

A Study of U.S. Inflight Icing Accidents and Incidents, 1978-2005

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Study Scope

- All U.S. accidents from 1978 through 2005
- All U.S. reportable incidents from 1978 through 2005
- All NASA ASRS reports related to inflight icing from 1988 through 2002

Data Sources

- National Transportation Safety Board
 - On-line database “Accident Synopses - By Month”
 - 140,859 reports downloaded (1962-2002)
 - 4554 reports queried on-line (2003-early 2006)
- National Aviation Safety Analysis Center (now ASIAS)
 - On-line database “FAA Accident/Incident Data System”
 - 88,093 events queried
 - On-line database “Aviation Safety Reporting System”
 - 112,700 reports queried

Evaluation Criteria

- Events which involved an aerodynamic occurrence due to icing anytime after the completion of the takeoff phase
 - Takeoff events were not included
 - Powerplant events were not included
 - Windshield events were screened for inclusion
 - Hard landings which remained on the runway centerline were included
 - Hard landings which departed from or missed the runway centerline were not included

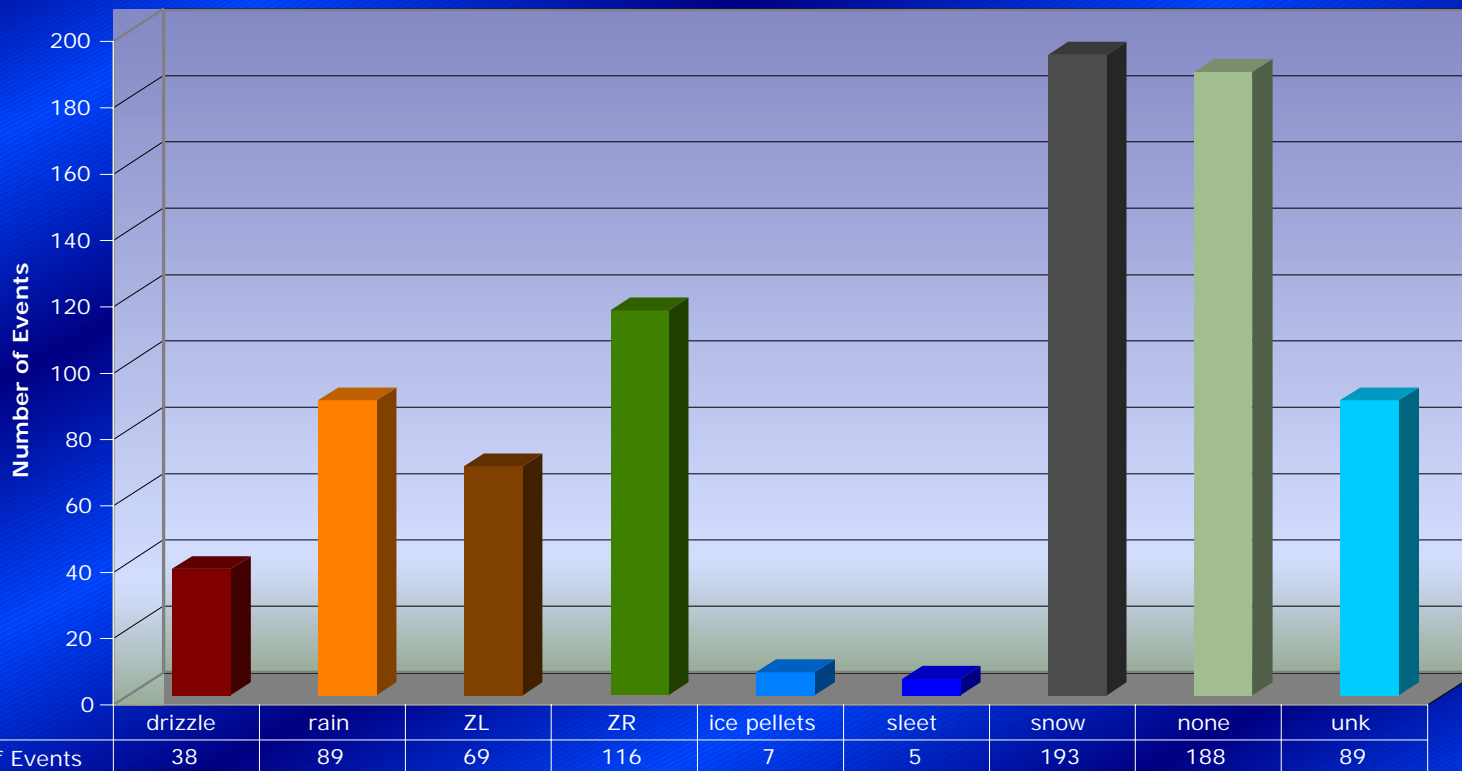
Current Database

- Master database composed of:
 - 556 NTSB reports
 - 142 AIDS reports
 - 101 data fields
- ASRS database composed of:
 - 299 reports
 - 20 data fields

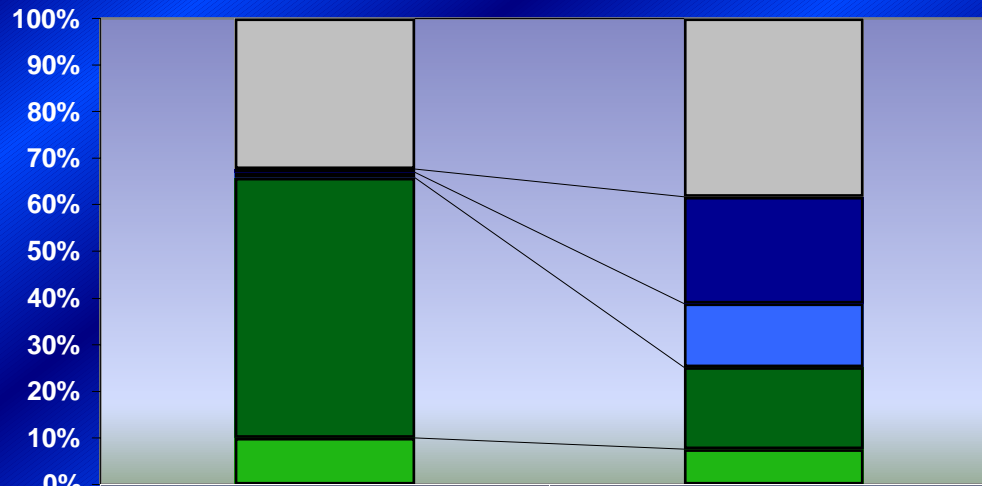
Study Results

- Surface Observation Data
- Scale
- Certification
- Pilot Experience
- Operating Rule
- IPS Operation
- Historical Trends
- Conclusions

Precipitation Associated with Icing Events



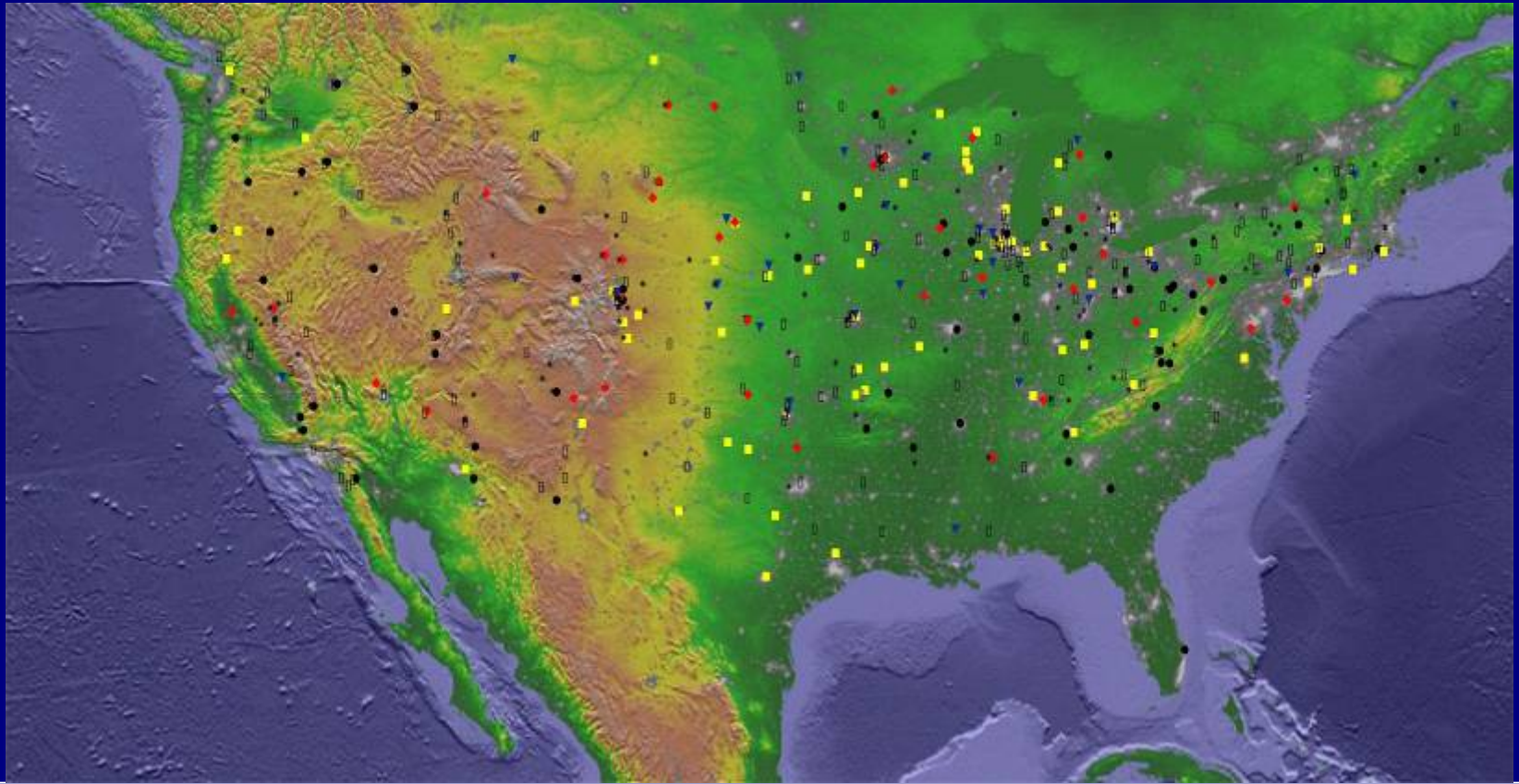
Number of Events Normalized to 30 Year Surface Observation Summary



