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Runway Incursions at U.S. Airports, 2017–2026: How Airfield Geometry, Operations, and Human Factors Shape Safety

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ABSTRACT

Runway incursions are the most closely watched measure of surface safety at U.S. airports, and the serious close calls of 2023 put them back under scrutiny. Federal Aviation Administration (FAA) runway incursion totals by type, month and region for fiscal years 2017 through 2026, are divided by FAA Operations Network airport operations and tested for trend and seasonality with Poisson regression. The coded fields and keyword-coded narratives of 1,528 NASA Aviation Safety Reporting System (ASRS) runway incursion reports from 2015 through 2025 are examined separately. Incursions fell from 34.7 per million operations in FY2017 to 28.6 in FY2025, an overall decline of approximately 2.0% per year. Pilot deviations showed a statistically significant decline and accounted for approximately 85% of the overall rate reduction. No significant trend was detected for controller operational incidents. Incursions per operation are about 16% higher in June than in January. Situational awareness (70%), communication breakdown (58%) and confusion (35%) dominate the coded factors. Controller reports more frequently include distraction and workload codes than pilot reports. Hold-short instructions and readbacks, signs, markings and lighting, construction and expectation bias recur in the narratives, and the airport is a contributing factor in 36% of reports. The results show where airfield geometry changes, phraseology discipline, vehicle-operator training and surface-detection technology are most likely to pay off.

Keywords: Runway incursion, Surface safety, Human error, ASRS, Air traffic control, Pilot deviation, Airfield geometry

INTRODUCTION

A runway incursion is "any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle or person on the protected area of a surface designated for the landing and take-off of aircraft" (International Civil Aviation Organization, 2007). The FAA classifies each incursion by type and severity (Federal Aviation Administration, 2026d). By type, it is an operational incident (OI) when an air traffic controller's action caused it, a pilot deviation (PD) when a pilot violated a clearance or a regulation, or a vehicle or pedestrian deviation (V/PD) when a vehicle driver or pedestrian entered the movement area without authorization. By severity, it is rated

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from A, a serious incident in which a collision was narrowly avoided, to D, an incident with no immediate safety consequence. About 1,700 incursions are recorded each year at towered U.S. airports, mostly in categories C and D. Serious events, A and B, rose from 16 in FY2022 to 22 in FY2023 and fell to 9 in FY2024 (U.S. Department of Transportation Office of Inspector General, 2025). The near collisions at New York Kennedy in January 2023 and Austin in February 2023 involved flightcrew and controller errors, respectively (National Transportation Safety Board, 2024a, 2024b). These events prompted the FAA to issue a safety call to action, convene an aviation safety summit in March 2023 and accelerate the deployment of surface-surveillance and runway-alerting technology (Federal Aviation Administration, 2023, 2026e).

One line of research treats runway incursions as human-error events and classifies the mechanisms with frameworks such as the Human Factors Analysis and Classification System (HFACS). Communication errors between controllers and pilots, loss of situational awareness, expectation bias, distraction and memory lapses recur in studies of pilot deviations and controller errors (Cardosi and Yost, 2001; Wiegmann and Shappell, 2003; Chang and Wong, 2012; Yan, Boufous and Molesworth, 2024), including the earlier analyses of ASRS pilot reports (DiFiore and Cardosi, 2006). A second line treats the airfield as a latent condition. Complex intersections, taxiways that give direct access from an apron to a runway, wide expanses of pavement and closely spaced parallel runways concentrate incursions at identifiable locations. The FAA charts 555 hot spots at 286 airports in the Chart Supplement. Its Runway Incursion Mitigation (RIM) program inventories locations with three or more incursions in one year or an average of at least one per year, currently encompassing 134 locations at 77 airports. Since 2015 the program has prioritized 248 locations for mitigation and mitigated 112 of them, with about 77% fewer incursions per year at mitigated locations (Federal Aviation Administration, 2024, 2026b; Healey et al., 2026). Statistical models likewise relate incursion counts and severity to airport layout, intersections and traffic (Wilke, Majumdar and Ochieng, 2015; Mathew et al., 2017). A third line evaluates the defenses including surface surveillance, runway status lights, cockpit moving maps and alerting, phraseology and vehicle-driver training (Schönefeld and Möller, 2012).

