HUMAN FACTORS ASSOCIATED WITH RUNWAY TRANSGRESSIONS

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ABSTRACT

Collisions between aircraft on the ground has heightened public and FAA interest in the phenomenon of runway transgressions. The study presented herein is an expansion of one recently completed by NASA's Aviation Safety Reporting System. Originally undertaken at the request of the FAA, it pointed to three general problem areas contributing to runway transgressions: information transfer, awareness, and spatial judgement. This study evaluates a random sample of more recent ASRS runway transgression reports using an approach consistent with the epidemiologic model as applied to aviation safety. It is found that certain predisposing conditions can be identified and related to the three problem areas. Distraction, excessive workload, pilot disorientation, and multiple runway operations are noticeable factors within transgression causal structures. Pertinents examples of ASRS runway transgression reports illustrate that, even though these predisposing conditions are often significant, the relationships between each problem area and each participating actor can be complex.

INTRODUCTION

As a result of several accidents dating back to the collision between two Boeing 747 airliners at Tenerife, Spain, an ever-increasing amount of public and aviation community attention has been focused on the topic of runway trangressions. A runway trangression is any unauthorized or improper occupation of a runway, by an aircraft or other vehicle, at a controlled airport. These transgressions can occur through a variety of scenarios, but each holds the potential for serious consequences in situations where more than one aircraft is present. The following is paraphrased from a National Transportation Safety Board accident report, and provides an illustration:

> In December 1983, a departing DC-10 cargo flight collided head-on with a scheduled commuter aircraft holding in position at Anchorage International Airport. The commuter was destroyed by the collision impact, and the DC-10 was destroyed by impact and post impact fire. Of the eight passengers aboard the commuter, three were slightly injured. The pilot was not. The three crew members of the DC-10 sustained serious injuries.
>
> The National Transportation Safety Board determines that the probable causes of the accident were the failure of the DC-10 pilot to follow accepted procedures during taxi which caused him to become disoriented while selecting the runway; the failure of the pilot to use the compass to confirm his position; and the decision of the pilot to take off when he was unsure that the aircraft was positioned on the correct runway. Contributing to the accident was the fog, which reduced visibility to a point that the pilot could

not ascertain his position visually and the control tower personnel could not assist him. Also contributing was a lack of legible taxiway and runway signs at several intersections passed by the aircraft while it was taxiing.(2)

In fact, the DC-10 had taxied to and aligned itself on the last third of runway 24R instead of the approach end of runway 32. Takeoff was attempted directly into the face of the commuter aircraft with only 2400 feet of runway available.

Background

NASA's Aviation Safety Reporting System (ASRS) has, to date, performed two studies on the topic of runway transgressions. ASRS is a voluntary, nonpunitive vehicle for the reporting of safety-related incidents by members of the aviation community. Since its inception in 1976 close to forty thousand reports have been submitted, primarily by pilots and air traffic controllers. The foundation for the program, and the reasons for its continued success, lie in the premise that, through the tracking and analysis of aviation safety incidents, or those anomalies that do not result in accidents, insight may be gained into the causal nature of accidents themselves. Reports received by ASRS are analyzed by experienced pilots and controllers, and reside in a database geared to record the human, operational, and systems factors pertinent to each event.

The first study of runway transgressions utilized reports gathered during the program's formative years, and was motivated by the tragic circumstances that resulted in the collision at Tenerife. The second effort, executed by this author and completed in 1984, was performed at the request of the Federal Aviation Administration. It updated the first and took advantage of a vastly increased volume of ASRS submissions as well as the fully matured coding capabilities of the database. In it, runway transgressions were categorized by phase of flight and enabling actor. Within each category, a qualitative assessment of risk was performed based upon the severity of reported consequences. In addition, the causal structure of each occurrence was modeled in terms of enabling factors linked to the chain of events, and associated factors pertinent to conditions that fostered errors or affected the severity. The study concluded that controller-enabled transgressions during the departure phase show a significantly greater risk of collision than all other categories. Of lesser but significant importance are the risks associated with pilot-enabled arrival and taxi transgressions.

