**Docket No. SA-530**

**Exhibit No. 12-B**

# NATIONAL TRANSPORTATION SAFETY BOARD

**Washington, D.C.**

HEMS Safety Date and Review

(14 Pages)

# Review of Helicopter EMS Accidents and the Effectiveness of Selected Interventions

Since the early 1990s, the volume of helicopter emergency medical services (HEMS) has increased steadily and significantly. Though growth in the industry now appears to be flattening out somewhat, the industry continues to expand, with more than 800 helicopters currently dedicated to HEMS operations in the United States. As the industry has grown, accidents and fatal accidents also have increased. HEMS operators had 6 fatal accidents in 2004 and 6 again in 2005. The number of fatal accidents decreased for 2 years, but then climbed to 7 in 2008.

The Federal Aviation Administration (FAA) responded to the 2004-2005 experience with increased surveillance and other efforts to reduce accidents. Simultaneously, the National Transportation Safety Board (NTSB) responded with a Special Study of the HEMS industry in 2006. In response to the increase in fatal accidents in 2008, the NTSB has announced that it will conduct a 4-day public hearing on HEMS operations, beginning February 3, 2009.

This paper reviews the accident history in HEMS and outlines general characteristics of accident flights. Since the NTSB Special Study in 2006 reviewed accidents from 1994 through 2004, this paper uses the same starting point of 1994 and extends the review through 2008. The paper also briefly assesses the likely effectiveness of five interventions that are commonly suggested by NTSB, as well as industry and the FAA.

## Accident Trends & Characteristics

As Figures 1 illustrates, the number of accidents peaked in 2003 but, with some annual variation, the number of fatal accidents has remained high. The 15-year trend lines for all accidents and fatal accidents both are increasing. However, Figure 2 shows the same trend lines for a more recent period. From 2002 through 2008, the trend line for accidents has been improving and the trend line for fatal accidents is essentially flat, albeit at relatively high levels. In short, whether accidents and fatal accidents are increasing or not increasing depends on the period selected.

Yet, even with the relatively high number of fatal accidents in recent years Figure 3 shows that overall accident rates and fatal accident rates for HEMS operators are improving, which reflects the high growth in HEMS operations. From 2002 to 2008, HEMS operators have had a cumulative fatal accident rate of 1.18 per 100,000 hours. This compares to a 7-year fatal accident rate for other turbine-powered helicopters of 1.0 and 1.13 per 100,000 hours for all other general aviation and on-demand Part 135 operations. In sum, the fatal accident rate for HEMS is relatively high, but it remains comparable to other operations.

Nevertheless, the overall accident rate is falling much more rapidly than the fatal accident rate. Over the first 10 years of the review period (1994-2003), 33 percent of all HEMS accidents were fatal. In the past 5 years (2004-2008), 75 percent (18 of 24) were fatal.

Most accident flights operated under visual flight rules (VFR), which accounted for 96 percent of all accidents and 91 percent of fatal accidents. Just 6 of 148 accidents involved IFR flights, though 5 of those 6 were fatal and just 1 occurred in weather.

Over the 15-year period, Part 91 flights accounted for 70 percent of all accidents and 69 percent of fatal accidents. However, Part 91 is decreasing as a share of accidents. In the past 7 years Part 91 accounted for 61 percent of fatal accidents versus 81 percent in the preceding 8 years.

Over the 15 years, a fairly stable 24 percent of all accidents had passengers onboard, including patients and a small number of family members who accompanied patients. Passengers were onboard 31.5 percent of fatal accidents.

Night operations accounted for 53 percent of all accidents, but night flying accounted for 69 percent of all fatal accidents versus 43 percent of non-fatal accidents. In the past 5 years, night flying has accounted for 75 percent of all fatal accidents. As in other segments of aviation, accidents at night tend to be more lethal because they involve a higher share of accidents types that have more severe outcomes, such as controlled flight into terrain and loss of control in flight. Conversely, accidents in daylight tend to include a higher share of relatively low-risk events.

Instrument meteorological conditions (IMC) accounted for 15.5 percent of all accidents in the 15 years, but IMC accounted for 30 percent of fatal accidents, versus just 7 percent of non-fatal accidents. Again, as in other segments of aviation, accidents in IMC tend involve a greater share of accident types that produce severe outcomes. (See Figure 4 for annual data.)

The combination of the above 3 characteristics is critical. Night VFR accounts for exactly half of all accidents. However night VFR accounts for 61 percent of fatal accidents. Similarly, VFR in IMC accounts for 37 percent of fatal accidents versus just 8.5 percent of non-fatal accidents. However that percentage has decreased in the past 5 years (4 of 23 fatal accidents, or 18 percent). Nevertheless, at least 37 percent of fatal accidents in the past 15 years occurred in conditions that indicate a failure to observe basic part 91 rules. A significant share of fatal accident flights combined high-risk characteristics by flying VFR into IMC at night: 22 percent of fatal accident flights were operating VFR in night IMC.

Other characteristics include the following. Of all fatal accidents, 16 involved CFIT and 15 involved various scenarios of loss of control en route. In contrast, non-fatal accidents involved 9 CFIT accidents and no loss of control en route. In addition, 15 percent of fatal HEMS accidents (8 of 54) involved mechanical issues, including power plant issues, while 29 percent of non-fatal accidents involved mechanical issues. Most of the 8 fatal cases involved scenarios from which recovery ranged from impossible to very difficult, such as airframe failure or blade separation. In most non-fatal cases with mechanical issues, the failure led to hard landings or emergency landings in uneven terrain, which damaged the helicopter but usually led to no fatalities.

## Effectiveness of Possible Interventions

Several interventions are commonly suggested to reduce the number of accidents and fatal accidents among HEMS operators. This paper assesses the likely effectiveness of 5 such interventions against each of the 148 accidents from 1994 through 2008 to estimate the likely reduction in risk. The 5 interventions assessed are: the use of night vision goggles; synthetic

vision systems; helicopter terrain alert warning system; 2-pilot crews; and allowing Part 135 IFR operations to remote sites that are within 15 miles of an approved weather reporting station.