This study examines national incursion statistics, normalized by traffic, alongside human-factors information from incident reports describing how incursions unfold. Therefore, it characterizes U.S. runway incursion trends by type, rate per operation, season and region for fiscal years 2017 through 2026. It then examines human factors, operational conditions and recovery actions described in 1,528 ASRS runway incursion reports from 2015–2025. Reported airfield conditions are also examined to inform airfield design, training, procedures and surface-safety technology deployment.

DATA AND METHODS

National incursion counts come from the FAA Runway Safety dashboard, which publishes the Air Traffic Organization's runway incursion totals by

fiscal year, month, incursion type and FAA region for all towered airports (Federal Aviation Administration, 2026c). Monthly counts cover October 2016–August 2026, including eleven months of FY2026. Exposure was taken from the FAA Operations Network (OPSNET) through the Air Traffic Activity Data System, which counts itinerant and local operations at every FAA and contract tower (Federal Aviation Administration, 2026a). The same eleven months were used for FY2026. The omitted month, September, has a pooled rate close to the annual mean, so the eleven-month FY2026 rate is comparable with full-year rates to within about 0.4%. The most recent months are subject to revision, and FY2026 was excluded from the trend models. Trends for FY2017 through FY2025 were estimated by Poisson regression of the annual count on fiscal year with the logarithm of operations as an offset and an indicator for the pandemic years FY2020 and FY2021. To account for overdispersion in the annual counts (Pearson dispersion 5.0 for all incursions, 2.8 for pilot deviations, 1.6 for operational incidents and 1.8 for vehicle and pedestrian deviations), standard errors were multiplied by the square root of the dispersion (quasi-Poisson) and confidence intervals use the t-distribution with 6 residual degrees of freedom. Seasonality was examined by pooling the nine complete fiscal years by calendar month and comparing monthly incursion totals with the distribution of operations using a chi-square test. A monthly Poisson model included month indicators, a linear trend and the pandemic indicator. Month effects were evaluated using a dispersion-scaled F test.

Incident reports were retrieved from the ASRS database through the FAA Aviation Safety Information Analysis and Sharing (ASIAS) portal (National Aeronautics and Space Administration, 2026). All 59,603 reports with an event date from January 2015 through December 2025 were downloaded with their coded fields and narratives, and the 1,528 reports whose anomaly coding includes a runway incursion (2.6% of all reports) form the study set. ASRS analysts code each report with the reporter's function and organization, the aircraft operator and operating rule, flight phase, light and weather, the detector, the primary problem and contributing factors, the result, and up to twelve human-factors codes. Reports were classified by reporter role, aircraft operator and operating rule. Reporter roles included pilot, controller, ground personnel, or mixed when both a pilot and a controller reported the same event. Operator categories included air carrier, corporate or fractional, personal or training general aviation, air taxi, and military. Reports with mixed operators were assigned using the hierarchy Part 121, Part 135, then Part 91. Codes are reported as percentages of reports containing them. Light and weather are coded in only 70% and 67% of reports.

Narratives were coded with a dictionary of eighteen themes derived from HFACS preconditions and from the runway-safety literature, each defined as a case-insensitive regular expression applied to the narrative, synopsis and callback text. Each report counts once per theme. A theme means the narrative mentions the item, whether the item caused the event. The ten most frequent appear with the results. ASRS data are voluntary, de-identified self-reports describing reported circumstances rather than population incidence. Airport identifiers appear in only some reports.

