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Assessment of Air Traffic Control Productivity Enhancements from the Corridor Integrated Weather System (CIWS)

Executive Summary

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16. Abstract

The Air Traffic Control (ATC) productivity benefits attributed to the Corridor Integrated Weather System (CIWS) were assessed using real-time observations of CIWS product usage during three multi-day thunderstorm events in 2005 at eight U.S. Air Route Traffic Control Centers (ARTCCs). CIWS improved ATC productivity by:

- Reducing the time required to develop, coordinate, and implement weather impact mitigation plans
- Increasing the number of safety and capacity-enhancing plans that were executed (e.g., more efficient, proactive rerouting and greater ability to keep routes open)
- Assisting with FAA staffing decisions.

Time savings per convective weather day for Traffic Management Coordinators (TMCs) in an ARTCC typically were 20–95 minutes.

The overall frequency of capacity-enhancing decisions increased by 177% relative to the CIWS benefits study conducted in 2003. The annual CIWS delay savings are in excess of 92,000 hours. Corresponding airline direct operations cost (DOC) savings exceed $94 M and passenger value of time (PVT) savings exceed $201 M. Annual jet fuel savings exceed 11 M gallons.

The ability of the Cleveland ARTCC to develop and execute weather impact mitigation plans improved significantly (e.g., by 50–80%) when CIWS products were available to Area supervisors as well as to the TMCs.

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EXECUTIVE SUMMARY

In an era of significant federal government budget austerity for civil aviation operations, it has become essential to improve Air Traffic Control (ATC) productivity. This report summarizes the results of an exploratory field measurement program conducted during summer 2005 to assess ATC productivity benefits of the Corridor Integrated Weather System (CIWS). Real-time observations of CIWS product usage during multi-day thunderstorm events were carried out at eight U.S. Air Route Traffic Control Centers (ARTCC). The real time observations data were used in conjunction with specific in-depth case study analyses to assess the CIWS productivity enhancements associated with convective weather impact mitigation plan development and implementation. Comparisons of ARTCC operations between facilities with and without access to CIWS were also made to further identify CIWS contributions to improved ATC productivity.

The results of this study show that productivity was enhanced in two ways: (1) less time to develop and implement operationally effective plans and (2) significant increases in the number of such plans implemented per convective weather day. This CIWS-derived increase in FAA operational efficiency resulted in significant delay and cost savings benefits to the National Airspace System (NAS) customers (e.g., airlines and passengers) [over 92,000 hours of delay saved per year with a monetary value of $90 M per year in airline direct operating cost (DOC) savings and $200 M per year in passenger value of time (PVT) savings].

Motivation for this Study

Improvements in ATC productivity are essential given the projected increases in air traffic anticipated in the next 10 years, coupled with an austere funding for NAS operations. The latest FAA aerospace growth forecast projects a 30% increase in ARTCC air carrier operations between 2004 and 2015 (FAA, 2005). An important component of this traffic growth that is not captured in the overall statistics is the growth in high altitude en route traffic due to the air carrier transition from turbo props to regional jets and the increased business aircraft use of jets.

Improved productivity in air traffic management during convective weather events is particularly important due to:

1. The current difficulties in managing convective weather impacts in highly congested airspace, as exemplified by the Great Lakes and Northeast NAS corridors and

2. Projections by the FAA that by 2014, with projected traffic growth of 27%, there could be 29 days of delays that exceed the worst single day of delay in 2004 (Hughes, 2006).

CIWS and other weather and traffic flow decision support tools aid in executing the operational weather impact mitigation decision loop shown in Figure ES-1. The challenge is that the process of determining ATC impacts, developing appropriate mitigation plans, and selecting from among them must be accomplished in a time period commensurate with the time variations in capacity impacts of convective weather.

This is particularly difficult to do in the congested Great Lakes and Northeast corridor airspace in which CIWS is deployed. Both within an ATC facility and between separate facilities, traffic management interactions associated with convective weather impacts in this region of the NAS need to be very extensive since actions taken within one facility can easily impact many other facilities (Figure ES-2). Hence, improving coordination through common situational awareness of the convective weather impacts among all affected users is very important in developing a robust traffic management plan.

