COMMERCIAL AVIATION ACCIDENTS BEFORE AND DURING THE ALASKA CAPSTONE IMPLEMENTATION OF ADS-B, FIS-B, TERRAIN SITUATIONAL AWARENESS, AND EXPANDED IFR INFRASTRUCTURE

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Abstract

Capstone is a joint initiative by the Federal Aviation Administration Alaska Region and the aviation industry to improve aviation safety and efficiency in Alaska by using ADS-B and related broadcast technologies for surveillance, enhanced situational awareness, and flight information. The "Phase 1" implementation 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 began installing avionics in aircraft in November 1999, and continues to install and improve ground infrastructure.

Capstone Phase 1 targets four serious safety problems in Alaska: enroute Controlled Flight Into Terrain (CFIT), mid-air collisions, inadequate flight information – particularly weather, and inadequate infrastructure supporting Instrument Flight Rules (IFR) operation. Capstone is closely related to the Safe Flight 21 program[1,2], which has been conducting evaluations of ADS-B and related capabilities at air-cargo hubs in the eastern-central United States.

This paper characterizes types and relative rates of commercial aviation accidents in the YK Delta before Capstone. It describes the Phase 1 capabilities, and calculates changes in accident rates for CFIT and mid-air collisions that should be expected from implementation progress to date. Rates and types of accidents during implementation are compared against these predictions. Rates of accidents are also compared between Capstone-equipped and non-equipped aircraft. Rates of accidents in categories specifically targeted by Capstone have decreased, and the rate of accidents for Capstone-equipped aircraft has been lower than for those not equipped. However, experience and data are not yet sufficient to confidently draw conclusions about long-term changes in safety and rates of accidents.

Alaska Aviation and Accidents

Aviation in rural Alaska lacks facilities and equipment that are available elsewhere in the US. Weather information is limited and there are few navigational aids. Radar coverage is largely unavailable below 5000 feet, while icing concerns and short flight-legs often keep operations below 2000 feet. Runways are short, mostly gravel or dirt, and are damaged regularly by freeze/thaw cycles and water. Commercial service to YK Delta villages is on small single-engine or light-twin aircraft which are often limited to visual operations.

The types and causes of accidents by commercial aircraft (operating under Federal Aviation Regulations Part-135) that were based in the YK Delta prior to Capstone (1990-1999) are shown in Figure **1** on the following page. These correspond to the aircraft that have been most directly affected by Capstone. The dark band and underlined categories and sub-categories identify causes of accidents that are targeted by Capstone.

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[3] 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

[1] *Cargo Airline Association & Safe Flight 21 Operational Evlaution-2 (OpEval-2),* Olmos et al, 4th USA/Europe ATM R&D Seminar, Santa Fe NM, 2001.

[2] *Safe Flight 21: The 1999 Operational Evaluation of ADS-B Applications*, Cieplak et al, 3rd USA/Europe ATM R&D Seminar, Napoli, 2000.

[3] *2001 Nall Report – General Aviation Accident Trends and Factors for 2000,* AOPA Air Safety Foundation

percentage associated with navigation was comparable. “Weather” accidents (which are split between several of the categories[4] used here) were often fatal in both the lower 48 and Alaska. The focus of Capstone is on these more serious types of accidents.