RESULTS

National Totals, Rates and Trends

Table 1 and Figure 1 summarize the FAA totals. Runway incursions numbered 1,745 in FY2017 and 1,636 in FY2025, with a trough of 1,261 in the pandemic year FY2020, while airport operations grew from 50.3 to 57.3 million. The incursion rate therefore declined from 34.7 to 28.6 per million operations. The dispersion adjusted Poisson model gives a rate ratio of 0.982 per year (95% CI 0.965–0.999), a decline of about 1.8% per year. The decline is concentrated in pilot deviations, whose rate fell from 22.6 to 17.4 per million operations (rate ratio 0.975, CI 0.960–0.991) and which account for about 85% of the fall in the overall rate. Vehicle and pedestrian deviations fell less clearly (0.979, CI 0.955–1.003). No significant trend was detected for operational incidents, the controller-attributed events (0.989, CI 0.967–1.011). The pilot-deviation and operational-incident slopes do not differ significantly ($p = 0.22$). The pandemic indicator shows that operational incidents per operation were about 30% lower in FY2020–FY2021 (rate ratio 0.70, CI 0.59–0.83), while pilot and vehicle deviations per operation were not. The timing complicates a traffic explanation. The operational-incident rate had already fallen to 3.9 per million operations in October 2019 to March 2020, before traffic declined, against 6.2 in the same months of FY2017–FY2019 and stayed near 3.5 until March 2021. Whether lighter traffic, staffing or a change in how controller errors were identified explains the dip cannot be determined from aggregate totals. The first eleven months of FY2026 (1,367 incursions, 26.4 per million operations against 28.4 in the same months of FY2025) are consistent with a lower rate, though the counts for the spring and summer of 2026 are preliminary.

Table 1: Runway incursions at U.S. towered airports by fiscal year and type (OI operational incident, PD pilot deviation, V/PD vehicle or pedestrian deviation), airport operations in millions and rates per million operations (*FY2026: October 2025–August 2026, preliminary).

Fiscal Year	OI	PD	V/PD	Other	Total	Operations (Millions)	Rate	PD Rate	OI Rate	V/PD Rate
FY2017	306	1,139	293	7	1,745	50.3	34.7	22.6	6.1	5.8
FY2018	344	1,131	332	10	1,817	51.8	35.1	21.8	6.6	6.4
FY2019	324	1,118	295	16	1,753	53.3	32.9	21.0	6.1	5.5
FY2020	164	841	241	15	1,261	44.4	28.4	19.0	3.7	5.4
FY2021	226	1,033	285	30	1,574	47.7	33.0	21.6	4.7	6.0
FY2022	309	1,084	311	26	1,730	52.6	32.9	20.6	5.9	5.9
FY2023	338	1,070	308	44	1,760	54.5	32.3	19.6	6.2	5.6
FY2024	315	1,081	306	56	1,758	56.5	31.1	19.1	5.6	5.4
FY2025	330	999	265	42	1,636	57.3	28.6	17.4	5.8	4.6
FY2026*	272	800	269	26	1,367	51.9	26.4	15.4	5.2	5.2

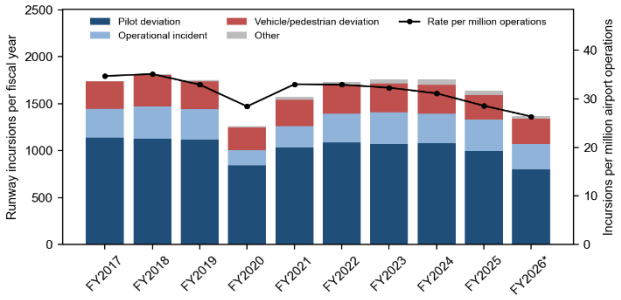


Figure 1: Runway incursions by type and fiscal year (bars) and incursions per million airport operations (line), FY2017–FY2026 (FY2026 through August).