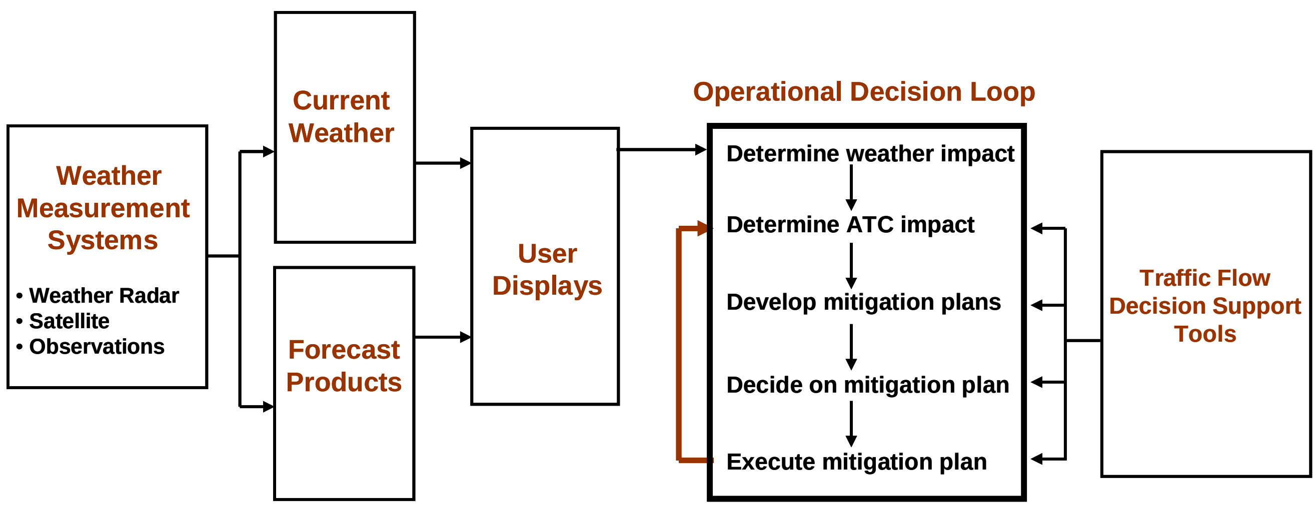

Figure ES-1. Overall convective weather impact mitigation process. The ATC (and airline) workload associated with convective weather management includes all five elements shown in the "operational decision loop."