Each intervention received a numerical score to indicate the likelihood that the intervention would have averted the accident. A score of zero indicated that the proposal would have had no effect, based on the details of the accident that actually occurred, while other scores indicated low, medium and high likelihood of effectiveness. A score of 100 would indicate that all risk associated with an accident would have been fully precluded. However, no intervention received a score of 100 percent, based on the assumption that no planned intervention can eliminate all risk of an accident; a 95-percent reduction in risk was the maximum score for any intervention against any single accident.

In addition, the algorithm for computing risk reduction avoided double-counting effectiveness against any single accident by applying the respective scores against remaining risk for each accident. For example, if intervention "A" and intervention "B" were both scored at 60 percent, "A" would leave 40 percent of the risk remaining. The score for intervention "B" then would be applied to the remaining risk of 40 percent, yielding a net additional reduction of 24 percent n risk. The sum of the 2 interventions would be 84 percent (60 + 24), not 120 percent. This approach ensures that no single accident is somehow eliminated multiple times.

**Night Vision Goggles (NVG)**

Night vision goggles (NVG) are designed to capture ambient light and provide pilots or other crew with a monochrome visual field. NVG may limit peripheral vision and thereby introduce some tradeoff, though this potential tradeoff is not addressed here in this review of the accident dataset. NVG clearly provides a significant net benefit.

Nevertheless, NVG has limitations. First, NVG requires that at least some degree of ambient light is available to be captured, though this limitation is easily overstated given the performance of the current generation NVG. In addition, NVG does not penetrate water droplets, so its effectiveness in IMC ranges from zero to very limited.

Consequently, NVG scores "zero" in accidents in IMC, as its effectiveness approaches zero with water in the atmosphere. NVG also is irrelevant to accidents that occur in daylight hours. Daylight and night IMC combine to eliminate NVG as an effective intervention in 62 percent of all accidents (92 of 148) and 61 percent of fatal accidents (33 of 54). In addition, the capacity of NVG to avoid accidents is restricted by any number of factors that influence particular cases, such as accidents in which NVG was being used, catastrophic systems failures, failure to recognize settling with power, generation of dust clouds at touchdown, fuel starvation, pilot impairment or incapacitation, etc.

In sum, NVG received scores greater than zero against 27 accidents and 13 fatal accidents. The scores for NVG reduced the risk of an accident by 7.1 percent. NVG reduced the risk of a fatal accident by 8.7 percent.

**Synthetic Vision Systems (SVS)**

SVS provides a visual field for the pilot. A helicopter would operate with an onboard digital map of all terrain, obstructions, and buildings. Integrated with onboard GPS, SVS generates a computer image of the visual field and enables a pilot to recognize current and future position. Like NVG, SVS would be irrelevant in most day VMC conditions and to a large degree the system duplicates much of the benefit of NVG. In addition, SVS likely would not be effective against random ground obstacles that are very unlikely to be identified on a digital map, such as low-level tree branches or surface debris at remote sites. However, SVS provides a much greater net benefit compared to NVG with its effectiveness in IMC, albeit at much higher cost.

SVS received scores against 44 accidents and 32 fatal accidents. The scores for SVS reduced the risk of an accident by 14.8 percent. NVG reduced the risk of a fatal accident by 29.4 percent. Given the significant overlap of benefits between NVG and SVS, they combined for a sub-total reduction in risk of 16.7 percent for all accidents and 30.5 percent of fatal accidents.

**H-TAWS**

H-TAWS functions much like TAWS does in air transport aircraft, with aural alerts and visual displays. The primary difference is a change in the algorithm to negate alerts when operating at relatively low altitudes within 30 miles of an airport. H-TAWS projects forward and downward. The system is sensitive not only to high terrain but also to excessive sink rate, thereby making it effective against controlled flight into level terrain or water and against selected approach-and-landing accidents. H-TAWS scores indicated a reduction of just 9 percent against all accidents. However, because the accident scenarios against which H-TAWS would be effective tend to have severe outcomes, it would reduce the risk of fatal accident by 20 percent.

**15-Mile Forecast at Remote Sites for 135 IFR**

Federal Aviation Regulations require Part 135 operators to have access to weather reporting at their destination before they can dispatch an IFR flight. As a result, HEMS operators can not operate IFR under Part 135 to remote sites because those sites do not have weather reporting capabilities. This intervention would allow Part 135 operators to fly IFR to remote sites provided that the site was within 15 miles of an approved weather reporting facility.

As with other interventions, this intervention faces practical limitations in its capacity to avoid certain accident scenarios. Those scenarios include cases in which a flight already was operating IFR and in which IFR already was but pilots chose VFR. Other scenarios include systems failures, very short flights in which the likelihood of an IFR flight was limited, and scenarios that began during hover or that began to develop at very low altitude on arrival at a remote site, after any IFR portion of a flight would have been completed, as well as other scenarios.

This intervention turned out to be a minor factor in the accident scenarios that actually occurred. Had this intervention been available as an option, it would have reduced the risk of an accident by just 2.7 percent and the risk of a fatal accident by 5.6 percent.

**Two Pilots**

This intervention assumes the presence of two pilots on all EMS flights. Presumably this would permit better scanning of the flight environment, better flight monitoring, an added source of professional opinion about risks, and perhaps a more disciplined pre-flight in some cases. This is a difficult intervention to score because arguing that the presence of another pilot would not help is a difficult argument to make in many cases. Consequently, this intervention received at least some score against 57 accidents (38.5 percent) and 28 fatal accidents (51.8 percent).

However, in most cases, though not all, the presence of a second pilot was hardly a guarantee of averting an accident. More than a few Part 121 accidents and Part 135 accidents with 2 or more pilots involve failure to monitor, failure to scan, etc. Consequently, most scores, though not all scores were low to moderate. Still, the presence of a second pilot indicated a likely decrease of 15.5 percent in the risk of an accident and a decrease of 22 percent in the risk of a fatal accident.