Seasonality and Regional Distribution

Most of the month-to-month variation in incursions follows traffic. After pooling FY2017–FY2025 by calendar month and dividing by operations, the rate still varies from 29.8 per million operations in February to 34.9 in June, about 9% above the annual mean. A chi-square test against an operations-proportional distribution gives 33 on 11 degrees of freedom. However, the monthly counts are over dispersed (dispersion 1.47) and the dispersion-scaled test of the eleven-month indicators gives $p = 0.02$. Rate ratios relative to January are 1.10 (95% CI 1.00–1.22) in May, 1.16 (1.05–1.28) in June, 1.12 (1.02–1.24) in July and 1.11 (1.01–1.23) in September. Only June remains significant after adjustment for eleven comparisons. Excluding FY2020–FY2021 reduces the June rate ratio to 1.06 (0.97–1.16) and the overall month effect is no longer significant ($p = 0.15$). The excess is present in all three types and is largest for vehicle and pedestrian deviations in June (7.2 per million operations against 5.0 in February). The data do not say why. Airfield construction, grounds maintenance and flight training all peak in the warm months, but none of them is measured here.

By region, the Western Pacific (Arizona, California, Hawaii, Nevada and the Pacific) recorded 420 incursions in FY2025, 26% of the national total, followed by the Southern and Great Lakes regions. Between FY2017 and FY2025 counts fell in eight of the nine regions and rose only in the Central region (+31%). The largest proportional changes, in Alaska (−32%) and the Central region, involve small counts within the range of year-to-year Poisson variation. The pilot-deviation share in FY2025 ranged from 51% in the Southwest region to 77% in the Central region. Where it is lowest, vehicle and pedestrian deviations and operational incidents make up more of the total. The FAA totals do not identify operator types, so the share cannot be related to the regional traffic mix here.

ASRS Report Characteristics

Table 2 describes the 1,528 ASRS runway incursion reports. Pilots submitted 75% of the reports and controllers 19%. In 5% of events both a pilot and a controller filed a report. Ground-personnel reports are rare in this sample,

so vehicle and pedestrian deviations, a sixth of FAA incursions, are seen here through the pilots and controllers who encountered them. The flight phase (more than one may be coded) is taxi in 53% of reports, take-off in 34%, landing in 30% and final approach in 21%, the pattern of an aircraft or vehicle crossing a hold-short line while another aircraft is departing or arriving. Where coded, daylight (80%) and visual meteorological conditions (93%) prevail. With no exposure denominator, these shares describe the typical report and cannot show whether darkness or low visibility raises risk. The event was detected by the flight crew in 65% of reports and by air traffic control (ATC) in 39%. A ground conflict was coded as critical in 38% and less severe in 20%. Recorded outcomes include crew evasive action (29%), revised ATC clearance (24%), requests for ATC clarification (16%), go-arounds (11%) and rejected take-offs (6%). Crew reorientation was recorded in 17% of reports.

Table 2: Characteristics of the 1,528 ASRS runway incursion reports, 2015–2025, percent of reports (categories other than reporter role and operating rule are not mutually exclusive, GA general aviation, VMC visual and IMC instrument meteorological conditions, light and weather percentages are of coded reports only).

Attribute	Value	%	Attribute	Value	%
Reporter role	Pilot	74.7%	Flight phase	Taxi	53.4%
	Controller	18.7%		Take-off	33.7%
	Both pilot and controller	5.4%		Landing	30.2%
Operator	Air carrier	35.0%		Final approach	21.3%
	GA personal or training	34.6%	Light (coded)	Daylight	80.3%
	Corporate or fractional	8.8%		Night, dusk or dawn	19.7%
Operating rule	Part 121	34.1%	Weather (coded)	VMC	92.6%
	Part 91	54.3%		IMC, marginal or mixed	7.4%
Conflict	Critical ground conflict	37.8%	Detected by	Flight crew	65.4%
	Less severe ground conflict	19.6%		Air traffic control	38.7%

Human Factors

Figure 2 gives the human-factors codes. Situational awareness is cited in 70% of reports, communication breakdown in 58%, confusion in 35%, distraction in 23%, time pressure in 15%, workload in 13% and training or qualification in 11%. Fatigue (2.1%) and human-machine interface (3.3%) are less frequently coded. Where a communication breakdown is coded, the parties are the flight crew and ATC in 32% of all reports and two members of the same flight crew in 17%, so roughly one breakdown in three occurs inside

the cockpit, between the pilot flying and the pilot monitoring. Controllers cite distraction (43% against 17% for pilots) and workload (24% against 10%) more frequently, and confusion (40% against 32%) somewhat more often. Pilots cite communication breakdown in 58% of their reports and controllers in 55%, and the pilots' situational-awareness lapses are typically a missed hold-short line, a wrong turn at an intersection or an assumption that a clearance had been received. By operator, air carrier and general aviation reports are similar except that a training or qualification code appears in 13% of general aviation reports and 5% of air carrier reports, as expected, since general aviation includes flight training.