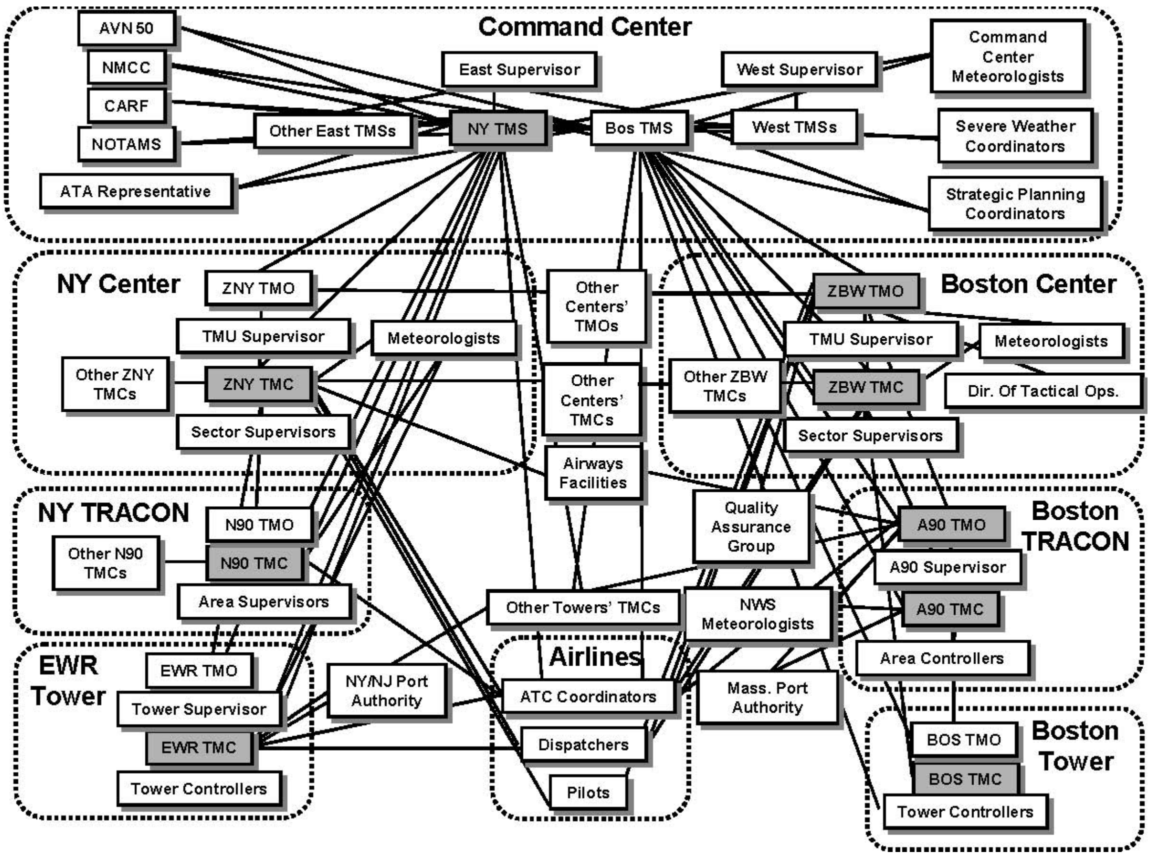

Figure ES-2. Complexity of NAS system coordination process assocated with solving traffic flow management problems at just two facilities within the CIWS domain (ZNY and ZBW). Complexity grows significantly with each additional facility required for traffic management coordination [from Davison and Hansman, (2001)].

During convective weather impact events, MIT Lincoln Laboratory and FAA observers at select ARTCCs obtained feedback from traffic managers (and Area Supervisors) on:

1. Convective weather impact mitigation decisions made using CIWS products
2. The time to monitor existing convective weather impact mitigation initiatives
3. The time associated with the mitigation plan development and execution process in relation to expected workload for similar convective events prior to CIWS.

Additionally, observers sought to determine whether there were substantive differences in the frequency and operational effectiveness of convective weather impact mitigation plans developed with and without CIWS.

The FAA facility participants for the 2005 CIWS field-use assessment included the Boston (ZBW), Chicago (ZAU), Cleveland (ZOB), Minneapolis (ZMP), New York (ZNY), and Washington, D.C. (ZDC) ARTCCs. These facilities were selected because they all must make highly complex traffic management decisions, particularly during adverse weather. ZMP was a relatively new user of CIWS, whereas the other five ARTCCs had been CIWS users since 2001.

Observations were also conducted at two non-CIWS facilities [the Atlanta (ZTL) and Jacksonville (ZJX) ARTCCs] to obtain supplementary data. These data were used to confirm current CIWS users' estimate of the workload associated with weather impact mitigation planning had they not had access to CIWS.

Finally, observations were taken at ARTCCs both with and without CIWS displays at Area Supervisor positions. During the 2003 CIWS benefits study, it was found that ZDC made capacity enhancing decisions 50–100% more frequently per convective weather day than any of the other ARTCCs. A key difference between ZDC and the other ARTCCs in 2003 was that only ZDC had CIWS displays at Area Supervisor positions in addition to the Traffic Management Unit (TMU). It was hypothesized that greater effectiveness at ZDC in achieving delay reduction benefits may have arisen in part from more efficient ATC decision support capabilities, due to enhanced, common situational awareness between the TMU and Area Supervisors. This hypothesis was confirmed experimentally in this study.

Results of the Study

Real time observations of ATC decision making at ARTCCs with varying levels of access to CIWS (i.e., no CIWS, CIWS in TMU only, CIWS in TMU and some Areas, CIWS in TMU and all Areas) were conducted on 14 convective weather impact days in 2005. The principal results are as follows:

> ***CIWS reduced the time required by the TMU to develop, coordinate, and implement weather impact mitigation plans by <u>20–95 minutes</u> per thunderstorm day per ARTCC***

Total TMU time savings attributed to CIWS per convective weather day, demonstrating productivity enhancements for individual elements of the operational impact mitigation planning loop (see Figure ES-1), are shown in Figure ES-3. CIWS proved most beneficial to traffic managers when identifying and prioritizing thunderstorm impact concerns and developing high-quality impact mitigation plans. On average, for all ARTCCs studied, 70% of total time savings in the TMU attributed to CIWS was in the plan *development* stage of the operational weather impact decision loop.

