase evaluation was selected. Phase I, which is being conducted at the National Aviation Facilities Experimental Center (NAFEC) Atlantic City, New Jersey, is designed to provide prototype system development and initial operational testing; Phase II involves the procurement, installation, testing, and evaluation of a total VICON system at the Bradley International Airport, Windsor Locks, Connecticut.

a. Phase I Test Environment

To carry out the initial technical and operational tests of the VICON system, runway 13, 31 and taxiway India (Figure 1) at NAFEC

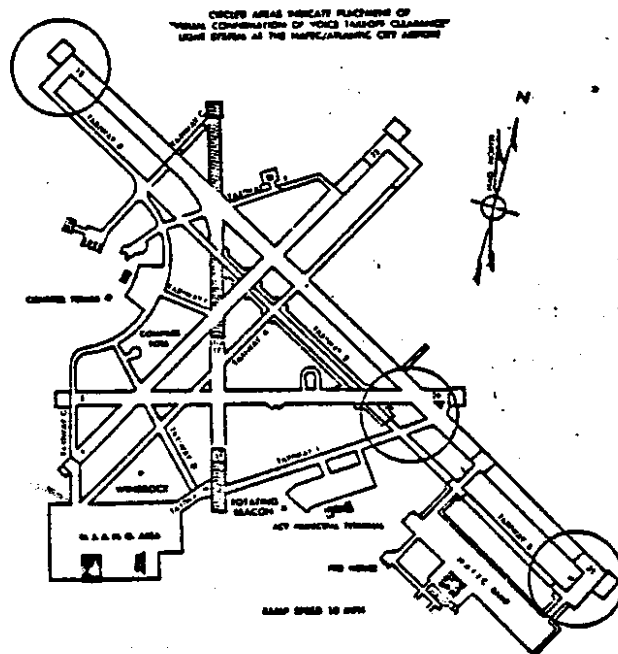


FIGURE 1. ATLANTIC CITY/NAFEC AIRPORT, ATLANTIC CITY, NEW JERSEY

was selected to serve as the test location. Also shown in Figure 1 are the initial locations of the light fixtures, which are standard highway traffic signal lights (Figure 2) complete with green lens and

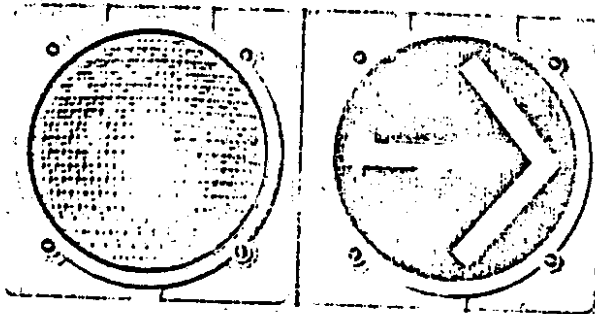


FIGURE 2. STANDARD HIGHWAY TRAFFIC LIGHT

a 100 watt bulb. Variations of this initial test arrangement will include:

- Lens color - red, green/red, green arrow, white strobe/green
- Bulb Wattage - 200, > 200 watts
- Fixture Posture - Horizontal
- Unit Arrangement - Triangular (3 lights)
- Light Configuration - 5 @ 200', 4 @ 300' and 600'
- Viewing Angles - 50°, 100°, 150°
- Lamps - PAR 56 in green and red (6 @ Runway 13 only)
- Louvers and Blinders - Single and multiple axis, eyebrow

The VICON lights are controlled from a control panel located in the Atlantic City (ACY) tower cab. As shown in Figure 3, the panel layout is a representation of the ACY runway and taxiway layout and contains several controls for activating the various operational functions. In addition to the console mounted VICON control panel, a remote control switch will be tested. This switch, allows the controller to move freely about the tower cab and not have to return to the console mounted panel each time an aircraft is cleared for takeoff. This remote control, which may be attached to the controller's belt, is capable of controlling the VICON signals from any two departure points.

An integral part of the Phase I development and test activity is to determine the best technique for deactivating the VICON runway lights once they have been activated by the controller. Following the ATC clearance, "Cleared for takeoff," the controller selects the button on the tower control panel that will illuminate the VICON runway light that

is located in the area of the departure aircraft. Once the pilot has aurally acknowledged the voice instruction and visually observed the light, there is no longer a need to display the VICON signal light. In fact, it needs to be extinguished so that a following aircraft does not interpret the light to mean that he is cleared for takeoff. Previous programs involving runway signal lights have shown that in order to eliminate the possibility of leaving the "cleared to go" lights in the "on" position, automatic deactivation of the signal lights, not requiring controller intervention, is a mandatory operational requirement. Hence, three techniques for automatically extinguishing the VICON lights are being evaluated.

1. Automatic Timer - Countdown deactivation device that is preadjusted to turn "off" (in seconds) each VICON runway or intersection takeoff position light. (Not a feature provided on the tower control panel).

2. Microwave Intrusion Device - Detects passage of an aircraft as it passes between the microwave sensors, deactivating previously illuminated VICON lights.

3. Induction Loops - Buried in ends of runways 13/31, senses aircraft passing over the loops extinguishing the visual clearance lights.

A major concern in airport lighting is that of lamp intensity under varying degrees of meteorological conditions and day/night operations. The VICON lights, available 24 hours a day, must be bright enough to be seen during sunny days (with the sun shining directly into the lens) and

controllable (to a lower intensity) at night so as not to cause glare in the pilot's eyes. Two schemes for providing control of the VICON signal light intensity are being evaluated: automatic intensity control using photoelectric cell; manual control provided on the tower cab control panel. Selectivity of the automatic feature or the manual five step intensity level control are provided on the mimic panel as shown in Figure 3.

The VICON control panel located in tower cab and the clearance lights located on the runway 13/31 and taxiway I are interfaced through a hardware control line link. Also, two commercial radio control links, to runways 13 and 31 will be evaluated during this Phase I effort.

b. Test Methods

Conclusions from tests conducted on the variables of the Phase I VICON system will be based solely upon the response from the users. The response from the pilots and controllers will be obtained from comments received via prepared questionnaires or

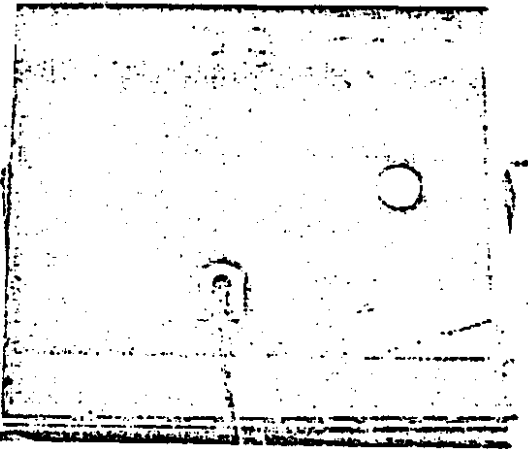


FIGURE 3. PHASE I VICON TOWER CONTROL (MIMIC) PANEL

received verbally via radio or telephone.

Prior to changing the VICON system configurations, the NAFEC user or pilot organizations will be notified as to the change being made, and date and time that the new configuration will be operational. To obtain an early response to each change, NAFEC pilots will be introduced to the new system variation by: (a) NAFEC aircraft conducting simulated takeoffs; (b) radio-equipped vehicles - pilots taken to departure points; (c) regular project flight schedules - use of questionnaires and telephone debriefing.

c. Data Collection

Due to the operational nature of this particular program practically all of the data, except for equipment reliability data, will be of a subjective nature and will be collected by means of:

1. Voice or tone actuated tapes of the tower cab controller (local) position.
2. Controller responses to prepared questionnaires.
3. Pilot responses to prepared questionnaires.

d. Phase II - Test Environment

Based on a technical description developed from the Phase I NAFEC efforts, a VICON system will be installed on all runways and tested at the Bradley International Airport (BDL), Windsor Locks, Connecticut. BDL was selected for the following reasons:

1. Traffic load and distribution representative of moderate size commercial operation, including international, national, shuttle, general aviation and some military flights.

2. Sufficiently complex runway configuration to provide meaningful demonstration of VICON system effectiveness in maintaining traffic flow.
3. User personnel (pilots and controllers) with favorable, neutral pretesting attitudes.
4. An airport administration that supports the objective of the evaluation program.