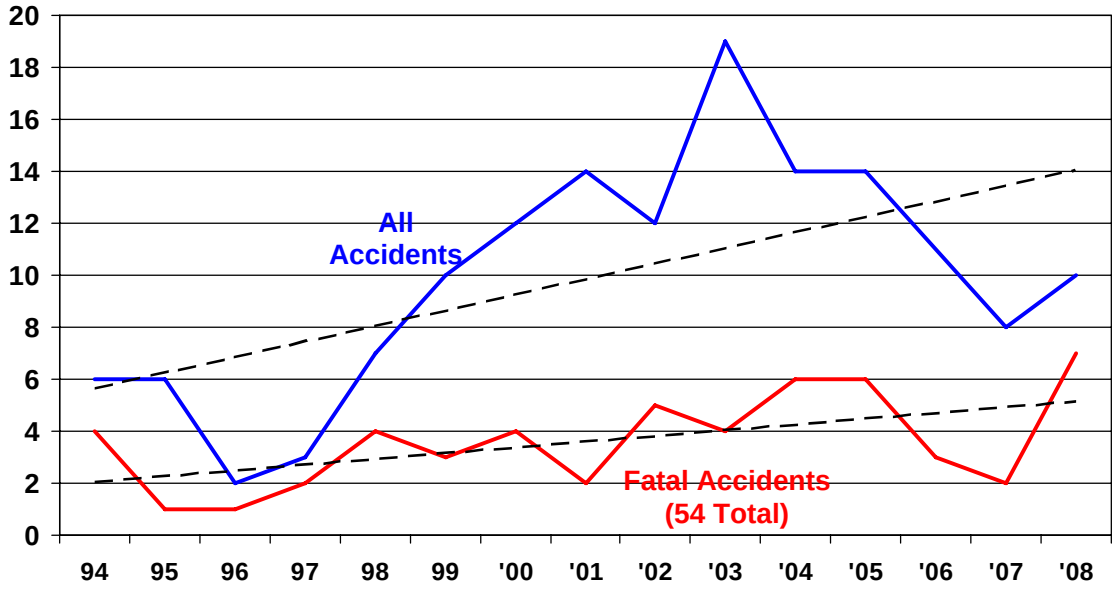
## Summary

HEMS accidents and especially fatal HEMS accidents have increased over the past 15 years. While accident and fatal accident rates appear to have peaked and are improving, HEMS remains a focus of concern for FAA and NTSB due to the high number of fatal accidents and fatalities.

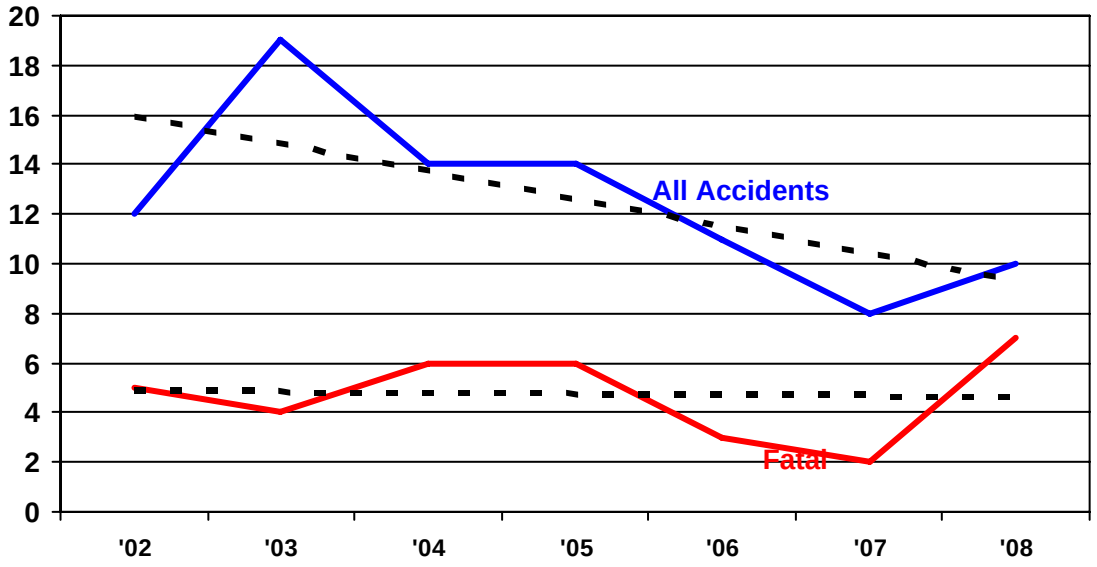
Given the continued concern, this paper assessed the likely effectiveness of 5 interventions to reduce the risk of accidents and fatal accidents. Of the 5 interventions tested against 15 years of HEMS accidents, SVS proved to be the most effective, followed by 2-pilot crews and H-TAWS. NVG and a 15-mile rule for Part 135 IFR proved to trail far behind in effectiveness. Note that this ranking does not consider benefit-cost ratios or feasibility.

Finally, since many accidents could be influenced by multiple interventions, a simple algorithm is applied to ensure that benefits were not double-counted. Consequently, the benefits of individual, free-standing interventions do not simply add to a sum of prevention. If all 5 interventions were implemented, the net benefit is estimated to be a reduction of 31.1 percent in the risk of an accident and a reduction of 50.2 percent in the risk of a fatal accident.