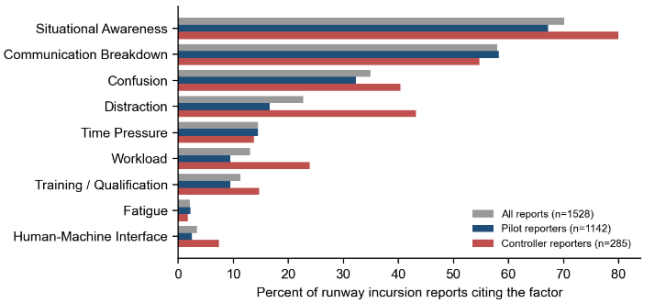


Figure 2: Human-factors coding percentages by reporter role, ASRS, 2015–2025.

Airfield Geometry, Operating Conditions and Narrative Themes

The airport is coded as a contributing factor in 36% of reports, procedure in 43%, non-weather environment (construction, lighting, glare) in 12% and charts or publications in 8%, and 781 reports (51%) retain an airport identifier covering 406 airports. The most frequent are Chicago O'Hare (24), San Francisco (17), Los Angeles (15), Dallas-Fort Worth (13) and Boston Logan (11), all large hubs with multiple intersecting or closely spaced runways and published hot spots. Table 3 gives the ten most frequent of the eighteen narrative themes. A hold-short instruction is mentioned in 36% of narratives and a readback or hear back in 13%, rising to 27% of controller narratives: the pilot reads back a hold-short instruction and crosses anyway, reads back a different runway, or the controller fails to catch an incorrect readback. Signs, markings or lighting are mentioned in 22% of narratives, construction or closed surfaces in 9% (and in 14% of controller narratives), and the term "hot spot" itself in 5%, so the published hot spots are known to the people who still err there. Line-up-and-wait or take-off clearance confusion, the mechanism of several of the 2023 serious incursions, is mentioned in 10% of narratives and in 15% of controller narratives. Student or instructional flights appear in 13%, distraction, task saturation or heads-down time in 9%, night or low visibility in 9%, and expectation bias (an assumed or anticipated clearance) in 7%. Technology appears mainly at the recovery stage. Moving maps and airport diagrams are mentioned in 7% of narratives, usually as how a crew recognized its position, and surface-surveillance or

runway-status-light alerts in 4%, almost exclusively in controller narratives (14%), as the alert that prompted a cancelled take-off or a go-around. A go-around or rejected take-off is the recovery in 23% of narratives.

Table 3: Themes mentioned in ASRS runway incursion narratives, 2015–2025 (ten most frequent of eighteen): reports matching each theme and percent of all, pilot and controller narratives.

Theme	Reports	% All	% Pilot	% Controller
Hold-short instruction mentioned	554	36.3%	34.5%	37.9%
Go-around or rejected take-off as recovery	353	23.1%	20.1%	30.9%
Signs, markings or lighting mentioned	331	21.7%	21.4%	17.9%
Readback or hear back mentioned	202	13.2%	8.0%	27.0%
Student or instructional flight	196	12.8%	13.5%	11.2%
Line-up-and-wait or take-off-clearance confusion	157	10.3%	7.8%	15.1%
Distraction, task saturation or heads-down	141	9.2%	9.2%	9.8%
Construction or closed surface	139	9.1%	7.4%	13.7%
Night or low visibility	137	9.0%	8.0%	10.9%
Moving map or airport diagram	108	7.1%	8.7%	0.0%