The FAA's New England Region will develop site plans and specifications from their BDL field survey, and then award a contract for the installation of the VICON system. Following installation and acceptance of the system, NAFEC will commence the technical and operational test and evaluation exercises. This operational/technical testing at BDL, a medium density, commercial airport, is most vital for it represents the VICON system and associated conceptual procedures that will be recommended for use throughout the country. For this part of the overall VICON test and evaluation, all of the runways ends and the intersections with taxiways (Figure 4) at BDL

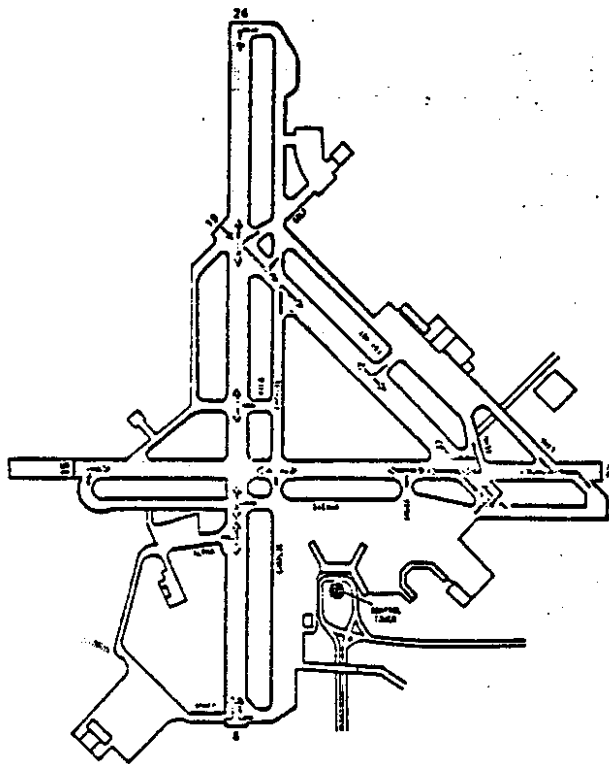


FIGURE 4. BRADLEY INTERNATIONAL AIRPORT, WINDSOR LOCKS, CONNECTICUT

will be equipped with the VICON light configuration as developed in Phase I. Proper location and aiming of the 55-60 lights: in 24 locations at BDL will be a real test of the technical portion of the program. The need to provide noninterfering lights at the intersection of runways 33 and 1 and taxiways S and E may dictate the requirement to use other types of visual signals, e.g., taxiway identification lights, signs, etc.

Previous tests of airport traffic signal lights (Reference 1) have provided several very important conclusions: (1) Any device placed in the tower cab that diverts the controller's attention away from his primary job of visually controlling traffic could lead to an unsafe situation; (2) A complicated, complex control panel located in a less than optimum location is not acceptable (most tower cabs have very little space, especially at the local control position, for installing additional control panels); (3) At the larger busy airports, the addition of control personnel may be necessary.

Two types of control panels will be tested at BDL. A mimic panel, representing the layout of the BDL runways and taxiways, shown in Figure 5, and a matrix panel as shown in Figure 6 are being considered for evaluation.

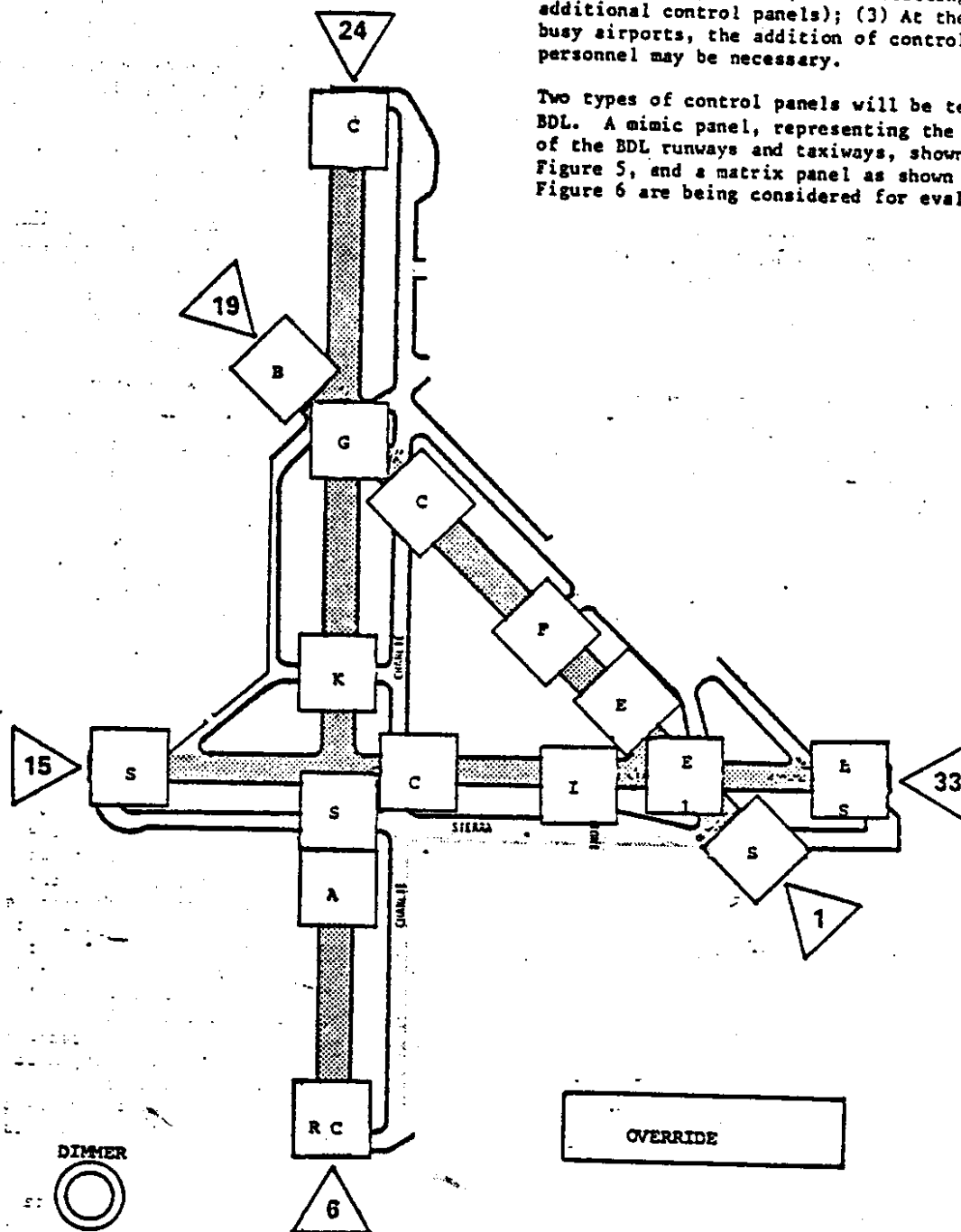


FIGURE 5. BRADLEY VICON MIMIC CONTROL PANEL

The remote control panel, a part of the main control panel, will be evaluated in conjunction with each console mounted main panel. A combination of the two panels, as shown in Figure 7, is another possibility. Human factors application exercises and laboratory test and evaluation efforts are planned to provide a simple, effective and efficient control panel. Fortunately the panel will be mounted in an exceptionally desirable location in the BDL tower that is readily accessible to the local controller.

As in Phase I, the VICON control panel in the tower cab will be interfaced with the VICON lights on the field by both hardwire and radio control links.

e. Test Methods

By the time the VICON system is installed and ready for test at BDL, the variables to be evaluated will have been reduced to a very minimum. It is anticipated that most of the changes will simply encompass minor adjustments to the lights (e.g., angles, louvers, etc.) located on the field and

