2007

1,001 Runway Incursions

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1,001 RUNWAY INCURSIONS

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Three years of recent ASRS reports were reviewed to seek factors contributing to runway incursions and taxi errors. Many factors not commonly discussed in ground safety were found in these 1,049 reports. These factors were then analyzed from a systems perspective, suggesting that all elements of the system, in the broadest sense, need improvement, but as a unified system. It seems unlikely that any meaningful improvements will be achieved without such a systems approach.

Introduction

"In fact, several investigators, some of whom were current airline pilots, were confused by the signage in this area [where the crew missed their turn] when they observed it on a clear day after the accident." NTSB/AAR-91/05, Runway Incursion and Collision, DTW, December 3, 1990.

Five years ago, an unpublished Boeing research project by this author investigated runway incursions and taxi errors for Part 121 operators. This paper is an update of that work.

Every factor hypothesized in advance was found in the data, as well as any number of unexpected and troubling factors. Training, human factors, and traditional problems were all found. But, from a systems engineering point of view, the "system" – including procedures, regulations, design, information, operations -- is an evolved system, not designed, with significant faults in all sectors and frequent lapses of coordination across sectors. The data suggest that sufficient factors are in place to permit a multi-hull loss event within the boundaries of a US airport, with an enormous social cost. Further, the data suggest that the present error rate will not significantly improve without system-wide changes and re-examination of current assumptions.

Purpose and Limitations

Voluntarily submitted incident reports by their nature do not support "statistically significant" analyses, but tidy statistical analyses are not the objective. Rather, modern systems theory accepts these reports as valid indicators of situations where accidents are likely or can be prevented. Conclusions based on incident reports are then invaluable in initiating more focused efforts.

Although it is tempting and traditional to assign some errors, such as mis-communicated instructions, exclusively to flight crew error, the data contains enough counter-examples to undermine such generalizations.

Methodology

The data were obtained from an online search, obtaining the most recent three-year data. At the time of the search, these data were from January, 2003 through January, 2006. The search criteria were "Conflict – Ground," Critical and Less Severe, and "Ground Incursion," Runway, and Taxiway. This search generated 2,070 records.

On the first pass through the data, a taxonomy of errors was generated and significant factors were noted and recorded. Also on the first pass, reports were noted as to their appropriateness for second-pass processing by omitting events that:

- Did not involve surface operations errors in the broadest sense
- For wrong runway landings, did not display human factors elements relative to surface operations.
- Were attributable to accents of foreign controllers.

This sorting yielded 1,082 reports for second pass processing.

Factors were grouped into:

- Flight crew factors
- Controller factors
- Information factors (e.g., NOTAMs, charts)
- Communications factors
- Airport factors

During second pass processing, each report was reread, and factors present were recorded on the spreadsheet. After this second pass, it became clear that a third pass through the data was called for to clarify a number of factors.

Third pass processing organized the tabular data, most significantly the airport location, and the kind of operation: "High End" (air carrier, air taxi, corporate, charter, government, military, generally turbine engines) with 723 reports, and "Low end GA" with 326 reports (personal, instructional, generally piston engines). These data suffice for giving general trends and indications, even though they do not support statistical rigor.

There are undoubtedly classification errors in this analysis as the tabulation work was so mind-numbing as to make consistency difficult and double-checking arduous. For example, the tabulation of confusion on "what's the active runway" was probably under-reported. However, the purpose of this analysis was to identify significant factors, not to generate statistically significant tallies – as if true statistical significance were possible from such data. The complete raw data and factors categorization are available from the author.

In a number of cases, hold short line locations and airport geometries were investigated using Google Earth. Airport diagrams were often accessed via www.airnav.com, and over 40 airport diagrams were accessed on line for clarification of narratives. In addition, communications with FAA personnel contributed to this paper.

