IMPACT OF ADS-B ON CONTROLLER WORKLOAD: RESULTS FROM ALASKA'S CAPSTONE PROGRAM

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Abstract

The Capstone program introduced avionics in Alaska that included ADS-B equipment, starting in the year 2000. The program succeeded in equipping 208 aircraft in the Yukon-Kuskokwim Delta by the end of 2004, resulting in Capstone-equipped aircraft accounting for nearly 100% of Part-135 operations by airplanes based in that region. This paper estimates the impact of the use of Capstone equipment on controller workload. It summarizes the results of a controller survey regarding the effect of Capstone equipment on controller tasks, and provides quantitative results regarding the effect of ADS-B equipment on controller workload. From the survey 57% of controllers indicated that they needed less time providing IFR separation services than without ADS-B, and 79% of the controllers felt that the overall efficiency of their operation had increased with ADS-B. An analysis of flight progress strips showed that the currently deployed Capstone equipment, when operating properly as required by ATC, would provide an 18% reduction in controller communications workload. The analysis also indicated that if all the aircraft in the Y-K Delta were properly equipped, the reduction in communications workload would be 26%.

Background

The transportation infrastructure in Alaska is focused primarily on aviation. The road system is found mostly in the populated areas around Anchorage and Fairbanks. Although there is a substantial cruise business in the southeast part of the state, the inland rivers in Alaska are generally navigable only a few months out of the year. Railroads connect only certain of the population centers. In many of the villages in Alaska the airplane is the only reliable transportation.

Even though air transportation is very important for Alaska, much of the aviation infrastructure that is enjoyed in the lower 48 is not available there. There are radar systems in Alaska but because of the mountainous terrain the coverage below 6000 feet is sparse except around sites such as Anchorage and Fairbanks. Many of the airports have neither instrument approaches nor weather reporting stations; therefore, instrument operations by commercial operators are not possible at most airports. This environment has contributed to an accident rate in Alaska that is 2.5 times greater than the U.S. average [1].

In the early 1990s the FAA, in collaboration with several aviation groups in Alaska, initiated the Capstone program to address these challenges[1] [2]. The Capstone program consists of three phases. Phase 1, completed in 2004, was a demonstration program focused on the southwest corner of the state (the Yukon-Kuskokwim Delta). Phase 2, currently underway, is focused on providing the technology to the southeast part of the state. Phase 3 proposes expanding its deployment to the entire state. Results of Phase 1 of the program are summarized in [3]. A decision on initiating Phase 3 is expected in September 2006.

As indicated above, the primary goal of the Capstone program is to increase the safety of aviation in the state of Alaska. This is being accomplished by facilitating an increase in the number of IFR approaches to airports with the introduction of additional weather reporting stations and instrument approaches at selected airports; increasing terrain awareness through providing a terrain data base and own position through GPS; and traffic awareness through Automatic Dependent Surveillance – Broadcast (ADS-B) and aeronautical information through Flight Information Service – Broadcast (FIS-B).

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[1] The major contributing factors for accidents in Alaska are landing, takeoff and mechanical [1]. Closely behind are the accidents involving weather and flight information, navigation and traffic. These latter categories are the ones that the Capstone program is designed to address. The program, which was associated with the FAA's Safe Flight 21 program, is now integrated with the FAA's National ADS-B program

The Capstone technology includes several components: ADS-B and GPS units, a terrain data base, and a multifunction cockpit display in the cockpit; and ground based transceivers (GBTs) and weather stations, on the ground. See Figure 1.

With ADS-B, the aircraft broadcast their positions every second both to nearby aircraft and the ground stations. The ADS-B unit also receives similar broadcasts from nearby aircraft. The position information is derived from GPS. The GPS units are IFR certified, and enable GPS approaches to the airports now equipped with AWOS weather stations and GPS based instrument approaches. The terrain map and a traffic display (CDTI[2]) are integrated on the multi-function display. This display thus allows the pilot to monitor the position of his or her aircraft with respect to the terrain as well as proximate traffic, in all weather conditions.

The network of ground based transceivers and servers are a powerful nexus of important aviation information. They collect weather information from weather sources; aircraft state vector information from ADS-B broadcasts by equipped aircraft; and radar data on non-equipped aircraft[3]. The GBTs then transmit the weather information to the aircraft. In the Anchorage area, they also transmit locations of other aircraft without ADS-B capability to aircraft[4].