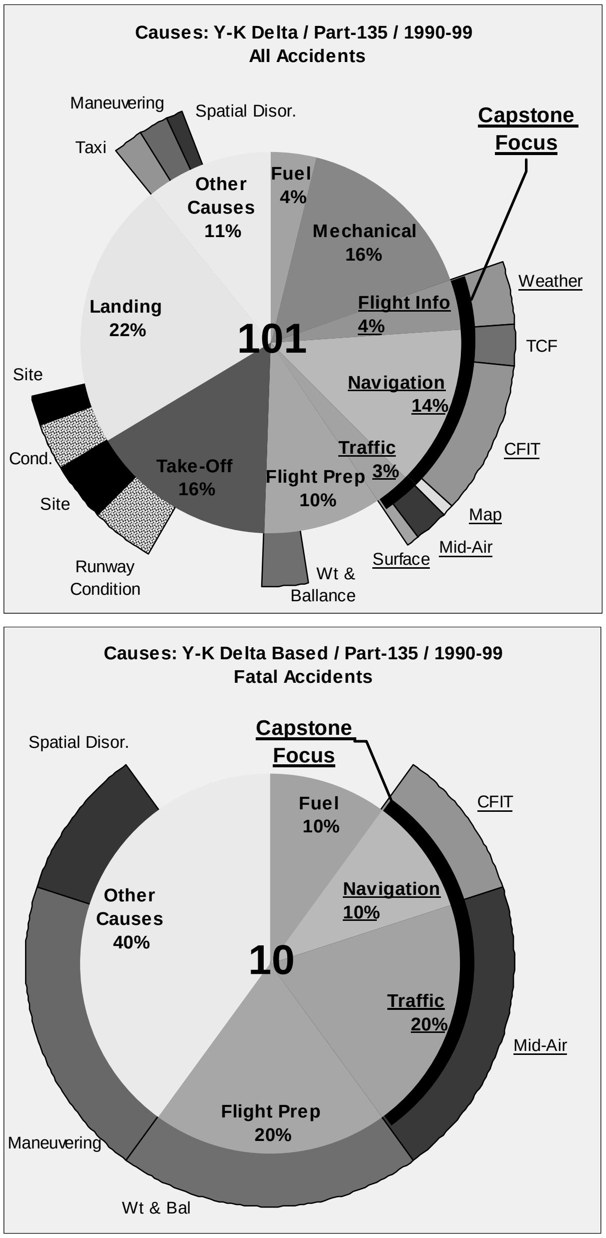

Figure 1. Accidents and Fatal Accidents by YK Delta Part-135 aircraft 1990-1999

The categories and sub-categories into which we have divided these accidents are:

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.)

Navigation – Usually enroute **CFIT**, 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[5]. Also includes accidents from last-moment avoidance of other aircraft and from jet blast on airport **Surface**.

Flight Preparation – Failure to ensure cargo is tied-down and within the aircraft’s Weight and Balance (**Wt & Bal**) 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 **Sit**e such as beaches and gravel bars, and from obstacles in water that are struck by float-planes.

Other – **Taxi** or airport vehicle accidents, low altitude **Maneuvering** for game spotting or photography, **Spatial Disor**ientation, improper carburetor heat, bird strikes.

[4] 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.)

[5] Consistent with ICAO practice and other safety presentations, a collision is counted as two accidents – one for each aircraft, though in some instances only one of these is included in the population being reported. See discussion in 2.3 1) c) note 3 of *A Review of Civil Aviation Accidents / ATM Related Accidents: 1980-1999*, van Es, 4th USA/Europe ATM R&D Seminar, Santa Fe NM, 2001.