Observations and Speculations

Analysis -- Expectations[1, 2]

The data recorded instances in which controllers stated in the reports that they expected that a flight crew:

- Will see and be able to follow all signs and markings
- Can accept a changed taxi clearance without error while taxiing
- Can accept a changed departure clearance while taxiing without a taxi error
- Will take a specific taxiway without being told
- Will expedite without being told
- Will taxi across runways and taxiways fast enough for separation (controllers can't tell a single engine taxi or starting a taxi uphill which can slow the speed of crossing)
- Can abort a takeoff at any time
- Will make the requested runway turnoff
- Will not go around unannounced
- Can perform a go around at any time
- Can accept a taxi clearance while on the landing roll, even during the noise of reverse thrust operation.
- Will handle conditions and procedures peculiar to that airport without any additional coaching from ATC
- Do not need readback for error avoidance
- Will pick up any changed conditions at that airport without ATC emphasizing the changes

The data recorded common pilot expectations that:

- Hold short lines will be near runway ends
- If there is an ILS line, there is a hold short line beyond
- They will be able to successfully operate at any airport using "standard" procedures
- There will be signs to support every turn of a taxi clearance.[3]

The data recorded pilots' frequent expectations at non-towered fields that:

- All transmissions from this aircraft were heard by all other pilots, regardless of how long ago those transmissions were made.
- No matter how short a time this aircraft has been on frequency, it's been long enough to have received all relevant transmissions.
- Received transmissions from other aircraft have been sufficient that looking for traffic is not required
- Turning on lights or making radio calls also obviate the need for looking
- Everybody flies a standard approach, so there is no need to look for short approaches, high approaches, etc.
- Everybody will see this aircraft regardless of the kind of approach flown
- "Position and hold" is safe if announced on the radio

The data recorded airport operators' expectations that:

- Hold short lines will be observed, regardless of the location relative to the runway end
- All signs and markings will be visible from both seats of a taxiing aircraft, or from the pilot of a tailwheel aircraft
- Construction markings will be seen, no matter how they are displayed.

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[1] The theme of "expectations" originates from Kathleen O'Brien, FAA Safety Program Manager, LGB. Personal conversation.

[2] Observations and Speculations are space-limited, and some points were omitted. Full data is available to support these summarizations.

[3] "They had begun to rely totally on the airfield signs and markings they observed through the fog to comply with the controller's instructions." NTSB/AAR-91/05, page 56. (Detroit runway incursion and collision.)

Comparing High End and Low End Operators

The earlier Boeing study was, naturally enough, limited to Part 121 and 135 operators only. For this study, operators were grouped into "high end" (air carrier / major, air carrier / regional, air taxi, corporate, etc.) and "low end" (personal and instructional.)

For all of the factors tabulated, per cent occurrences were generated for high end and low end operators. Many factors were found more commonly in high end, such as having the first officer doing tasks related to the flight but unrelated to taxiing the aircraft when the taxi error occurred. Uncleared or wrong runway takeoffs and landings were more prevalent in low end operations, but those statistics are misleading – from a systems safety point of view, what's important is not which group makes the error more often; what's important is what those errors point out as opportunities for improvement.

Events occurring more frequently with high end operators include:

- Second pilot off line or distracted, such as with checklists and closeout tasks, when the taxi error or runway incursion occurred
- Taxiing pilot did not back up the Pilot Not Flying (PNF) on the radio, sometimes abrogating responsibility for listening to radio communications.
- Fatigue
- Receiving instructions from ATC too late for compliance, that caused confusion, or that came on rollout

Events occurring more frequently with low end operators include:

- Stress and time pressure
- Uncleared or wrong runway takeoffs and landings

Other Human Factors

Hold short lines in unexpected places were a common problem, with 35 events noted. The data suggest that pilots may not start looking for hold short lines until cued by the end of the runway. There were also cases of single hold short lines serving multiple runways, no hold short line past an ILS critical area line, and one report of hold short lines that all had the dashed and solid sections reversed. It is clear that hold short lines in unexpected locations with no additional cues will create errors.