Although the controller-enabled departure transgression yielded the highest risk level, it also showed the strongest correlations between causal factors. The most frequent errors precipitating this type of event were a controller's failure to visually locate traffic, his misjudgement of traffic spacing, and the failure to properly coordinate with other controllers. Each of these, however, was consistently associated with conditions of restricted visibility, the use of intersecting runways, and intersection takeoffs. Similar correlations were seen in other transgression categories. In summary, the study pointed to three general problem areas: information transfer, awareness, and spatial judgement.(3)

Objective

The purpose of the present endeavor is to extend and generalize relationships between these three areas and the specific errors and predisposing conditions that relate to them. Whereas previous inquiries have dissected runway transgressions based upon the type of event, the approach related herein is an attempt to uncover common threads that increase the probability of any runway transgression. In this manner, those specific characteristics of flight operations and human behavior that precipitate such events may be identified as the focal points for enhanced pilot/controller training and potential system modification.

METHODOLOGY

In 1980, Cheaney and Billings related an approach to the study of human error in aviation based upon the epidemiological model.(1) Using this method, incident reports are decomposed into discrete events and other influential factors. In epidemiology, disease is modeled as emanating from environmental circumstances, and manifests itself in the form of symptoms that may lead to some degree of illness. The corresponding aviation analogy, depicted below, models human errors arising from a set of predisposing conditions which, in turn, may emanate from characteristics of the operational or physical environment. These errors have the potential for culminating in an accident or incident should the system lack the flexibility to damp perturbations or allow for corrective action.

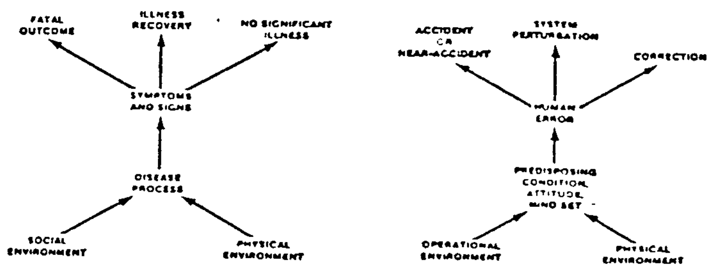

FIGURE 1. THE EPIDEMIOLOGICAL MODEL AND ITS AVIATION SYSTEM ANALOGY (From Cheaney and Billings, Reference 1)

Using this approach, 104 ASRS runway transgression reports were studied. This set was a one-out-of-three sample of all such reported incidents occurring between December 1983 and November 1984. Although every third report was read, not every incident retrieved truly qualified as a runway transgression. Those that failed this criteria were discarded. In a manner consistent with the previous research, these were categorized on the basis of occurrence type and enabling actor. Utilizing a slightly different method than before, however, the factors characterizing a given incident were distinguished in terms of human error and predisposing conditions. Each incident was further classified in terms of its applicability to issues involving information transfer, awareness, and spatial judgement.

The primary method of analysis involved the cross tabulation of problem areas associated with errors and the corresponding predisposing conditions. By constructing the resulting hierarchies it may be possible to determine which predisposing conditions relate to the various categories of error and to some extent, their qualitative significance.

ASRS data has always been found most useful when used in identifying patterns of behavior. The ability to perceive a pattern, however, is limited by the extent to which reporters supply detailed information. Historically, ASRS reporters are more prone to elucidate the conditions under which an incident occurred rather than the entire chain of events. This being the case, it seems a more productive endeavor to focus on the conditions and the known errors with which they are associated, rather than attempt to identify probable chains of events. It may even be argued that there is more practicality in asking pilots and controllers to recognize combinations of circumstances rather than risky patterns of behavior.