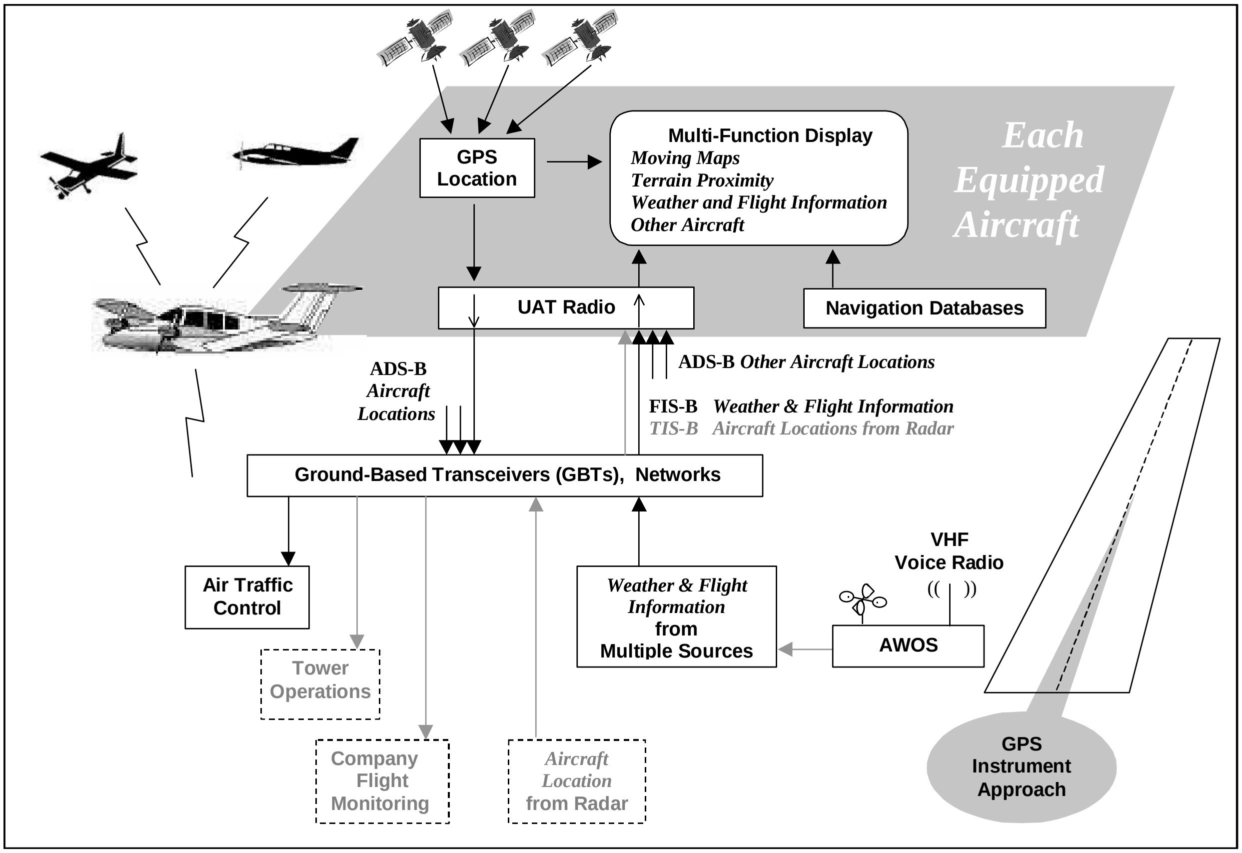

Figure 2. Capstone Avionics, Ground Systems, and Capabilities
Capabilities not operational in 2000-2001 are gray

The Capstone Program

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 available only recently or are being implemented for the first time. How Capstone works is illustrated in Figure 2 and described below.

Accidents associated with navigation are addressed by showing pilots their location on a moving map on a Multi-Function Display (MFD). Aircraft position is derived from GPS Location, and the map is obtained from navigation databases stored on board. 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 over 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[6] graphics. FIS-B is distributed by

[6] Next Generation Weather Radar

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 non-precision instrument approaches to be approved for commercial operations. For qualified aircraft, this allows for 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[7] 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. .

Though not present in 2000-2001, tower operations at Bethel airport now use a "Brite" display of ADS-B targets to help them visually locate aircraft and better coordinate arrival and departure sequencing.

Also not present in the interim period, managers in companies that operate Capstone equipped aircraft now use flight monitoring on PCs connected to the Internet to monitor the locations of their aircraft. This has the potential to significantly improve awareness of risks and to facilitate further improvements in safety posture.

Progress on Implementation

Progress by Capstone on implementation has been measured in terms of avionics installations, pilot training, ground system implementation, IFR capable operations, and flight information availability.

Avionics

In 2000-2001 Capstone equipped almost 6 aircraft per month, reaching 140 by December 2001. Equipage is now nearly complete for YK Delta Part-135 aircraft, and additional aircraft have been equipped as well – several of which operate as government or "public use" aircraft. The heavy irregular line in Figure 3 shows this growth based on the equipped count out of 165 active YK Delta Part-135 airframes. (The associated narrow line is the best linear approximation.) In this same period, operations by the YK Delta Part-135 aircraft were monitored during SVFR operations at Bethel. The number of these operations each day varied depending on weather conditions, but the percentage of these aircraft that were equipped grew relatively consistently[8].