One phenomenon discovered in these data is the "greater than 90 degree turn" problem. It appears that pilots associate the word "turn" with a turn of 90 degrees or less. And although English has verbs for proceed, zig, and veer, English does not have a commonly used verb or even an adverb to describe turning more than 90 degrees. There were eleven reports involving turns greater than 90 degrees, nine from high end operators.[4]

An hypothesized phenomena found in the data were runway signs not visible to the taxiing pilot, for both high and low end operators. In another case, a B737 pilot was unable to see any of the taxiway when instructed to make a 135 degree right turn.

In addition to the problems with the first officer off line, there were a number of cases in which the pilot taxiing paid inadequate attention to the radio. Sometimes company policy dictated that the pilot taxiing monitor Comm 2 or perform distracting duties while taxiing.

Some reports support speculation that pilot age may be a factor in inattentiveness, as captains are generally older than first officers. However, ASRS does not capture pilot age.

There were also cases in which onboard mechanical voices blocked reception of radio messages. The Honeywell Runway Awareness and Advisory System (RAAS) systems was cited in two cases, and the other report was of a traffic warning system that went off on the ground.

Also noted were eight instances of taxiway names, wherein the flight crew had difficulty or were unable to find a designated taxiway on the chart because of arbitrary and capricious taxiway naming schemes. One reporter observed that inner and outer loops were not labeled consistently at different airports, suggesting that letters and numerals alone may not always suffice.

There were numerous cases of inadequately marked runway and taxiway closures, and where poor markings caused confusion.

There were also cases of "rote reply, no comply" where the flight crew parroted an instruction and then did something else. Only three of these eight reports were from low end operators.

[4] It may or may not be significant that the 1990 Detroit runway incursion accident and the 2006 Lexington wrong runway takeoff each involved critical turns of more than 90 degrees.

The data also suggest that airline crews may not be able to see hold short lines under the nose, not just because of taxi lights but also because of poor visibility.

It is significant that acknowledgement of transmissions is the first line defense against communications errors. However, four per cent of reports were of frequency congestion or busy controllers, situations compromising this defense.

There were, of course, the traditional problems of frequency congestion, readback / hearback, poorly maintained markings, signs and lights.

Four per cent of the reports (39) related to confusion between "hold position," "hold short," "position and hold," and even takeoff clearance, with similar rates from both high- and low-end operators. Reports suggest this is because different instructions re-use the same words, and not from confusion with ICAO terminology.

A major surprise in these data is the number of reports of controllers either berating or deliberately delaying flight crews following a perceived error.[5] The data showed 43 events, of which seven contributed to a further problem. These data showed low-end operators receiving such treatment 1.8 times more frequently than high end operators. And, in the study of five years ago, such events were unheard of. There were also 12 cases of controller unintelligibility (at US airports) due to poor enunciation or excessive speech rate.

Last are the questions of, "What is an active runway? And how do you find out which ones are active?" Information so important ought to be extremely easy to find. However, a brief search of FAR 91, the Aeronautical Information Manual, and the Pilot-Controller glossary gave no guidance on how to determine which runway(s) are active. Reports indicate that pilots are not alone in this confusion, and with some reports of controllers regarding all runways as "active" and not to be crossed without a clearance.

Systems Engineering Observations

Both Reason's model and its derivative, HFACS, state in effect that management is the ultimate cause of all problems. A similar concept is to look at the "system" in the broadest sense and examine the system for potential flaws.[6]

From that perspective, the "system" has serious and troubling problems, both at the component level and at the higher level. Many of the components seem to have evolved in isolation from the other components, so there is no obvious coherent design, let alone tight coordination among components.