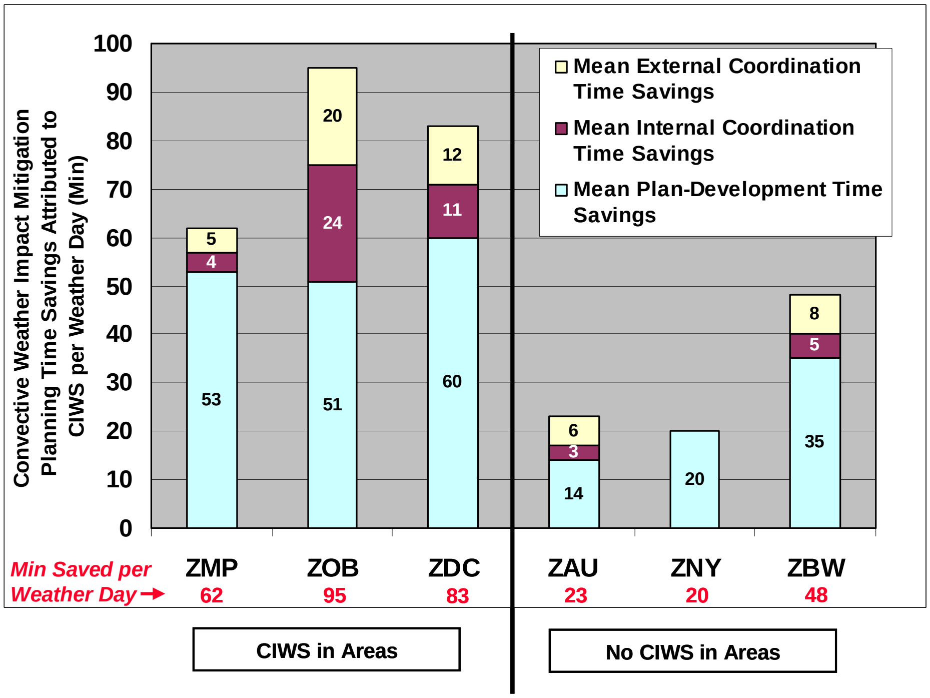

Figure ES-3. TMU time-savings attributed to CIWS at each ARTCC investigated in 2005. Productivity enhancements per convective weather day are segmented to demonstrate CIWS contributions to the specific legs of the operation decision loop for weather impact mitigation. ARTCCs with and without access to CIWS displays in the Areas are noted.

Availability of CIWS in ARTCC TMUs <u>and</u> sector Areas significantly increased ATC productivity and the frequency of realized operational effectiveness benefits

Time-saving results for TMU weather impact mitigation in Figure ES-3 demonstrate a significant relationship between enhanced TMU productivity and availability of CIWS displays in ARTCC Areas. Total time-savings by TMU traffic management coordinators (TMC) from the 3 ARTCCs with CIWS in both the TMU and the Areas was 164% greater than TMC time-savings from 3 ARTCCs with CIWS only in the TMU. ATC observations during weather impact events revealed that collaborative efforts between an ARTCC TMU and an Area involving traffic plan development, coordination, and monitoring required less time and effort when both parties had direct access to CIWS displays.

Analysis of specific weather impact events suggests that significant reductions in TMU workload at ZOB, ZDC, and ZMP (ARTCCs with CIWS in TMU and Areas) were achieved when Area Supervisors used CIWS to *avoid* the use of traffic management initiatives. These workload reductions derived from Area use of CIWS often extended to other ATC facilities.

The frequency of implemented en route capacity-enhancing decisions, another measure of ATC productivity, was also substantially higher at ARTCCs with CIWS displays in both the TMU and Areas. Figure ES-4 shows that for the five most common CIWS en route capacity enhancement benefits, the frequency of these improved decisions at ARTCC with access to CIWS in both the TMU and the Areas was 140% greater than ARTCCs with CIWS only in the TMU.