RESULTS

Breakdowns of occurrence type, human errors, and predisposing conditions were tallied for both controller and pilot enabled incidents. As can be seen in Table 1, there is little variation in the frequency with which each general problem area is cited. Since ASRS data is received voluntarily, and is subject to unknown biases affecting reporter motivation, such quantitative observations have little meaning in any statistical sense. They only lend weight to the presumption that each problem area is pertinent to the various controller errors.

Table 2, on the other hand, does not indicate the same uniformity in depicting pilot enabled events. Irrespective of the particular occurrence type, problems with awareness stand out significantly, while citations referencing spatial judgement are virtually negligible. Again, the absolute numbers tell us little with regard to frequency of occurrence. As will be illustrated, the three problem areas are not mutually exclusive, and this further mitigates the significance of statistical comparisons.

	Problem Areas Associated with Human Errors		
Occurrence Type	Information Transfer	Awareness	Spatial Judgement
Improper Landing Clearance	2	4	6
Improper Position & Hold Clearance	0	2	1
Improper Takeoff Clearance	3	4	4
Improper Runway Crossing Clearance	4	2	1
TOTALS	9	12	12

TABLE 1. Controller Enabled Runway Transgressions
Breakdown By Number of Problem Area Citations

	Problem Areas Associated with Human Errors		
Occurrence Type	Information Transfer	Awareness	Spatial Judgement
Unauthorized Landing	5	26	0
Unauthorized Runway Crossing/Taxi	10	13	2
Unauthorized Runway Entry	3	7	0
Unauthorized Takeoff	7	4	0
Wrong Runway Landing	2	4	2
TOTALS	27	54	4

TABLE 2. Pilot Enabled Runway Transgressions
Breakdown By Number of Problem Area Citations

Tabulations of the predominant predisposing conditions are shown in Tables 3 and 4. Controller enabled occurrences are led by errors arising from job-related distractions or what may also be characterized as transient increases in workload. This is followed by errors associated with the so-called "anticipatory clearance" where instructions issued are based upon the controller's prediction of traffic movements. Restricted visibility stands out as the only characteristic of the physical environment having significant impact on controller errors. It's effect on the controller's operational demands is not obvious, but will be addressed in examples that follow.

Predisposing Conditions	Problem Areas Associated With Human Errors: Information Transfer	Awareness	Spatial Judgement	Total
Controller Distractions (Job Related)	6	6	1	13
Traffic Volume	4	1	3	8
Frequency Congestion	1	1	0	2
Permissability of the Anticipatory Clearance	1	1	3	5
Pilot Failure to Vacate Runway	1	1	3	5
Restricted Visibility	1	3	5	9
Multiple Runway Operations	2	2	2	6
Controller Workload	2	2	1	5

TABLE 3. Predominant Predisposing Conditions for Controller Enabled Runway Transgressions

Predisposing Conditions	Problem Areas Associated With Human Errors: Information Transfer	Awareness	Spatial Judgement	Total
All Pilot Distractions	6	36	0	42
Pilot Distraction/Flying	3	17	0	20
Pilot Distraction/Traffic	1	8	0	9
Pilot Distraction/Radio	1	5	0	6
Pilot Workload	4	9	0	13
Pilot Disorientation	0	12	0	12
Multiple Runway Operations				
Parallel Runways	4	6	0	10
Intersecting Runways	2	4	0	6
Pilot Fatigue	2	6	0	8
Airport Configuration	2	5	1	8
Runway/Taxiway Markings & Signs	1	5	1	7
Pilot Unfamiliarity with Airport	1	6	0	7
Restricted Visibility	3	4	0	7
Traffic Volume	2	5	0	7
Simultaneous Radio Transmissions	6	0	0	6
Frequency Congestion	3	3	0	6

TABLE 4. Predominant Predisposing Conditions For Pilot Enabled Runway Transgressions

As is immediately apparent from Table 4, pilot errors associated with spatial judgement are rare. It is equally obvious, however, that clear distinctions cannot be drawn between pilot errors involving information transfer versus those involving awareness. Since it is not always feasible to relate a particular incident to a single error, the tallies of problem area citations exceed the total number of incidents.

