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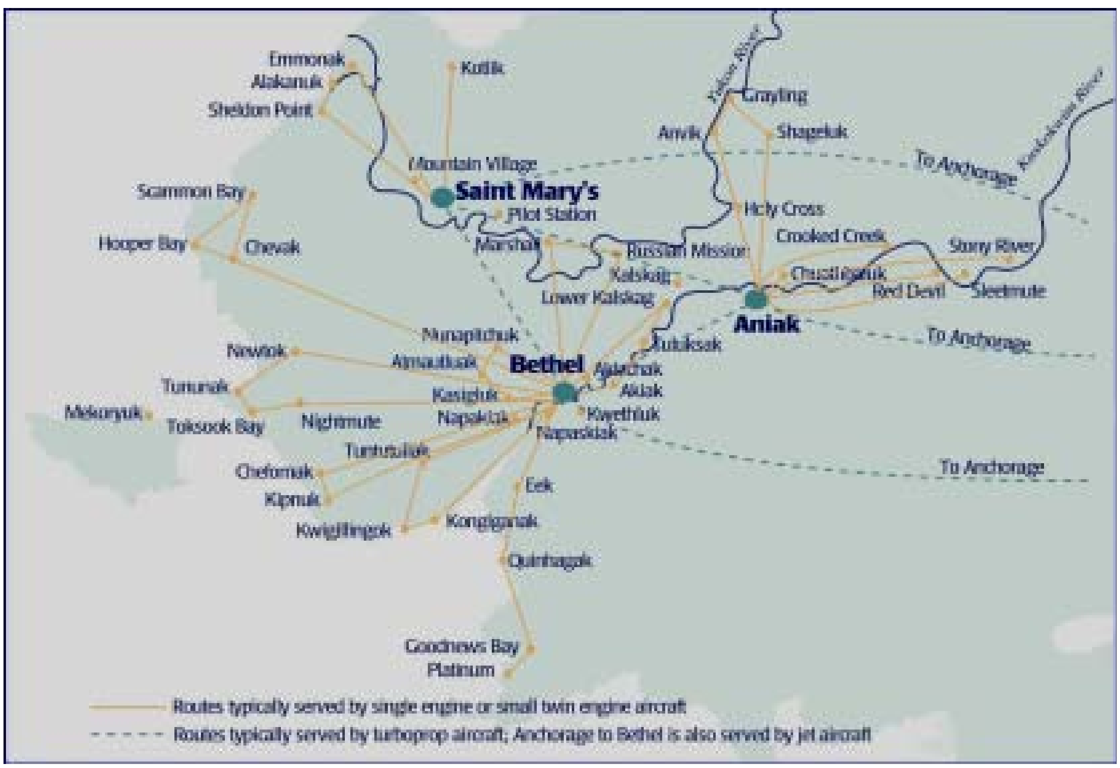
MITRE PRODUCT

The Safety Impact of Capstone Phase 1
Quick-Look Assessment: 2002

August 2003

W. Worth Kirkman



Center for Advanced Aviation System Development
McLean, Virginia

Summary of Quick-Look Assessment: 2002

From 2000 through 2002 the Capstone program made significant progress toward implementing safety and efficiency capabilities for commercial aviation in the YK Delta, but important steps remain.

- The over-all rate of accidents for Capstone equipped aircraft is consistently lower than for non-equipped aircraft. The amount of reduction is likely in the range of 20 to 25%.

- There is insufficient data to determine whether specific Capstone capabilities are preventing the types of accidents for which they are intended

- Local Part-135 aircraft are now 95% equipped with Capstone avionics, but pilots are only trained to about 67% effectiveness.

- Flight Monitoring for operators is now available and in use.

- Weather text and Bethel NEXRAD graphics are available on FIS-B in many locations in the YK Delta for aircraft at sufficient altitude, but FIS-B service has not been reliably available. NOTAMs, and PIREPs are not yet implemented and graphical icing products that would benefit Capstone are still being researched.

- AWOS installation and creation of part-135 approved GPS approaches is complete at all ten of the planned airports. The AWOS are not connected to national weather-data collection networks so data from them is unavailable for FIS-B transmissions to Capstone aircraft or for the weather modeling and analyses that provide aviation and other weather forecasts.

- Radar-like services are operational at Bethel, Aniak, and Saint Mary’s. ADS-B surveillance for the remainder of the Delta, and approach/departure control at Bethel, are not yet available. With the cut-over of Aniak and Saint Mary’s to ATC service, flight monitoring and FIS-B were disabled at those locations.

- The availability of ADS-B surveillance data to the Anchorage Center has expedited search and rescue for a downed Capstone equipped aircraft.

- The Bethel tower “Brite” display is in operation but has not been reliably available.

The Safety Impact of Capstone Phase 1

Quick-Look Assessment: 2002[1]

Worth Kirkman
The MITRE Corporation
Center for Advanced Aviation System Development
August, 2003

Capstone is a joint initiative by the FAA Alaska Region and the aviation industry to improve aviation safety and efficiency in Alaska by using new technologies. Phase 1 of Capstone is taking place in the watershed of the Yukon and Kuskokwim rivers in Southwest Alaska – the YK Delta – which is relatively isolated, has had limited infrastructure, and has had a high rate of aviation accidents. Capstone has installed new avionics in nearly all the Part-135 aircraft based in the Delta. Phase 1 continues with new ground-based capabilities, expanded services and training, and information gathering on the safety of YK Delta aviation. This report briefly evaluates operations and accidents in 2002, and updates last year's *Interim Assessment* of the safety impact of Capstone Phase 1 in 2000-2001.