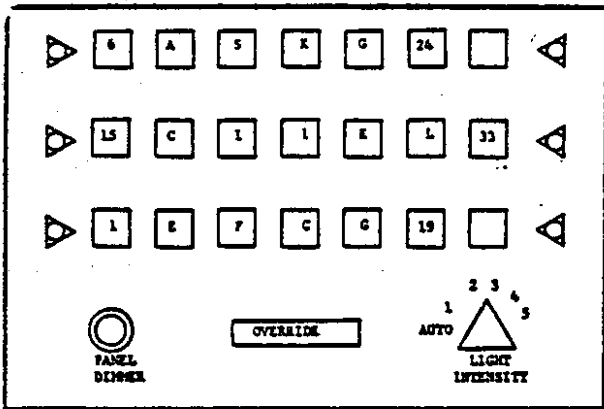


FIGURE 6. BRADLEY VICON MATRIX CONTROL PANEL

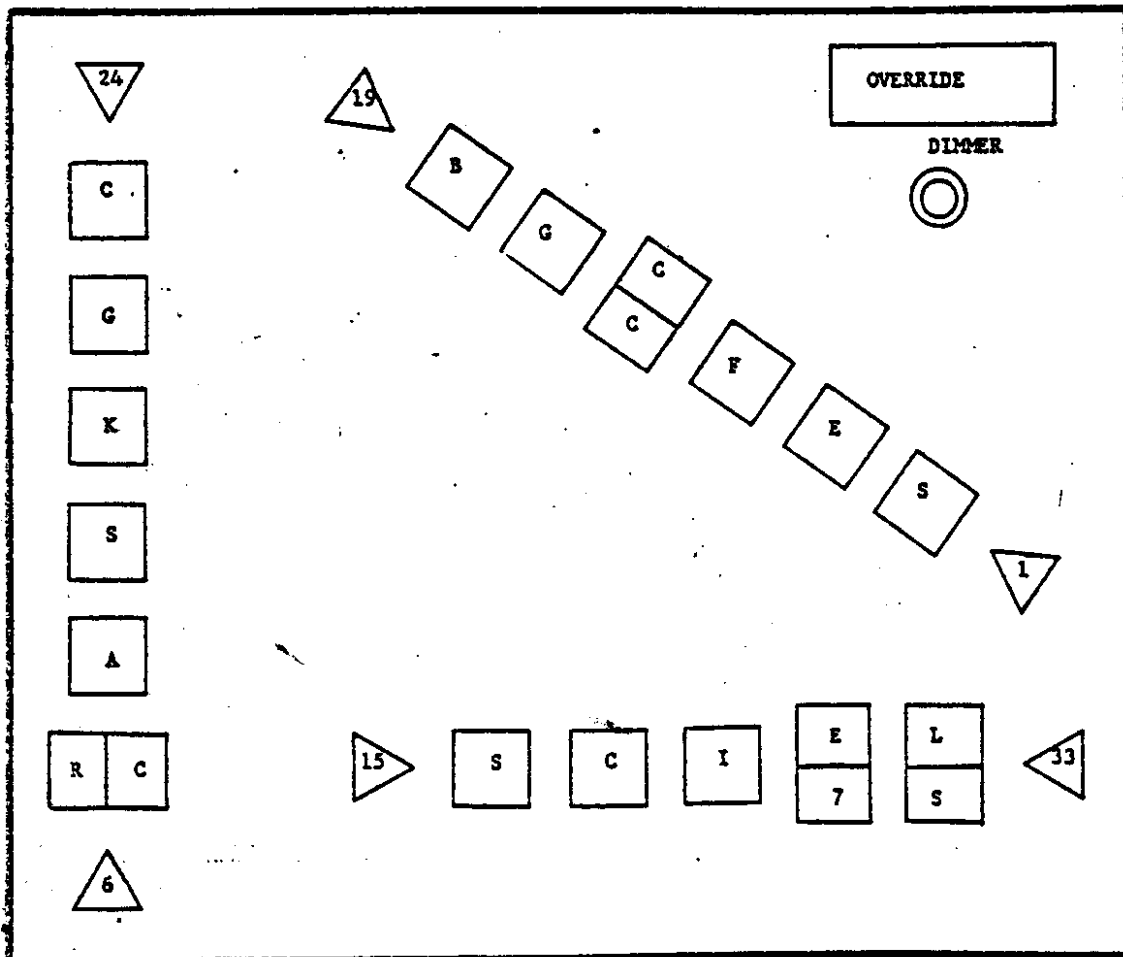


FIGURE 7. BRADLEY VICON MIMIC/MATRIX CONTROL PANEL

possibly minor modifications to the tower cab control panel. During the Phase II test period a technical log will be maintained of the performance of each VICON subsystem so that at the end of the test period, the suitability of each component can be determined. The BDL technical evaluation data will be used to determine: (1) system reliability; (2) cost effectiveness (3) installation criteria and maintenance details.

The operational evaluation at BDL encompasses the basic technique used during the Phase I effort; i.e., pilot and controller reactions to the system. Questionnaires for these user groups will be prepared and administered only after extensive efforts to familiarize the controllers and pilots with the VICON system has been accomplished. Efforts are underway to develop means of obtaining more objective data for this phase of the program, such as air traffic delays, aborts, communication repeats, workload, etc. Depending on the controller workload under heavy traffic conditions, it may become necessary to add a VICON controller to the tower team.

f. Data Collection

Information about the controller's attitude toward system effectiveness will encompass four areas of concern:

1. The capability of a properly designed and operating VICON system to provide the pilot with confirmation information comparable to currently used radio only techniques.
2. The degree of confidence in the accuracy and reliability of VICON performance to the extent that the safety of surface traffic is maintained.
3. Reactions to the installation and suggestions for modifications and improvements. This includes technical items such as panel location and size, switch sizes, etc., and such operational items as the requirement for and procedures pertaining to an additional VICON controller.
4. Subjective reaction on affect to controller workload listed above can be summarized to obtain the general consensus of controllers concerning the VICON. Where questions dealing with specific items of interest; e.g., safety, visibility limitations or conflicting message resolution, differ significantly in the number of favorable and/or unfavorable responses, these differences can be used as diagnostic tools for system improvement, or as trade-offs in the overall assessment of VICON versus other methods of confirming takeoff clearance.

Analysis of these results should pay particular attention to the experience of the controller responding and any change in attitude or response which occur many times (repeated submission) during the test schedule.

Since the pilot will be the ultimate beneficiary of the system to be used for takeoff clearance confirmation, his responses are critical to acceptance of the VICON concept. Information concerning four areas of pilot attitude will be obtained through use of the questionnaire:

1. Does the takeoff clearance confirmation signal reduce or increase pilot workload during normal operating conditions?
2. Is sufficient information provided by the visual signals to maintain traffic flow efficiency and safety without excess radio contact?
3. Does the use of the signal permit safe takeoff clearance confirmation under severely limited visibility conditions?
4. Is there a positive overall reaction to the VICON signal concept and are there suggestions for modification and improvements?

The data obtained from pilot questionnaires will be treated in essentially the same manner as that derived from the controller. In analyzing these data, particular attention must be paid to any differences in response associated with aircraft type, familiarity with airport, and nationality (language facility) of pilots.

SCHEDULE

Installation of the NAFEC VICON prototype system was completed in April 1978 and testing commenced the following month. The NAFEC test and evaluation exercises will be completed during 1978. If everything goes according to schedule, the BDL VICON system should be completely installed and ready for field in-service test and evaluation in August 1979. The BDL tests will run until March of 1980 and the technical data package should be completed the following month - April 1980.

SUMMARY

To avoid the tragedy of another Tenerife, a technique for confirming the controller's voice takeoff instructions is being developed, tested and implemented. The mission of the VICON system, which is the manual forerunner of more sophisticated automated systems yet to be developed, is to improve safety; its role is to provide a second sensory stimulus to confirm voice takeoff clearance. Four major questions that must be answered during the NAFEC and BDL tests are:

1. Does the VICON system improve safety?
2. Is the technique feasible?
3. Can VICON be integrated into the present ATC system?
4. What are the associated costs?

The technical engineering data and the operational data gathered during the planning, installation, test and evaluation of the VICON system at NAFEC and BDL will be used to develop a Technical Data Package (TDP). If the answer to the first three questions stated above is "yes," then the TDP can be used for providing an engineering standard for operational implementation of VICON at other airports in the National Airspace System if the cost results (question 4) are favorable.

REFERENCES

1. Wright, Enoch. "Evaluation of an Airport Traffic Signal System Concept," Report No. RD-67-30, June 1967.

APPENDIX 6. NASA Report - Human Factors Associated with
Runway Incursions

NASA Technical Memorandum 78540

**NASA AVIATION SAFETY REPORTING SYSTEM
EIGHTH QUARTERLY REPORT**

January 1 -- March 31, 1978

**Ames Research Center
Moffett Field, Calif. 94035**

and

**Aviation Safety Reporting System Office
Battelle's Columbus Division
Mountain View, Calif. 94043**

October 1978

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HUMAN FACTORS ASSOCIATED WITH RUNWAY INCURSIONS

Charles E. Billings and Dolores B. O'Hara

Introduction

Though few aircraft collisions have occurred on or immediately above runways at controlled airports, incidents involving incursions of aircraft or surface vehicles into aircraft movement areas have been a continuing source of concern to those responsible for management of the national aviation system. In response to requests from the National Transportation Safety Board and the Federal Aviation Administration, a study has been conducted of ASRS reports relating to such incursions. This study was not designed to provide quantitative data regarding the prevalence of such occurrences; rather, it was focused on the behavioral aspects of potential and actual conflicts on controlled airports. The reports which were used in the study were submitted between July 1, 1976 and June 30, 1978, a period of 24 months. This report is a summary of the findings to date in the study, which is continuing. A final report will be published separately.