Finally, Tables 5 and 6 delineate the predominant error categories applicable to each problem area. Although it is difficult to relate particular errors with specific conditions, it is useful to note which errors recur with regularity, and to recognize the specific problems that precipitate an individual transgression event.

Controller Error	General Problem Area: Information Transfer	Awareness	Spatial Judgement	Total
Misjudgement of Traffic Separation	1	2	11	14
Controller Lack of Vigilance	1	7	1	9
Failure to Visually Locate Traffic	2	3	2	7
Misstatement of Intended Clearance	3	0	0	3
Failure to Issue "Hold Short" Restriction	2	0	1	3

TABLE 5. Predominant Controller Errors Associated with General Problem Areas

Pilot Error	General Problem Area: Information Transfer	Awareness	Spatial Judgement	Total
Pilot Failure to Contact ATCT	28	24	0	52
Controller Failure to Issue Frequency Change	1	4	0	5
Pilot Misunderstanding of Clearance	13	5	1	19
Pilot Lack of Vigilance	3	8	0	11
Pilot Failure to Obey Clearance	3	7	0	10
Pilot Failure to Request Clearance	3	4	0	7
Pilot Misoperation of Radio	3	1	0	4
Pilot Clearance Expectation	3	1	0	4
Pilot Acting on Clearance for Another Aircraft	4	0	0	4

TABLE 6. Predominant Pilot Errors by Number of Citations

DISCUSSION

ASRS reports consistently indicate that a combination of actors, errors, and conditions are usually interwoven within the fabric of any particular incident. The trends represented in the foregoing tables, however, do not adequately depict the subtle influences that play between one actor and another. Categorizing one individual as the enabling actor is often an oversimplified, highly subjective determination, used herein for classification purposes only. In addition, the three problem areas are also frequently interrelated. A pilot who forgets to call the tower for landing clearance may, on one hand, be guilty of an error involving awareness: He has lost track of a particular operational requirement. On the other hand, his failure to establish communication is also an information transfer problem. The example below illustrates the convoluted nature of problems within one occurrence:

> "We were cleared on to runway and...cleared for takeoff....Then we were told to hold short. In the meantime, a light twin was... cleared to land....We called the tower and told them we were on the runway but received no response. We initiated a second transmission to the tower. The tower then told the light twin to go around and again there was no response. After a second call...the light twin acknowledged....It appeared as if controller training [was] in progress. The radio frequency was very busy. I don't think there was any danger as the other aircraft saw us and went around at 300 to 400 feet agl."

In the first two sentences, the controller's spatial judgement is immediately called into question. He apparently cleared the aircraft onto the runway when the light twin was too close. Alternately, it is possible that the controller simply misstated the intended runway; saying 36R when he really meant 36L. In either case, he attempts to correct the situation by directing the reporter to hold short, though clearly, he is unaware of the aircraft's position. When attempts to advise him of the impending problem go unacknowledged, information transfer becomes a problem.

The examples that follow illustrate the various influences actors have on one another within the context of each problem area. First, however, a clarification of problem area definitions is in order.

Information transfer entails any and all aspects of messages that are purposely sent or are required to be so. This is not just limited to verbal communication over the radio. Messages may also originate from electro-mechanical devices, such as computers or aircraft instruments. Message types include clearances, advisories, intentions, warnings, and requests, to name a few, and may be communicated verbally or visually.

Procedures within the air traffic control system are predicated upon the accurate conveyance of information describing the positions of aircraft and their intended movements. When the communication process suffers from inaccuracy or otherwise fails, it is logical that a noticeable decrease in safety may result.