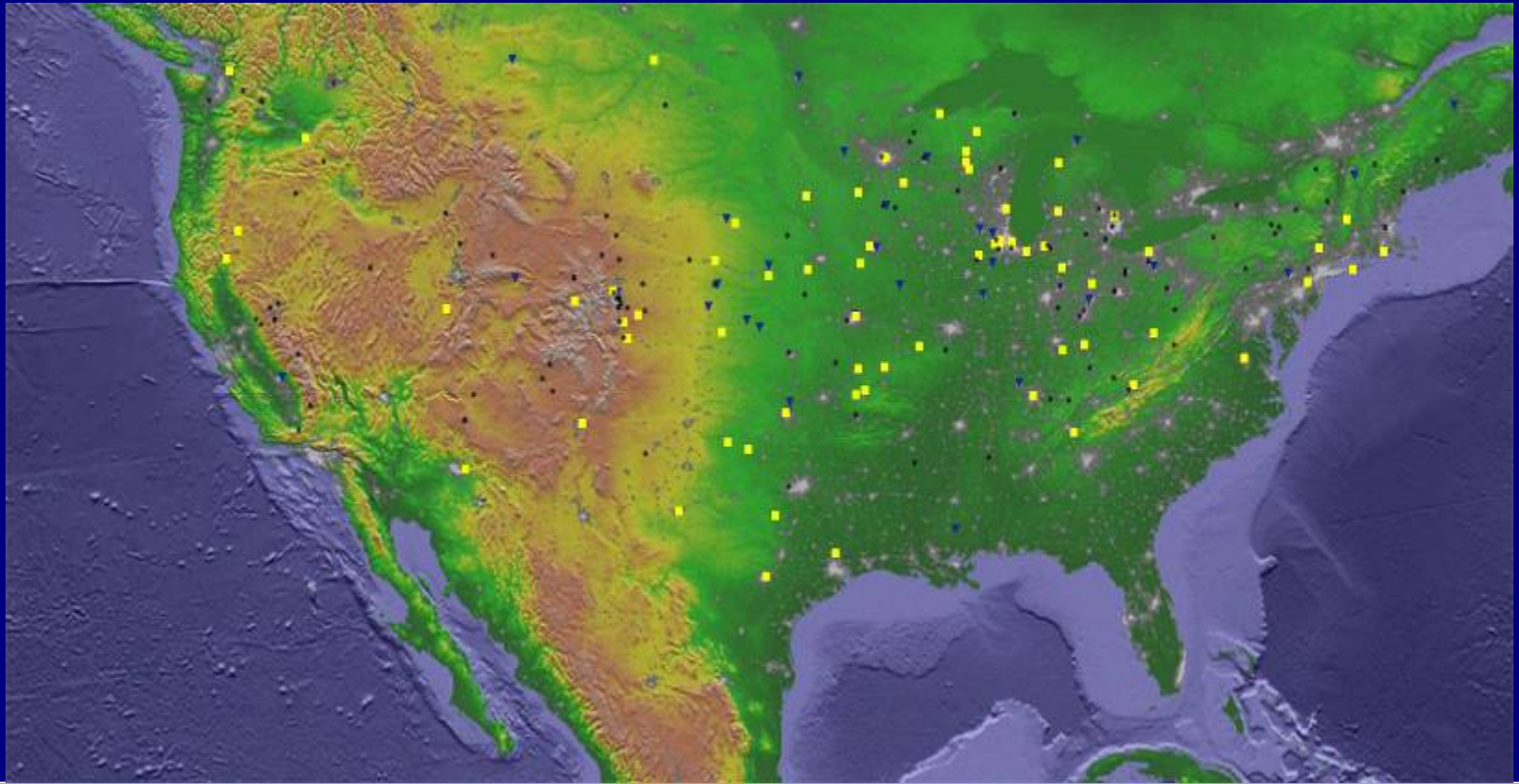
	Precipitation Reports	Icing Events
■ snow	1,587,054	193
■ FZRA	36,417	116
■ FZDZ	50,332	69
■ rain	2,742,978	89
■ drizzle	490,046	38

■ drizzle ■ rain ■ FZDZ ■ FZRA ■ snow

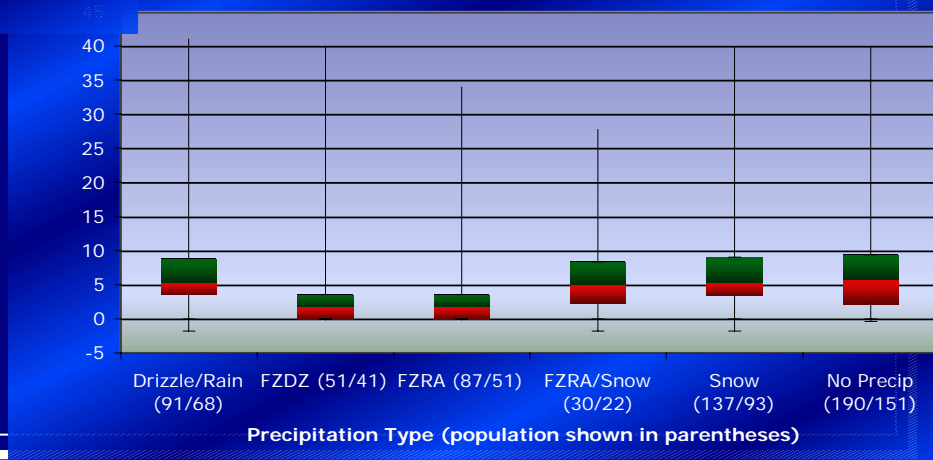
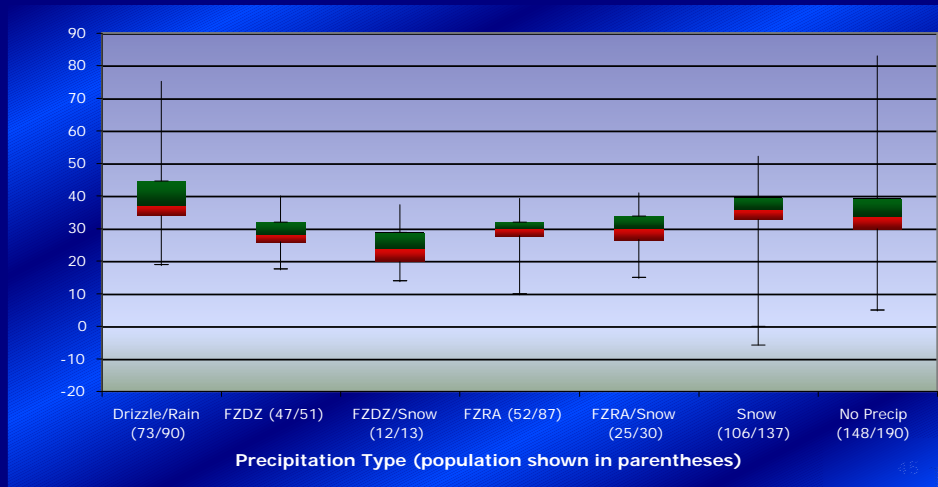
Geographic Distribution of Complete Database



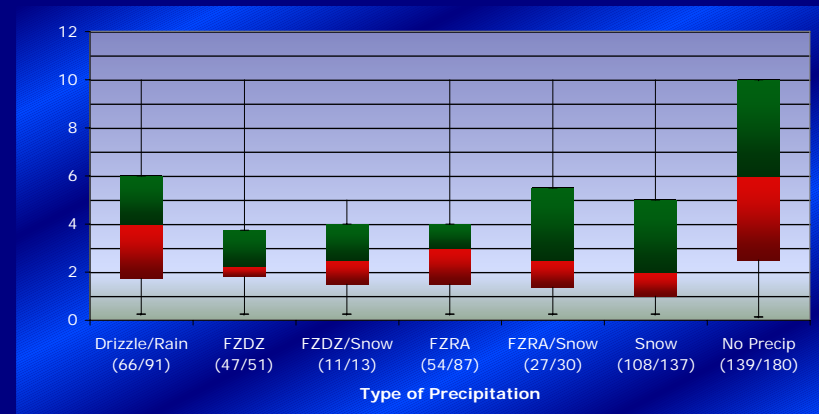
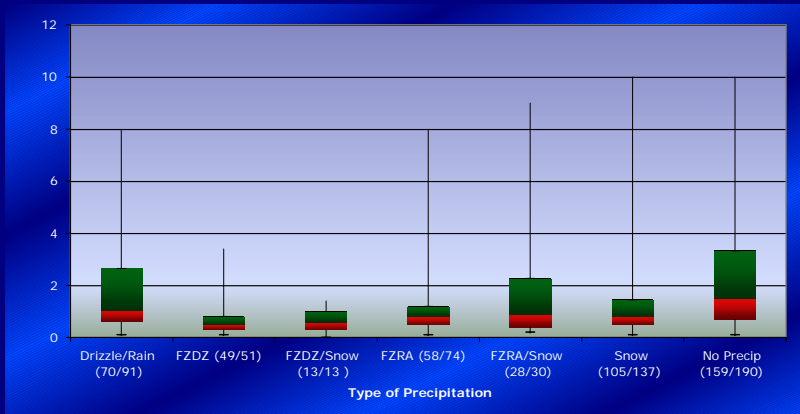
Geographic Distribution of Freezing Precipitation and Snow Events