Finally, the ADS-B surveillance received by the GBTs is processed and retransmitted via the Alaska NAS Interfacility Communications System (ANICS) to the Anchorage ATC Center. This position information for the ADS-B aircraft is then provided to the controllers on their primary displays.[5] The surveillance information is also forwarded to the ATC control towers and the aircraft operators.

Capstone Phase 1 Operations

During Phase I, Capstone operations were confined to the Yukon-Kuskokwim Delta (YK Delta). There are 53 airports in this area. In Phase 1 the FAA outfitted 208 Part-135 aircraft as part of the demonstration. These aircraft almost exclusively fly on a route structure between 33 of the YK Delta airports. See Figure 2.

The “hubs” of this route structure are Bethel, Saint Mary’s and Aniak, the primary being Bethel. At Bethel there is a contract control tower.[6] The number of total instrument operations at Bethel in 2005 was the third highest in the state of Alaska behind Anchorage and Fairbanks. In terms of total operations Bethel is fifth behind Anchorage, Merrill Field (Anchorage), Fairbanks, and Juneau. The predominant users of the airport are Part-135 scheduled operators. There are also scheduled air carrier (Part-121) and general aviation (Part-91) operations at the airport.

The radar coverage at Bethel has a floor of coverage between 5000 and 6000 feet. Because of this, the final approach and much of the transition airspace into Bethel are not covered by radar. When visual operations can be conducted, aircraft can be released to the tower on visual approaches, with aircraft providing visual separation. However, when visual approaches can not be conducted, IFR operations must be conducted with non-radar procedures.

Purpose

The purpose of this paper is to estimate the impact of the use of Capstone equipment on controller workload. This will be done by showing that the percentage of Capstone equipped aircraft and instrument operations have increased, while at the same time, the controllers providing services to this traffic indicate that they are spending less time providing IFR services and that their operation has become more efficient.

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[2] CDTI – Cockpit Display of Traffic Information

[3] Currently in units serving the Anchorage area.

[4] This function is known as TIS-B (Traffic Information System – Broadcast). It provides the transition to a state when full ADS-B equipage will become available.

[5] ADS-B surveillance information on equipped aircraft was first provided to controllers on 1 January 2001 for operational use. However, from March 24th 2006 through June 14, 2006 the ADS-B information to the controllers was suspended while the FAA reevaluated how the ADS-B targets would be separated from radar targets. Since mid-June 2006 ADS-B surveillance on aircraft has been resumed for controller use, and its use in Anchorage Center has subsequently been expanded for flights in the areas of King Salmon and Dillingham.

[6] A contract control tower is one whose operations are conducted by controllers that are contracted by the FAA. These controllers are not FAA personnel.