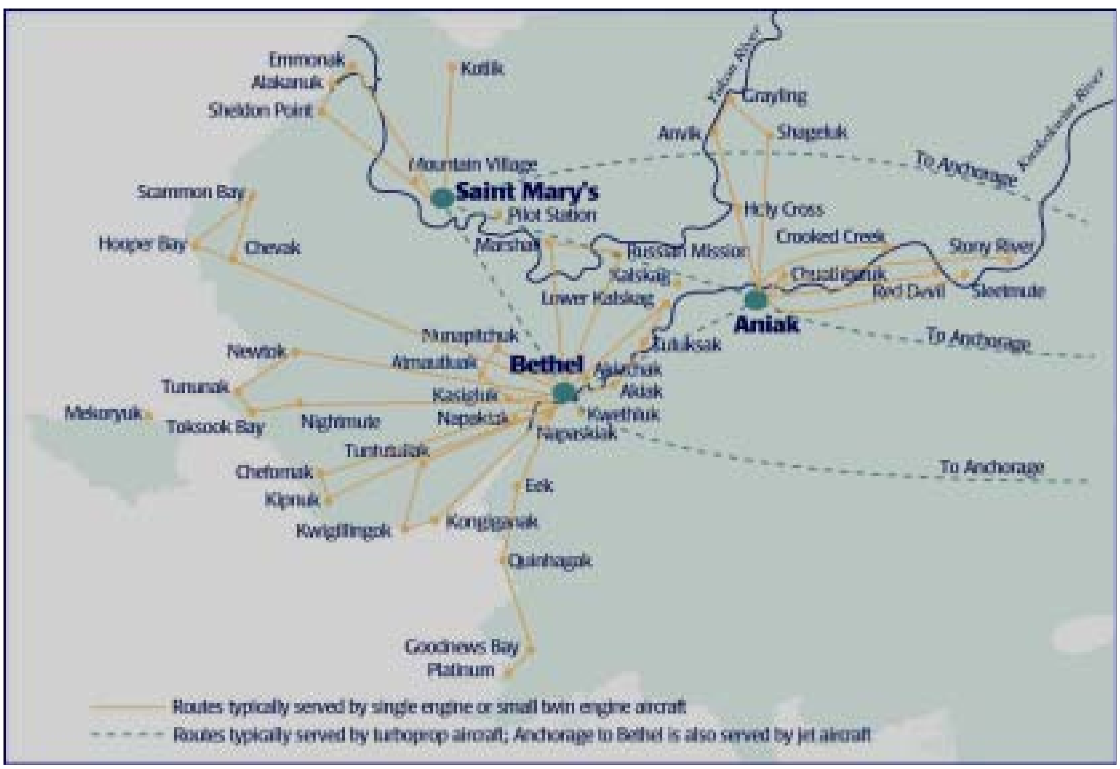


Figure 1 The Capstone Phase 1 Area in Southwest Alaska showing Airports in the Yukon-Kuskokwim Delta

[1] The contents of this material reflect the views of the author. Neither the Federal Aviation Administration nor the Department of Transportation, makes any warranty or guarantee, or promise, expressed or implied, concerning the content or accuracy of the views expressed herein.

Aviation is critical to Alaska not only for routine travel and commerce, but for nearly any kind of emergency – only 10% of Alaska is accessible by road, and waterways are impassible most of each year. But Alaska is also very large, sparsely populated, and crisscrossed by mountains that block radio and radar so that services and infrastructure that would be available in the lower 48 are missing from many areas. The benefits of aviation as a lifeline are substantial, but the safety consequences of operating in these conditions are also substantial: the accident rate for rural Alaskan commercial aviation is 2.5 times the US average.

Accident rates in the YK Delta have been similarly high. Essentially all passengers and 95% of all cargo arrives in the YK Delta by scheduled air service through Bethel or through smaller hubs at Aniak and St Mary's. Service between Bethel and Anchorage is by larger turbine and jet aircraft, but service to YK Delta villages is on small single-engine or light-twin aircraft that have been limited to visual operations. Pilots for these flights often face weather hazards – fog, ice-fog, white-out or flat-light conditions that can be localized and change rapidly – but weather information has been limited. There are few navigational aids. Radar coverage is largely unavailable below 5000 feet, while icing concerns and short distances often keep operations below 2000 feet. Runways are short, mostly gravel or dirt, and are damaged regularly by freeze/thaw and water.

Accidents Before Capstone

The types and causes of accidents prior to Capstone are shown in Figure 2 for commercial aircraft (operating under Federal Aviation Regulations Part-135) based in the YK Delta. These are the aircraft most directly affected by Capstone. Major categories (the inner pie slices) are explained below. Some accidents also fall within some special sub-category (outer pie segments) but many do not. The dark band and underlined categories and sub-categories identify causes of accidents that are targeted by Capstone.

Fuel Mismanagement	Usually fuel exhaustion. Occasionally, failure to switch fuel tanks.
Mechanical Failure	Engine failure, inoperable control surfaces, failed landing gear, propeller or shaft failure. (There were no fatal accidents in this category by YK Delta based Part-135. In the lower 48, 10% of mechanical accidents are fatal.)
Flight Information	Usually inadequate weather information, especially icing, but also visibility; rarely convective weather. (Surface winds contributing to take-off or landing accidents have been included under take-off or landing rather than here.) Occasionally, lack of information on changes in procedures or facility status.
Navigation	Usually Controlled Flight into Terrain (**CFIT**) while en route, most often associated with reduced visibility. In the YK Delta, CFIT also occurs in nominal VFR conditions when "flat light" on snow-covered ground prevents recognition of terrain. Terrain Clearance Floor (**TCF**) warnings are a Terrain Awareness and Warning System (TAWS) function planned for Capstone Phase 2 that addresses the 20%-30% of CFIT accidents on approach or departure. These are not directly addressed by Capstone Phase 1 avionics. Rarely, accidents are due to mis-location, which can be addressed by a GPS- **map** display.
Traffic	Usually mid-air collisions between aircraft. Also includes accidents from last-moment avoidance of other aircraft.
Flight Preparation	Failure to ensure cargo is tied-down and within the aircraft's **weight and balance** limits. Failure to check fuel for the presence of water. Rare in the lower 48 but significant in the YK Delta is failure to remove ice or snow from the aircraft – often resulting in serious or fatal accidents.

Take-off and **Landing** Failure to maintain control (especially in wind), improper airspeed, or inadequate care near vehicles or obstacles. The YK Delta also includes unusually high numbers of accidents from poor runway **conditions**, from hazards at an off-runway **site** such as beaches and gravel bars, and from obstacles in water that are struck by float-planes.

Other Taxi[2] or airport vehicle accidents, low altitude maneuvering for game spotting or photography, spatial disorientation, improper carburetor heat, bird strikes.