Surface Temperature and Temperature – Dew Point Spread Reported with Types of Precipitation



Cloud Ceiling and Surface Visibility Reported with Types of Precipitation



Typical Surface Conditions Model

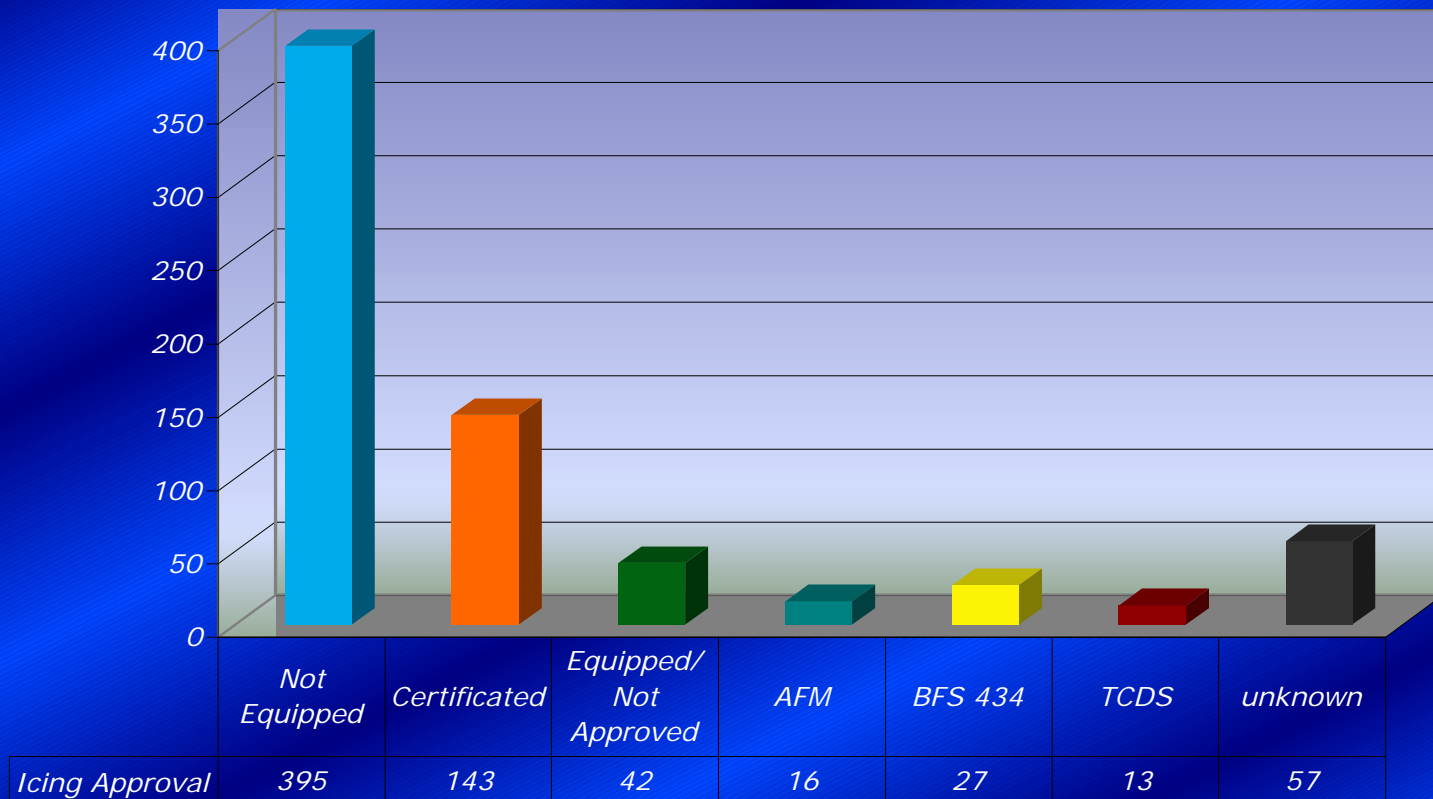
Statistical Measure	Encounter Altitude*	Ceiling	Visibility	Surface Temperature	Temp-Dew Point Spread
IQM	6494 feet*	856 feet	3.98 statute miles	0.09°C	1.83°C
1st Quartile	4000 feet*	400 feet	2.00 statute miles	-2.20°C	1.00°C
3rd Quartile	11000 feet*	2000 feet	8.00 statute miles	2.20°C	3.89°C

*Data obtained from protected aircraft only

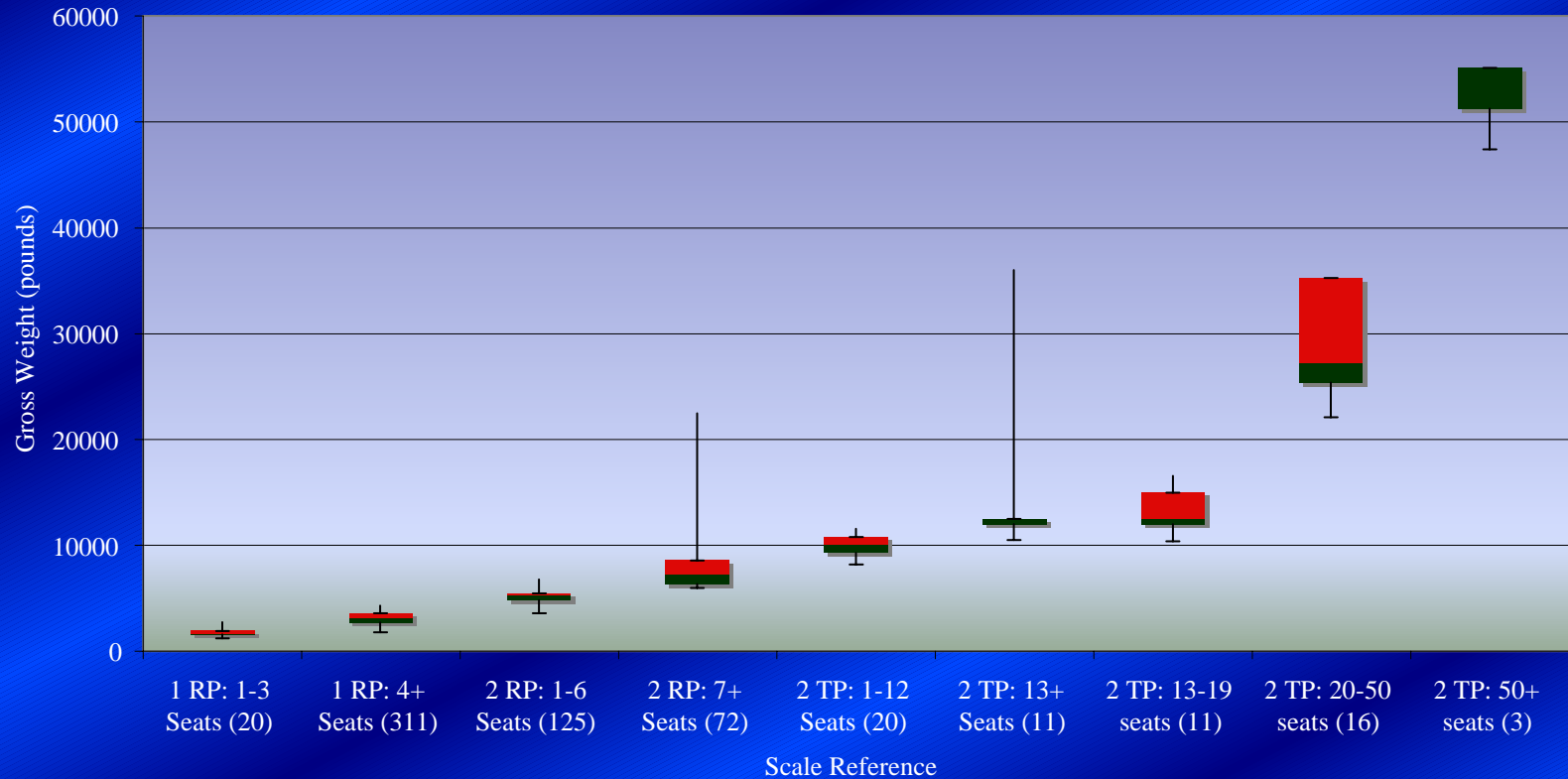
Scenario Models

- Early Landing Decision
 - Successful in less than 25% of reportable events
- Maintain Altitude
 - Typical in western states
- No problem until approach
 - Undershoot, hard landing, stall/loss of control
- No problem until landing flare
 - Hard landing