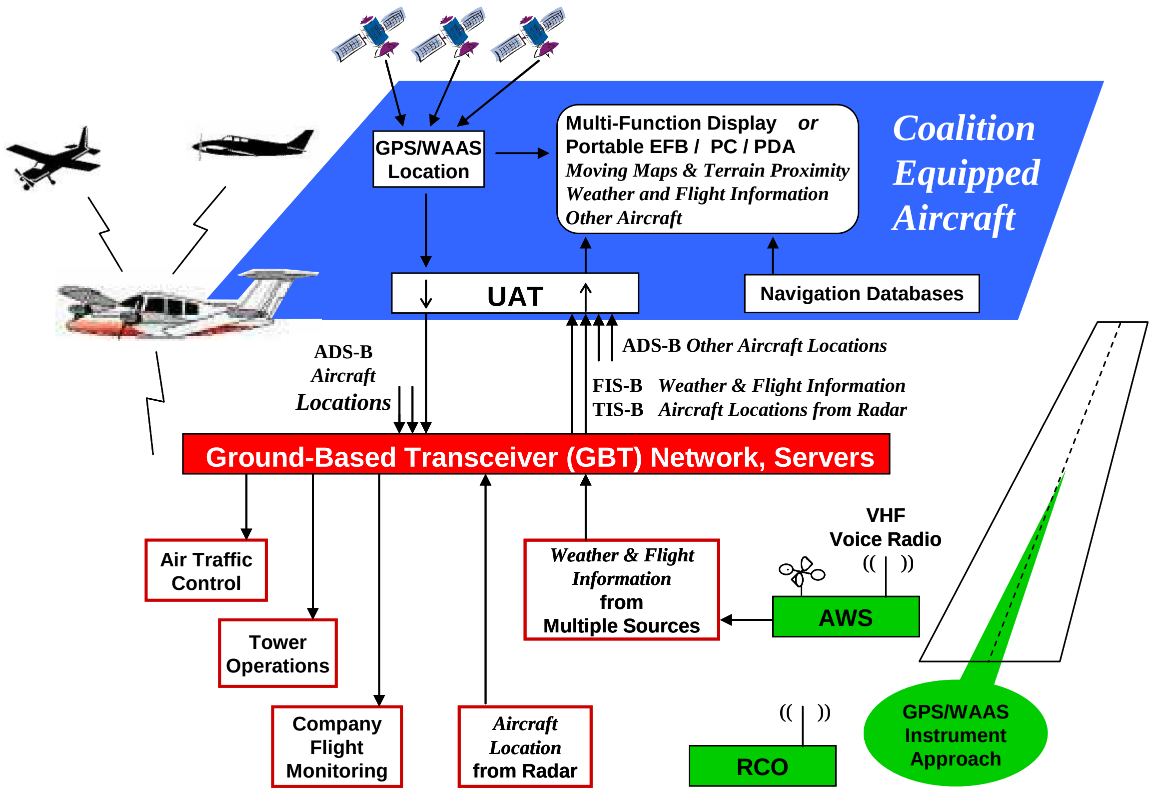

Figure 1. Capstone Avionics, Ground Systems, and Capabilities

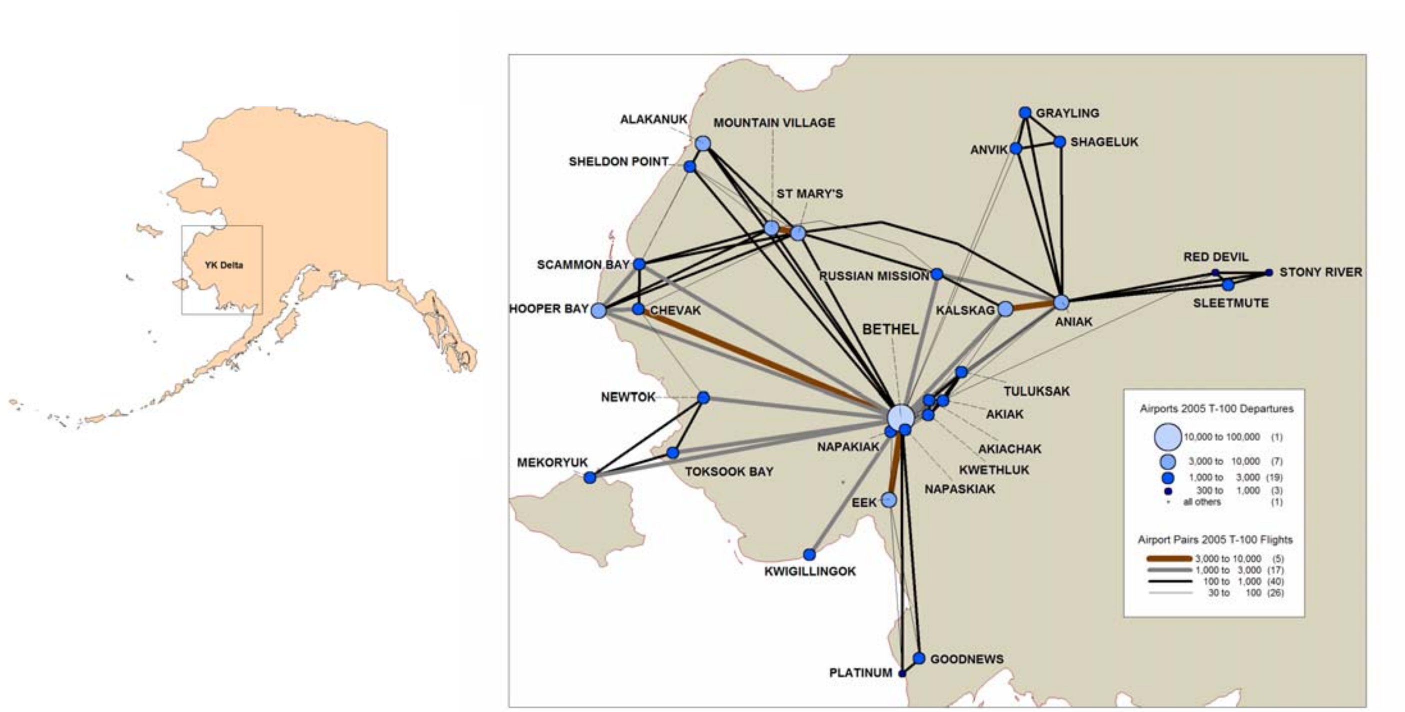

Figure 2. Airport Departures and Route Traffic in the YK Delta

Capstone Equipage

The Capstone equipment that impacts the level of instrument operations are the AWOS weather systems and the ADS-B avionics.

IFR operations are 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 ATC use of ADS-B to support radar-like services. This allows controllers to provide flight following and surveillance-based separation services in airspace that is not visible to radar.

As mentioned earlier, by the end of 2004, Capstone had equipped 208 aircraft in the Y-K delta. Of these, 189 were operating commercially under FAA Part-135 