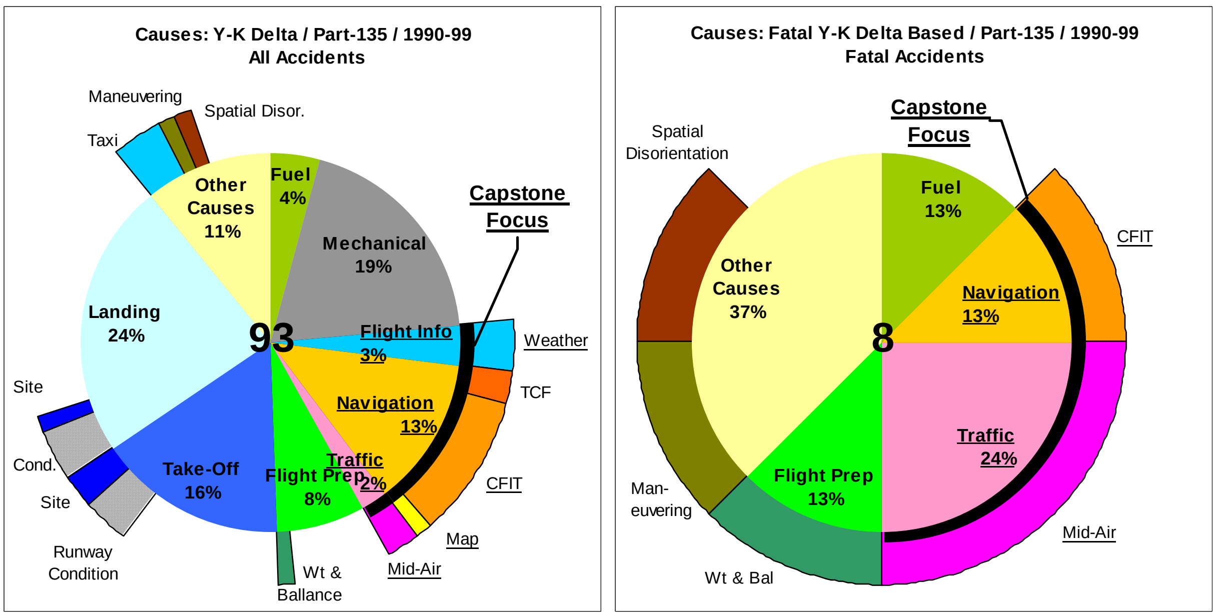


Figure 2 93 Accidents and 8 fatal accidents by YK Delta Part-135 aircraft 1990-1999[3]

Causes of accidents over-all and causes of fatal accidents had very different percentages. Many accidents were associated with take-off, landing and mechanical problems, but relatively few of these caused injuries and none caused fatalities. By contrast, accidents from inadequate flight preparation, fuel mismanagement, lack of flight information, collisions with other aircraft, and difficulty navigating were much more likely to cause injuries and fatalities. Differences such as these are consistent with recent accident studies[4] for the US as a whole. The percentage of fatal accidents associated with traffic (collision or interaction with other aircraft) was higher than in the lower 48; the percentage associated with navigation was comparable. "Weather" accidents (which are split between several of the categories[5] used here) were often fatal in both the lower 48 and Alaska. The focus of Capstone is on these more serious types of accidents.

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[3] These summaries are revised from last year. Damage by one aircraft to another on ramps or while taxiing are now shown in the Taxi category. Several Part-135 aircraft in accidents previously included in the baseline were found not to have been based in the YK Delta and have been removed.

[4] *2002 Nall Report – General Aviation Accident Trends and Factors for 2001*, AOPA Air Safety Foundation

[5] Weather contributes to accidents associated with navigation, flight preparation, and spatial disorientation, which have a high fraction of fatal accidents. It also contributes to take-off and landing accidents that cause few fatalities in the YK Delta – none from 1990 to 1999. (In the lower 48 take-off accidents have significant fatalities.)

The Capstone Program

The capabilities of Capstone Phase 1 target four serious safety problems in Alaska:

- CFIT accidents (within the navigation category)
- Accidents associated with aircraft traffic – especially mid-air collisions
- Inadequate flight information – especially weather information
- Inadequate infrastructure to support IFR operations

Capstone's Phase 1 capabilities also target problems with efficiency, and while efficiency is not the subject of this paper, it is important to recognize that there are safety consequences to landing delays and to flights that attempt but are unable to reach their intended destinations. These inefficiencies typically occur in marginal visibility when the potential for icing is higher than otherwise and when it is more difficult to see-and-avoid aircraft circling to wait for Special VFR (SVFR)[6] clearance. Because of these factors, decreasing arrival delays or aborted flights (from radar like services or increased IFR capability) seems likely to decrease accidents by much more than the proportion of flight time avoided.

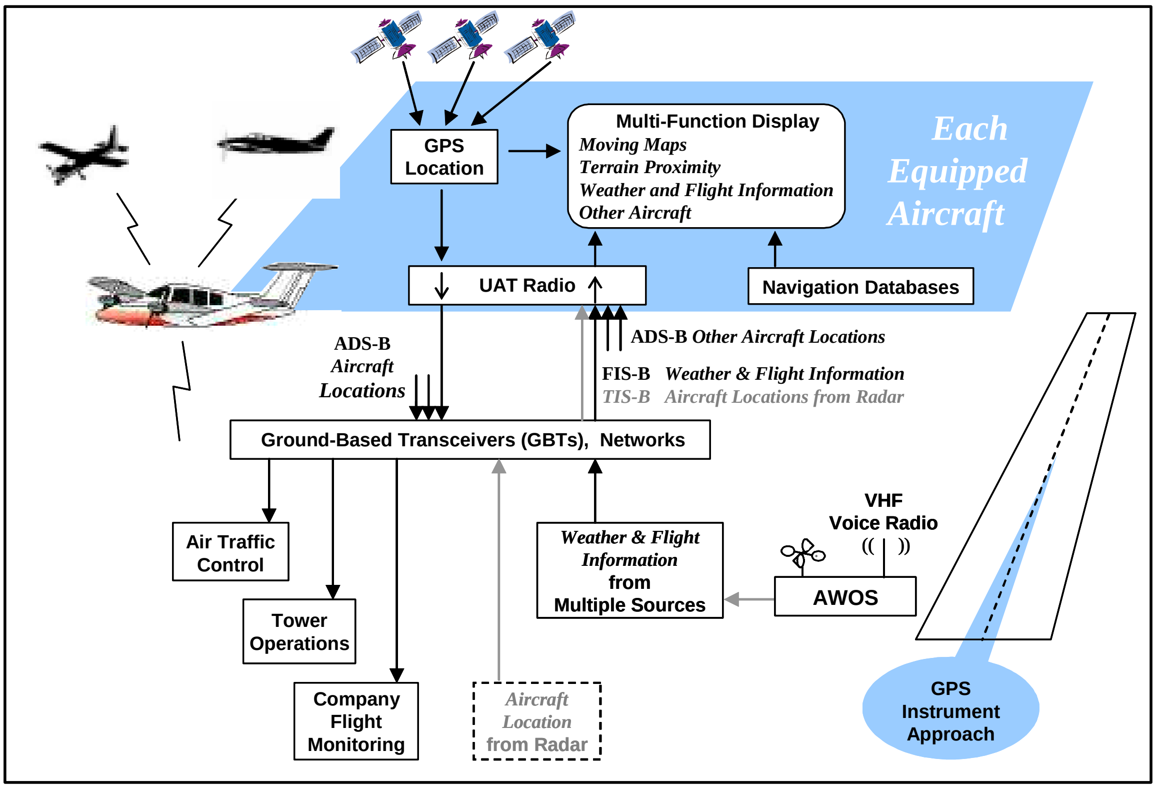

Figure 3 Capstone Avionics, Ground Systems, and Capabilities Capabilities not operational in 2002 are gray

Capstone's Phase 1 capabilities are based on new ground systems and services for the YK Delta and new avionics installed in commercial aircraft based there. Many use new technologies that have become

[6] Special VFR operations occur in visibility that is less than is required for conventional VFR operation.

available only recently or are being implemented for the first time. How Capstone works is illustrated in Figure 3 and described below.