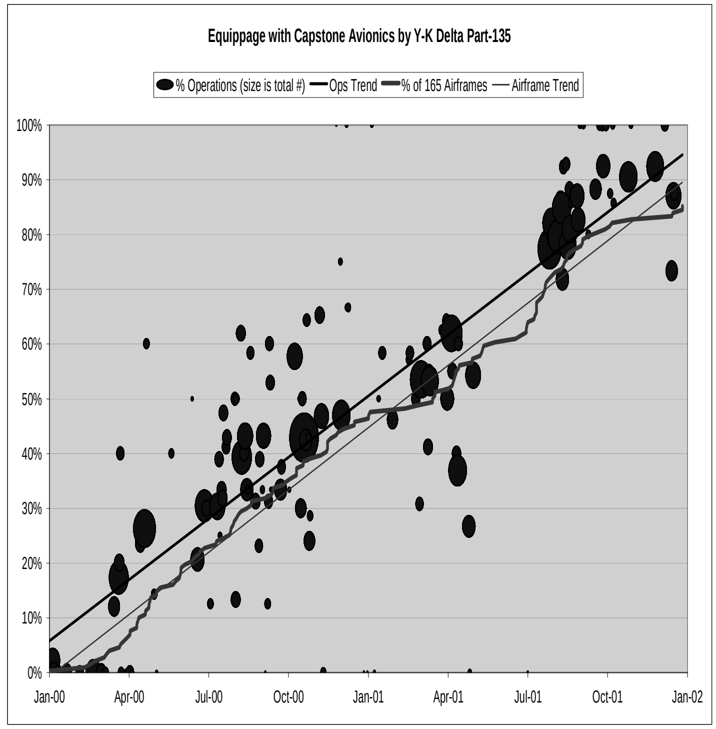

Figure 3 YK Delta-based Part-135 Equipage with Capstone Avionics: Percentage of Arrivals and Departures during SVFR at Bethel and Percentage of the 165 active Airframes

Through the end of 2001, operations showed a higher level of equipage than the count of airframes would suggest. These are plotted as dots, with the size of each dot scaled to the number of operations it represents. The best-fit line for operations equipped is 5% higher than for airframes equipped. This

[7] 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.

[8] SVFR is used as a surrogate for over-all operations to establish the equipage ratio only within the local part-135 population – other populations reschedule flights to different degrees and their representation in SVFR would be different. The equipped operations ratio may have been higher than shown. Some SVFR operation reports were not dated, accumulated for an unknown length of time before being transferred for tabulation, and were dated only when transferred. These reports show "old" equipage ratios and lower the trend. Dates with reports of more than 400 operations were omitted. All others were included and appear as outliers below the trend.

corresponds to an average rate of operations by Capstone equipped aircraft that is 20% higher than the rate of operations by non-equipped aircraft.

Training

Pilot training to use Capstone avionics was conducted through in-company training programs of the Part-135 operators. Training material, videotapes, four simulators, and assistance with instruction were made available through the University of Alaska at Anchorage Aviation Technology Division (UAA-AT). Initial training was provided to 127 pilots. Operators also checked out materials and simulators for additional training. Through 2001, demand for simulators exceeded supply. Two additional simulators have since been added.

UAA[9] surveyed the population of YK Delta commercial pilots, measuring hours of classroom instruction, simulator training, and flight training on Capstone avionics. From observations (during simulator and flight training and follow-ups) they assessed the training's effectiveness. UAA-AT concluded that at pilots' current levels of training they would be about 50% effective at using Capstone avionics to prevent accidents.[10] In other words, half of preventable accidents would still occur unless pilots were better trained.

Radar-Like Services

Beginning January 1, 2001, radar displays for air traffic controllers at Anchorage Center have shown all 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.

At this time, surveillance for air traffic control is supported only through the GBT located at Bethel, so radar-like services are not yet available in other parts of the Capstone area. Also, the FAA has not yet re-structured air traffic control sectors to take full advantage of ADS-B surveillance or to support approach and departure operations. These further implementation steps are expected later in Capstone Phase 1.

[9] Aviation Technology Division in collaboration with the Institute for Social and Economic Research.