or Part-121. The Capstone equipped aircraft accounted for nearly 100% of the part 135 operations[7]. Figure 3 depicts equipage growth, and Figure 4 depicts the current percentage of Capstone-equipped operations in the Y-K Delta. It shows that the number of equipped Class 4 (turbine) aircraft had increased by 180% of its previous level - from 15 in 2000 to 42 in 2004. The number of equipped IFR aircraft had increased by 252% of its previous level - from 21 in 2000 to 74 in 2004.

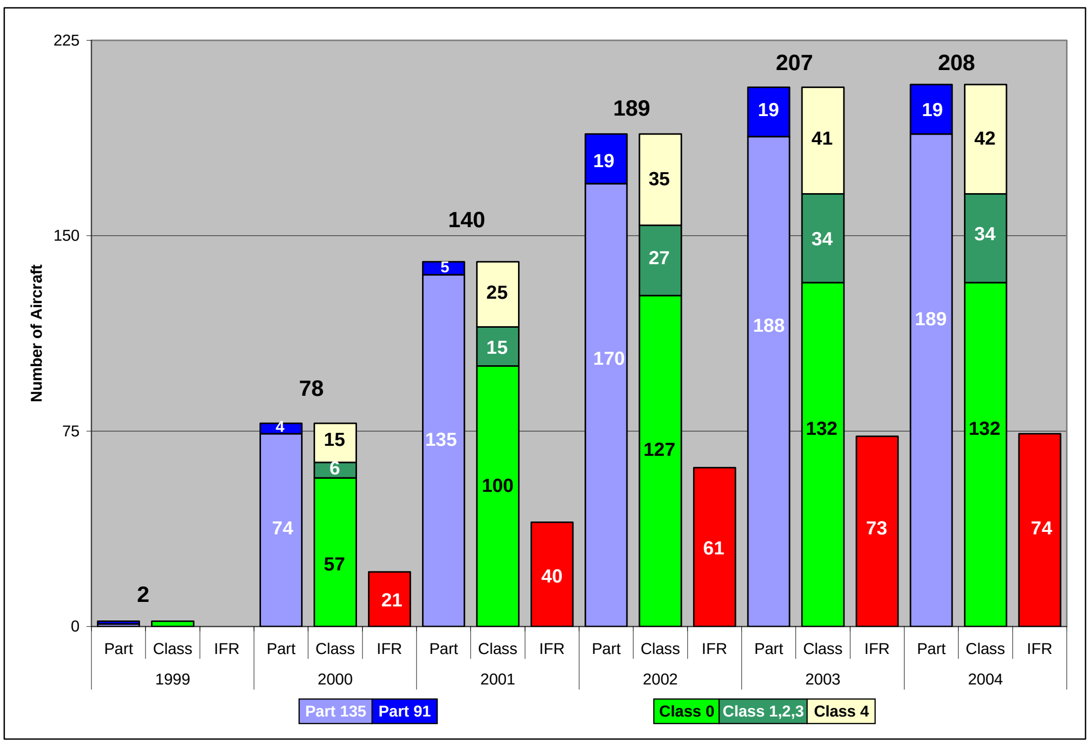

Figure 3 Equipage with Capstone Avionics by Aircraft Based in the Y-K Delta by December 2004

[7] One aircraft was purchased near the end of 2004 and was operating while waiting to be outfitted with commercially available Capstone equipment.