- Accidents associated with ***navigation*** are addressed by showing pilots their location on a ***moving map*** on a Multi-Function Display (MFD). The location of the aircraft is derived from GPS, and the map is stored as part of an onboard navigation database. ***En route CFIT*** is addressed using terrain elevations from the database. Nearby terrain is compared to the aircraft's altitude and GPS location and then color-coded on the MFD (yellow if close in altitude, red if immediately hazardous). The GPS unit also has programmable functions to aid en route flight planning and may reduce pilot navigation workload.

- Accidents associated with aircraft ***traffic*** are addressed by ATC radar-like services (below) and by showing pilots the relative locations of other Capstone-equipped aircraft. This is derived from Automatic Dependent Surveillance Broadcast (ADS-B) messages transmitted via a Universal Access Transceiver (UAT) by other aircraft and received and processed to provide a Cockpit Display of Traffic Information (CDTI) – one of the functions of the MFD. CDTI also enhances pilot situational awareness and aids pilot-pilot coordination at non-towered airfields. In the future, locations of aircraft that are not Capstone equipped but are visible to ATC radar might be provided by Traffic Information Service Broadcast (TIS-B) from a network of Ground Based Transceivers (GBTs).

- ***Weather and flight information*** are provided by new Automated Weather Observing Systems (AWOS) at remote airports, and by Flight Information System Broadcast (FIS-B) of weather text and NEXRAD[7] graphics. FIS-B is distributed by data-network to GBTs that broadcast to equipped aircraft. Aircraft with Capstone avionics receive these broadcasts on a UAT and display them to pilots on the MFD.

- ***Increased IFR operation*** is supported at remote airfields by AWOS installations, which allow GPS instrument approaches to be approved for commercial operations. For qualified aircraft, this allows safe IFR operations in low visibility conditions that would be unsafe for VFR operations. IFR operations are improved and expanded by Air Traffic Control (ATC) use of ADS-B to support cost-effective ***radar-like services***. ADS-B takes an aircraft's location from GPS[8] and transmits it once per second over the UAT. GBTs receive these messages from all nearby Capstone equipped aircraft, and forward them to ATC computers where they are processed and the aircraft locations displayed much like aircraft locations from radar. This allows controllers to provide flight following and surveillance-based separation services in airspace that is not visible to radar.

- Late in 2002, tower operators at Bethel airport began regular use of a "Brite" display of ADS-B targets to help them visually locate aircraft and better coordinate arrival sequencing.

- In 2002, managers in companies that operate Capstone equipped aircraft began using ***flight monitoring*** on PCs connected to the Internet to monitor the location of their aircraft. This has the potential to significantly improve awareness of risks and to facilitate further improvements in safety posture.

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[7] Next Generation Weather Radar

[8] ADS-B applications may use or require other on-board navigation sources instead off or in addition to GPS. Capstone avionics use GPS and barometric altimetry.

Capstone's Progress on Implementation: Avionics

In 2000-2001 Capstone equipped almost 6 aircraft per month, reaching 140 of 165 active YK Delta Part-135 aircraft by December 2001. By early 2003 a total of 200 aircraft were equipped – several of which operate as government or "public use" aircraft. Equipped airframes account for approximately 95% of operations by Part-135 aircraft based in the YK Delta [9].

Commercial pilots using Capstone are trained by their companies, often using training materials, videotapes, simulators, and assistance with instruction made available through the University of Alaska at Anchorage Aviation Technology Division (UAA-AT). From observations of pilots (during simulator and flight training and follow-ups) UAA-AT assessed the effectiveness of different training levels at enabling pilots to use Capstone avionics to avoid targeted types of accidents[10]. Their assessments range from 25% for pilots with little or no training, to 90% for pilots with at least 4 hours of classroom/simulator instruction followed by at least 1 hour of flight training.

UAA[11] has surveyed YK Delta commercial pilots on hours and types of training to estimate their effectiveness at avoiding accidents with Capstone. Near the end of 2001, they estimated this at 50% - suggesting only *half* of Capstone-preventable accidents would be avoided. By the end of 2002, this had increased to *two-thirds*.

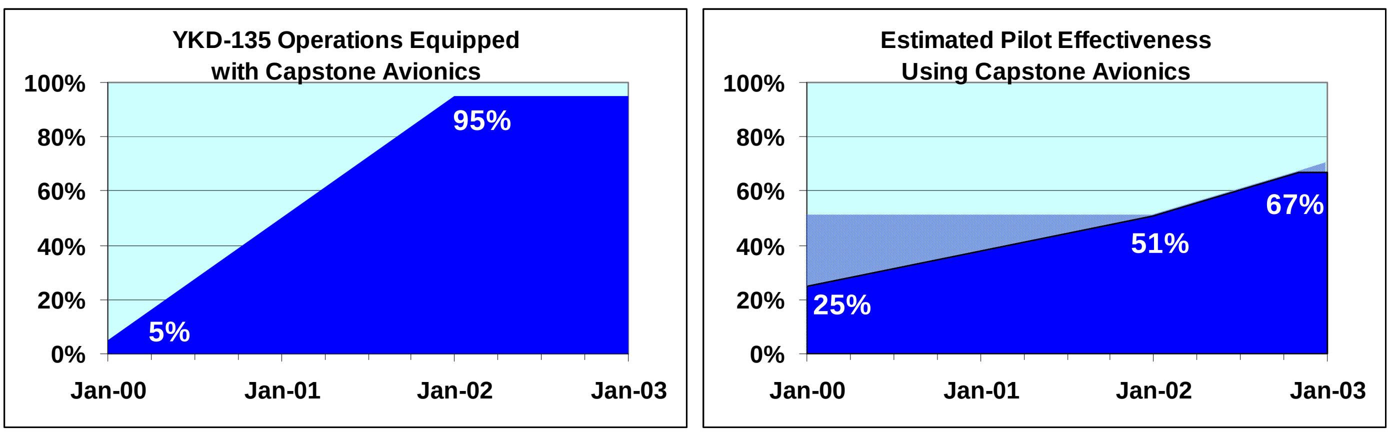

Figure 4 Equipage and Effectiveness of Training with Capstone Avionics for Operations by Part-135 Aircraft based in the YK Delta

Radar-Like Services

Beginning January 1, 2001, radar displays for air traffic controllers at Anchorage Center have shown Capstone-equipped aircraft near Bethel even though radar coverage is not available below 5000 feet. This operational approval of ADS-B to provide "radar-like services" is the first of its kind in the world. Controllers can monitor aircraft and vector them to provide air-to-air and air-to-ground separation that is based on very accurate surveillance. This allows operations that are much more precise and efficient than the non-radar procedural separation of IFR aircraft that was in use before Capstone.