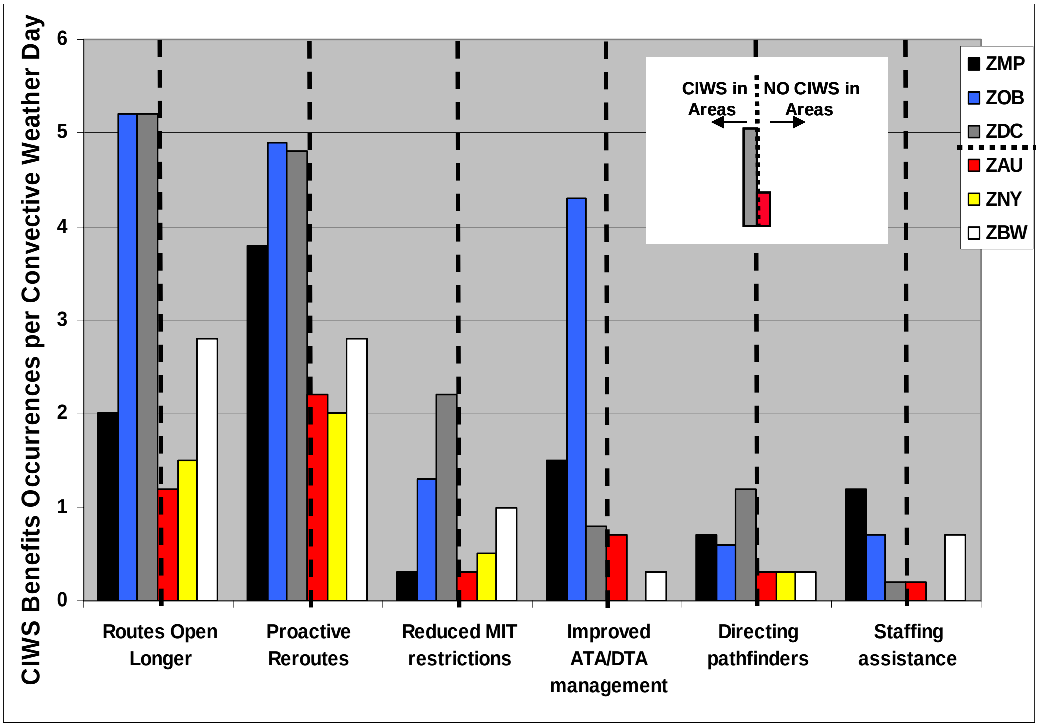

Figure ES-4. CIWS benefits per convective weather day at each ARTCC included in the 2005 CIWS field use assessment. Benefit categories shown here are typically considered key en route delay reduction benefits attributed to CIWS at ARTCCs. The benefit category, "FAA staffing assistance," is also included. ARTCC results are separated into two groups: those facilities with access to CIWS at Areas Supervisor positions and those without. ZMP was a new CIWS user in 2005, while ZBW had several very intensive users in the TMU.

Improvements in ARTCC-TRACON transition airspace management in ZOB demonstrates the importance of common situational awareness of high-quality tactical weather information provided by CIWS

The frequency of CIWS benefits occurrence (see Figure ES-4) show that the rate at which improved arrival/departure ARTCC-TRACON transition airspace (ATA/DTA) management decisions are made at ZOB was 180–1300% greater than any other ARTCC under study in 2005. A principal reason for this significant difference is that ZOB plan development, coordination, and execution decisions for improved ARTCC/TRACON transition airspace management were facilitated by providing access to CIWS at all of the primary FAA inter/intra-facility coordination points (Table ES-1). In particular, our observations of ZOB operations during weather impact events found that direct access to CIWS by the TRACON facility significantly improved ZOB productivity when managing traffic flows to/from TRACONs within the parent-ARTCC (e.g., Detroit TRACON within ZOB) while these flows are disrupted by thunderstorms.

TABLE ES-1
CIWS Availability Comparisons

CIWS available at:	ZOB	ZDC	ZMP	ZNY	ZAU	ZBW
ARTCC TMU	YES	YES	YES	YES	YES	YES
All TMU spacing positions	YES	No	No	No	No	No
ARTCC Areas	YES	YES	YES	No	No	No
Large TRACONs within parent-ARTCC	YES	No	No	YES	YES	No
All neighboring ARTCCs	YES	No	No	YES	YES	YES

Use of CIWS helped address FAA staffing issues during convective weather impact events

Field-use observations in 2005 identified a number of uses of CIWS weather products to assist in FAA staffing decisions, including:

- Justifying controller/TMC overtime based upon weather impacts forecasted by CIWS
- Adding "D-side" controllers to reduce radar controller workload based upon current or pending weather impacts as depicted by CIWS
- Optimizing Area controller break schedules based upon CIWS weather information
- Managing ATC staffing in super-high sectors based upon CIWS Echo Tops and Echo Tops Forecast products
- Determining Area/TMC staffing levels needed for diversion recovery programs
- Avoiding controller/TMU overtime (staffing levels acceptable, despite convective weather impacts, based upon CIWS weather depictions and forecasts).