Approach

Dimensions of the study— The study examined 165 potential conflicts, actual conflicts, and situations which under other circumstances could have resulted in conflicts on or immediately above the aircraft movement areas of controlled airports in North America. The search of the ASRS data base was not inclusive for such events; it is known that not all reports relating to or describing such events were retrieved by the search strategies employed. Nonetheless, enough relevant reports were retrieved to permit a systematic study of the characteristics and dynamics of such occurrences.

Categorization of occurrences— Each report was categorized as to each of the following characteristics:

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

These categories are defined and explained as they are discussed. All occurrences were assumed to involve human error; although there were a few cases in which mechanical or environmental factors were important, the assumption proved to be generally valid.

Analysis of the data— All reports were categorized as described above. After the categorizations were checked for accuracy, the reports were re-read and enabling factors were added. The analysis thereafter was designed to examine associations among descriptive and enabling factors, with the hope of answering the following questions for as many occurrences as possible:

1. Where did the event occur? When? What happened?
2. What errors, by whom, contributed to the occurrence?
3. What were the characteristics of the occurrence?
4. Who first recognized the problem? How was recovery effected?
5. What factors were associated with the occurrence? In particular, did certain human or system factors tend to be associated with particular occurrence characteristics?

Results

Initial evaluation of the reports indicated that 30 of the 165 occurrences involved no conflict. This category was assigned when only one aircraft was involved in the occurrence; there was no potential conflict with another aircraft or vehicle because there was no other vehicle in the vicinity. The remaining 135 reports did involve a threatened or actual conflict.

Month of occurrence— Somewhat more reports were noted during spring, summer and fall months than during the winter. The differences were not striking.

Locations— The 165 occurrences took place at 73 different locations. Five or more occurrences were reported at nine hub airports. Specific location data will be discussed in the final report of this study.

Reporters— Pilots and crewmembers provided 66% of the occurrence reports; controllers reported 32%; other persons provided 2%.

Types of operations— While a simple listing cannot fully account for operational types in those cases involving more than two aircraft or vehicles, table 1 shows types of operations, where known, for the 135 cases involving a potential or actual conflict between aircraft.

TABLE 1.— TYPES OF OPERATIONS IN CONFLICT OCCURRENCES

Operator classes in conflict occurrence	Number of occurrences
Air transport/air transport	41
Air transport/general aviation	29
Air transport/military or government	3
Air transport/other or unknown	36
General aviation/general aviation	7
General aviation/military or government	2
General aviation/other or unknown	13
Other or unknown/other or unknown	4
	<u>135</u>

Initiators of occurrence— As noted above, it was assumed that all these occurrences involved human error. The person believed by the authors to be responsible for the initial error associated with the occurrence was the controller in 54% of 165 occurrences, the pilot in 39% of the occurrences, and the operator of a surface vehicle in 4% of the occurrences. In five cases (3%), the data did not permit categorization.

Outcome— An occurrence was classed as a near collision if, in the opinion of the authors, two vehicles came perilously close to colliding. This, of course, depends on the size, type, and speed of the vehicles, as well as their relative courses, all of which were taken into account. Unless it was fairly certain that the event was a near collision, it was classified as “less than safe separation” if a conflict occurred, or “recognized error” if one or more persons recognized the problem and took action in sufficient time to prevent a conflict. Other cases were classified as “no conflict.”

One occurrence involved a collision (wing tip with motor vehicle); 37 involved near collisions; 50 involved less than safe separation. In 47 cases, the problem was recognized before a conflict occurred. There was no actual or threatened conflict in 30 cases, because no other aircraft or vehicle was in the vicinity.

Phase of flight— The flight (or ground operation) phases for the two aircraft principally involved in aircraft/aircraft conflicts are shown in table 2 for all cases in which two aircraft were involved and in which both phases were known.

TABLE 2.— PHASE OF FLIGHT AT TIME OF OCCURRENCE

Flight phase, aircraft 2	Flight phase, aircraft 1 ^a					
	Hold	Taxi	Takeoff	Approach	Land	Other
Hold	0	6	1	4	4	0
Taxi		3	21	8	14	1
Takeoff			8	7	11	0
Approach				1	1	0
Land					8	2
Other						0

^a Figures are percentages of sample.

It is worth noting that the two most frequent categories for both pilot- and controller-initiated incidents were taxi/takeoff and taxi/land. The other major categories were takeoff/land, takeoff/takeoff, land/land, and taxi/approach.

Occurrence types— The 135 occurrences which involved conflicts were classified as shown in table 3. The data are summarized for occurrences initiated by pilots and by controllers.

TABLE 3.— RUNWAY INCURSIONS: OCCURRENCE TYPES

Pilot occurrences		Controller occurrences	
Lack of clearance to:		Failure to insure separation:	
Cross a runway	33%	Intersecting	47%
Take off	23	In trail	24
Land	6	Other	12
Taxi to ramp	2	Confusion	9
Disorientation/confusion	21	Lack of information	4
Confusion about clearance	2	Late clearance change	3
Other	<u>13</u>	Other	<u>1</u>
	100%		100%

Recognition of problem— The problem was first recognized and recovery action initiated, by a pilot in 50% of 135 cases; recognition was by a controller in 25% of the cases. Simultaneous recognition and action by controller and pilot occurred in 3%; there was no recognition of the problem in time to take recovery action in 20%, and in 2% of the cases the data were inadequate to permit categorization.

Enabling and associated factors— The factors that were assigned to reports containing enough data to permit such analysis, together with their frequency of occurrence in events believed to have been initiated by pilots and controllers, are shown in table 4. As many factors as were believed pertinent were assigned to each occurrence.

Occurrences initiated by drivers and those in which the initiators of the occurrence could not be determined are not included in table 4.

It should not be inferred that the factors in table 4 are inclusive of all factors pertinent to the cases under study, nor should it be inferred that each factor listed was necessarily causal in the occurrences. Rather, the factors listed are in the best judgment of the authors, pertinent to the occurrences, based on the information available in the reports.

It is interesting to note certain apparent anomalies in the list. Controller technique was cited as a factor in nine reports in which a pilot error apparently initiated the occurrence. Similarly, pilot technique was cited in 11 controller error reports. These findings and certain others like them are discussed below.

The enabling and associated factors were partitioned by occurrence type and outcome in an effort to find whether certain types of occurrence, or certain outcomes, are associated with particular human and system factors. The results of these analyses are discussed below.

TABLE 4.— ENABLING/ASSOCIATED FACTORS IN RUNWAY INCURSIONS:
65 OCCURRENCES INITIATED BY PILOT, 89 BY CONTROLLERS

Factor	Occurrence initiated by:	
	Pilot	Controller
Coordination problem in cockpit	11	0
Coordination problem between aircraft and ATC	17	19
Coordination problem within tower	3	29
Coordination problem between tower and approach control	1	8
Phraseology	3	2
Language problem	3	1
Frequency congestion	3	3
Similar flight numbers	1	0
Controller technique	9	61
Pilot technique	43	11
Intersection takeoff	2	4
Landing to hold short of intersection	0	2
Airport lighting and markings	4	3
Airport, other factors including staff	3	7
ATC and controller procedures	3	8
Pilot/flight procedures	7	1
Training in progress	0	5
Environment (weather)	4	6
Workload	3	2
Fatigue	0	1
Other factors	0	2
Total factors	120	175

Discussion

Introductory comments— Unplanned incursions onto aircraft movement areas represent a serious potential threat to system integrity. In this sample of occurrences, 82% represented at least a potential conflict; there was an actual conflict in 53%, a near collision in 22%, and an actual collision in 1%. Air carrier aircraft were involved in 81% of the potential and actual conflicts.

Virtually all the occurrences involved human error. In at least 13%, both controller and pilot errors were involved. In 65 occurrences initiated by pilot actions, 64% involved a lack of clearance to perform some maneuver. Eighty-three percent of the 89 occurrences initiated by controller action involved a failure to insure separation.

There was no difference between the two groups with respect to outcome: 22% of both pilot- and controller-initiated occurrences resulted in a near-collision.