[9] Detailed in last year's report.
[10] Capstone Phase 1 Interim Safety Study 2000/2001 http://alaska.faa.gov/capstone/docs/2001%20UAA%20report.pdf
[11] Aviation Technology Division in collaboration with the Institute for Social and Economic Research.

Initially, surveillance for air traffic control was supported only through the GBTs located at Bethel, so radar-like services were not available in other parts of the Capstone area. In August 2002 operational ATC surveillance was also added at Aniak and Saint Mary's. FAA has vertically divided the Bethel air traffic control sector to take better advantage of ADS-B surveillance. More complete services for approach and departure are planned with establishment of a Bethel Approach Control in 2004.

Tower Display

The "Brite" display of ADS-B targets is now in operational use at the Bethel tower, but was unavailable during most of the study period. Technical problems with ground processing and communications continue to limit its availability. Impact of the tower display on operations and safety will be assessed in a later report.

Flight Monitoring

Beginning in 2002, Capstone has provided internet/PC software for flight monitoring, and aircraft location data from the GBT network, to air-transport companies operating in the YK Delta. How flight monitoring changes operations and safety posture will be assessed in a late report.

AWOS Installations, Non-Precision Approaches, and IFR Operations

Ten airports in or near the YK Delta have received AWOS stations and associated GPS non-precision instrument approaches. New AWOS more than double the number of full-time weather reporting sites in the YK Delta, and reduce the distance between weather observations to less than 50 miles on most flight routes. Pilots can listen to vocalized current weather observations by phone prior to departure, or by radio when in flight near these sites. Because these AWOS are not connected to networks for national weather-data distribution, observations from these sights are not yet available on Capstone avionics via FIS-B. Of potentially greater significance, these observations are also unavailable to improve the weather analyses that provide forecasts (including aviation forecasts) for the region as a whole.

The new GPS approaches more than double the percentage of aircraft operations in the YK Delta that have IFR infrastructure available to them (to 34%). Partially as a result of these improvements, commercial operators expanded the number of IFR-qualified aircraft based in the YK Delta from *two* in January '00 to *fourteen* in December '01, which provided 45% of the passenger carrying capacity (seats) into and out-of the YK Delta's IFR capable airports. The 2002 fleet will be studied in a later report.

Flight Information

In addition to the AWOS capabilities described above, the network of GBTs provide FIS-B to Capstone aircraft in most of the YK Delta. The products available to pilots are Meteorological Aviation Reports (METARs), Terminal Area Forecasts (TAFs), and NEXRAD graphics from the weather radar at Bethel. Notices to Airmen (NOTAMs), Pilot Reports (PIREPs) and weather messages based on the newly installed AWOS are not yet available on FIS-B. In the future, graphical icing products may become available which would be much more effective in helping pilots avoid localized icing – of particular value to Capstone.

FIS-B (as well as operator flight monitoring) are currently provided via prototype systems that are sometime not available for service. The availability of these services is now being monitored and reported on the Capstone website. With commissioning of ATC surveillance at Aniak and Saint Mary's, these services became unavailable at those locations. (Capstone plans to add these back in the future.)

Safety Expectations based on Progress

The safety benefit we should expect from Capstone depends on the types (and rates of occurrence) of accidents before Capstone, the projected effectiveness of a complete implementation, and the progress on implementation that Capstone has actually made. As the safety impact of Capstone is better quantified over time, we expect to see changes from increased IFR capability, changes in safety posture from Capstone and other causes, and changes in operations from using Capstone capabilities in ways we might not predict. For now, the expectations we can quantify are for two of the accident types that are the direct focus of Capstone: accidents associated with navigation, and traffic[12].

Capstone's progress on implementation affects the prevention of navigation/CFIT accidents through the level of equipage and the effectiveness of pilot training. From 2000-2002 an average of 65% of YK Delta-based Part-135 flight operations were equipped, and the average effectiveness of pilots using Capstone avionics was assessed to be 54%. **In 2000-2002 we estimate 32% of preventable navigation and CFIT accidents would be avoided because of Capstone.** Warnings on violating Terrain Clearance Floor are not included in Phase 1 avionics (they are planned for phase 2) so collisions with terrain <u>during approach</u> are not directly affected. (For en route CFIT the full-implementation effectiveness was assumed to be 90%.)

Progress on implementation affects traffic/mid-air accidents differently. While 50% of YK Delta Part-135 flight operations were equipped, only 2/3 of flights in the Delta are Part-135. (The remainder are mostly Part-91 and public use.) Averaged across 2000-2002, if a Part-135 aircraft were at risk of mid-air collision with a second aircraft, the chance they were both Capstone equipped was 28%. Limited training levels reduces this further. **In 2000-2002 we estimate that 19% of mid-air accidents would be avoided because of Capstone.** (This assumes a full-implementation effectiveness of 100%.)

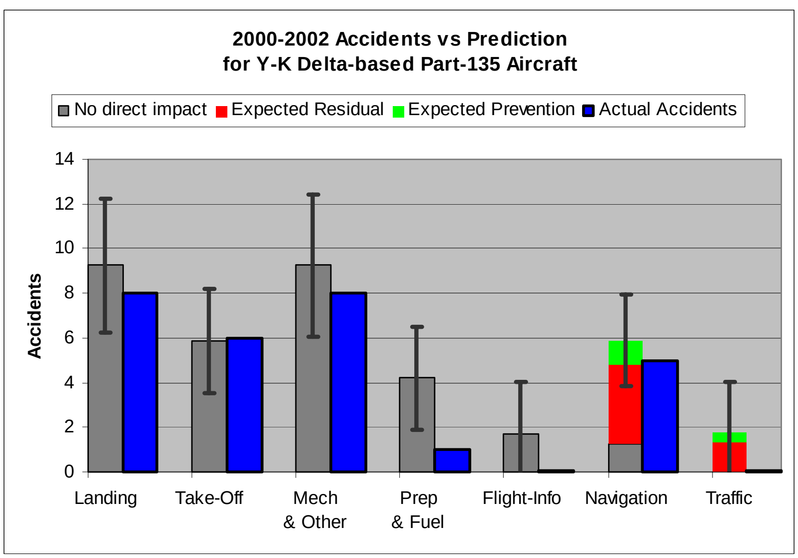

Figure 5 2000-2002 Accidents vs Prediction for YK Delta Part-135

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[12] The impact of flight information might also be quantified, but the accidents that would clearly be preventable are due to icing. Graphical icing products, when available, should help significantly. NEXRAD graphics, METARs, TAFs and AWOS information should contribute to safer operations, but the change they would have made in historical accident counts cannot be confidently assessed.