[10] This is an over-all assessment that does not separate the different capabilities based on usability.

AWOS and Non-Precision Approach

Nine airports received AWOS stations and associated GPS non-precision instrument approaches, eight of these during 2001. (A tenth is scheduled for 2002.) The 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. 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%).

IFR Capable Operations

Partially as a result of these improvements, commercial operators have expanded the number of IFR-qualified aircraft based in the YK Delta from two in January '00 to fourteen in December '01. By December '01, these IFR-qualified aircraft provided 45% of the passenger carrying capacity (seats) into and out-of the YK Delta's IFR capable airports.

Flight Information

In addition to the AWOS installations described above, the network of GBTs now makes FIS-B available to Capstone aircraft in most of the YK Delta. The information available to pilots in 2000-2001 included 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.

Changes in Accidents

It is still early in the Capstone implementation for potential changes in accident rates to be accurately determined. Indication of possible changes are derived here in three ways: by quantifying changes that are expected based the degree of implementation, by comparing accident types and rates in 2000-2001 against previous years, and by comparing 2000-2001 accidents between Capstone-equipped and non-equipped aircraft.

Expectations from Implementation Progress

The safety benefit expected 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, improvements are expected 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[11].

Navigation/CFIT accidents depend on implementation progress measured by the level of equipage and the effectiveness of pilot training. For 2000-2001 an average of 50% of YK Delta-based Part-135 flight operations were equipped, and the effectiveness of pilots using Capstone avionics was assessed to be 51%. In 2000-2001 we estimate 25% 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 during approach are not directly affected.

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.) In 2000-2001 if two aircraft were at risk of collision, the chance they were both Capstone equipped was one in five, and training levels reduce effectiveness to 51% of that number. In 2000-2001 we estimate that 11% of mid-air accidents would be avoided because of Capstone.

Accidents in 2000 and 2001

Accidents by YK Delta Part-135 aircraft[12] in 2000-2001 are sorted by their causes in Figure 4 and compared both to previous years and to our implementation-based expectations in Figure 5. For the most part these are similar to previous years, but there are variations worth noting:

1. There were no accidents caused by improper flight preparation or by fuel mismanagement, and zero is more than one standard deviation below the baseline. It is possible this decrease is only a statistical anomaly. However, this category more than any other is directly affected by the safety posture of pilots and their companies. We have characterized an improvement in safety posture that could be manifested in just this way. This change was not observed in nearby areas outside the YK Delta.
2. There are no accidents attributable to lack of flight information. This might be due to improved weather information from FIS- B or