There is no question (table 3) that a substantial majority of both pilot- and controller-initiated occurrences involved deficiencies in technique. Failure to obtain a clearance, for whatever reason, is a deficiency in pilot technique; failure to maintain assured separation, for whatever reason, is a deficiency in controller technique. It is hardly surprising, then, that the most commonly cited enabling/associated factor in table 4 is a technique deficiency. This citation, however, is hardly enlightening unless accompanied by information that suggests why the break in technique may have occurred. The remainder of this analysis is devoted to this question.

Pilot-initiated occurrences— Although pilot technique was involved in most of these occurrences (43 of 65), it is necessary to ask what other factors were also present and pertinent to the event (table 4). One notes that coordination problems were cited 32 times; most of these involved within-cockpit or cockpit-ATC coordination, though in 4 cases, there was an associated coordination problem within ATC.

Typical breakdowns in cockpit coordination are illustrated in the following examples.

On taxi out, we were issued a clearance to taxi to runway 27L. Normal departure runways are 26 and 27R with landings on 26 and 27L. There is extensive airport construction which causes extensive diversions while taxiing. After crossing runway 26 we were given multiple taxi instructions during the process of running the taxi checklist. My attention was evidently diverted when we were given instructions to hold short of runway 27R. The first officer rogered. We were following another aircraft and as we approached 27R we were told to switch to tower frequency. We did so as the aircraft ahead was crossing 27R. I hadn't heard the instructions to hold short, nor had I heard the previous aircraft being cleared to cross. I continued to cross 27R, not thinking of it as an active landing runway, and the first officer didn't caution me to stop. . . . My first knowledge that we were crossing an active runway came when, just as I was approaching the runway, I looked left and noticed an airliner on about a 1/4-mile final. I could have slammed on the brakes and stopped short of the runway, but feeling that I had plenty of time to cross and not wanting to injure a flight attendant with the sudden stop, I simultaneously asked the first officer if we had been issued clearance to cross (he replied that we had not) and proceeded on across. The tower directed the airliner to go around which I didn't think was necessary but from his vantage point I'm sure he acted according to his own best judgment. . . .

In the following case, the initial portion of the taxi clearance was transmitted during rollout. As we have noted in earlier reports, both cockpit noise levels and flight crew workload are high at this time. ASRS reports continue to describe misunderstandings of clearances delivered during this phase of flight. It appears that some controllers are not sufficiently aware of this problem.

After landing on runway 10R, we were advised by tower to turn off runway 10R onto runway 5 and to hold short of runway 14. While decelerating the aircraft and turning off runway 10R, I failed to hear the instructions to hold short of 14. As we approached the intersection of runway 14, the first officer said "hold short," and

I stopped the aircraft short of the runway. We would have collided with another airline aircraft had not the first officer advised me to hold short. He later told me that he had also applied brakes. The major factor in this occurrence is that I failed to hear the clearance limitation. Also, I was not completely familiar with the closeness of runway 14, having never landed on 10R before. I am aware that affirmative clearance is required to cross a runway and would have stopped notwithstanding the failure to hear the clearance to hold short had the intersecting runway been clearly recognizable as a runway.

Cockpit-ATC coordination problems usually involved either misunderstandings between pilots and controllers, inadequate information transfer, or nonstandard procedures or phraseology.

The pilot of aircraft A had been issued clearance for takeoff on runway 27 while taxiing out from the loading ramp . . . the A pilot had just completed engine start and was not yet on tower frequency when the clearance was given. The STOL aircraft was on another ramp approximately 250 ft from the taxiway-runway intersection normally used as the initial takeoff position by STOL aircraft. The instructions which were seemingly received were that he was cleared for takeoff. He reached the intersection at approximately the same time as A started its takeoff roll. The tower immediately ordered B to clear the runway and A to abort his takeoff. Reaction was immediate and a collision was averted by a good margin.

* * *

. . . After push-back, I was cleared for taxi with the following phrase: "Cleared to taxi runway 8R via Charlie-4 and hold short of runway 8L." The weather at the time was rain showers and an overhead thunderstorm. Runways were wet. After passing the "Bravo" complex and approaching taxiway C-4, we received further instructions, "go right on out there at Charlie-4." I interpreted this to mean that I was cleared to cross runway 8L and proceed to 8R. However, as a precaution, I asked the copilot to check. He was unable due to frequency congestion. Prior to entering the runway, I checked visually and spotted aircraft B on short final for landing on runway 8L. A panic stop was initiated using brakes and reverse. Due to the wet conditions, the anti-skid cycled continuously. The aircraft was turned slightly to the right to present a smaller target to the landing aircraft. After we came to a complete stop, the controller said something to the effect, "You stopped pretty close to the runway." I repeated his previous instructions regarding going out on Charlie-4 and he replied, "I told you to hold short. . . ."

In one case, it is questionable whether the pilot communicated his intentions, or whether he was affected by a wind shear late in the approach.

We were awaiting departure on runway 8R on taxiway. Airline aircraft B in position on runway holding for takeoff clearance. Flight check aircraft approaching runway on final, checking back course approach. Tower advised aircraft B to hold in position. Flight check aircraft continued approach to end of runway at a low altitude, then suddenly deviated downward from flight path and passed over the top

of aircraft B, clearing the aircraft by about 20 ft; he then executed a pull-up maneuver. Aircraft B was unable to see the incident since it was approached from the rear; our crew felt that an impact was imminent for an instant. . . .

Pilot procedures, especially visual monitoring procedures, were inadequate in seven cases. The following examples are typical of the consequences of failure to monitor outside the cockpit even after receipt of a clearance.

Airline aircraft B landing on runway 28R; I was landing on 28L. Airline aircraft B was told by tower to use taxiway Echo, hold short of 28L. Aircraft B didn't even slow down but just taxied across 28L in front of me. If he'd looked out his window, the captain would very easily have seen me boring down on him . . . he should have known from previous conversations with tower that there was traffic on 28L. . . .

* * *

Aircraft A cleared for ILS to runway 25L. ATIS info, 8 broken 1-1/2 smoke and fog. We had the runway at about 500 ft; visibility was about a mile. Landing was routine; rollout was to the high speed exit opposite the XXX airline terminal. Tower cleared out aircraft A, to cross 25R, "Ground .75 on other side." My first officer's response was "Roger." So I continued my roll across 25R. (The clearance was verified about the time we entered the high-speed from 25L.) As the nose of our aircraft entered the edge of 25R, aircraft B, taking off, passed over us. The clearance could not have been more than 50-75 ft. We had heard no radio clearance or conversation whatsoever about activity on 25R, so aircraft B either took off without clearance or the runways were being handled on separate frequencies. . . . I must accept responsibility for trusting the clearance to cross 25R without asking my copilot to verify that we were clear by looking to the right up runway 25R.

Problems relating to airport lighting and markings appeared in seven reports of pilot- and controller-initiated occurrences.

Aircraft A was taxied to runway 33L via the outer terminal taxiway to hold short of Charlie taxiway. When next observed, the aircraft was stopped on the centerline of runway 22R, at the approach end of runway 4L. At this time aircraft B was starting to rotate on runway 22R about three-fourths of the way down the runway. Aircraft A was instructed to taxi straight ahead and clear the runway immediately. Controllers feel that field lighting and poorly marked taxiways are the prime reasons for this recurring problem. . . .

* * *

I called for progressive taxi instructions, notifying the tower that I was unfamiliar with the airport. The controller cleared the aircraft to runway 34R. I taxied south following the blue lights until the lights turned west toward the runway, then turned west, held short, and did my run-up. I called "Ready for takeoff," and the tower cleared me into position to hold. As I took the active,

another light aircraft passed me on its takeoff run, deviating to the west side of the runway; our wing-tip clearance was about 20-30 ft. I asked what had happened and the tower told me that they thought I was at the end of the runway and thus would be behind the departing aircraft.

I am responsible for the safe operation of my aircraft, and that includes not taxiing into the path of a departing aircraft, even if cleared by the tower. However, as one high-ranking GADO official once said to me, "A pilot sometimes gets a lot of help going down the tubes." First, I too thought that I was at the end of runway 34R. I had asked; "Do I just follow the blue lights south to the end?" Ground control said, "Yes." When I finally turned west on the taxiway, there were no more blue lights to the south, only to the west (leading to an intersection). As I turned west on the taxiway, I saw a sign pointing to R34R and R32. . . . As I held just east of the hold line, I could see a large painted area on 34R which appeared to be the numbers. . . . When I received clearance into position, I looked to my left. It may be difficult to believe that I looked and did not see an aircraft coming toward me, but as I reconstruct the matter, I looked up for an aircraft on final . . . I should have seen the other aircraft, and I bear the responsibility for not having seen it . . . however, the tower certainly cleared two aircraft to operate on the same runway at the same time. . . .