Figure 5 uses these estimated safety benefits for Navigation and Traffic accidents to project the number of accidents we should expect in 2000-2002 for Part-135 aircraft based in the YK Delta, and compares this to the number that actually occurred. The projection uses the types and rates of accidents from 1990-99 scaled-up for observed growth in operations. The figure also shows error bars for the numbers of accidents that should be expected from history. This is the standard deviation for three-year periods, scaled for growth. If there were no underlying changes in accident rates, the chance of observing a number in this range would be about 2/3. For small numbers such as these, this variability is large compared to the average value. (This is particularly true for fatal accidents, only about one tenth as numerous.) In many cases, observing zero accidents is well within typical variations, and a gap in accidents would need to persist for several years before it should be seen as significant. The estimated prevention of navigation and traffic accidents by Capstone in 2000-2002 are still less than these expected random variations. This means that more time will be needed at higher levels of equipage and training before any changes could become statistically significant.

Accidents in 2002

For 2000-2002 all accident types are within or near one standard deviation of the scaled baseline mean, including the navigation and traffic categories targeted by Capstone.

Figure 6 gives a full break-out of accident categories, with YK Delta Part-135 aircraft in accidents in 2002 shown on the left side. Nearly all the Part-135 aircraft were Capstone equipped, so there was only one non-equipped aircraft involved in an accident. The right side of the figure shows all accidents that have occurred to all YK Delta Part-135 aircraft[13] since Capstone implementation began.

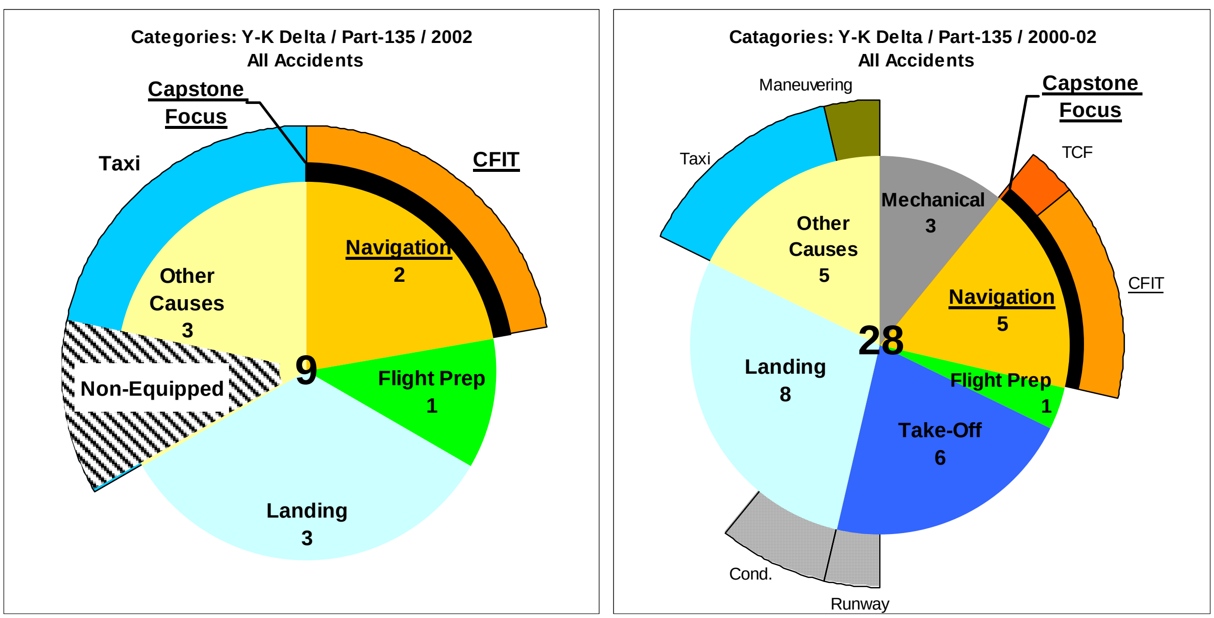

Figure 6 Categories of Accidents to YK Delta Part-135 Aircraft in 2002, and Since the Beginning of Capstone Implementation

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[13] Using the YK Delta Part-135 population excludes one 2001 accident of a Capstone-equipped aircraft that had been permanently removed from the YK-Delta. The accident occurred near Dillingham, and was not caused by factors addressed by Capston.

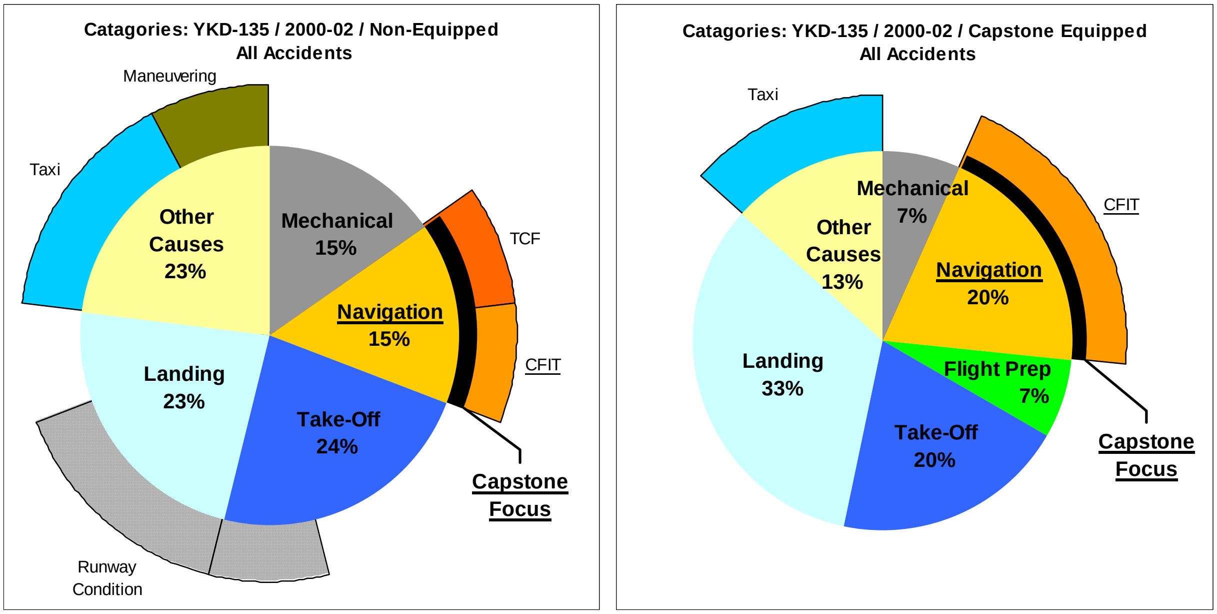

Figure 7 Categories of Accidents by Non-Equipped and Capstone-Equipped YK Delta Part-135 Aircraft 2000--2002