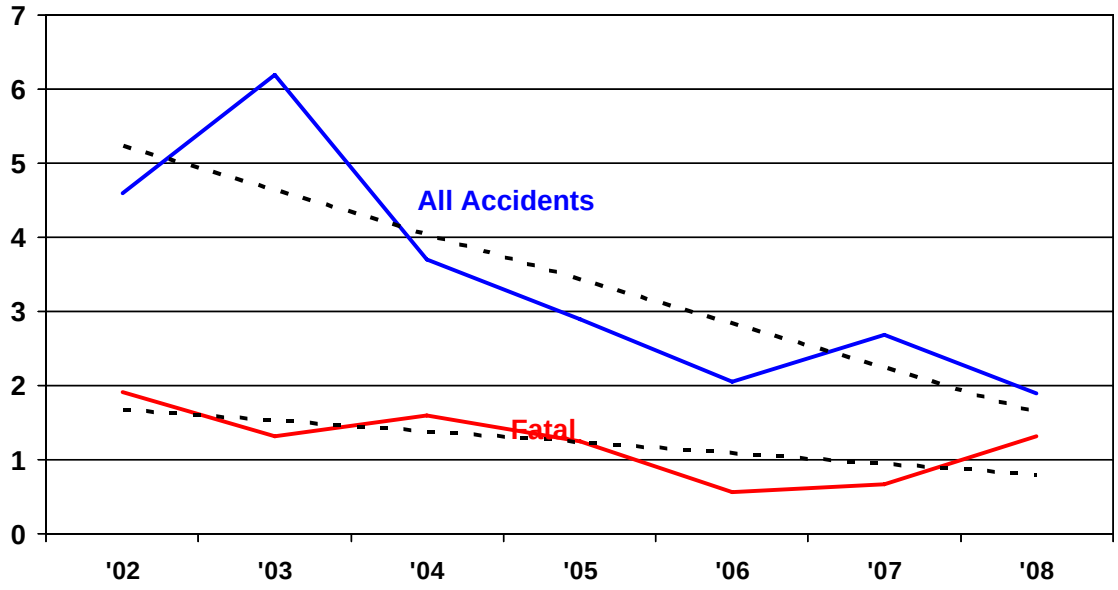
## Figure 1: Number of Accidents & Fatal Accidents, HEMS Operations, CY 1995 - 2008