* * *

I was the captain on flight A departing Atlanta. We were cleared to taxi to runway 27L by runway 15 to hold short of runway 26 and 27R and to follow an aircraft B. Aircraft B ahead held short of 26 and was then cleared across. I asked the first officer to request clearance to cross with the other aircraft; we were advised to hold short. We were holding short of what I believed at the time to be the east-west taxiway. While holding, I saw landing lights on an airplane C in position at the east end of runway 26. At that time I realized I had inadvertently crossed the E-W taxiway and was very close to runway 26. I believed we were too close and immediately had the first officer alert ground control of our position and need to cross. We expedited across the runway when clearance was received. . . . On runway 15 in relation to the east-west taxiway for runway 26 there is a very large concrete area to the east of the position I was holding . . . much of this area is either not lighted or inadequately lighted with respect to designating the edge of the runway. . . . This area did not provide an adequate reference. . . .

Other airport problems were cited in ten cases. They included inadequate taxiways, taxiways too close to runways, parallel runways too close to permit holding between them without intruding on one or the other, and inadequate maintenance. Two reports of pilot-initiated occurrences cited obstructions to tower visibility; one is quoted here.

I was doing touch-and-go practice, and was cleared for touch-and-go runway 31. I was informed aircraft B, a wide-body, was to hold short of runway 31. He was taxiing from the ramp to runway 6R for takeoff. At any rate, he did not hold short. Fortunately, I was practicing zero flap landings, so my airspeed was higher than usual. As soon as we concluded aircraft B was not going to stop, I

applied full flaps, full power and made a hard climbing right turn. I missed B by less than 100 ft . . . part of the problem is that the personnel in the old tower cannot see the activity on runway 31 north of runway 6L, so they were more or less helpless in this situation. . . .

In summary, pilot-initiated occurrences often involved performing some maneuver without clearance (46 of 65 cases). This was often associated with a coordination problem within the cockpit or between flight crew and ATC (22 of 46). Pilot disorientation or confusion was noted in 12 of 65 occurrences.

Controller-initiated occurrences— These occurrences usually involved failure to insure that separation would exist (74 of 89 cases). In 45 of the 74 cases in this category, there were associated coordination problems (with the aircraft in 16 cases, within the tower in 26 cases, and between tower and approach control in 3 cases). Inadequate information transfer within ATC is strongly associated with controller actions involving failure of separation.

Inadequacies in coordination among tower personnel (usually between local and ground controllers) were associated with serious problems relating to runway incursions. Note in the first two reports the role of visual monitoring. In the third report, visibility restrictions were a factor, though there is no question that visual recognition of the conflict led to its resolution.

At about 1215 hours, I was cleared for takeoff on runway 25. As I approached the intersection of runways 25 and 15 during my takeoff roll, aircraft B, which was previously facing west, turned toward runway 25 to taxi north. As B's nose neared the centerline of the runway my position was 100 ft or less from the aircraft and closing with a speed of 55–60 knots. At this point I rotated (at a slightly premature speed) and lifted off. I turned right at about 10 ft of altitude, avoiding the nose of the other aircraft by 10–20 ft. I contacted the tower and was informed that B was cleared by ground control and that the ground controller was in error . . . as a secondary cause, the crew of the air carrier aircraft should have looked both ways prior to taxiing onto runway 7-25.

* * *

We landed on 23L at (a foreign airport). Tower cleared us to turn off on taxiway B and contact ground control. Ground control cleared us across runway 23R to our gate via taxiway A. My first officer rogered and we started to cross 23R. He hollered "Stop, somebody is takeoff!" or words to that effect. We stopped and a corporate jet passed right in front of us. Had we moved 10 ft farther the smaller jet would have hit us. It appeared he was just breaking ground as he passed us. . . .

* * *

(From one pilot) We were a (four-engine jet) ferry, cleared to taxi from the hangar area to the northwest runway, 32L, via the active runway parallel taxiway for an intersection takeoff at T-1 . . . the weather was -X 2³/₈ fog, ceiling 1⁰VAR3⁰. On reaching the intersection we advised ground control and were cleared to tower.

On initial call, we were number one for takeoff and advised the tower . . . tower cleared us into position and hold. A short time thereafter, tower cleared another aircraft to land. I had taxied onto the runway and was about to make the 90° right turn when landing lights appeared on the left side. Visibility was restricted. I promptly added power to clear the runway instead of turning. I continued straight across onto the continuation of T-1. While waiting for the engines to spool up after throttle application a wide-body in a landing flare appeared with the landing lights on and as we cleared the runway while still moving the wide-body passed behind us.

I cannot say for sure how to detect the fact you have been cleared into position in front of a landing aircraft in restricted visibility especially at an airport with multiple runway operations. . . .

(From the other pilot) We were cleared to land by the tower when we reported Romeo inbound. Weather reported 2 $\frac{3}{8}$ fog, RVR 3500 approach 3000 middle and end of runway. Copilot flying, approach normal. About 1,000 ft past threshold at the point where engineer called 30 ft altitude and at the point where I was taking control for touchdown, I saw a heavy jet in the middle of the runway. I applied full power for go-around and started climb. Saw the other airplane clearing so cut power and landed. Our approach speed was 145 knots, weight at landing 478,000 lb.

One coordination problem involved a shift change in the tower.

The visibility was RVR 1200; we had takeoff minimums and were holding short on the taxiway. We called ready for takeoff and received a takeoff clearance. I spooled the engines and started to taxi. Just as we started to move I caught a glimpse of an aircraft passing by and disappearing into the fog on 35R, the runway on which we were cleared for takeoff. I checked with tower; he apparently was taken aback by the event and was unaware the aircraft existed. He did not have him on radar . . . somehow the aircraft, on a Category II approach, had gotten lost in the shuffle of changing shifts. . . .

Phraseology problems were associated with five runway incursions. Examples are shown here.

Aircraft A requested departure clearance on runway 4. I cleared aircraft A for takeoff. Aircraft B was advised to taxi into position and hold runway 7 for traffic departing runway 4. Aircraft A called again for verification of departure clearance. Aircraft A was advised, "Cleared for takeoff, minimum delay, traffic awaiting departure on runway 7." I was then momentarily distracted and when I looked up both aircraft A and aircraft B were airborne and rapidly converging. I gave aircraft A a right turn to avoid traffic. Traffic separated and no further conflict occurred . . . the aircraft came within 500 ft of each other . . . I believe a contributing factor was fatigue. Two of us have worked the day shift without a break; even lunch had to be eaten in position. . . . I am thoroughly bushed, and I still have 1 hr to go. . . .

* * *

Airline aircraft A was told to round a corner of the departure runway and not to plan on stopping. Traffic, aircraft B, was landing on an intersecting runway. I turned my head to look at another of my departure runways and A departed. The landing aircraft stopped short of the runway being used for departure and the pilot called for an explanation . . . better phraseology should have been used to A about holding in position.

ATC and controller procedures were associated with specific problems in 11 reports, not all involving controller-initiated occurrences. The difficulty posed by a hold-point very close to a landing runway was cited in two reports.

After landing on runway 9, tower cleared us to turn off the runway via Romeo and contact ground control. . . . Upon turning off, the after-landing checklist was accomplished. As I adjusted the frequency and volume for ground control, I heard them calling us to hold our position. We were approximately 1,000 ft from the turnoff point when the captain and I heard ground calling us and when we stopped we were in the middle of another active runway (22) and a light airplane was flying at, up and over us . . . the turnoff of runway 9 to 22 is a very short distance and narrow, requiring the full attention of the pilot taxiing. There is no ATIS to warn the crew of multiple active runways and I do not recall the approach or tower controllers advising of this . . . the tower supervisor after the incident advised me that this had happened several times previously. . . .

* * *

After instrument approach, on landing rollout runway 5L, tower instructed aircraft to turn off on runway 10. Instructions were acknowledged by first officer. We changed to ground control and were told to hold short of taxiway N. Taxiway N occurs near the turnoff so aircraft was almost through N at the time of the transmission. Ground control told aircraft both he and tower had instructed the aircraft to hold short of N. . . .

Simultaneous intersecting ILS approaches were cited in one report.