DISCUSSION

The national rate of incursions per operation is falling by roughly 2% a year, and the improvement comes from pilot deviations. No decline was detected for operational incidents, whose rate per operation has been essentially level since FY2017 and fell only in FY2020–FY2021. The most serious event of 2023, at Austin, turned on a controller's decision to clear a departure with an arrival on short final in low visibility (National Transportation Safety Board, 2024b), and controller narratives in ASRS are dominated by distraction, workload and confusion. The local controller's task environment (staffing, combined positions and memory aids) therefore deserves attention. Whether operational incidents are over-represented among category A and B incursions cannot be tested with aggregate totals. The typical reported incursion in this dataset happened in daylight and visual conditions, when a crew or a controller lost track of where an aircraft was relative to a hold-short line, often after a readback that sounded correct. The ASRS codes and narratives agree that situational awareness and communication matter most, and that a substantial share of communication failures occur within the cockpit. That argues for cross-check procedures during taxi, sterile-cockpit discipline and both pilots verbalizing hold-short instructions, as much as for phraseology on the frequency. One report in three names the airport as a contributing factor and one in five mentions signs, markings or lighting. The FAA's RIM program and hot-spot designations target these conditions. The Western Pacific region contains 61 of the 134 current RIM locations and records the most incursions (Federal Aviation Administration, 2026b). Some narratives name the hot spot, so awareness alone is not enough where

the geometry invites the error. Geometric fixes (removing direct apron-to-runway access, eliminating acute-angle intersections and wide pavement expanses, standardizing taxiway naming) remove the opportunity to err, and the reduction reported at mitigated RIM locations is consistent with that reading (Healey et al., 2026).

The seasonal pattern, if it holds up, has a practical use. Incursions per operation run higher in late spring and summer, and vehicle and pedestrian deviations peak in June. Construction, mowing and training activity are plausible contributors, though none was measured, and airport operators and runway safety action teams could schedule driver refresher training, construction-phasing briefings and hot-spot reviews ahead of that period at little cost. A quarter of all incursions occur in the Western Pacific region, where pilot deviations make up 67% of events and general aviation training airports are concentrated. Outreach to flight schools there, adding taxi planning and readback discipline to the private-pilot syllabus, would target a large share of events.

The results support the FAA's post-2023 emphasis on surface-detection technology and runway alerting. The FAA is expanding surface-surveillance coverage through its Surface Awareness Initiative (Federal Aviation Administration, 2026e). The narratives add a caveat. The technology is a last line of defense that lets the controller intervene after the incursion has begun, and cockpit runway alerting is still rare outside large air carriers. Moving maps with own-ship position, which crews cite as how they recognized a wrong turn, are a low-cost defense for the general aviation and corporate aircraft that generate most pilot deviations.

This analysis has limits. FAA totals are available only in aggregate, so rates by airport and by severity could not be computed, and the comparison of regions is unadjusted for traffic. ASRS reports are voluntary and self-selected, which encourages pilot reporting of pilot deviations and under-represents vehicle operators, so proportions in the ASRS set describe how reported incursions unfold, not how often. The narrative coding is lexical. It counts mentions regardless of cause and misses themes worded differently. Airport identifiers are also stripped from part of the reports, so the link between individual hot spots and incursion reports remains qualitative.

CONCLUSION

Runway incursions at U.S. towered airports fell from 34.7 to 28.6 per million operations between FY2017 and FY2025. Pilot deviations accounted for approximately 85% of the rate reduction. No significant trend was detected for controller operational incidents. In the 1,528 ASRS reports, the typical incursion is a daylight, visual-conditions event built on lapses of situational awareness and on communication breakdowns, inside the cockpit as well as with ATC. Controllers report distraction and workload far more often than pilots. Hold-short instructions and readbacks, signs, markings and lighting, construction and instructional flights recur in the narratives, and the airport is a contributing factor in a third of reports. Surface safety depends on airfield geometry that does not invite the error, procedures that verify position and

clearance instead of assuming them, vehicle-operator training timed to the construction season, and surveillance and alerting technology that gives a last chance to stop. Public FAA and ASRS data allow continued monitoring of trends following post-2023 safety initiatives.

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