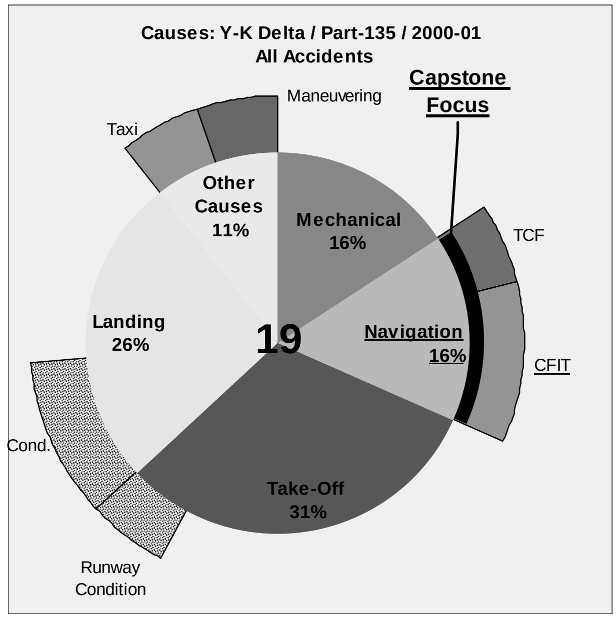

Figure 4 Causes of the 19 Accidents to YK Delta Part-135 2000-2001

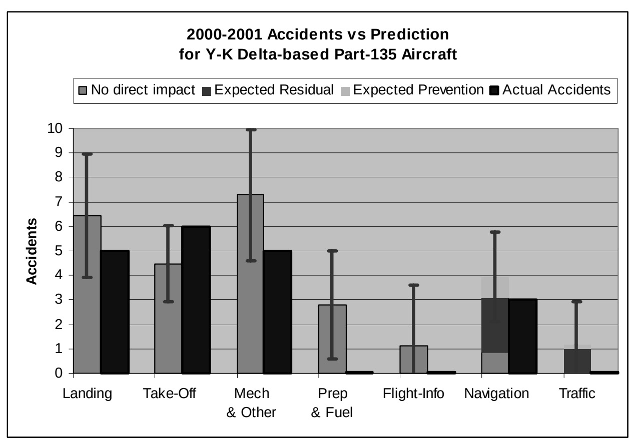

Figure 5 2000-2001 Accidents vs Prediction for YK Delta Part-135

[11] 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.

[12] Using the YK Delta Part-135 population excludes one accident of a Capstone-equipped aircraft that had been removed from the YK-Delta. The accident occurred near Dillingham, was not caused by factors addressed by Capstone, but resulted in 10 fatalities.

Capstone AWOS installations or due to better risk avoidance by pilots from improved safety posture. This reduction (even to zero) is within one standard deviation from before Capstone, but it is nevertheless a desirable result.

3. The number of accidents caused by other aircraft traffic also was zero in the evaluation period. While this is a direct focus of Capstone capabilities, limited implementation has meant that very little improvement could be expected from those capabilities. This reduction also is less than the standard deviation from before Capstone, but still a desirable result.

All other accident types are within one standard deviation of the baseline mean, including the navigation category targeted by Capstone GPS-Map and CFIT-avoidance capabilities. This is consistent with projections when the limited level of implementation in the evaluation period is taken into account.

Capstone Equipped vs Non-Equipped

A second way of comparing within YK delta part-135 is to examine the differences between Capstone equipped and non-equipped aircraft. Equipage was gradual through the interim evaluation period, and for much of the period variables such as weather and operations intensity affected both groups similarly. This similarity is decreased toward the beginning of the period when variations would primarily impact only non-equipped aircraft. This similarity is decreased more significantly near the end of the period as equipage approaches 100% because there may be mission differences between most YK delta part-135 and the residual non-equipped aircraft. Nevertheless, these sub-populations still provide the most sensitive measurement of the safety impact of Capstone avionics.

Evaluating accidents for Capstone equipped and non-equipped fractions of the YK delta part-135 population shows several differences. Figure 6 shows the accident causes for each group. The breakdown of accidents between major categories is essentially similar and is within the levels of variation one should expect for this number of occurrences. Examining sub-categories finds that 25% (three) of the non-equipped accidents are due to poor runway conditions encountered either on take-off or landing while there were no accidents from runway conditions by Capstone equipped aircraft. While there are ways the avionics may help avoid such accidents, detailed review of both the recent and historical runway-condition accidents make these