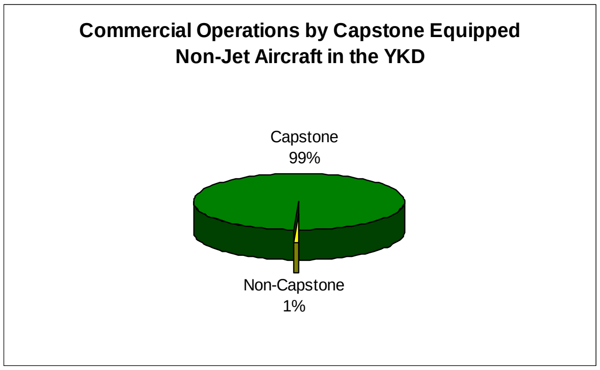

Figure 4. Total Operations by Part 135 with Capstone Avionics by Aircraft Based in the Y-K Delta by December 2004

Instrument Operations

The impact on controller workload due to traffic is influenced primarily by the number of instructions that the controller has to issue to IFR aircraft.

Figure 5 shows the time series of monthly counts of instrument operations of air taxis at Bethel [5]. It shows an increase in instrument operations for air taxis of 57% since the start of radar-like service at the Anchorage Center with Capstone.

Figure 6 shows that at the time that Capstone was equipping aircraft in the YK Delta in 2000, 56% of all IFR operations for Bethel consist of Air Taxi operations[8]. Since 2000 the percentage has grown to 65%. Since 99% of the air taxis were ADS-B equipped, this indicates that nearly 65% of all IFR operations to Bethel are now conducted with ADS-B equipped aircraft.

Figure 7 shows the time series of monthly counts of total instrument operations at Bethel. It shows that in spite of the large growth in equipped IFR aircraft, there was only a small increase in total instrument operations at Bethel, from an average of 1009 operations per month to an average of 1042 operations per month. These are counts as measured at the Anchorage Center since the beginning of radar-like services through ADS-B. This increase is not statistically significant.

[8] Air taxi operations in Alaska include both scheduled and chartered flights, and are all part 135 operations.

Controller Workload Results

A controller survey was conducted at the Anchorage Center (ZAN) during the week of 28 February to 4 March 2005 to assess the impact of ADS-B on ATC. The survey was extensive, consisting of 33 questions covering numerous aspects of the impact of the Capstone equipment on ATC. Results of this survey are summarized in reference [3] and was fully described in reference [4].

The survey was voluntary. Although nearly 50 controllers had been exposed to ADS-B in the Bethel area at the time of the survey, only 30 had by then worked in that sector. Of the 30, five controllers were on leave the week the questionnaire was administered. Of the remaining 25, 14 filled out the questionnaire.

Responses indicated that in virtually all aspects surveyed, the Capstone equipment had either improved the controllers' ability or the environment for the performance of their duties. In particular, there was a consensus that the ADS-B technology was useful, the returns were accurate, the acquisition of the track was quick, and the technology provided target information where none was previously available with radar.

Figure 8 summarizes the key findings affecting controller performance and workload with respect to ADS-B. Figure 8A shows that 57% of the controllers estimated that they needed *less time providing IFR separation services* than without ADS-B. (The other 43 % were neutral.) Figure 8B shows that 79% of the controllers felt that the overall *efficiency* of their operation had either *increased or greatly increased* with ADS-B. (14% of the controllers felt it was reduced.) The other two figures show that the controllers preferred ADS-B info over radar info. Seventy-nine percent of the controllers agreed with the statement that the ADS-B targets are an improvement over radar targets. Eighty-two percent of the controllers preferred ADS-B to radar.