Icing Equipment and Approvals



Distribution of Gross Weight Based on Modified GAATA Scale Index



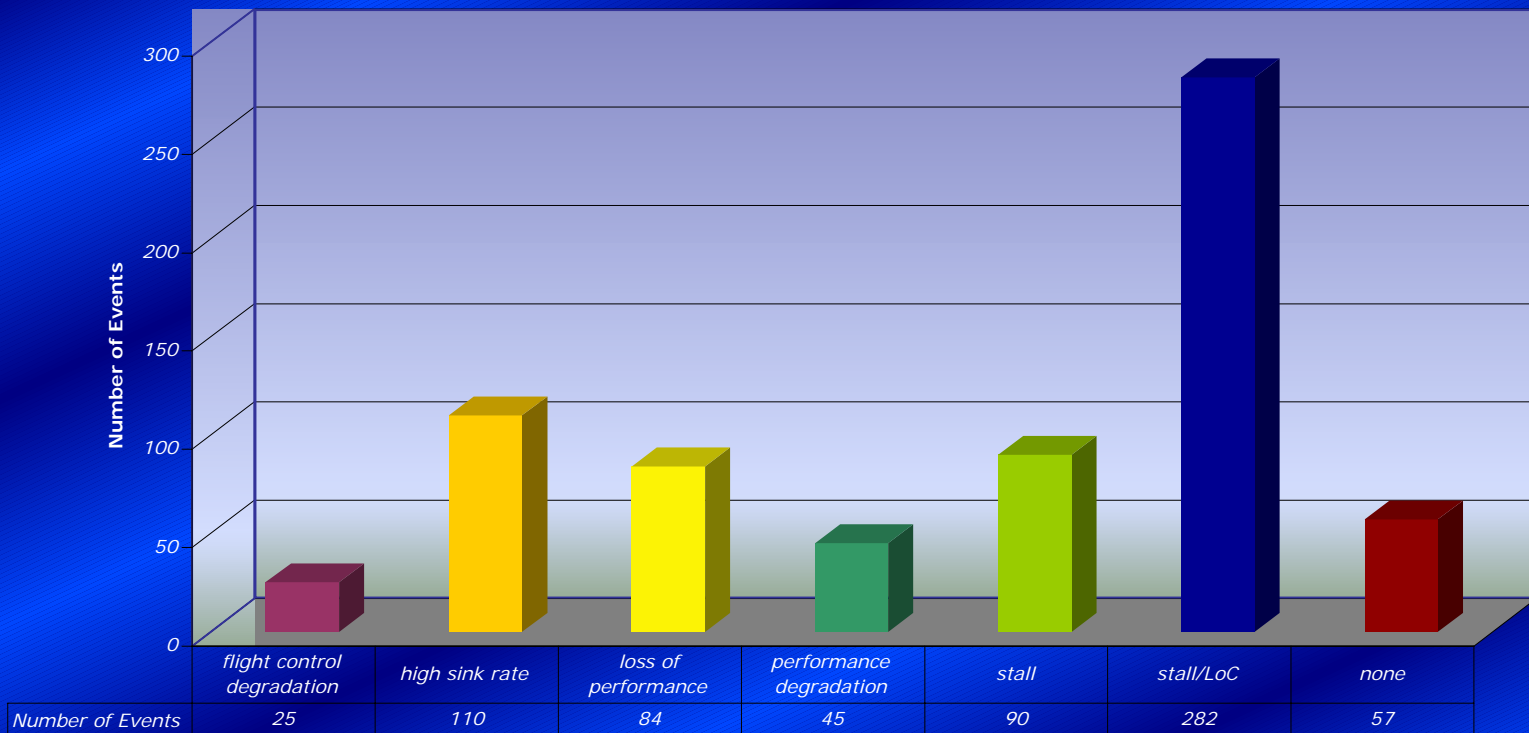
Aerodynamics, Stability or Control Events

- “ASC” events:
 - Stall
 - Loss of Control
 - High Sink Rate
 - Loss of Performance
 - Performance Degradation
 - Flight Control Degradation

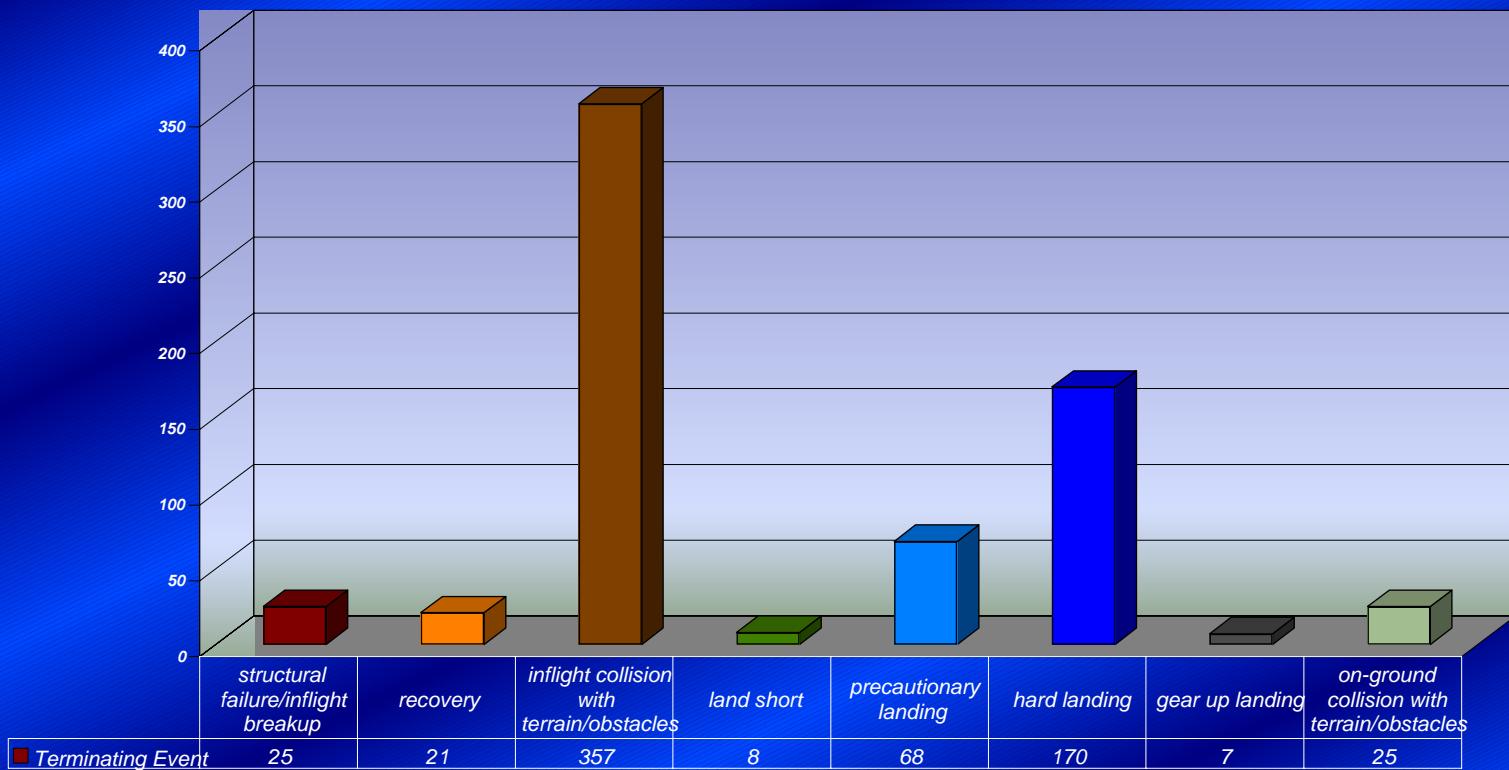
Terminating Event

- Terminating Events:
 - Inflight Collision with Terrain/Water
 - Hard Landing
 - Inflight Breakup/Structural Failure
 - Land Short
 - Precautionary Landing