Staffing decisions made by Area Supervisors using CIWS to add or extend overtime for controllers at first glance appears counter to FAA goals to reduce operating costs. However, from an air traffic management perspective, these staffing decisions, which decrease individual controller workload and thus maintain or increase sector capacity, allow ARTCCs to proactively address convective weather impact concerns. The potential end result of this proactive staffing approach in the Areas, based upon CIWS, was often reduced air traffic delays and reduced duration of late evening impacts, when controller staffing is extremely limited and costs for off-peak ATC overtime (needed to handle ongoing peak traffic demand) would be significantly greater.

The estimated frequency of annual CIWS operational effectiveness benefits increased significantly when based on the 2005 field-use observations

The frequency of higher-quality ATC decisions derived from CIWS, resulting in greater airspace capacity and more efficient routing strategies during convective weather, increased 177% from 2003 to 2005. A comparison of the estimated annual frequency of beneficial CIWS decisions is shown in Figure ES-5. These estimates are based on observations in 2003 and 2005 at ARTCCs with access to CIWS in both years and the 20+ year thunderstorm climatology for the various ARTCCs. Annual occurrences of the two primary CIWS en route capacity enhancement benefit categories, "More Proactive Reroutes" and "Keeping Routes Open Longer," to which substantial delay/cost savings were attributed in the 2003–2004 CIWS field-use study, increased 142% from 2003 to 2005. The increased frequency in all operational effectiveness benefits is likely due to a combination of (a) CIWS product enhancements such as the introduction of the 0–2 hour Echo Tops, (b) increased confidence by ATC users in the CIWS products, and (c) increased availability of CIWS displays at ARTCC Area Supervisor positions. With continuing increases in air traffic demand, particularly in high altitude en route airspace, it is encouraging that the number of times CIWS is used per thunderstorm to make capacity enhancing decisions has also increased.

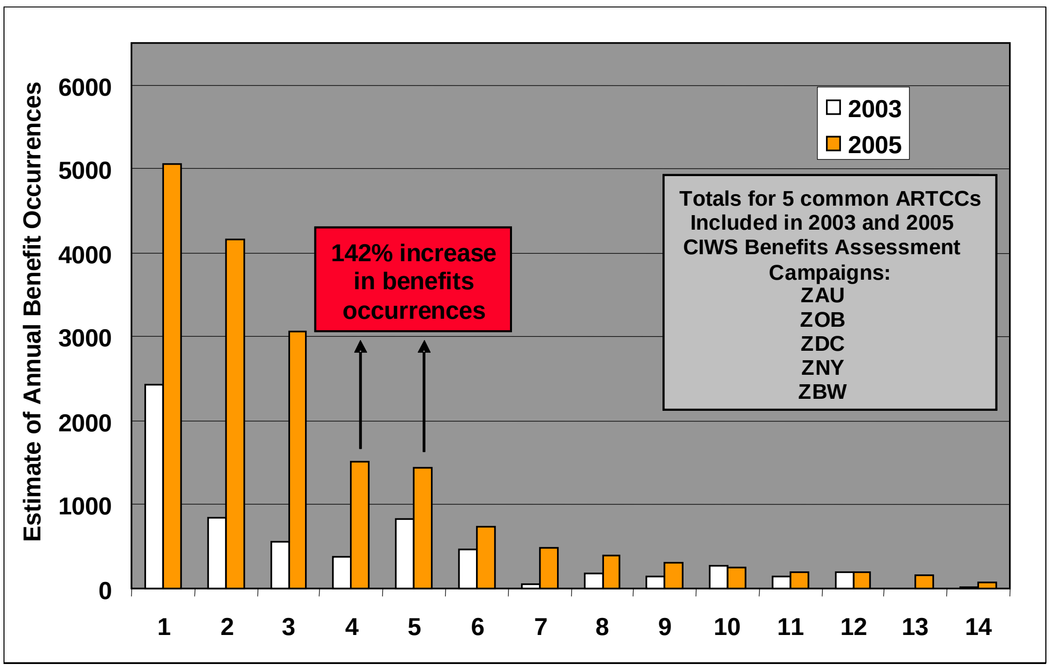

Figure ES-5. Estimate of annual occurrences of CIWS benefits realized at 5 ARTCCs in 2003 vs. 2005. Two specific en route benefit categories, "Proactive Reroutes" and "Keeping Established Routes Open Longer/Reopening Closed Routes Earlier," are highlighted to indicate the increased user frequency for realizing these significant delay and workload saving applications.