## Figure 2: Trends in Number of HEMS Accidents & Fatal Accidents, CY 2002-2008



# Figure 3: Rate of HEMS Accidents & Fatal Accidents Per 100,000 Flight Hours, CY 2002-2008




# Figure 4: HEMS Accidents, Fatal Accidents & Selected Characteristics, CY 2002-2008

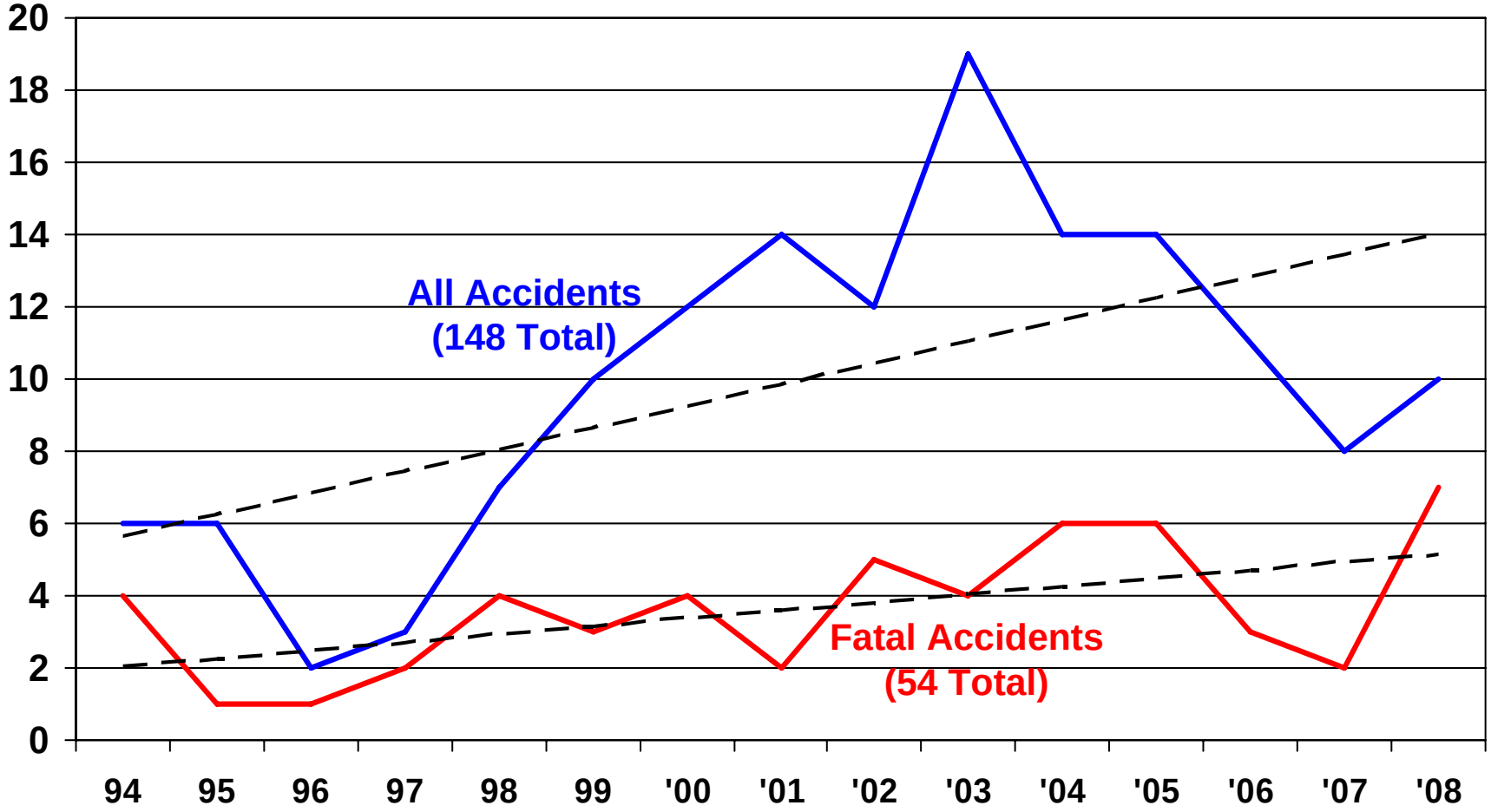
### All HEMS Accidents

| Year | # Acc | FAR 91 | 135 | Day | Night | VFR | IFR | VMC | IMC | Night VFR | VFR in IMC | No Pax |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | 6 | 6 | 0 | 5 | 1 | 5 | 1 | 5 | 1 | 6 | 6 | 6 |
| 1995 | 6 | 5 | 1 | 3 | 3 | 6 | 0 | 4 | 2 | 4 | 3 | 5 |
| 1996 | 2 | 1 | 1 | 0 | 2 | 2 | 0 | 2 | 0 | 2 | 0 | 1 |
| 1997 | 3 | 2 | 1 | 1 | 2 | 3 | 0 | 2 | 1 | 2 | 1 | 2 |
| 1998 | 7 | 5 | 2 | 2 | 5 | 7 | 0 | 5 | 2 | 5 | 2 | 4 |
| 1999 | 10 | 8 | 2 | 5 | 5 | 9 | 1 | 7 | 3 | 8 | 6 | 8 |
| 2000 | 12 | 9 | 3 | 4 | 8 | 12 | 0 | 11 | 1 | 11 | 4 | 10 |
| 2001 | 14 | 11 | 3 | 9 | 5 | 14 | 0 | 14 | 0 | 14 | 9 | 12 |
| 2002 | 12 | 9 | 3 | 7 | 5 | 12 | 0 | 10 | 2 | 10 | 7 | 9 |
| 2003 | 19 | 14 | 5 | 9 | 10 | 19 | 0 | 14 | 5 | 14 | 9 | 17 |
| 2004 | 14 | 8 | 6 | 5 | 9 | 13 | 1 | 10 | 4 | 11 | 6 | 9 |
| 2005 | 14 | 9 | 5 | 8 | 6 | 12 | 2 | 12 | 2 | 14 | 10 | 11 |
| 2006 | 11 | 9 | 2 | 5 | 6 | 11 | 0 | 10 | 1 | 10 | 5 | 9 |
| 2007 | 8 | 2 | 6 | 4 | 4 | 8 | 0 | 7 | 1 | 7 | 4 | 3 |
| 2008 | 10 | 6 | 4 | 3 | 7 | 9 | 1 | 9 | 1 | 10 | 4 | 6 |
| Total | 148 | 104 | 44 | 70 | 78 | 142 | 6 | 122 | 26 | 128 | 76 | 112 |