The elements of the system, in the broadest sense, include:

1. Airport designers, specifying pavements, signs, and markings and changes to those. In many cases, the present pavement arrangements, signage, and markings are setups for accidents. Indeed, from a systems safety point of view, a "hot spot" is a public admission that the system is known to be broken and has not been fixed. "WE WERE LOOKING FOR A RWY SIGN THAT HAS A 3 ON IT… IF THE RWY SIGNAGE WOULD HAVE SAID 3-21 I WOULD HAVE HELD SHORT…. EVERYONE INVOLVED IN THIS INCIDENT EXCEPT THE PLTS WERE WELL AWARE OF THE SIGN AND MISIDENTIFICATION OF THE RWY PROB" (666402).[7] Other reports suggest that Cleveland airport has an elevated risk of a major surface collision accident with its three closely spaced runways because pilots often crossed the center runway unknowingly and thought they were cleared across the "next" runway.
2. Airport maintainers, who insure that signs, lights and markings are in order and clearly visible, who implement airport designs, and who mark areas and runways closed for construction. "THIS IS A RECURRING PROB, THERE IS NO INTENTION AT THIS TIME TO SPEND MONEY ON REPLACING THE SIGN WITH A PROPERLY DESCRIPTIVE ONE." (666402)
3. Pilots, who operate within the system. There were 16 cases of pilots crossing the runway cleared to, split equally among high and low end operators. "TAXI TO RWY 17… RWYS 17 AND 13… WERE BOTH ACTIVE. SINCE NO HOLD SHORT OF ANY TXWY OR RWY WAS GIVEN, ACCORDINGLY NO HOLD

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5 Multiple sources suggest that the problem is not new, but has not been previously reported.

6 Leveson, Nancy. "A New Accident Model for Engineering Safer Systems" http://sunnyday.mit.edu/accidents/safetyscience-single.pdf

7 Quotes in ALL CAPS are from ASRS reports, and the number in parentheses is the ASRS ACN (access control number).

SHORT INSTRUCTIONS WERE READ BACK. I UNDERSTOOD THAT I COULD CROSS BOTH RWYS." (626096)

4. Government, including controllers, briefers, NOTAM maintainers, showed inadequate attention to detail and procedures. "THE ACFT PASSED THE HOLD SIGN FOR RWY 28L/10R AND HELD SHORT OF THE RWY EDGE PAINT STRIPE. TFC WAS ROLLING OUT RWY 28L LNDG ROLL... THE CONCERN I HAVE IS THAT MY FELLOW CTLRS, INCLUDING THE CIC AT THE TIME WHO I BROUGHT THE INCIDENT UP TO, DID NOT UNDERSTAND THAT THIS IN FACT IS A RWY INCURSION." (663936)
5. Regulators, who write and update regulations and government publications. In my opinion, the suite of government regulations and guidelines need major revision. For example, the pilot / controller glossary contains this prose: "In the metering sense, a selectable adapted item which specifies the landing runway configuration or direction of traffic flow. The adapted optimum flight plan from each transition fix to the vertex is determined by the runway configuration for arrival metering processing purposes." All pilots will, of course, recognize that prose as the second half of the definition of "active runway."
6. Training material writers and approvers. Failings in online training and Flight Instructor Refresher clinics could be the subject of multiple papers. Other research indicated that online training materials for the FAA Wings program are not reviewed for correctness by the FAA, and AOPA Air Safety Foundation offerings were found to contain numerous errors.[8]
7. Operators and POIs, who specify operating procedures. "COMPANY PROC IS TO GET OUR WT AND BAL DATA DURING TAXI. DOING THIS PRIOR TO TAXI WOULD BE A MEANS OF REDUCING DISTRS DURING TAXI." (615367)
8. The general public. There seems to be public pressure to accept unknown risks for the unquantified perceived benefits of greater system capacity. "THEIR ATTEMPT TO COMPLETE TOO MANY OPS CREATED AN UNSAFE OP. LAHSO'S ARE NO LONGER ALLOWED ON THAT RWY AND THEY WERE TRYING TO DO IT 'UNDER THE TABLE.' " (577057) From a systems safety point of view, where are the policy documents quantifying the risks of and justifying such public policy?