The next category, awareness, is purposely vague. Very often, ASRS reports allude to awareness in terms of one's vigilance, i.e., perceptual awareness. Due to the procedures under which aircraft operate, however, situational and intellectual awareness is also required. This includes cognizance of one's physical and operational surroundings. The channels through which pilots and controllers are expected to perceive their changing environment are several, and may vary with time. When their performance is deficient relative to demands of the moment, the capability for adequate decision-making is lost.

The final problem area, spatial judgement, is actually the one most rigorously defined. Evidenced by its appearance in the preceding tables, it refers specifically to the human ability to accurately perceive separation of objects in time and space—a trait fundamentally required of air traffic controllers. As with awareness, the channels by which spatial information arrive may vary. For the controller directing traffic from an airport tower, the medium is usually visual. Frequently, though, that same controller may be required to assess aircraft spacing on the basis of verbal position reports. The radar controller, on the other hand, must perceive the separation of aircraft radar returns, and his ability to assess positional rates of change are largely shaped by peculiarities of the radar medium.

Information Transfer

Table 4 clearly shows the recurrence of pilot distractions and pilot workload as being related to information transfer problems. In the report excerpt that follows the pilot of a small transport describes some of the influences that can affect the ability to communicate:

> "...tower advised 'Taxi on runway 35 via Alpha taxiway'....I monitored a call and reply concerning taxi and takeoff request of a second aircraft. I was unable to (or for some reason did not) monitor the full transmission...but assumed second aircraft was following me....A follow-on transmission requested aircraft to hold short of runway 23. I apparently missed my trip number as the intended receiver and assumed it was for second aircraft....In reality...I was aircraft directed to hold short of runway 23. Second aircraft held in position and I crossed down field. Tower advised that I had erred....It happened for three reasons: First,...hurrying to minimize late arrival at turn-around. Second, missed call sign....Last, tower operator cleared second aircraft to conflicting runway....To prevent recurrence: First...do not rush procedures. Second, ensure the full tower transmission is received. Third, avoid cockpit distractions....Last, make no assumptions...."

Although the ultimate error here was a simple clearance misunderstanding, it came about through a variety of factors recognized by the reporter. Schedule pressure and the accompanying increase in pilot workload left little room for any additional distractions. It can also be asserted that the pilot allowed his message interpretation to be shaped by his assumptions, made as a result of the increased workload situation.

Historically, an often innocuous information transfer problem found in ASRS records is the landing without clearance, and these events occur more frequently than any other form of transgression. It is also clear, however, that most of these incidents do not happen in the presence of conflicting aircraft; thus, the associated risk is relatively small. As low as this may seem, there is still no denying the potential consequences of such an error if committed under the "right" circumstances:

> "We (air carrier A) were waiting for departure from runway 8....The weather...was indefinite zero, sky obscured, visibility 1/4 mile....We were number one for departure waiting on arrival of a large transport air carrier, B. Tower asked us to advise them when B went by the approach end of the runway so we could take position.

> So B landed and we were cleared into position and hold. Also at this time there was a large transport C on approach to runway 8. After approximately 2 minutes waiting for B to clear the runway, we were cleared for takeoff. After rolling approximately 200 feet we were told to hold our position and cancel takeoff clearance due to C still on the approach. At this time tower advised C to go around because we were still sitting on the runway...but we never heard an acknowledgement....Still in position, the next thing we knew, C came right over the top of us, missing us by—it seemed like—inches. His thrust rocked our aircraft as he initiated a go-around. His aircraft came within 5 feet of touching down....We later learned that C was never on tower frequency, but still on approach control throughout the entire approach and go-around, and C never heard the go-around call from tower...."

The failure to change to tower frequency put this aircraft out of communication at a critical phase of flight. Avenues for the transfer of information in the event of unforeseen or unexpected circumstances were closed, leaving the situation at the mercy of a pilot who, hopefully, was only distracted from calling the tower by his keen vigilance through the front window and his finger on the go-around button. The importance of accurate information, especially in situations of restricted visibility, is obvious. In this situation, the pilot's information transfer problem led to the controller's inability to determine traffic separation.