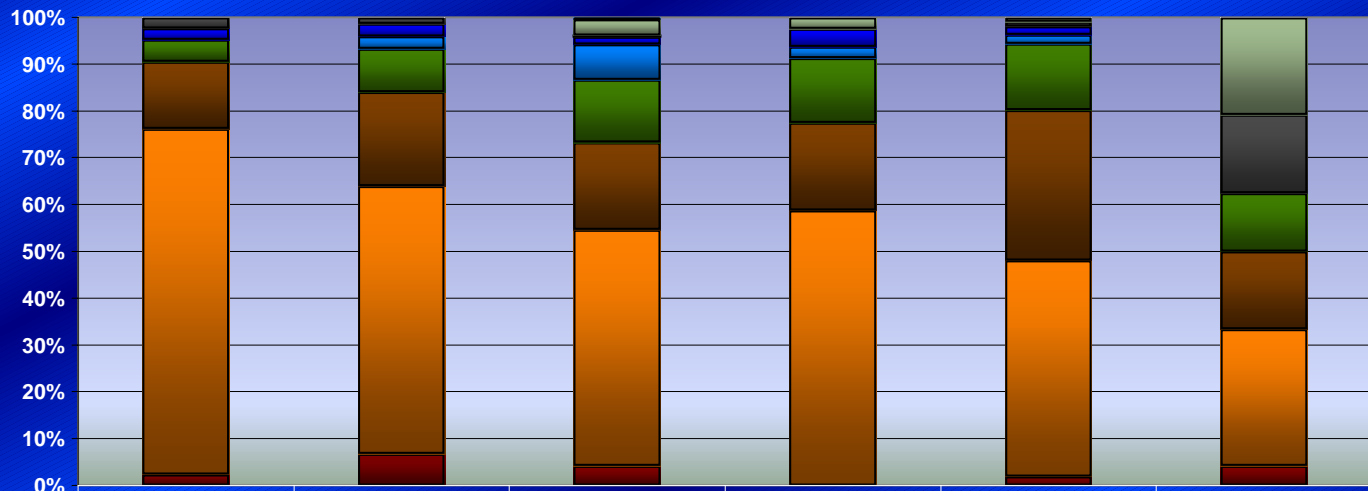
Distribution of Primary ASC Occurrences



Distribution of Terminating Occurrences

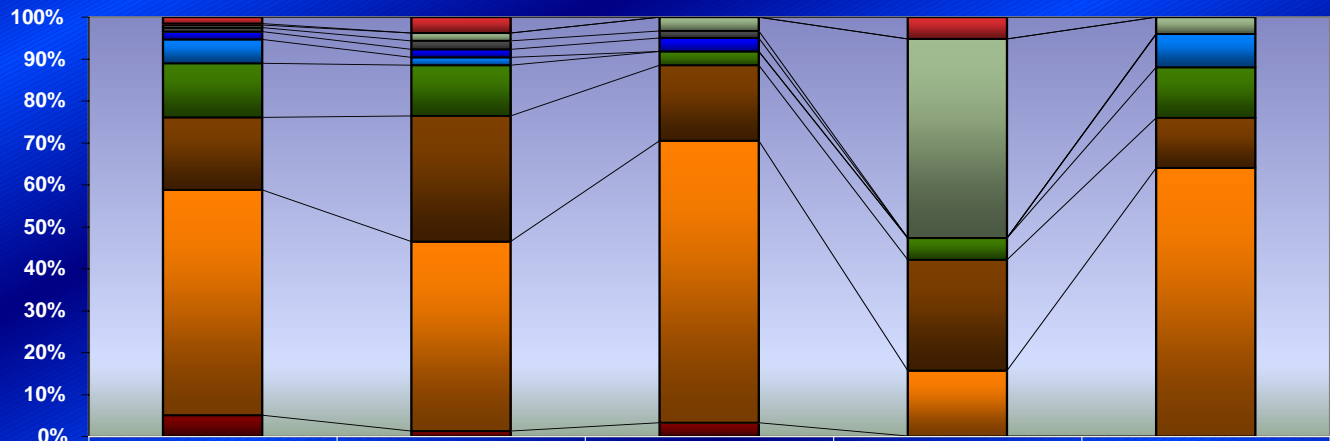


Distribution of Primary ASC Event by Scale



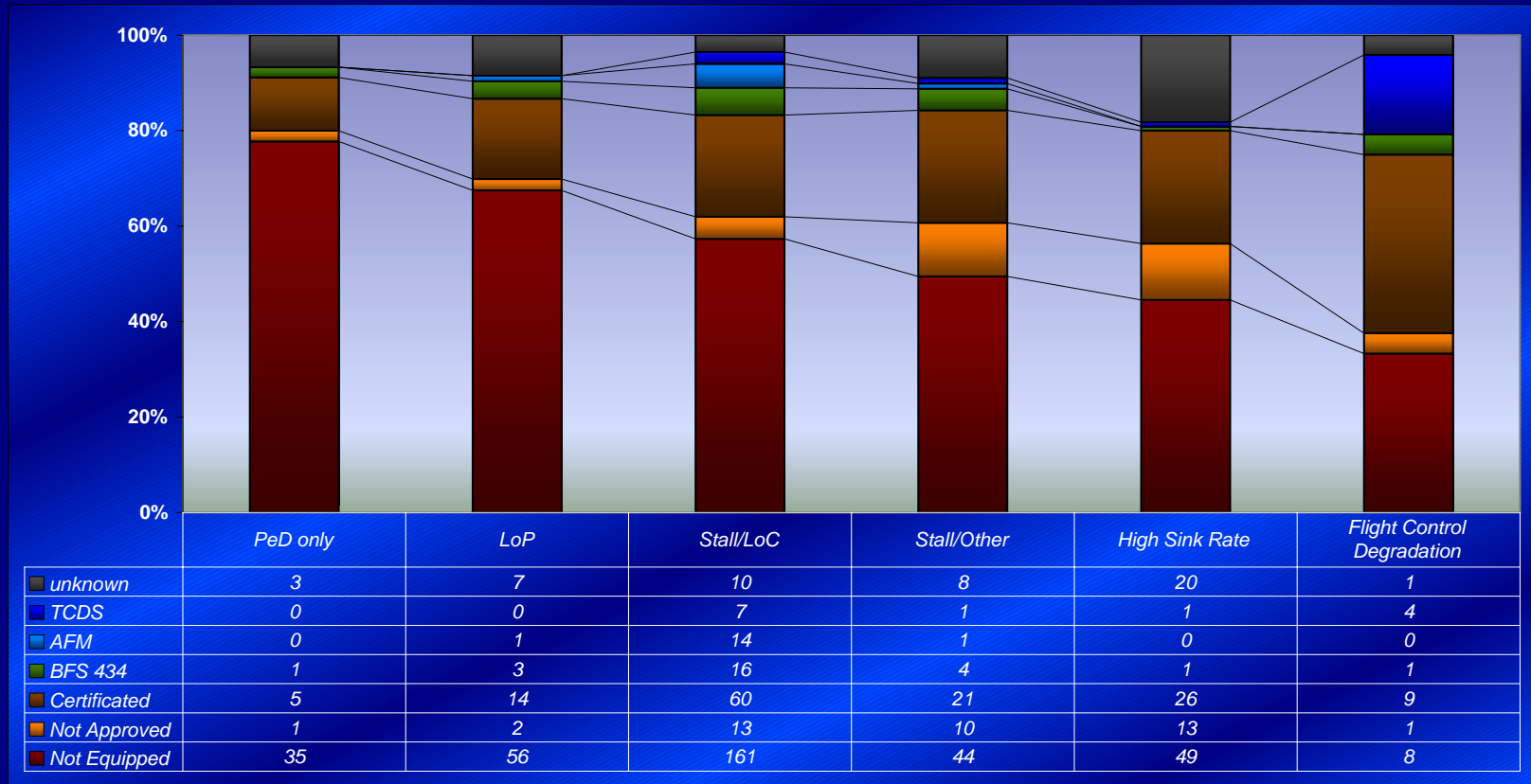
	PeD only	LoP	Stall/LoC	Stall/Other	High Sink Rate	Flight Control Degradation
2 Eng Turboprop: 50+ Seats	0	0	1	0	0	0
2 Eng Turboprop: 20-50 Seats	0	0	9	2	1	5
2 Eng Turboprop: 13-19 Seats	1	1	1	0	1	4
2 Eng Turboprop: 13+ Seats	1	2	4	3	2	0
2 Eng Turboprop: 1-12 Seats	0	2	20	2	2	0
2 Eng Recip: 7+ Seats	2	7	35	11	15	3
2 Eng Recip: 1-6 Seats	6	15	49	15	34	4
1 Eng Recip: 4+ Seats	31	43	132	47	49	7
1 Eng Recip: 1-3 Seats	1	5	11	0	2	1