Meaningful improvements will *not* come from ATC working on terminology in isolation; nor by a review of signage and markings in isolation; nor by recommendations for new procedures and rules; nor by any other system component being addressed in isolation. Systems engineering and safety science theory state that meaningful improvements will come when each component of the system is reviewed and improved within the context of the entire system.

Conclusions and Speculations

Although accidents are used to generate specific recommendations for improvement, modern safety science suggests that additional factors may be gleaned from the implications and hints present is the "soft" data of incident reports, such as were analyzed for this paper.

The reasonable inferences from this data set are:

1. Sufficient elements are currently in place to permit a multi-hull loss airline accident within boundaries of a major US airport. For example, there was a surface collision between two small freighters at Milwaukee on January 25, 2007, with one hull loss.
2. Unless sweeping and overdue improvements are made to the entire airport system, there is little reason to expect any significant improvement in runway incursion and taxi error rates. Training and additional flight crew procedures have not been shown to generate sufficient safety improvements.[9]
3. The most likely means of substantially reducing error rate is with a systems approach, re-examining all assumptions.
4. The greatest safety improvement available in the short term is to remove distractions from taxiing pilots, such as weight and balance calculations, company radio calls, and FMS programming. For airline crews, this may mean changes in SOPs so that whenever the aircraft is in motion, all crewmembers are paying full attention to the taxi task.
5. The frequent reports of controllers berating and allegedly unnecessarily delaying pilots indicate a need for prompt improvement.
6. The public policy that compromises the risks of runway incursions and taxi errors for greater system capacity and reduced regulatory costs does not seem to be documented and signed.

[8] Wischmeyer, Ed. "AOPA Air Safety Foundation Online 'Training,' Anybody Minding the Store?" InFlight USA, March, 2006, page 25. Published in San Mateo, CA.

[9] John Cox, personal conversation.

As one wide-body captain wrote after a near-collision at SFO, "WE (THE INDUSTRY) COULD DO BETTER ABOUT AIRING SOLUTIONS AS WELL AS HAMMERING INTO THE CREWS THAT WE HAVE A PROB." (614437)

Appendices

Appendix 1. *Number of reports by airport for "high end" operators (air carrier, air taxi, charter, corporate, government, military)*

Rank	Airport	Number	Rank	Airport	Number
1	ORD	31	13	LAS	13
2	CLE	26	14	EWR	12
3	MIA	22	15	SAT	11
3	PHL	22	15	CLT	11
5	DFW	21	17	CYYZ	10
6	SFO	19	17	MKE	10
7	LAX	16	17	SNA	10
8	ATL	15	17	TEB	10
8	MDW	15	21	IAD	9
10	BOS	14	22	CVG	8
10	BWI	14	22	LGB	8
10	LGA	14	22	ONT	8
			22	STL	8

Appendix 2. *Number of reports by airport for "Low End (GA)" operators (personal and instructional)*

Rank	Airport	Number	Rank	Airport	Number
1	LGB	13	4	SBA	6
2	HOU	7	6	PBI	5
2	PDK	7	7	DAB	4
4	SGJ	6	7	HPN	4

Appendix 3. *Reports by operator category*

Air Carrier / Major	378
Air Carrier / Regional	129
Air Taxi	53
Charter	14
Corporate	138
Government	5
Military	6
Total "high end" reports	732
Instructional	44
Personal	282
Total "low end" reports	326

Quotes from Privileged Safety Sources

- I was in a car [at a confusing taxiway intersection] with a controller supervisor who'd been working there 15 years, and he said, I don't know where we are.
- I knew what I was looking for, and it was still ready hard. (at North Las Vegas)

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About the Author

Ed Wischmeyer was the lead engineer on major safety projects for NASA Ames, Honeywell, and Boeing, and spent two years teaching graduate-level aviation safety courses. Over the years, he has contributed substantially to aviation operational safety as a volunteer to the Experimental Aircraft Association, AOPA, and FAA. His papers are at www.greatusermanuals.com/clips.

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