Controllers also, are prone to making communications errors. One that appears quite often is the misstated call sign. However, it is not always clear whether the wrong call sign was actually used, or whether it was misinterpreted by the recipient. Given similar call signs, a pilot is more likely to mistake someone else's clearance as his own than fail to hear a call actually intended for him.

> "With the sun a few degrees above the runway...I could see neither landing aircraft...nor aircraft taking off....I then heard, 'Aircraft ABC, cross runway 8.' I notified my student to cross and answered, 'ABC'. Once we reached the runway (from the hold line), I heard, 'ABC hold short,' Too late, it was either stop in the middle or continue. We continued. I then heard 'ABF cross 8,' (ABF was somewhere near the approach end, I couldn't see it). The ground controller called to say he had called ABF. I responded that I was sure he said ABC (they don't sound much alike, and I had heard all the calls to ABF)....Maybe I heard wrong. I don't think so...."

Fortunately, the aviation system is characterized by redundant methods of verification. In this example, however, the system was deprived of one due to the position of the sun. Restricted visibility is a significant factor in runway transgression reports and is not always due to clouds, fog, or darkness.

Awareness

Many ASRS reports speak to the lack of perceptual clues inherent to night operations. The following example illustrates that, when combined with other factors, such as a complacent attitude and pilot fatigue, what may otherwise appear as a normal situation is surprisingly not:

> "Flight inbound...on a visual approach, landed...16R...notamed closed runway....The flight received ATIS which advised of a north operation. Center was contacted with the request for a left turn to a South landing....approved....We advised approach that 'We have the...runway in sight', and confirmed receiving ATIS.... Approach...cleared us for a visual approach and switched us to the tower....At that time we were cleared to land runway 16....All runway lights were on and appeared normal as we turned approximately a 3 mile final. The tower asked that we clear the runway at the first available taxiway, we complied, and were cleared to the gate....The tower supervisor advised that I had landed on a closed runway....I landed on runway 16R, thinking left closed. Airliners normally use the west runway 16R instead of 16L. The runway was lighted and everything appeared normal."

In this instance, his mindset and the mere existence of a parallel runway configuration predisposed the pilot towards this mistake. The crew, vigilant in the sense of being visually aware, was not coordinating this perceptual input with their other knowledge. As a result, no flags were raised.

<u>Spatial Judgement</u>

The ability of air traffic control to keep aircraft adequately separated is constantly being balanced against the need to promote expeditious operations. As previously mentioned, the channels by which tower controllers determine relative aircraft positions are many. Unconsciously, controller's are likely to coordinate and compare these various inputs when making their best estimates. Visual sightings are probably most reliable, however, they're not always possible. When other channels are also lost, confusion and separation errors are a predictable result. The following incident occurred one night at LAX:

> "...holding short of 24L awaiting takeoff. An air carrier was cleared for takeoff and did. We were immediately cleared into position and then, without a break...cleared for takeoff....I looked at the approach path and did not see anyone. When I was approximately 70 degrees from alignment, my copilot...said, 'I think he's coming for our runway, he is, he's going to hit us.' I started a turn to the right...to get clear except the wide body initiated his own go around...."

In this instance, the wide body on approach had not turned on his landing lights until the last minute. The reporter described the weather condition as being "extremely hazy", and could not recall hearing the wide body's landing clearance.

CONCLUSIONS

In summary, we can identify several classes of predisposing conditions that contribute to occurrences arising from anomalies in each problem area. For pilots, any type of distraction or other components of increased workload are most frequently associated with information transfer and awareness problems. Problems with spatial judgement, when they occur, can usually be related to airport markings, signs, and complex configurations. Similarly, distraction is also the primary contributor to controller problems with information transfer and awareness. This is followed by other types of workload increases such as traffic volume and the use of multiple runways. The primary factor affecting controller spatial judgement is restricted visibility. After this, traffic volume and the use of anticipatory clearances are also found significant.

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