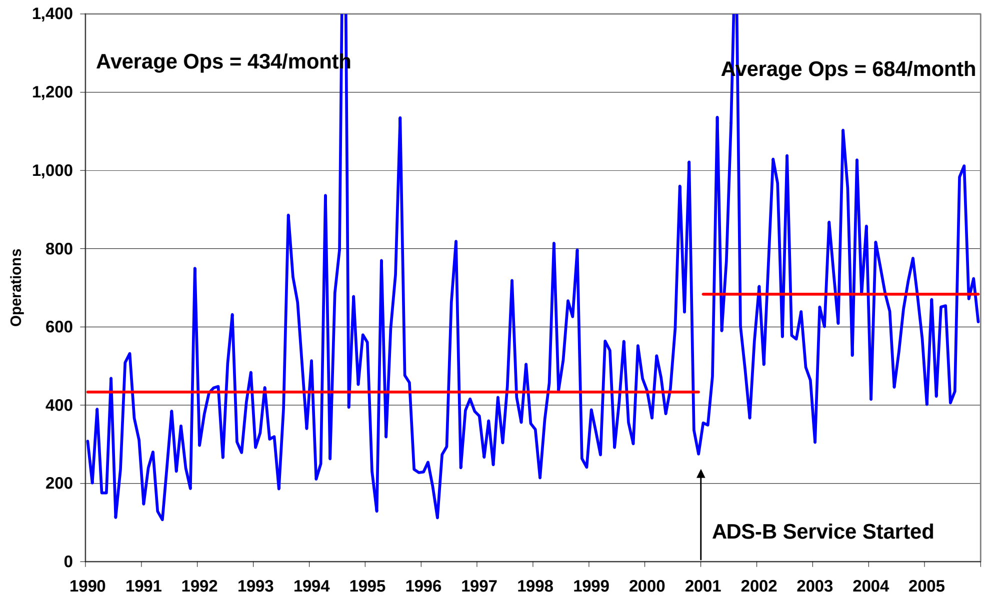

Figure 5. Air Taxi Instrument Operations at Bethel Since 1990

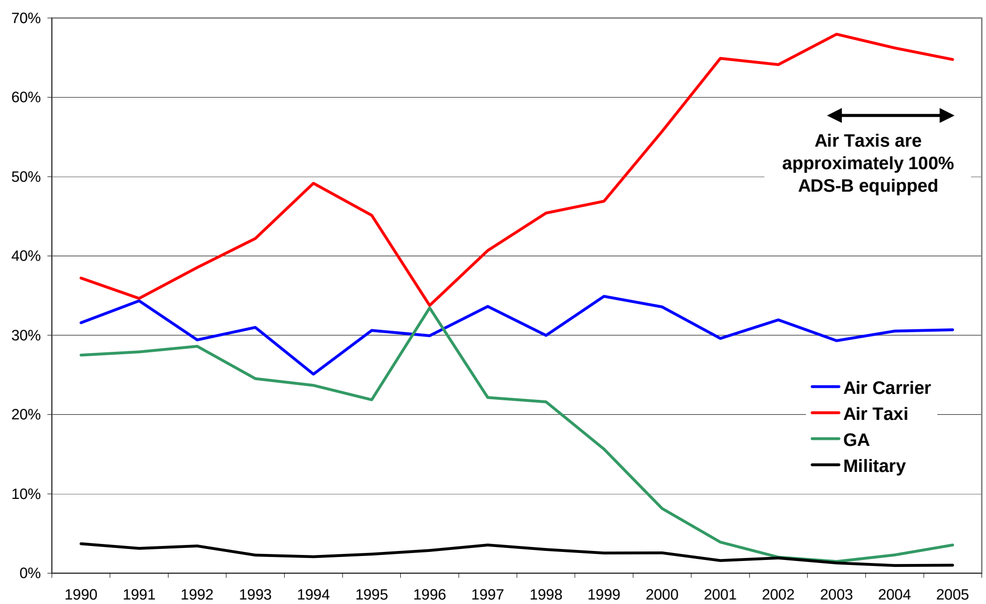

Figure 6. IFR Operations at Bethel

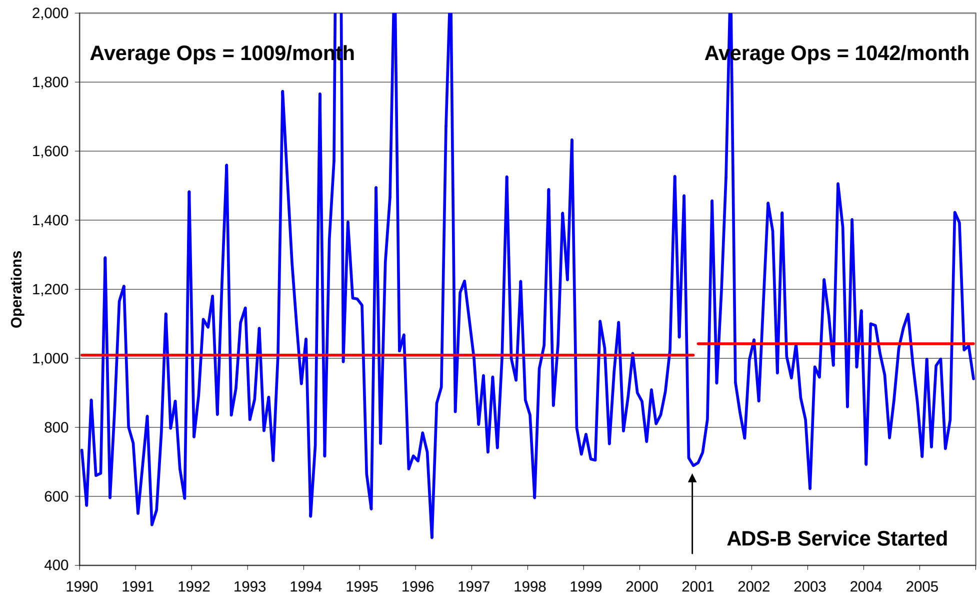

Figure 7. Total Instrument Operations at Bethel

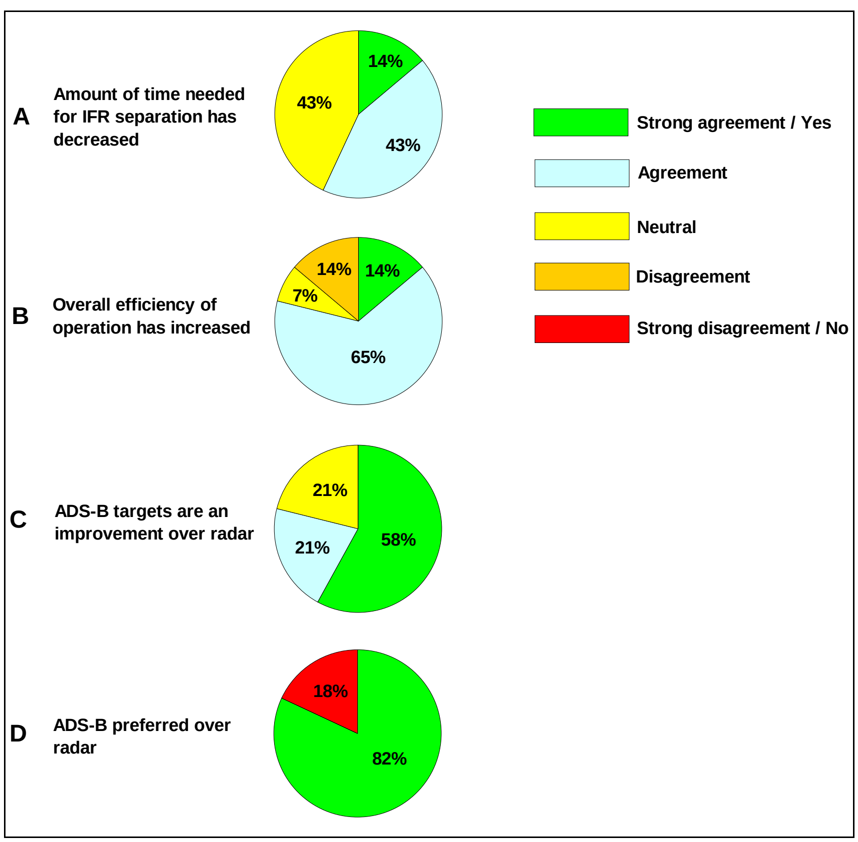

Figure 8. Anchorage Center Survey Results from Controllers then Working Sector 13

An informal survey was also conducted of the controllers at the Bethel tower during the week of December 6, 2004. Six controllers from the Bethel tower were interviewed. The controllers were asked their opinions about the Capstone equipment. Other demographic information was also obtained. In general, the tower controllers indicated that the Capstone equipment was reliable and that it provided improved situational awareness for both the pilot and the controller[9].