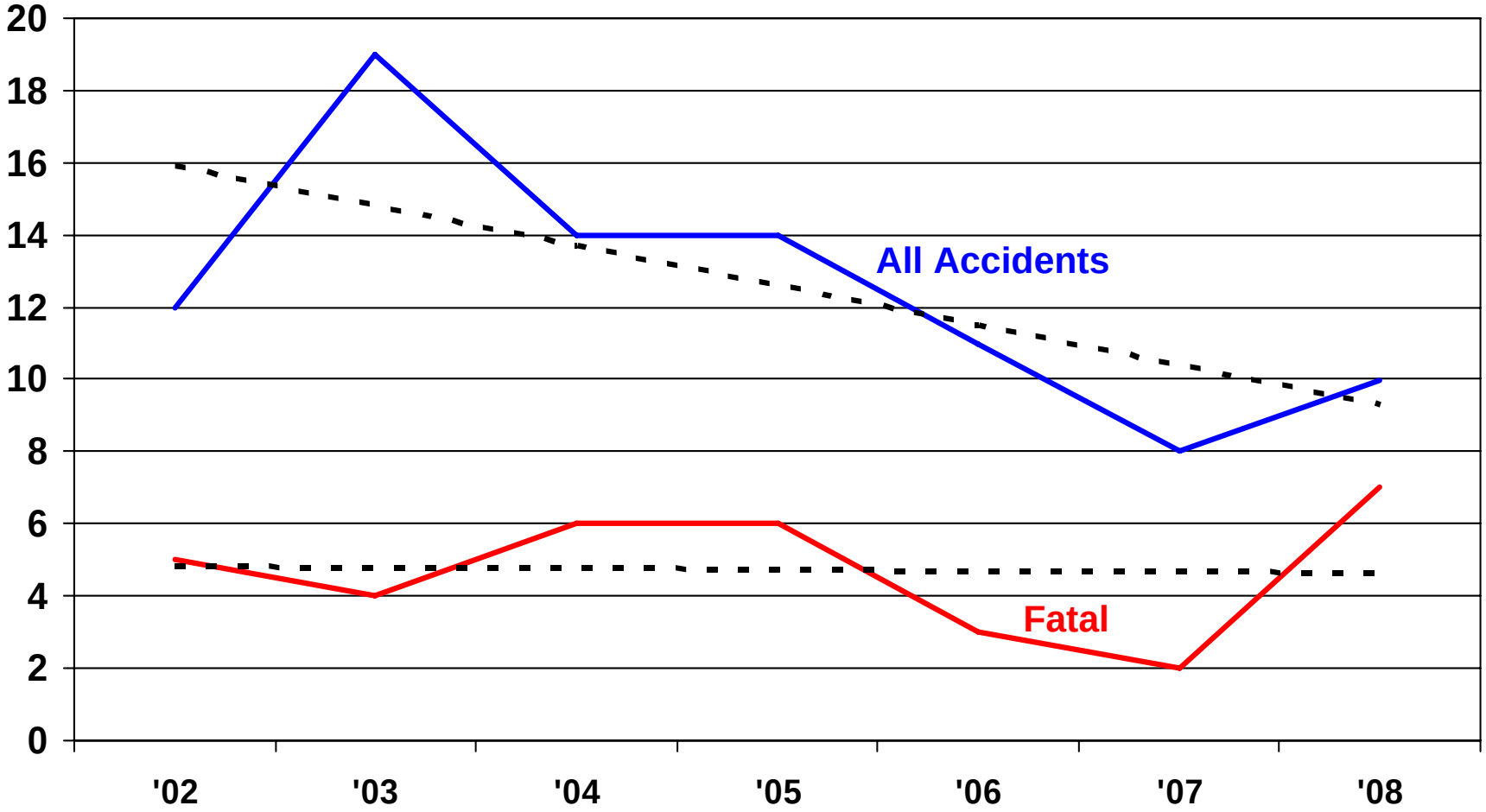
### Fatal HEMS Accidents

| | # Acc | FAR 91 | 135 | Day | Night | VFR | IFR | VMC | IMC | Night VFR | VFR in IMC | No Pax | # Fatal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | 4 | 4 | 0 | 4 | 0 | 3 | 1 | 3 | 1 | 4 | 1 | 4 | 11 |
| 1995 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 3 |
| 1996 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 3 |
| 1997 | 2 | 1 | 1 | 0 | 2 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | 5 |
| 1998 | 4 | 3 | 1 | 1 | 3 | 4 | 0 | 2 | 2 | 2 | 2 | 2 | 14 |
| 1999 | 3 | 3 | 0 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 3 | 10 |
| 2000 | 4 | 3 | 1 | 1 | 3 | 4 | 0 | 3 | 1 | 3 | 1 | 3 | 11 |
| 2001 | 2 | 2 | 0 | 1 | 1 | 2 | 0 | 2 | 0 | 2 | 0 | 2 | 3 |
| 2002 | 5 | 4 | 1 | 2 | 3 | 5 | 0 | 5 | 0 | 5 | 0 | 4 | 13 |
| 2003 | 4 | 3 | 1 | 1 | 3 | 4 | 0 | 1 | 3 | 1 | 3 | 4 | 7 |
| 2004 | 6 | 2 | 4 | 0 | 6 | 6 | 0 | 3 | 3 | 3 | 3 | 2 | 18 |
| 2005 | 6 | 4 | 2 | 2 | 4 | 4 | 2 | 4 | 2 | 6 | 0 | 5 | 11 |
| 2006 | 3 | 2 | 1 | 2 | 1 | 3 | 0 | 3 | 0 | 3 | 0 | 2 | 5 |
| 2007 | 2 | 1 | 1 | 0 | 2 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | 7 |
| 2008 | 7 | 4 | 3 | 2 | 5 | 6 | 1 | 6 | 1 | 7 | 0 | 3 | 28 |
| Total | 54 | 37 | 17 | 17 | 37 | 49 | 5 | 36 | 18 | 41 | 14 | 37 | 149 |

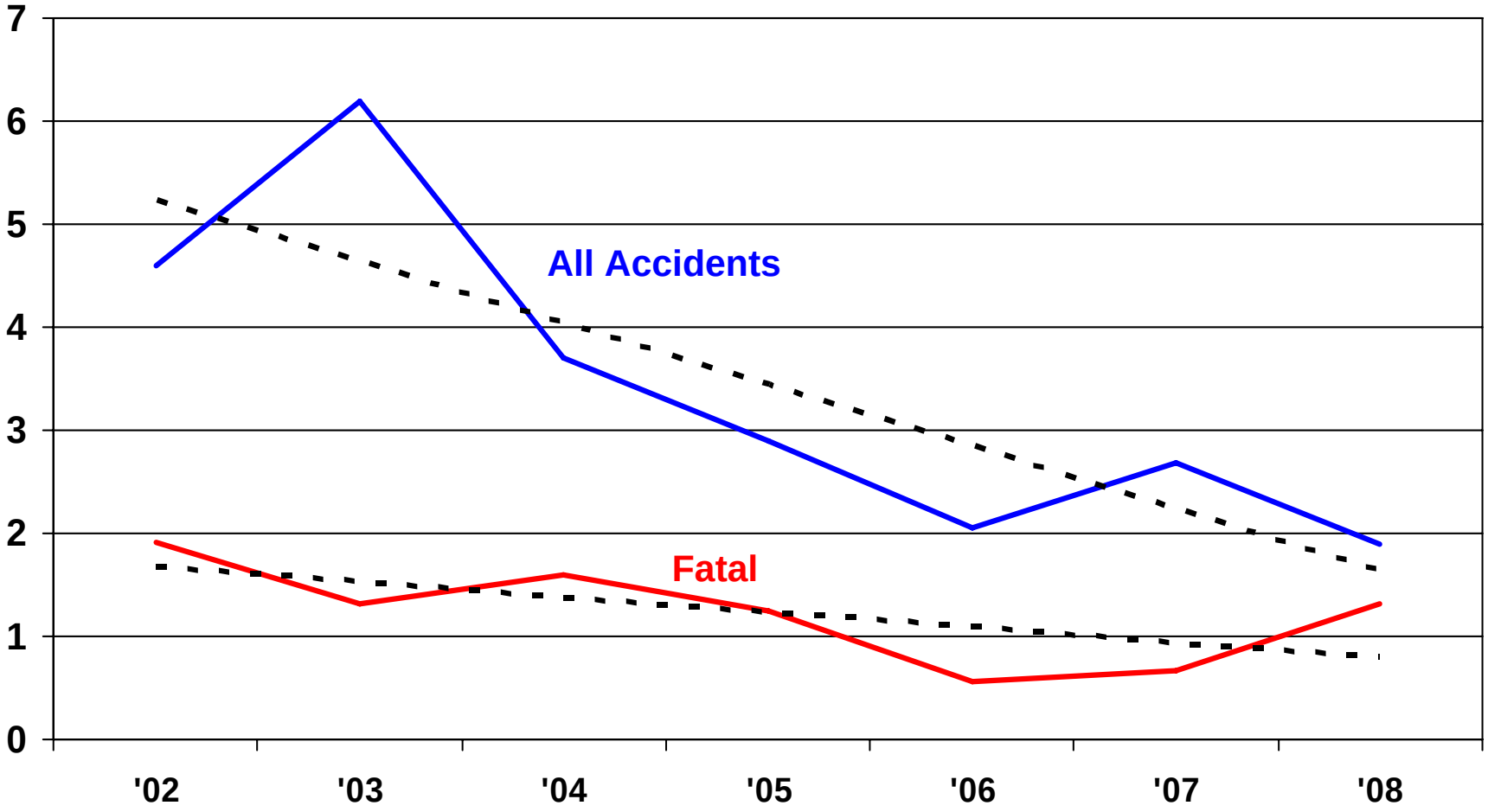
# Number of Accidents & Fatal Accidents, HEMS Operations, CY 1995 - 2008