Distribution of Primary Terminating Event by Scale

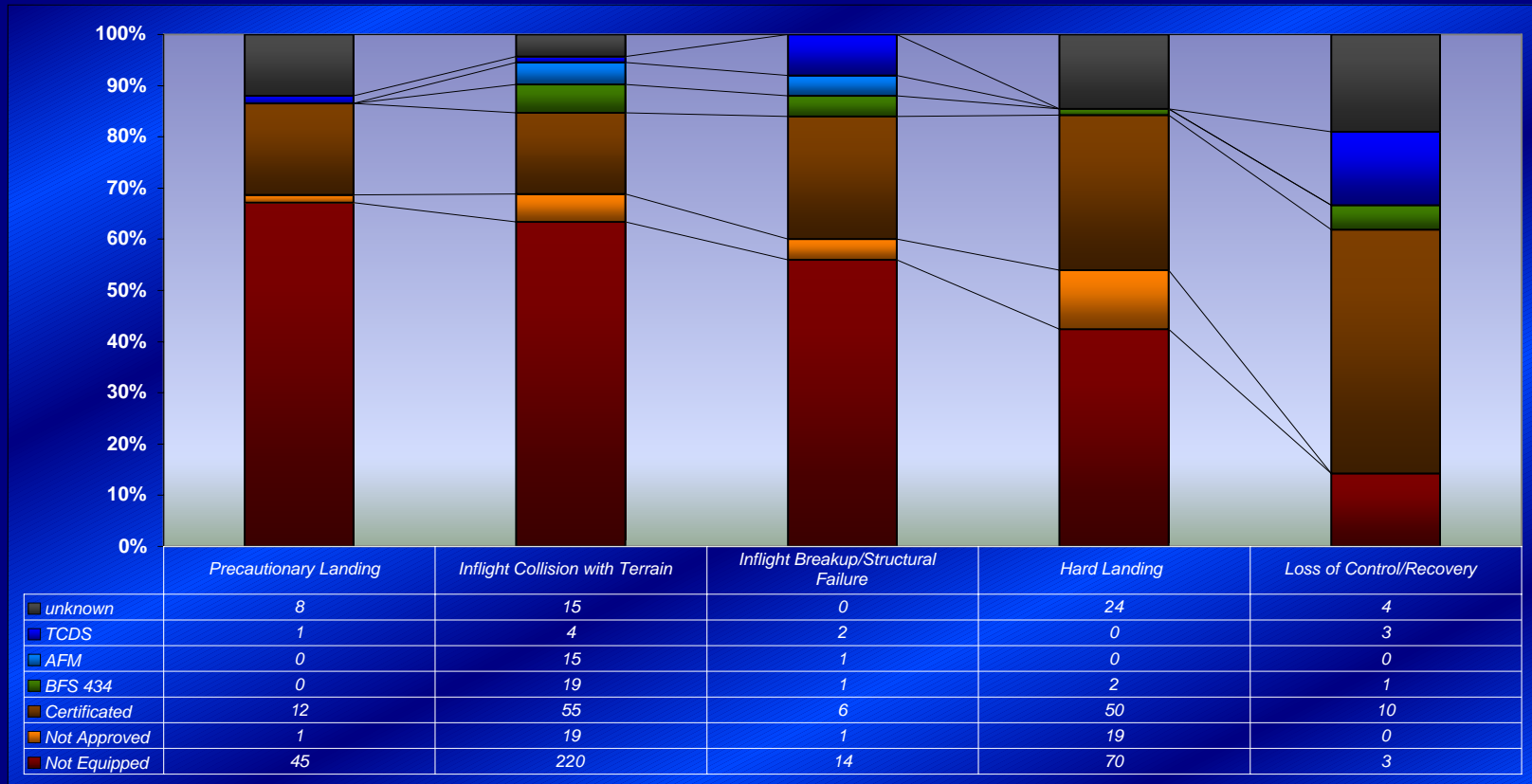


	<i>Inflight Collision with terrain</i>	<i>Hard Landing</i>	<i>Precautionary Landing</i>	<i>Loss of Control/Recovery</i>	<i>Inflight Breakup/Structural Failure</i>
2 Eng Turbojet	5	6	0	1	0
2 Eng Turboprop: 50+ Seats	1	0	0	0	0
2 Eng Turboprop: 20-50 Seats	2	3	2	9	1
2 Eng Turboprop: 13-19 Seats	3	3	1	0	0
2 Eng Turboprop: 13+ Seats	6	3	2	0	0
2 Eng Turboprop: 1-12 Seats	18	3	0	0	2
2 Eng Recip: 7+ Seats	41	19	2	1	3
2 Eng Recip: 1-6 Seats	55	47	11	5	3
1 Eng Recip: 4+ Seats	171	71	41	3	16
1 Eng Recip: 1-3 Seats	16	2	2	0	0

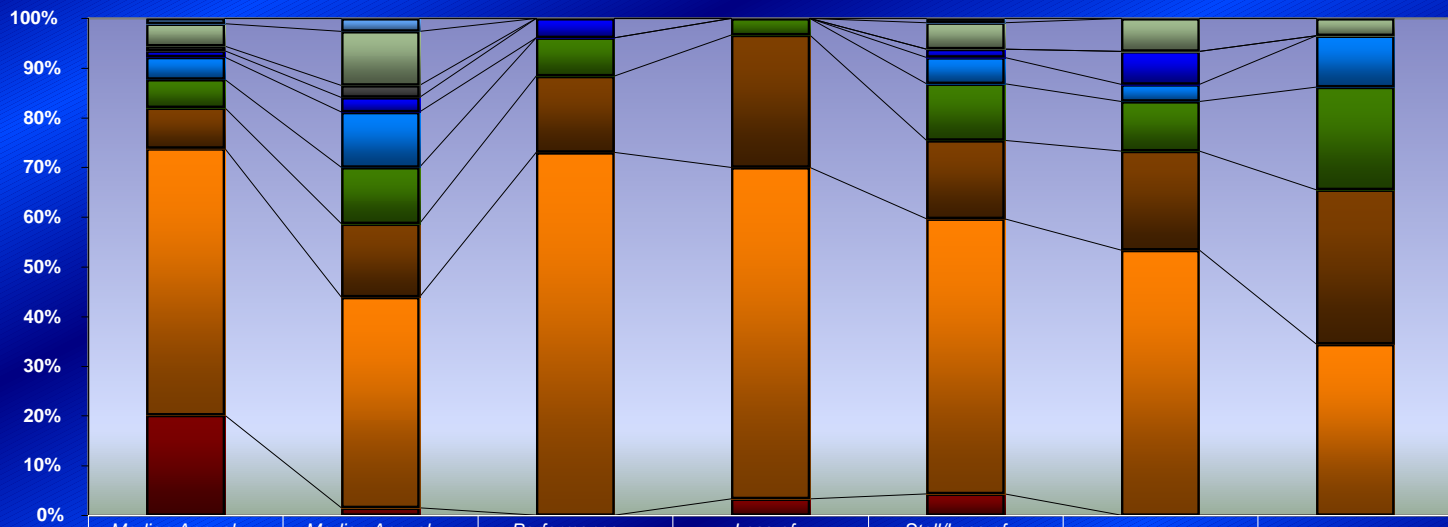
Distribution of Primary ASC Event by Icing Approval



Distribution of Primary Terminating Event Event by Icing Approval

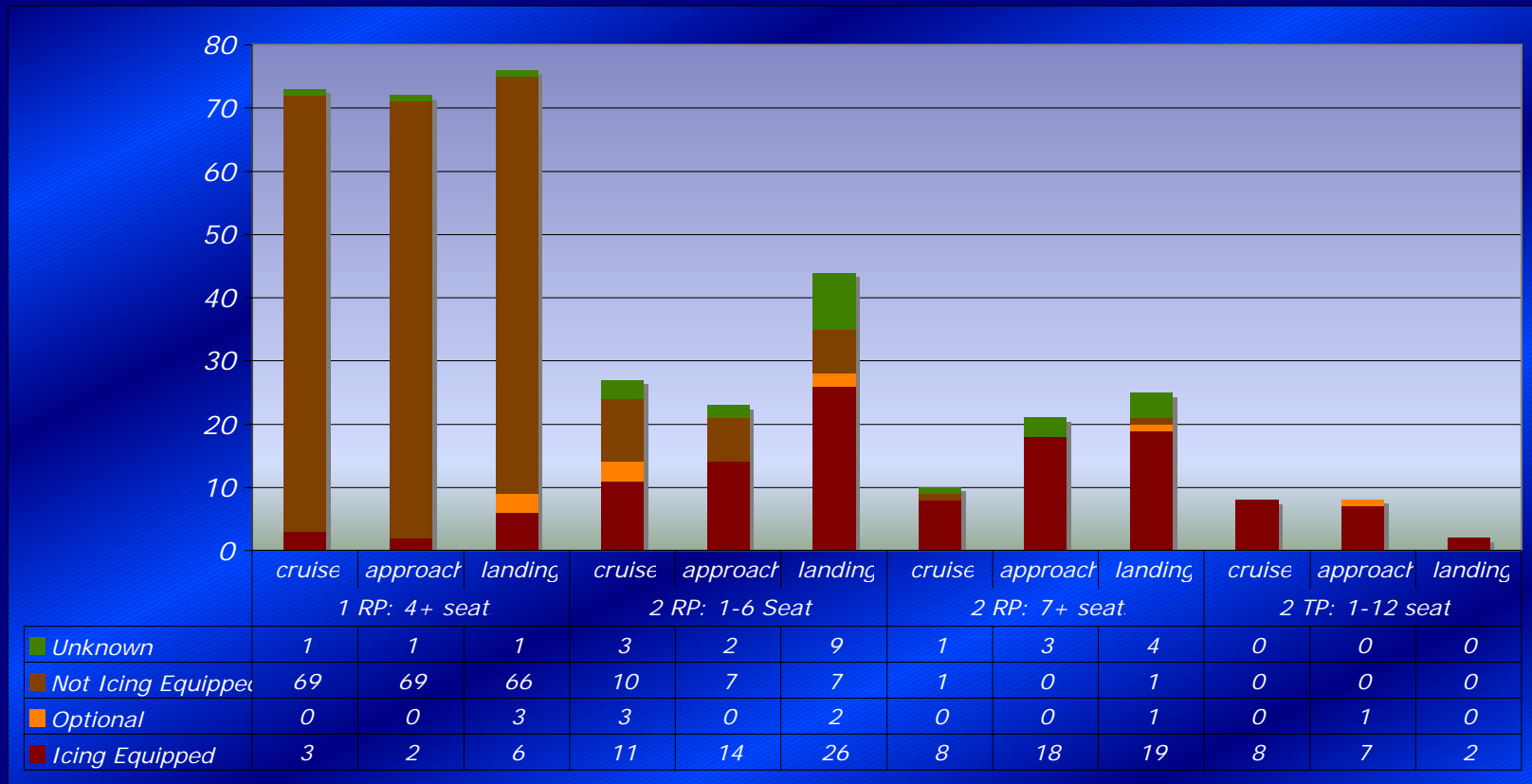


Primary A^C Events Normalized to IMC Exposure (1991-2005)