Estimated annual CIWS delay reduction benefits increased substantially from 2003 to 2005

The results in Figure ES-5 were converted to estimates of the annual CIWS delay reduction in hours and airline cost savings by using the 2003 case benefits analyses together with the 2005 fuel costs and ARTCC thunderstorm climatology records. The annual hours of delay saved and total cost savings in 2005 attributed to CIWS usage in “keeping jet routes open longer” and “proactively and more efficiently rerouting traffic” exceeded **92,000 hours and $295 M**; increases of 121% (hours saved) and 126% (costs saved) compared to the estimates based on 2003 benefits frequency data. Since the same methodology was used for converting annual CIWS benefits frequencies to delay/cost savings as in the 2003 CIWS study, the significant increase in CIWS delay reduction benefits in 2005 are attributed solely to the combination of increased benefits frequencies per ARTCC (see Figure ES-5) and increased fuel costs. The annual CIWS delay savings results based on the 2005 benefits frequency data are considered conservative for several reasons, including the fact that the annual ZMP benefits (21% of the total beneficial decisions observed in the six ARTCCs with access to CIWS visited in 2005) and the ZKC benefits were not considered in the annual delay reduction benefits calculations.

The projected annual CIWS delay reduction benefits are greatest at ZOB, where benefits increased 250% from 2003 (Figure ES-6). This increase is not surprising given that, of the five ARTCCs under study in 2003 and 2005, ZOB is the only facility where access to CIWS at Area Supervisor positions was added after 2003.

Annual jet fuel cost and consumption savings for commercial airlines attributed to CIWS usage at six ARTCCs in 2005 exceeded $18.6 M and 11.4 M gallons. The 2005 jet fuel consumption savings increased 136% since 2003, an increase directly related to improved ATC proficiency in implementing higher-quality, capacity-enhancing convective weather impact mitigation plans. The 2005 jet fuel cost savings attributed to CIWS increased 355% since 2003, due to a combination of the increased rate of achieved capacity-enhancement benefits by ATC and the 94% increase in jet fuel cost from 2003 to 2005. Given forecasts for fuel prices to remain high through at least 2007, these jet fuel savings derived from CIWS are a significant benefit to airlines and passengers, and also support national efforts to reduce oil consumption.

Field observations at ARTCCs without access to CIWS suggest access to this tool would improve the quality of some weather impact mitigation plans

Traffic management decisions at the Atlanta ARTCC (ZTL), made using convective weather decision support tools other than CIWS, often occurred just as quickly as the CIWS-based decisions made in an adjacent CIWS facility (ZDC) and the weather impact mitigation plans generally yielded good results. However, post-analysis identification of opportunities to utilize available capacity and/or decrease airspace complexity (and thus ATC workload) that were missed suggests that CIWS could have improved the quality of weather planning decisions at ZTL.