# Trends in Number of HEMS Accidents & Fatal Accidents, CY 2002-2008



# Rate of HEMS Accidents & Fatal Accidents Per 100,000 Flight Hours, CY 2002-2008



# HEMS Accidents, Fatal Accidents & Selected Characteristics, CY 2002-2008

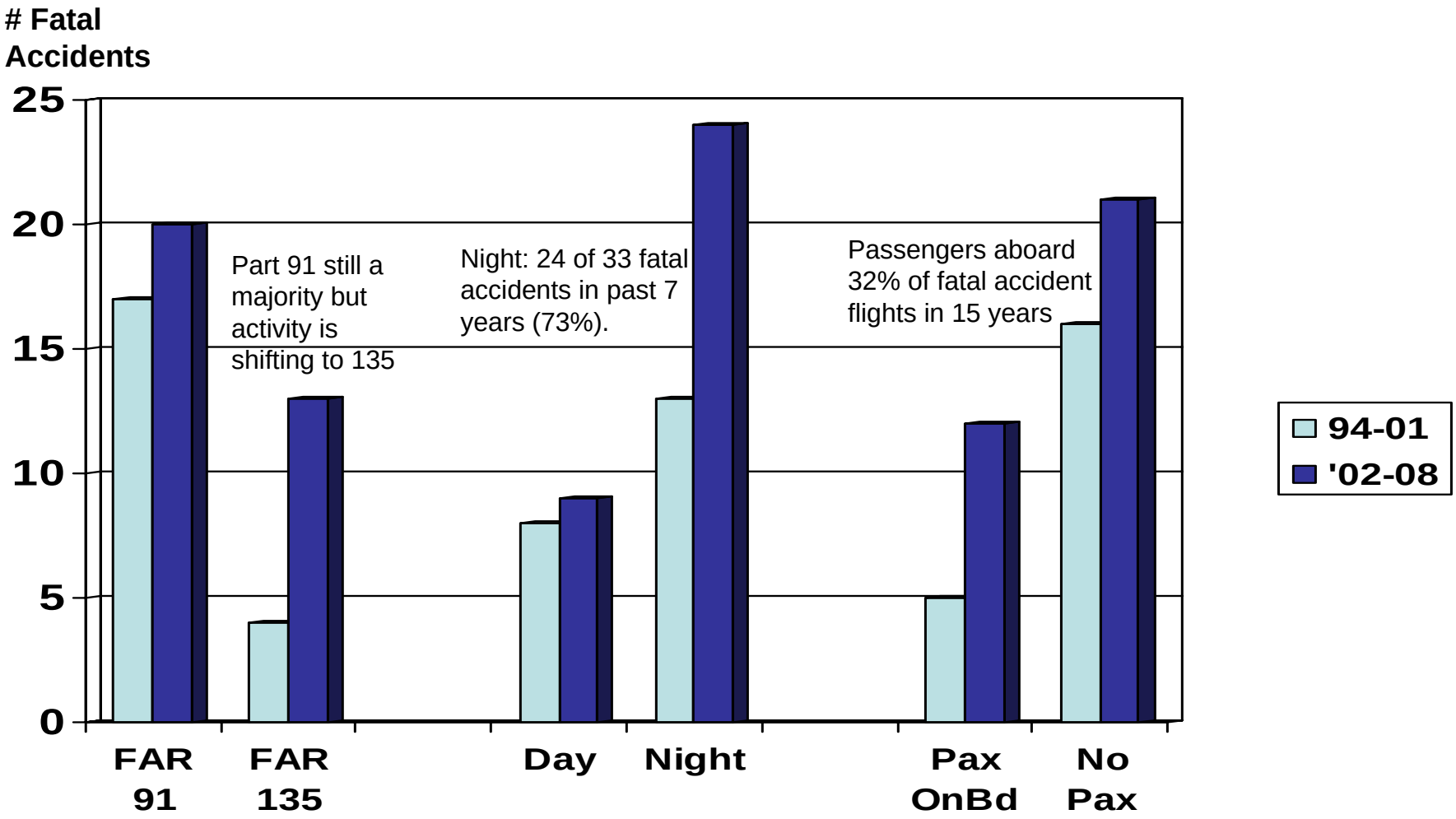
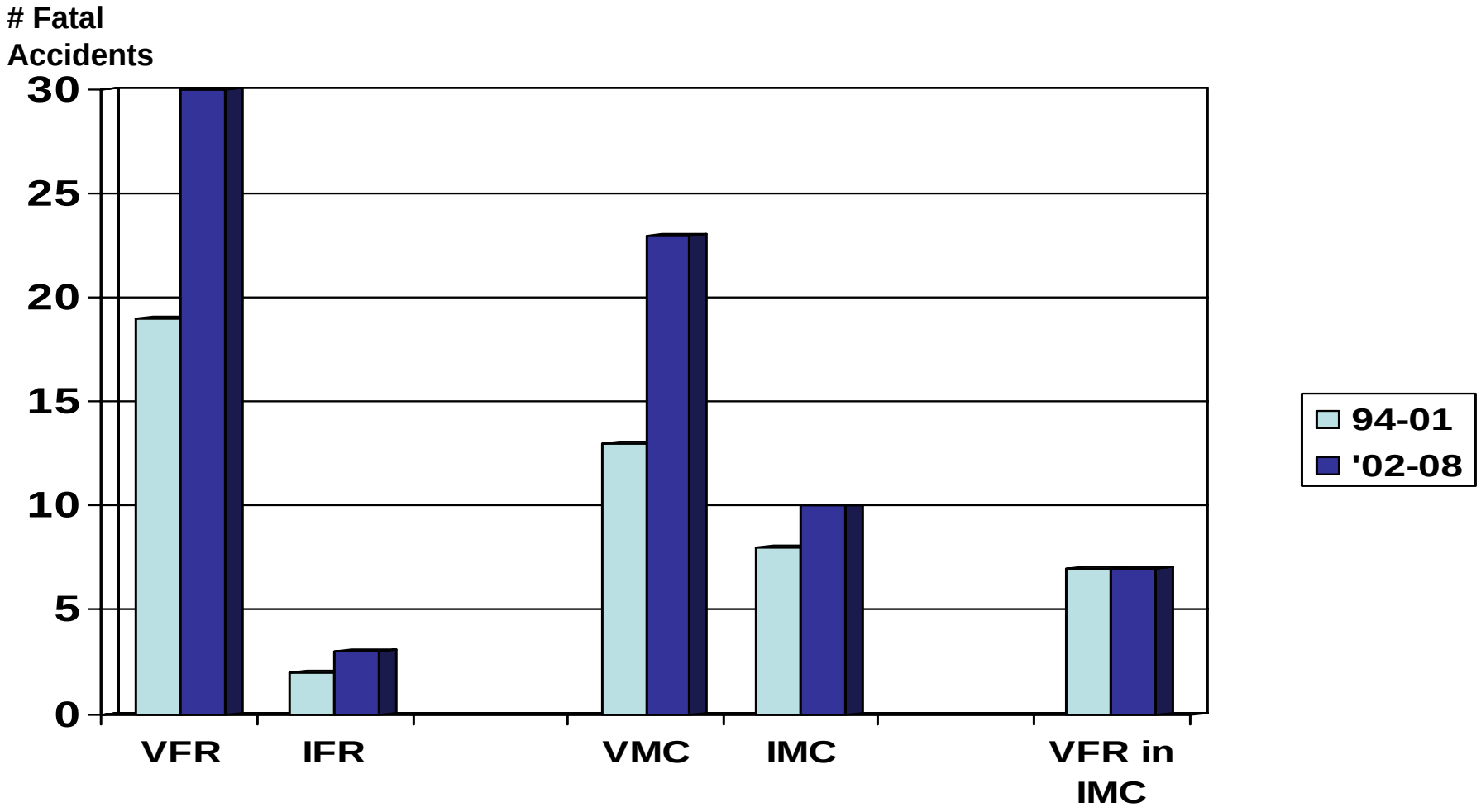
## All HEMS Accidents