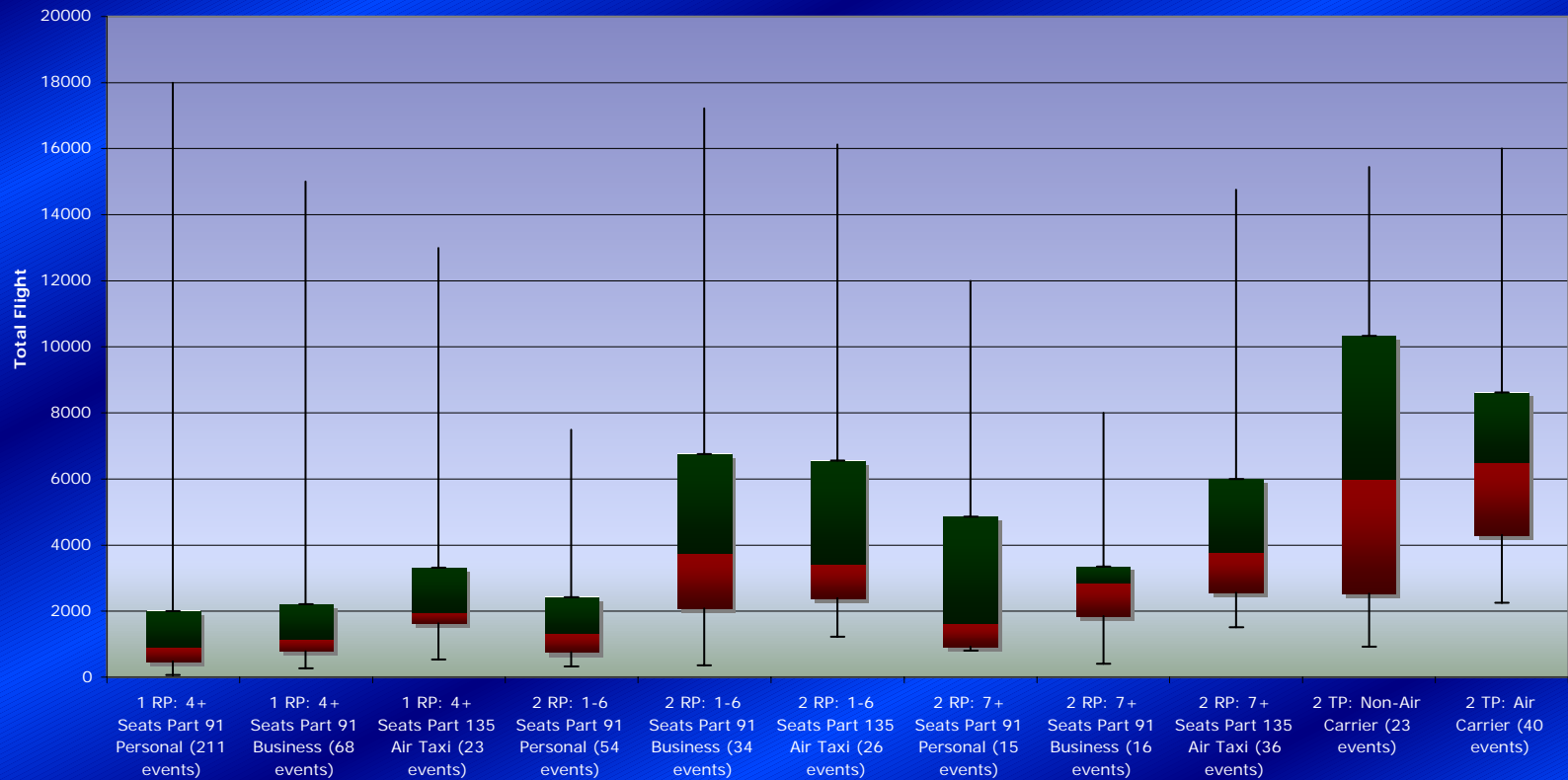


	Median Annual Operating Hours	Median Annual IMC Exposure	Performance Degradation Only	Loss of Performance	Stall/Loss of Control	Stall/Other	High Sink Rate
2 TP: 50+ seats	250,811	68,333	0	0	1	0	0
2 TP: 20-50 seats	1,049,088	285,824	0	0	6	2	1
2 TP: 13-19 seats	233,170	63,527	0	0	0	0	0
2 TP: 13+ seats	290,849	77,817	1	0	2	2	0
2 TP: 1-12 seats	1,055,207	292,659	0	0	6	1	3
2 RP: 7+ seats	1,353,605	297,740	2	1	13	3	6
2 RP: 1-6 Seats	1,920,529	388,696	4	8	18	6	9
1 RP: 4+ seats	12,622,707	1,117,246	19	20	63	16	10
1 RP: 1-3 seats	4,757,842	40,613	0	1	5	0	0

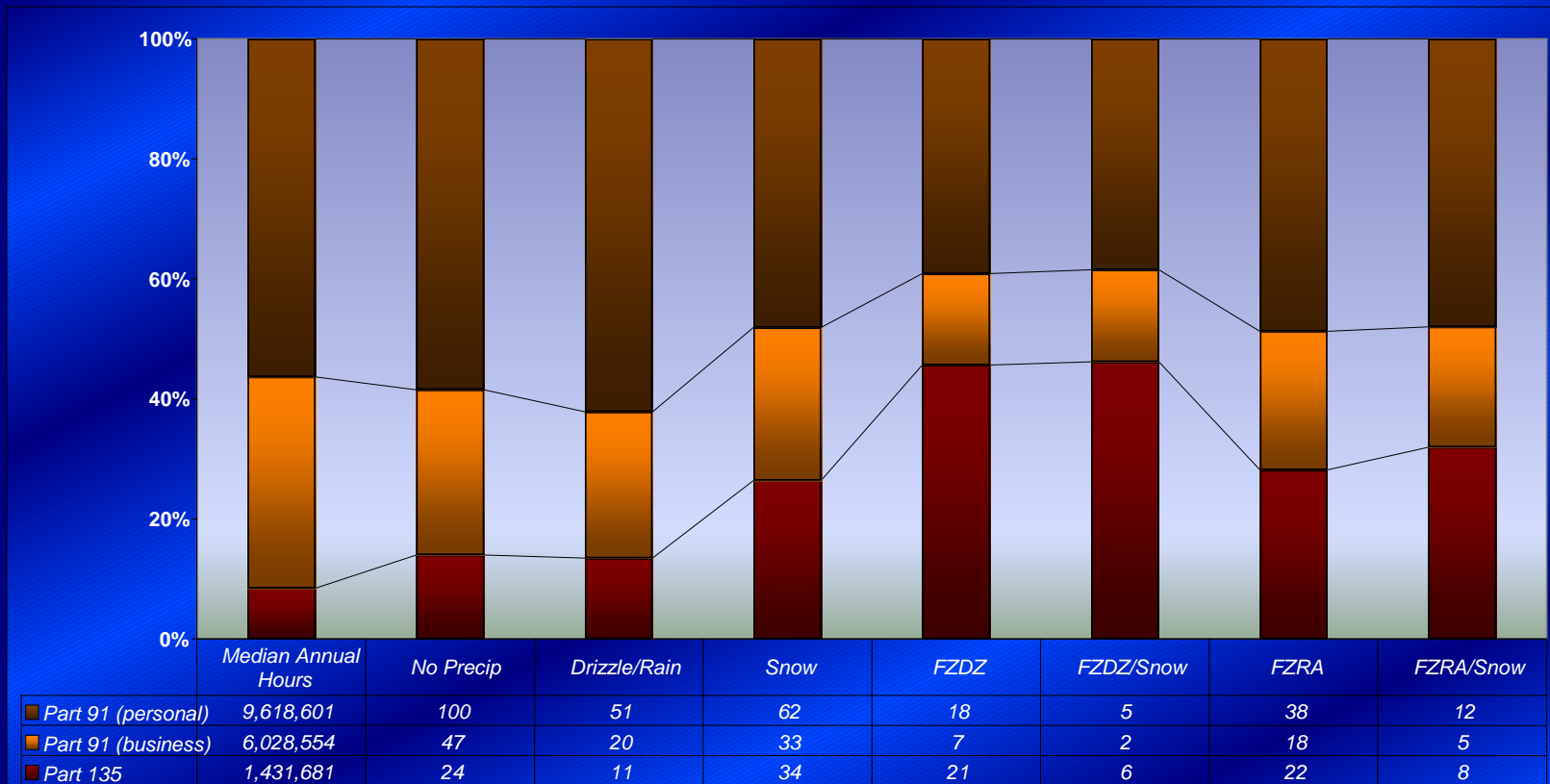
Comparison of Scale and Flight Phase Based on Ice Protection Equipage