Figure 7 shows the accident categories for non-equipped and equipped aircraft since 2000. The breakdowns of accidents by major category are essentially similar and within the levels of variation one should expect for this number of occurrences. However, 2002 continues a trend noted last year that no accidents to equipped aircraft involved poor runway conditions (two *sub*-categories), compared to 23% (three) of the accidents for non-equipped aircraft. While an explanation for this has been proposed[14], it remains uncertain whether this is an actual Capstone benefit or the result of random variations.

In 2002 an accident due to inadequate flight preparation (which with fuel management appears to be an excellent indicator of safety posture) occurred for the first time since the beginning of Capstone implementation. The aircraft had been taken out of Part-135 service (not carrying passengers or cargo) and was flying as Part-91 for pilot training.

Three CFIT accidents have occurred to Capstone equipped aircraft since the beginning of implementation. Non-prevention of the accident in 2001 was clearly associated with limited training and the pilot's attitude toward use of the equipment. In the first 2002 accident, the information available is consistent with an attempt by the pilot to avoid clouds by descending, and then losing visibility. He subsequently reversed his course prior to impacting terrain. Information on the pilot's level of training on Capstone and on his attitude and habits of using it are not yet available.

Information on the second 2002 CFIT accident is more complete; the pilot reports he was using the Capstone terrain-awareness display at the time of the accident – shortly after a night take-off from Marshall for a return flight to Bethel. The airstrip with which the pilot was familiar had been relocated

[14] From observations and discussions during surveys it was observed that when flying to a remote village airstrip, some pilots are monitoring the traffic display to identify other aircraft that go there before them. The pilots contact the other aircraft by voice radio, request information on conditions at their destination, and are forewarned of hazards they should avoid. In the baseline, most YKD-135 runway condition accidents were from general deterioration of a runway that pilots were aware of and had misjudged to be manageable.

several days before, necessitating a different departure path to avoid proximity to a ridge. Neither printed sectional charts nor the avionics navigation database were updated yet to show the new airstrip, though the pilot had flown from it once. The pilot apparently departed the new airstrip using the old departure path, and encountered a down-draft as he approached the crest of the ridge with inadequate clearance. The Capstone Phase 1 terrain awareness display does not assist during approach or departure. This accident, which can be categorized as a Terrain Clearance Floor violation could likely have been prevented by Capstone Phase 2 avionics (that detect and alert on this condition), but only if the new airstrip and departure path were included in its TCF database.

Capstone capabilities may never the less have saved the life of the pilot, who was seriously injured during the impact and would have been unlikely to survive until the following morning. The aircraft was reported overdue to the Anchorage En Route Air Traffic Control Center where it had been tracked by ADS-B as it departed Bethel. The plane left coverage as it descended to land in Marshall, but a single ADS-B report had been received as the aircraft was departing from Marshall, presumably as it rose above the ridge-line and encountered the downdraft. A helicopter was dispatched which used night-vision technology to quickly locate the downed aircraft near its last reported ADS-B position.

Over-All Accident Rates

Evaluating accident rates in Alaska is made difficult by the minimal data available on aircraft flight-times and operations-counts[15]. Operations levels for Part-135 aircraft as reported by the Bethel tower correspond well with variations in YK Delta passenger enplanements, mail, and cargo[16]. For this reason, Figure 8 and Figure 9 use tower operations as a basis for characterizing how accident rates have varied over time.