| Year | # Acc | FAR 91 | 135 | Day | Night | VFR | IFR | VMC | IMC | Night VFR | VFR in IMC | No Pax |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | 6 | 6 | 0 | 5 | 1 | 5 | 1 | 5 | 1 | 6 | 6 | 6 |
| 1995 | 6 | 5 | 1 | 3 | 3 | 6 | 0 | 4 | 2 | 4 | 3 | 5 |
| 1996 | 2 | 1 | 1 | 0 | 2 | 2 | 0 | 2 | 0 | 2 | 0 | 1 |
| 1997 | 3 | 2 | 1 | 1 | 2 | 3 | 0 | 2 | 1 | 2 | 1 | 2 |
| 1998 | 7 | 5 | 2 | 2 | 5 | 7 | 0 | 5 | 2 | 5 | 2 | 4 |
| 1999 | 10 | 8 | 2 | 5 | 5 | 9 | 1 | 7 | 3 | 8 | 6 | 8 |
| 2000 | 12 | 9 | 3 | 4 | 8 | 12 | 0 | 11 | 1 | 11 | 4 | 10 |
| 2001 | 14 | 11 | 3 | 9 | 5 | 14 | 0 | 14 | 0 | 14 | 9 | 12 |
| 2002 | 12 | 9 | 3 | 7 | 5 | 12 | 0 | 10 | 2 | 10 | 7 | 9 |
| 2003 | 19 | 14 | 5 | 9 | 10 | 19 | 0 | 14 | 5 | 14 | 9 | 17 |
| 2004 | 14 | 8 | 6 | 5 | 9 | 13 | 1 | 10 | 4 | 11 | 6 | 9 |
| 2005 | 14 | 9 | 5 | 8 | 6 | 12 | 2 | 12 | 2 | 14 | 10 | 11 |
| 2006 | 11 | 9 | 2 | 5 | 6 | 11 | 0 | 10 | 1 | 10 | 5 | 9 |
| 2007 | 8 | 2 | 6 | 4 | 4 | 8 | 0 | 7 | 1 | 7 | 4 | 3 |
| 2008 | 10 | 6 | 4 | 3 | 7 | 9 | 1 | 9 | 1 | 10 | 4 | 6 |
| Total | 148 | 104 | 44 | 70 | 78 | 142 | 6 | 122 | 26 | 128 | 76 | 112 |

## Fatal HEMS Accidents

| | # Acc | FAR 91 | 135 | Day | Night | VFR | IFR | VMC | IMC | Night VFR | VFR in IMC | No Pax | # Fatal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | 4 | 4 | 0 | 4 | 0 | 3 | 1 | 3 | 1 | 4 | 1 | 4 | 11 |
| 1995 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 3 |
| 1996 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 3 |
| 1997 | 2 | 1 | 1 | 0 | 2 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | 5 |
| 1998 | 4 | 3 | 1 | 1 | 3 | 4 | 0 | 2 | 2 | 2 | 2 | 2 | 14 |
| 1999 | 3 | 3 | 0 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 3 | 10 |
| 2000 | 4 | 3 | 1 | 1 | 3 | 4 | 0 | 3 | 1 | 3 | 1 | 3 | 11 |
| 2001 | 2 | 2 | 0 | 1 | 1 | 2 | 0 | 2 | 0 | 2 | 0 | 2 | 3 |
| 2002 | 5 | 4 | 1 | 2 | 3 | 5 | 0 | 5 | 0 | 5 | 0 | 4 | 13 |
| 2003 | 4 | 3 | 1 | 1 | 3 | 4 | 0 | 1 | 3 | 1 | 3 | 4 | 7 |
| 2004 | 6 | 2 | 4 | 0 | 6 | 6 | 0 | 3 | 3 | 3 | 3 | 2 | 18 |
| 2005 | 6 | 4 | 2 | 2 | 4 | 4 | 2 | 4 | 2 | 6 | 0 | 5 | 11 |
| 2006 | 3 | 2 | 1 | 2 | 1 | 3 | 0 | 3 | 0 | 3 | 0 | 2 | 5 |
| 2007 | 2 | 1 | 1 | 0 | 2 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | 7 |
| 2008 | 7 | 4 | 3 | 2 | 5 | 6 | 1 | 6 | 1 | 7 | 0 | 3 | 28 |
| Total | 54 | 37 | 17 | 17 | 37 | 49 | 5 | 36 | 18 | 41 | 14 | 37 | 149 |

# Selected Characteristics, HEMS Fatal Accidents: 1994-2001 versus 2002-2008



# Selected Characteristics, HEMS Fatal Accidents: 1994-2001 Versus 2002-2008