Aircraft A was established on the ILS course for runway 7. We were advised by approach control of traffic at ten o'clock, 4 miles, on an ILS for runway 10. Approximately 2 minutes later I inquired about the traffic and was informed he was "ten o'clock, 3 miles." The first officer informed me that the outer marker light had started blinking just as we broke out of the clouds and saw the traffic, which seemed closer than 3 miles. The distance between the outer markers for runways 7 and 10, according to the scale on the approach plate, is just under 2 miles, but the issue is not whether we were 3 miles or closer. The real issue is that both aircraft were inbound on intersecting localizer courses. To compound the problem, both aircraft were at similar airspeeds. The use of simultaneous ILS on intersecting courses might seem to be efficient and safe to ATC, but it is potentially hazardous. Because of the converging courses which it inherently provides, all the ingredients for a midair collision lie in wait for a triggering last-minute event: a simple controller distraction, or a communications failure, or radio congestion. Procedures should be fail-safe. . . .

The control of intersecting patterns by different control positions was discussed in one report in this sample (other ASRS reports have also cited this problem).

I was flying airline aircraft A on the above date. Tower issued takeoff instructions and we broke ground off runway 35R . . . at that time I saw corporate jet B cross directly in front of me, having taken off from runway 27. Upon reaching a safe altitude, I asked the tower operator if he was aware that the aircraft were taking off simultaneously. He said "No." Subsequent inquiries . . . indicate that the tower personnel felt nothing of significance occurred. I feel that it was highly dangerous. . . .

A specific procedural problem was cited in several reports, all of which mentioned difficulties associated with simultaneous use of intersecting runways. The issue in these and other reports concerning these procedures is what happens when a problem is encountered by one or the other aircraft if the procedures leave little room for a "fall-back" position.

Airline captain was cleared to land on runway 14L and at the same time tower cleared another airline aircraft for takeoff on intersecting runway 27L. We were given no warning by approach control or tower of the departing aircraft on the intersecting runway. If we had to make a go-around it would have been very close. We had made a long landing to save taxi time, and had to use heavy braking to avoid the intersection. . . .

* * *

Tower cleared aircraft A to land on runway 27L and aircraft B to land on 32L at the same time. The runways intersect. Had aircraft A not been able to hold short of the intersection the two aircraft would have collided. When questioned about the practice the tower answered, "I've been directed to use the runways in this manner."

* * *

As we were cleared to land on 14L the tower asked us to expedite through the intersection of 4L and we agreed. On touchdown we experienced difficulty with the aircraft due to very poor braking action and crosswinds. With this difficulty we did not, in fact, expedite through the intersection. I believe the tower was not observant as they cleared another aircraft for takeoff on 4L before we were through the intersection. . . . I personally believe that this runway configuration is undesirable unless more attention is paid, and the landing aircraft should not be questioned. One week previously, I experienced the same problem departing on 4L. I aborted takeoff due to an aircraft in the intersection of 4L and 14L.

* * *

We were cleared to land on 27R. Another aircraft was cleared for landing on 22R to hold short of 27R. Both aircraft touched down at nearly the same time. We landed normally on 27R but could not tell for certain that the aircraft on 22R would in fact be able to hold short of the intersection. He did not ever come to a

full stop because he was playing his taxi to expedite traffic (there are no turnoffs on 22R). We braked to a slow taxi to be certain of our clearance and so that we could stop if he couldn't. Tower immediately told us to expedite off the runway for landing traffic. After we turned off a twin and a tri-engine jet touched down on the two runways with the same result, only the trimotor braked heavily. This operation is unsafe; it adds too many additional variables during the critical landing phase.

Training was involved in five controller-initiated occurrences. A typical example follows.

Aircraft A landed on runway 12, then aircraft B was told to taxi into position and hold runway 12, which he did. Aircraft C was on a 3-mile dog-leg to final for 12 at this time. By the time aircraft A cleared the runway aircraft C was on 1-mile final. When aircraft C touched down aircraft B was 3,000 ft ahead of him and just lifting off. Controller training was in progress at the time and the trainee apparently didn't realize it would be that close. By the time I decided to send aircraft C around it was too late; he was already committed to land. The pilot remarked that he should have gone around, but he did not. The trainee should either have sent him around or not taxied B onto the runway but did not. I should have sent C around but I did not. None of us reacted to this situation as we had been trained to and the result was less than standard separation.

Several of the reports in this sample described situations in which a go-around was initiated by the pilot because of a perceived threat to separation. Such an action was taken in 17 cases. In at least some of these, the action produced new problems, although it obviously averted problems in other cases.

We were cleared for immediate takeoff from 'in position' on runway 31 and began our roll without delay. Aircraft B was on final approach to runway 22. Our spacing was slightly less than what we've been used to at this airport, but we felt that we had more than adequate separation. During our takeoff roll aircraft B initiated a go-around. We crossed the runway intersection at about 300 ft AGL and at that time B appeared to be near level with us and perhaps over the approach lights. The fact that he pulled up and possibly accelerated put our aircraft in closer proximity than if he had continued his approach and landed. We would not classify this as a near miss but the potential exists in this situation.

* * *

Aircraft A reported to tower on downwind. I cleared A to land. Aircraft B called for takeoff. B was cleared for takeoff, then cleared for immediate takeoff and given traffic, aircraft A, 1-mile final. A declared the approach too close to departing traffic and went around on the right side of the departure. In my opinion if A had continued his landing I would have had minimum departure separation. However, due to the pilot's initiation of a go-around he reduced longitudinal separation and passed B at midfield.

In 20 occurrences, both the pilot and the controller erred in some manner. Eight, or 40%, of these occurrences involved a near collision. These reports were therefore singled out for

examination. It was found that these occurrences, like the others in this study, involved a variety of factors. One factor noticeable in this subset of reports, however, was very tight spacing of traffic (in eight cases) which produced problems when not all participants behaved as expected. Two examples follow. In both cases, one or more of the pilots, as well as a controller, contributed to the situation.

Aircraft A, landing 4R, was instructed to roll to the end. Aircraft B was in position runway 8L awaiting the landing A to roll through the intersection. Anticipating separation, the controller instructed B to start a fast taxi since there was a heavy aircraft C on short final for 8L. Aircraft A slowed and tried to use a diagonal taxiway that saves time to the gates. Controller instructed A to cross the intersection without delay; A did so and takeoff clearance was given to the fast-taxiing B. This was not a safe operation by the local controller and will not be tried again. This airport is extremely hard to work because of crossing runways and numerous intersections for takeoff. . . . In the above incident the two aircraft missed by 300 ft or so; too close. . . .

* * *

Transport aircraft A taxied out and was holding for takeoff. Another flight had landed and was still on the runway. Aircraft A was cleared for something and the transmission ended. Only a couple of seconds later, A was cleared into position and cleared for takeoff. Just as we were about to start our takeoff an aircraft B who was on final said he was going around. As I made the last 90° turn onto the runway I saw lights and he appeared about a mile or so out on final. When he elected to go around I elected not to start my takeoff roll as it appeared that from his position and my takeoff and climb we would be very close (visibility was 1 to 1-1/2 miles, ceiling about 300 ft). Since I had not started to take off, and since aircraft B was not going to land, I made a right turn back off the runway. Aircraft B said he could land but the tower told him to go around, then immediately told him to go ahead and land. Aircraft B advised that he would have a moment earlier but he could not at that time. In aircraft A, we advised that we would continue with our takeoff and that we were starting our takeoff roll. The tower advised to turn left and taxi clear of the runway.

There is no taxiway off to the left of the runway except at the very end so we did a quick turn and cleared the runway on the east side. As we were clearing, an aircraft C was told to go around. The result of this incident was at no time a hazardous condition, but it did result in two aircraft having to go around . . . air traffic was very heavy at the time . . . during these conditions radio communications are so congested that it leads to misunderstandings and confusion on the part of both the pilot and the controller. Expediting the situation only adds to the confusion. . . .

In summary, controller-initiated occurrences generally involved failure to insure that separation would exist. An important corollary factor was a failure of coordination with other tower positions. Training may have been a factor in a few cases; procedures may also have been a factor in some. Tight traffic spacing appeared to be a factor in cases in which a flight crew error compounded the controller's error, or vice versa.

Other factors— A number of other factors were also present in and pertinent to these occurrences. Environmental factors were cited in 12 cases. Five of these involved restricted visibility; in one, the controller's alertness averted a problem.