During this time period there were several issues regarding the use of Capstone information by the controllers. These issues centered on the fact that the Capstone equipment did not use the 4096 Beacon code for aircraft identification whereas the Anchorage Center's MEARTS computer did. The Capstone equipment used what is known as the Mode S code which is permanently assigned to each airframe. This caused additional tracks to be started which, in turn, caused self induced conflict alerts and data-block track swapping. There was also no way for the controllers to filter the Capstone targets from their screen so all the aircraft on the ground at Bethel, for instance, would be shown on the controller's display at the center.

Since that time, changes have been made to the cockpit equipment and the MEARTS computer to suppress these problems. Unfortunately the current solution requires that pilots enter transponder codes into two different systems in the cockpit, which creates its own problems: not all pilots enter both codes. In such cases, the surveillance for these aircraft is not available to the controller. Thus, solutions to system issues are still in progress. It is noteworthy that the survey indicated such positive results in spite of these issues. The importance of these issues is fully recognized by the program and efforts are underway to remedy them.

[9] They also indicated that since the display in the tower was not certified to provide separation services, some of the valuable information on targets could not be used to provide traffic call-outs.

Flight Strip Analysis

An analysis was conducted of the communications workload for ZAN controllers for the sectors where most of the Capstone equipment in the Y-K Delta is currently used[10]. The analysis was based on archived controller flight progress strips data from early May 2005. Three controllers from the center who currently control traffic in these sectors provided the interpretation of the control and communications activity reflected in the flight progress strips.

For this period in May 2005 of IMC at Bethel, i.e., during a period when VFR operations could not be conducted at Bethel, it was determined that the currently deployed Capstone equipment, when operating properly as required by ATC, would provide an 18% reduction in controller communications workload. If all the aircraft in the Y-K Delta were properly equipped, the reduction in communications workload would be 26%.

Prior to the introduction of ADS-B in the YK Delta the controllers at the Anchorage Center relied on radar above 6000 feet and non-radar procedures below 6000 feet. Non-radar procedures imply coordination with the Bethel tower for the landings and departures and step down altitude assignments. Each of these actions takes time and additional communication transmissions. "Acquiring" each aircraft for non-radar services also depends on communicating with the aircraft. With the "radar-like" service provided by ADS-B the need for these actions are reduced. The results of the flight strip analysis are consistent with these changes.

Conclusions

For the Capstone Phase 1 area, IFR operations at affected facilities had increased slightly since the introduction of Capstone equipment. 65% of IFR operations there at the beginning of 2005 were by ADS-B equipped aircraft.

A controller survey indicated the following:

- 57% of the controllers estimate that they need *less time providing IFR separation services*

[10] Sectors 13, 3 and 9

than without ADS-B. (The other 43 % were neutral.)

- 79% of the controllers felt that the overall *efficiency* of their operation had either *increased or greatly increased* with ADS-B.

These results were during the previous implementation when beacon codes were not available for ADS-B aircraft causing track swapping and self-induced conflict alerts. The system upgrade in May, 2005 was designed to remove this limitation. Some further remedies are still needed, and are in progress.

An analysis of flight progress strips for the period immediately preceding the May 2005 upgrade showed that:

- The currently deployed Capstone equipment, when operating properly as required by ATC, would provide an 18% reduction in controller communications workload.

- If all the aircraft in the Y-K Delta were properly equipped, the reduction in communications workload would be 26%.

However, *appropriate pilots inputs of the beacon code are required* to realize these gains. At the time of the analysis, controllers indicated that this was not being performed. Subsequent software upgrades to the avionics have substantially mitigated the issue. In any case, the system performance should be closely monitored and analyzed to ensure that all required actions are accomplished, that all systems are performing as expected, and the full extent of expected ATC benefits are realized.

References

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