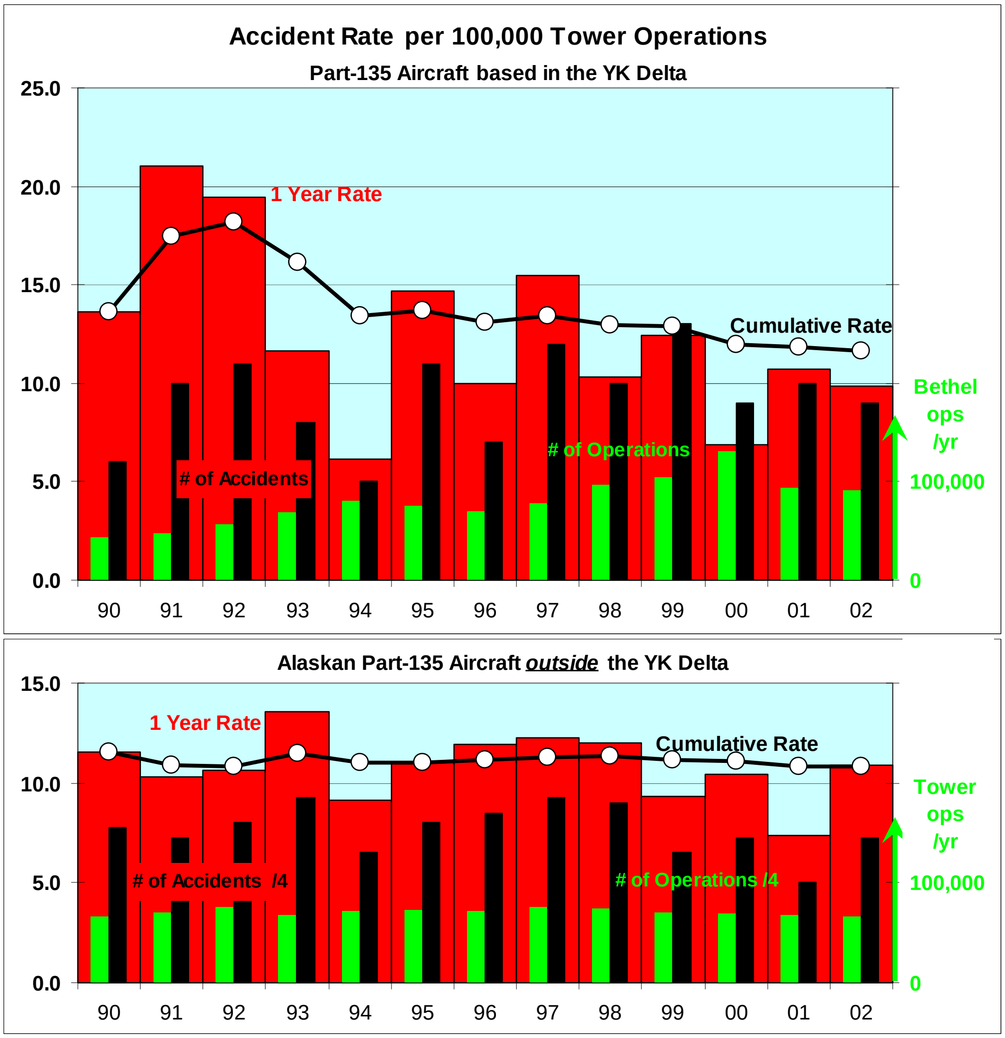

Figure 8 Variability in accident rates for YK Delta Part-135 aircraft and Part-135 aircraft based elsewhere in Alaska[17]

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[15] Substantially more data on Capstone equipped aircraft operations is becoming available from flight monitoring data, but could not be analyzed in time for this Quick-Look Assessment.
[16] Enplanements alone do not correspond well. There was a substantial increase in tower operations during and following the winter of 99-00 that corresponds with an increase in mail and air cargo volumes.
[17] Absolute rates should not be compared between these two graphs. While the ratios between actual operations levels and tower operations are believed relatively constant over time, they differ between the two locations.

Figure 8 shows tower operations levels, accident count, and accidents per 100,000 tower operations for Part-135 in the YK Delta (relative to Bethel) and for other parts of Alaska (relative to all other towers). From year to year, these are much more variable in the YK Delta than in the remainder of Alaska. Also shown on the charts is a continuous curve that is the cumulative total rate of accidents per operations from 1990 to the year shown (based on yearly data). For other parts of Alaska, this cumulative rate has been quite stable. For Part-135 operations in the YK-Delta, there was a substantially higher rate of accidents in the early '90s from which the cumulative average is slowly falling. A similar curve (not shown) beginning after 1992 stabilizes quickly then remains essentially flat.

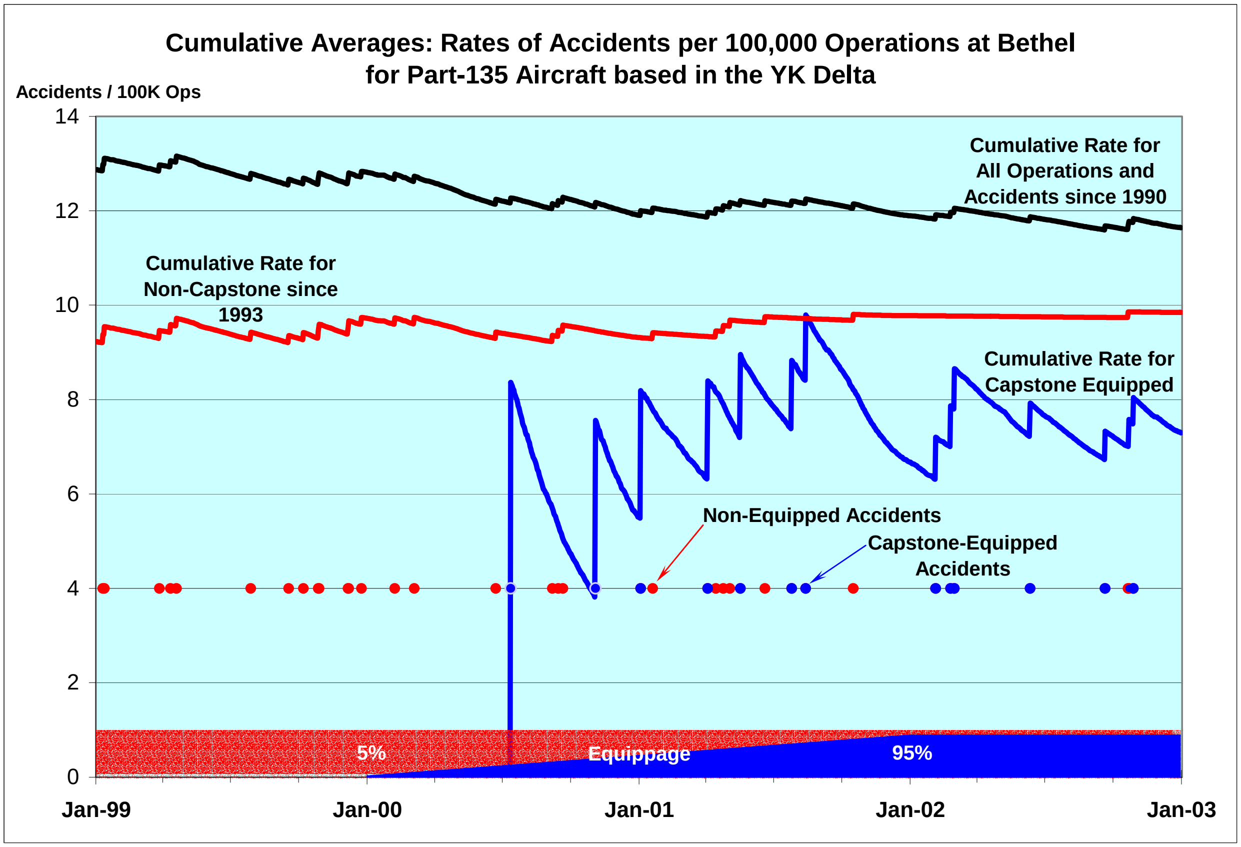

Figure 9 Relative accident rates for YK delta part-135 aircraft without and with Capstone avionics

The relative stability of Part-135 accident rates in the YK Delta since 1993 extends through the end of 2002 for aircraft not equipped with Capstone. A time-magnified view for 1999-2002 (using daily data), is shown in red on Figure 9. The blue line is the equivalent curve for Capstone equipped aircraft. There were no accidents and few operations before July '00, so this curve is less stable. Nevertheless, the Capstone equipped accident rate appears to have trended strongly towards stability at a rate significantly below that for non-equipped aircraft. **The rate of accidents by Capstone equipped aircraft is lower than that for non-equipped aircraft.** The rate for equipped aircraft still varies[18] due to the smaller volume of data. **The percentage improvement is about 20% to 25%.** These results do not determine whether the improvement is due to safety benefits of the specific Capstone capabilities, or to a heightened attention to safety on the part of pilots and companies flying Capstone equipped aircraft.

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[18]The end of 2001 was a low-point, corresponding to the 40% difference observed at the time of last year's report.