Aircraft A requested taxi clearance from the south ramp to the active runway. Visibility was 3/16 mile in ground fog; taxi instructions were given and the RVR for runway 10. The aircraft advised he was "slightly unfamiliar" with the airport layout and detailed instructions were given. In his taxi, he was required to cross the active runway at midfield. Aircraft B was holding in position for departure and I requested A to report crossing runway 15R at taxiway F, a point that is clear of the active runway 10. From past progress reports, after a sufficient lapse of time, I asked A for a confirmation of his position and was told he had cleared the checkpoint. I had a ground vehicle holding clear for the A on yet another taxiway and was awaiting his report of sighting A. Again, from A's past reports and the time lapse, he should have passed the ground vehicle, but had not. Unsure of his position, I elected to advise local control to hold his departure. Upon further inquiry, the pilot of A admitted he was not sure of his location. B was held until A reported sighting an airline ramp, a point known to be clear of the active. . . .

In a second report, a late hand-off and a missed approach presented the controller with a potentially critical situation.

Aircraft A was on a VOR approach to runway 13L and aircraft B was departing runway 31R with a right turn out northeast-bound. Approach control did not give the tower a hand-off on the VOR approach. The weather was marginal with low ceiling and the VOR approach called well inside the normal hand-off point, after the tower controller had released the VFR 31R departure, not knowing about the opposite direction IFR aircraft. Due to the ceiling coming down, the IFR aircraft executed a missed approach. The tower controller separated the aircraft visually by seeing aircraft B and climbing aircraft A. . . .

Intersecting runway operations in wet weather caused another problem.

Airline aircraft A on short final for landing on runway 12L made a touch-and-go in order to pass over aircraft B who, after landing on runway 17, could not hold short of the intersection of runway 12L. Runway 17 intersects 12L 3,000 ft from the approach end. The runways were wet at the time.

Several reports discussed controller visual problems; in this case, night compounded the problem.

Aircraft A was cleared to land on runway 16 with aircraft B cleared for touch-and-go on intersecting runway 30R. At the time both clearances were issued, judgment and experience indicated standard separation would exist. It did not, but due to the angles involved, this less than standard separation situation was not apparent until it was too late to do anything about it. The situation occurred at night, with both aircraft landing toward the tower. As a result, both distance and

speed determinations are extremely difficult. . . . The aircraft involved were not that close, but it was potentially unsafe. A bright display would have helped here. . . .

Frequency congestion was a factor in six reports. It was usually cited as a factor that made it more difficult to confirm unclear or partially missed instructions. Language problems were cited as a factor in four runway incursions; similar flight numbers were a factor in one case. Workload was cited as a contributing factor in five occurrences, fatigue as a factor in one.

When this study was initiated, it was the opinion of the authors that surface vehicles would be found to be an important facet of the runway incursion problem. This proved not to be the case. Motor vehicles were a factor in only 8 of 165 occurrences.

The driver of a vehicle was the initiator of six of the occurrences. In three cases, the driver crossed an aircraft movement area without clearance; the other three involved disorientation or confusion as to his position on the part of a driver. The outcome was a collision in one case, less than safe separation in one, a recognized error in two, and no conflict in two. In one case, a motor vehicle wandered onto an airport from outside; the other cases involved airport service vehicles.

Motor vehicles have been a persistent problem at certain airports that have deficient security fencing; however, they did not appear to be a frequent problem in this sample of reports from controlled airports.

General discussion— What, in summary, can be learned from these data? In particular, do the data suggest any measures that might assist in solving the problem of runway incursions, if these occurrences do represent a problem?

First, while we are uncertain as to the magnitude of the problem, it seems certain that a problem exists. That some of these near collisions were not accidents instead appears to have been due to chance alone (the occurrences in which no recovery action was taken are an example).

Given the existence of the problem, how may it be characterized? The problem appears at first glance to be twofold. One aspect involves pilots who do not have, or who misunderstand, a clearance prior to executing a maneuver. The second aspect involves controllers who fail to insure that separation exists and that it will continue to exist before they issue a clearance. Both problems, however, appear in a large number of cases to involve a common factor: lack of information. In the case of the pilots (and the vehicle operators), the information they lack is a timely, unambiguous clearance. In the case of many of the controllers, the information relates to their or other traffic, or about the intentions of pilots (or drivers).

In many of these reports, it is clear that considerable pacing stress is involved. The pilot has schedule pressures, the need to conserve fuel, and the constant knowledge that he cannot "get there by sitting here." The controller's problem is more pervasive; he must move traffic, simply because he knows there is more coming. One of these reports is illuminating, for it illustrates that controllers will sometimes go further than perhaps they should to provide whatever services are requested of them.

Aircraft B executing practice ILS 31L approach to a full stop . . . aircraft A advised on left base with B in sight. Local control cleared A to land 31R. . . . local control had other distractions and did not continue to watch A . . . radar was not

painting the aircraft. . . . A stated that an aircraft was on the runway; local control did not observe an aircraft on 31R and checked 31L. I observed A about 20 ft AGL about to land on top of B. I told A to go around. As A started his go-around on 31L additional traffic was C on short final on runway 36. I told C to make an emergency pull-up to avoid A. Contributing factors: poor radar reception and only one local control position. Just prior to this incident I had worked 107 operations using three runways . . . one local controller has difficulty observing all of the critical areas for three different traffic patterns. . . .

Frequency congestion, shortcuts, nonstandard phraseology, unpredictable and unannounced flight crew actions, visibility restrictions, and other factors all play a part in this problem, but it appears that the information transfer problem, for whatever reasons, is at the heart of a substantial part of it. Given that over half these occurrences involve an aircraft taxiing, and therefore able to stop almost at will, it is suggested that it should be productive to examine closely ways to insure that taxiing aircraft (and motor vehicles) are under all circumstances absolutely certain of what they are supposed to be doing.

There are three facets to this part of the information transfer problem; each is important, but the relative importance will vary as a function of geographic features, airport layout, and procedures in various locations.

Standard operating procedures for taxiing, either system-wide or airport-specific, will help to insure compliance with desired patterns of behavior in most cases, if they are known to all users and if they are simple enough to be understood. Although steps have been taken to clarify taxi clearance limitations, it appears from the number of occurrences involving this factor that additional attention might be helpful.

Taxiway lighting and markings appear to be a problem at a number of locations, especially during periods of construction or repairs. While many improvements have been made in signs over the past several years, markings, especially at night, still appear to represent a deficiency. The problem is most acute at the junctions of taxiways with runways.

Clearances were a problem in a number of reports, particularly when ground control frequencies were congested. The dangers of nonstandard or abbreviated clearances are clear; maintaining clearance discipline under severe time constraints, however, is a constant struggle. One pertinent location-specific situation noted several times in the study involved being directed to "follow another aircraft," then uncertainty as to whether to follow the other aircraft across an active runway. Some pilots did, some pilots did not, and some pilots queried ground control for clarification. It is this sort of ambiguity the system should seek to avoid.

Lack of clearance for takeoff or landing was noted in 14 reports. This can hardly be due to a lack of knowledge of the requirements for such a clearance. Data regarding the four aircraft that landed without clearance indicate two were not in contact with the tower; the reasons why the other two landed are unknown. In the case of takeoffs without clearance, however, a pattern was more evident. In 7 of 10 cases, an aircraft took off immediately after a takeoff clearance was delivered to another aircraft. One case involved similar flight numbers, one involved an incomplete (no aircraft identification) repeat of a previously issued takeoff clearance, after which two aircraft took off simultaneously on intersecting runways. In the other cases, the reason for takeoff was

unknown in one, a probable language problem in a second, and a crew member's misinterpretation of a question from the other pilot in the third.

The tone of several of these reports suggests that pilots already in position and awaiting takeoff clearance may have heard what they expected to hear, without recognizing that the clearance was for another aircraft on another (or even the same) runway. It is in this subset of cases that devices for visual confirmation of takeoff clearance would be useful, but it is also suggested that with the multiple-runway and intersection takeoff operations, which characterize nearly all of our busier airports, a heightened level of caution on the part of pilots, perhaps accompanied by a readback of the flight or aircraft numbers in acknowledgment of the clearance, might accomplish the same thing.

It is clear that problems in coordination between local and ground controllers are a factor in a substantial number of runway incursions. It is equally clear that pacing stress is a contributing factor in these and probably in other failures of coordination. Though a recent FAA directive mandating verbal coordination prior to permitting the crossing of one of two active parallel runways may be of help, a recent ASRS report describes the difficulties associated with implementing this directive at an extremely busy VFR tower serving a multiple parallel runway operation.

Conclusions

The following conclusions are drawn:

1. Incursions of aircraft onto runways at controlled airports represents a significant safety problem
2. An important factor in both pilot-initiated and controller-initiated runway incursions is failure of information transfer among the relevant system participants
3. Taxiing aircraft, a major contributor to these occurrences, represent the most effective single point of attack on the problem, if ASRS data are representative.

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