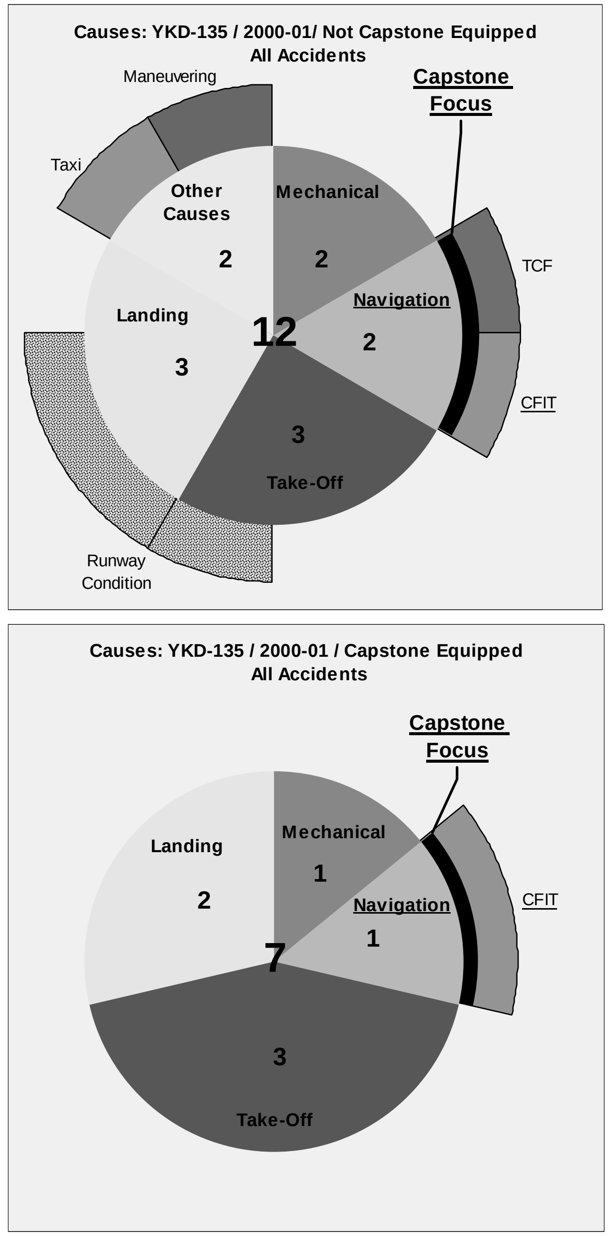

Figure 6 Causes of the 12 Accidents to Non-Equipped and 7 to Capstone-Equipped YK Delta Part-135 Aircraft 2000--2001

seem less likely[13]. At the present time we are unable to tell if this is an actual benefit or the result of random variations.

[13] From observations and discussions during surveys it was observed that before 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. However most of the YKD-135

The single Navigation/CFIT accident by a Capstone equipped YK delta part-135 aircraft bears examination: Why wasn't the accident prevented? Did limited pilot training on Capstone avionics interfere with use of the CFIT-avoidance capability?

The NTSB narrative for this accident identifies the pilot's non-use of the Capstone avionics terrain awareness functions as a contributing cause of the accident. Interviews with the pilot conducted after the accident by Leonard Kirk of the University of Alaska Aviation Technology Center go further[14]. The limited training of the pilot, the pilot's attitude toward accident risks, and the pilot's concern that his activities might be monitored by the FAA led him to actively defeat the operation of the CFIT-avoidance capability. While this is a rather extreme example of the limitations of training, it nevertheless is consistent with our characterizations. Also, had the accident been avoided, the lack of equipped Navigation accidents would still have been only suggestive of improvement, and would not have achieved statistical significance for YK delta part-135 as a whole within the interim evaluation period.

While the rates of accidents for specific causes have not changed in a way that is statistically significant yet, the over-all accident counts for the equipped and non-equipped groups were different: 12 accidents for non-equipped versus 7 for equipped even though each had nearly identical operations counts. The best way to see whether this is significant is to look at the accumulated accident rates for the two groups over time to see whether the rates and the differences in rates have become consistent.

Figure 7 shows how the cumulative average accident rate has evolved from month-to-month for the two groups. While the accident rate for Capstone equipped aircraft is mostly below that for non-equipped aircraft, it isn't always so, and both rates shift over time – suggesting that they have not yet converged to consistent long-term values. Equally important, the operations estimates for these graphs required merging and interpolating data from several sources – suggesting cautious interpretation. Capstone equipped aircraft have had 40% fewer accidents than those not equipped and determining whether this as a long-term trend must wait for further data.

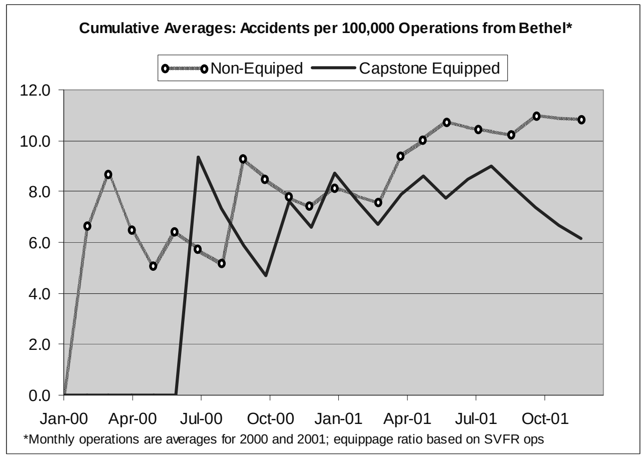

Figure 7 Relative accident rates for YK delta part-135 aircraft without and with Capstone avionics