Total Flight Time for Pilot-in-Command by Scale and Category of Operation



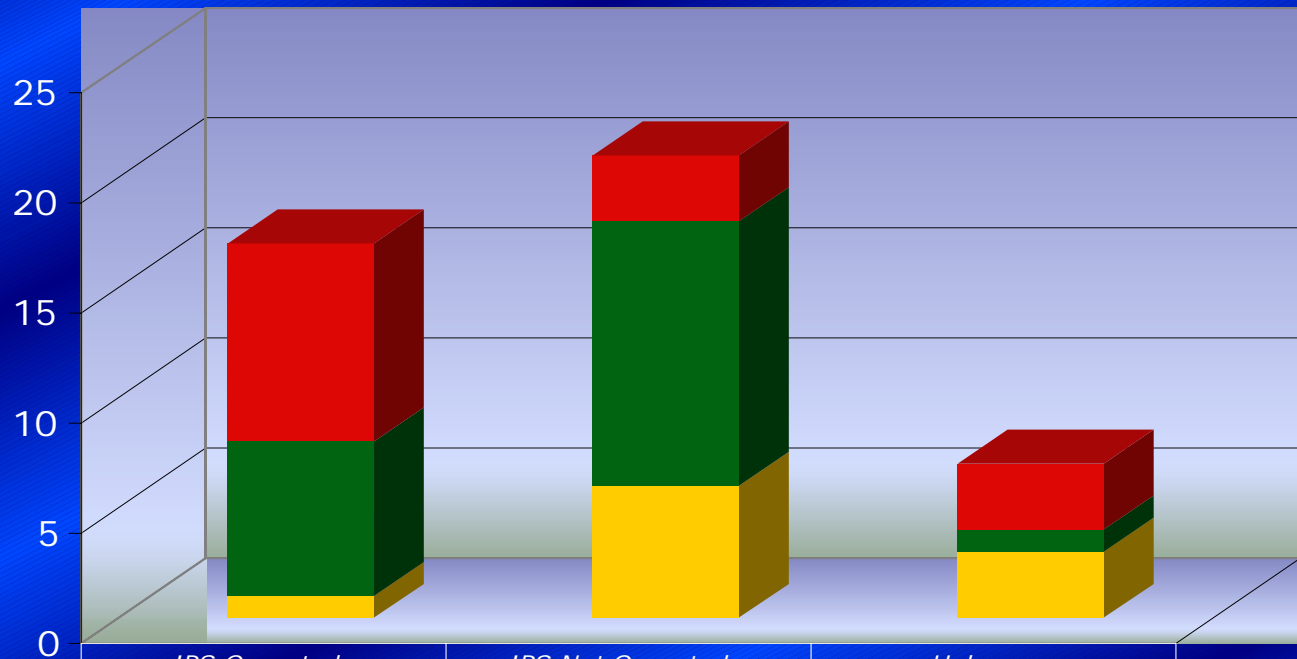
Distribution of Events By Surface Precipitation and Category of Operation



Observed or Recovered Ice Shape Characteristics

- Ice observed by pilot and/or passengers
 - Clearly subjective
- Ice recovered at site after event
 - No data regarding sublimation/melting over time
 - No data regarding accuracy of measurement
- 55 events reporting
- Mean Range = 0.38" to 0.69"
- Median Range = 0.25" to 0.50"

Ice Thickness Threshold for Ice Protected Aircraft



■ Above Threshold
■ In Threshold Range
■ Below Threshold

IPS Operated

9

IPS Not Operated

3

Unknown

3

In Threshold Range

7

12

1

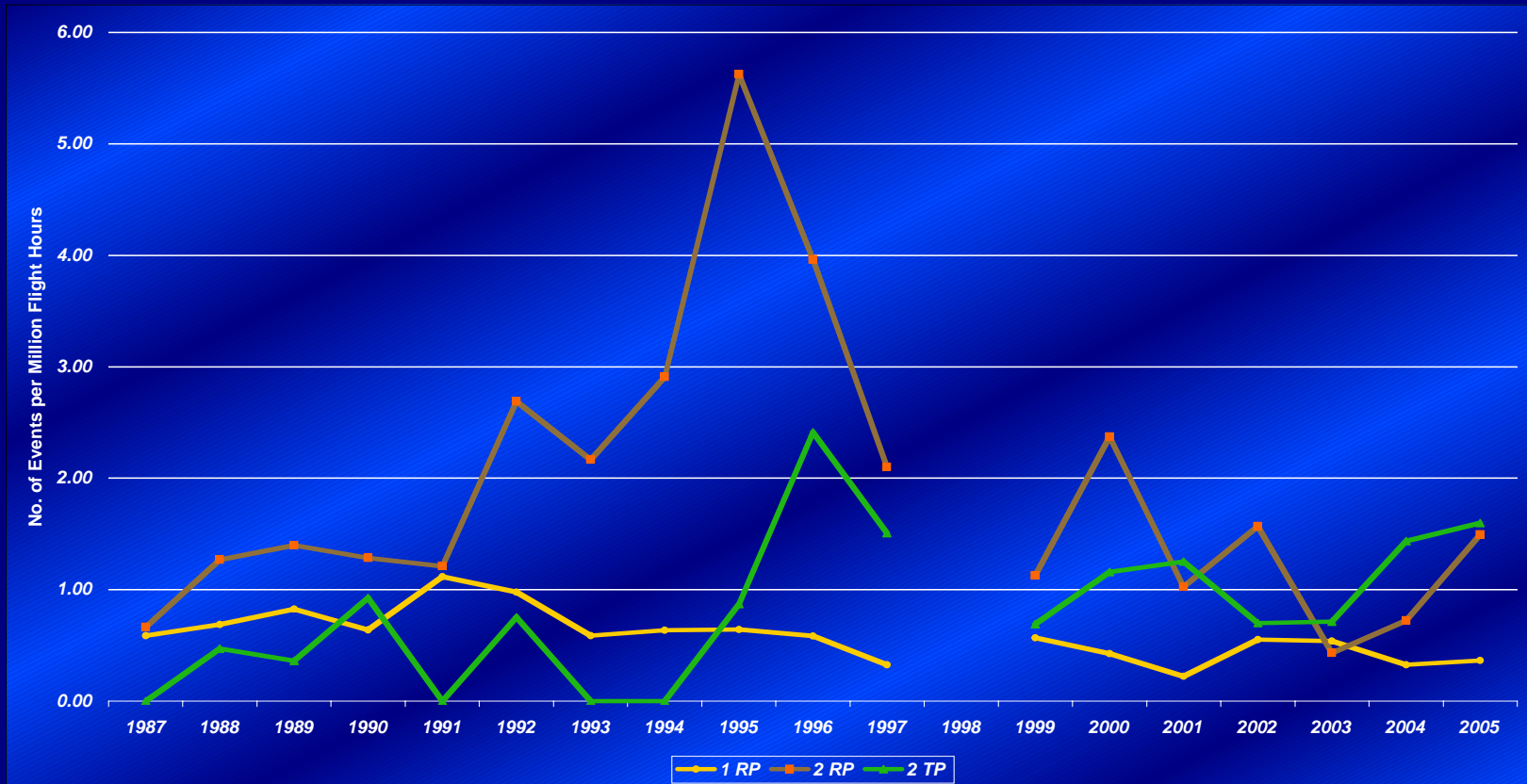
Below Threshold

1

6

3

Icing Event Rate for General Aviation Operations (1987-2005)



Freezing Precipitation Event Rate for General Aviation Operations (1987-2005)



Conclusions

- **Freezing precipitation is involved in 33% of the events for which precipitation data was available, but only accounts for 1.8% of the reported surface precipitation in the United States.**
 - Snow, on the other hand, was associated with 32% of the events and also with 32% of the surface observations of precipitation.
- **The surface weather observation at the time of an icing event will typically exhibit temperatures which average between -2.2°C and 2.2°C, cloud ceilings which average between 400 and 2000 feet, and surface visibilities which range between 1.5 and 5.5 statute miles in precipitation, and 3 to 10 miles with no precipitation. The dew point spread will rarely be greater than 4 degrees Celsius.**
- **Events involving freezing precipitation are predominantly experienced in the Great Plains area, along with a portion of the northeast.**

Conclusions

- **Encounters with freezing precipitation within the general aviation fleet appear to be declining**
- **While the predominant sequence of events involves a stall followed by loss of control, a significant number of events occur during the landing phase, resulting in a hard landing.**
 - This type of event may be coupled with a smaller subset in which sufficient performance is lost during the approach so as to force descent below the glide path. In both cases, the pilot may be unfamiliar with or unable to cope with the effects of icing previously accreted when the angle of attack is increased.
- **Smaller scale reciprocating engine aircraft, which *are not equipped* with ice protection systems, experience the significant majority of the events that involve only performance degradation.**
 - For this fleet, events that are more severe are distributed somewhat evenly across the phases of flight, with larger portions taking place in cruise and descent than during approach and landing.

Conclusions

- **Smaller scale reciprocating engine aircraft, which *are equipped* with ice protection, do not experience many events that involve only performance degradation.**
 - However, the more severe events experienced by this fleet tend to occur during the approach and landing phases, with fewer taking place during cruise and descent. This may indicate that, for smaller scales, ice protection equipment as currently utilized is effective at reducing en route performance degradations but is not as effective at minimizing the effects experienced when the angle of attack is increased.
- **There is generally a trend in which icing events, as a function of IMC exposure, diminish with larger scale.**
 - This may be due to the greater percentage of aircraft equipped with ice protection systems, or due to a greater power margin, or due to the effects of airfoil scale, or some combination thereof.

Conclusions

- **The decision to land, in which a pilot elects to divert and make an unscheduled landing due to ice accretion, is effective in less than 25% of the cases that reached the required threshold of an accident or reported incident.**
- **Despite more rigorous operating criteria and training requirements, the Part 135 air taxi fleet experiences a number of events in freezing precipitation that is disproportionate to the median annual operating hours of this fleet.**
 - This relationship is not consistent with the number of events experienced by the Part 91 business fleet with respect to its median annual operating hours, and thus suggests that Part 135 operating rules and training are not effective at preventing these types of events.
- Based on measurements of ice accretion reported in the event documentation, pilots may be tending to delay operation of the IPS until they estimate the ice accretion to be near the upper end of the manufacturer's recommended range for IPS operation.

Questions?