Assessment

From 2000 through 2001 the Capstone program made significant progress toward implementing safety and efficiency capabilities for commercial aviation in the YK Delta, but important steps remain. Local Part-135 aircraft are now 95% equipped with Capstone avionics, but pilots are only trained to about 50% effectiveness. Radar-like services became operational at Bethel halfway through the period, but surveillance for the remainder of the Delta, and approach/departure control at Bethel, are not yet available. The Bethel tower "Brite" display and operator flight monitoring were not available during 2000-2001 but are complete now. AWOS and part-135 approved GPS approaches are nearly complete. Weather text and Bethel NEXRAD graphics are available on FIS-B throughout the YK Delta, but NOTAMs, PIREPs, and data feeds from the new AWOS are not yet implemented. Graphical icing products that would benefit Capstone are still being researched.

Evaluating the progress on Capstone's implementation, the effectiveness expected from that progress, and the accident history before and after Capstone leads to several observations:

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runway condition accidents are from general deterioration of a runway that pilots are aware of and have misjudged to be manageable. They are not point-hazards on the runway that could be described and avoided.

[14] *Capstone Phase I Interim Safety Study, 2000/2001, Appendix C*, Institute of Social and Economic Research, University of Alaska Anchorage, December 2002 http://www.alaska.faa.gov/capstone/docs/2001%20UAA%20report.pdf

1. Though averaging only 45% of the fleet, Capstone equipped aircraft flew as many operations as non-equipped aircraft and had fewer accidents in the 2000-2001 period.

	Non-Capstone	Capstone
Aircraft Days	55%	45%
Operations	50%	50%
Accidents	63%	37%

2. Installing AWOS and establishing non-precision GPS approaches is dramatically expanding the IFR-capability of local commercial operations in the YK Delta[15]. This should significantly decrease the risk of injuries to passengers.

	Before Capstone	With Capstone
AWOS	8	17
Instrument Approaches	3	13
% YK Delta Operations at Airfields w/ IFR Infrastructure	16%	34%
IFR Qualified Commercial Aircraft	2	14
IFR Aircraft Passenger Capacity at airfields w/ IFR Infrastructure	(not available)	45%

3. Pilots are finding creative ways to use the tools. Some use the traffic display to identify aircraft that have already been where they want to go and call them by radio to get weather and runway conditions. While it is uncertain whether we can attribute the difference to Capstone, of the aircraft based in the Delta in 2000-2001, non-equipped part-135's had 3 accidents from poor runway conditions while equipped had zero.

4. From Capstone and other changes, YK Delta-based part-135 safety posture appears to be improving. The number of accidents due to inadequate flight preparation and fuel mismanagement were zero for the two years, which is better than the historic standard deviation. The new availability of flight monitoring to operator managers will likely pay even greater benefits to pilot decision-making and safety-awareness and to each organization's safety posture over-all.

[15] Data on increase IFR operations is from analysis by the University of Alaska Aviation Technology center. See footnote 14.

At this time, the limited data available suggest that Capstone is improving safety in the YK Delta. Over time, conclusions about the effectiveness of Capstone's ADS-B, Radar-like services, CDTI, FIS and CFIT avoidance tools will reach higher confidence. Capstone should provide useful guidance for other regions of the world that currently have minimal infrastructure but might be upgraded with broadcast capabilities to improve air traffic management and safety.

Author Biography

Worth Kirkman is a Lead Engineer performing systems engineering in the Center for Advanced Aviation System Development (CAASD) at the Mitre Corporation. He received his Bachelor of Science in Electrical Engineering from UVA in 1979 and his Master of Science in Electrical Engineering from Stanford in 1980. Since joining CAASD in 1997 he has performed analyses on FAA programs including Data Link, NexCom, Safe Flight 21, and Alaska Capstone.