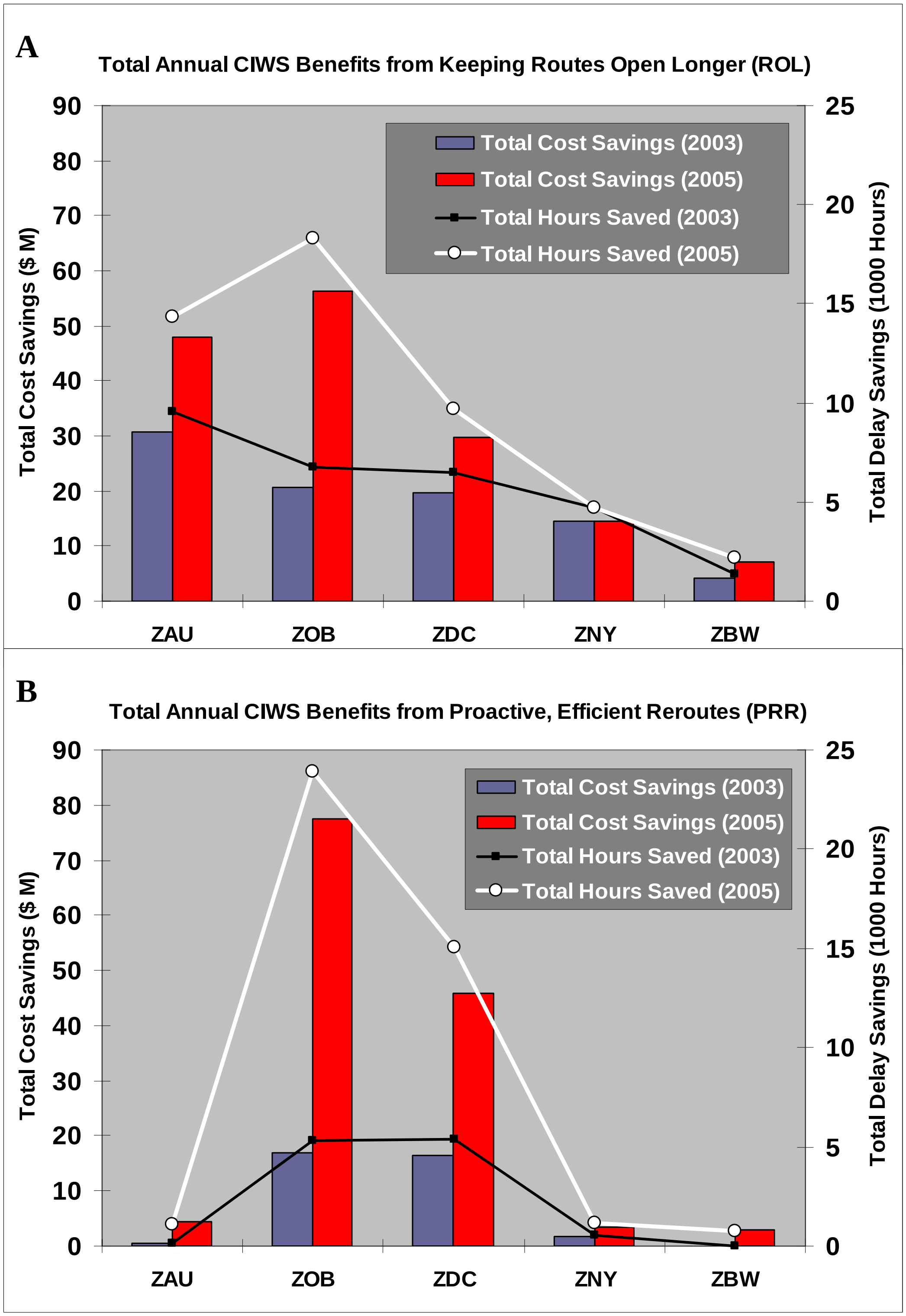

Figure ES-6. Total annual CIWS delay reduction benefits by ARTCC, in terms of operating and passenger cost savings (bars) and hours of delay saved (lines), from (A) keeping routes open longer (ROL) and (B) more proactive, efficient reroutes (PRR).

Based on the 2005 ZTL observations, we projected that the primary benefits of CIWS in ZTL would be:

1. Improved operational efficiency of ARTCC-TRACON transition airspace management, including improved tactical reroute efficiency

2. Improved use of departure restrictions

3. Improved efficiency in managing holding stacks

4. Improved Ground Stop and Ground Delay Program efficiency.

Next Steps for CIWS Productivity Enhancement and Delay Reduction Benefits Studies

Several analysis tasks are planned to extend the 2005 CIWS benefits results presented in this report, including:

- Use of sector/route capacity assessment models to quantify improvements in effective sector capacity attributed to CIWS-derived convective weather impact mitigation plan enhancements

- Detailed analyses of weather and aircraft flight track data in ARTCCs with and without access to CIWS in order to independently confirm that the use of CIWS results in fewer missed opportunities for mitigating the adverse impacts of convective weather.

More work is also required to reduce the uncertainty associated with overall CIWS delay reduction benefits. The limited sample size for quantifying CIWS delay savings, upon which projected annual delay/cost savings are based, is recognized by the authors as a significant caveat to CIWS benefits results to date. The effects of the limited sample size are as follows: The CIWS delay reduction benefits associated with a given decision are modeled as random variables drawn from a statistical ensemble whose probability distribution has slowly decreasing tails. Since there were typically two or three events analyzed per ARTCC, the statistical variance associated with the mean or median benefits is undoubtedly high and has not been quantified. A two-phase approach is recommended to address this CIWS delay reduction statistical uncertainty issue:

1. Analyze additional (e.g., 3–5) cases for quantified beneficial decisions in both ZDC and ZOB, since those two ARTCCs account for the bulk of the overall CIWS delay reduction benefits. These cases should be drawn from the 2005 observed events (especially for ZOB) to see if there is any substantive difference between the TMU-only beneficial decisions versus TMU-Area Supervisor collaborative beneficial decisions.

2. Develop automated tools that could reduce the time to carry out individual case analyses. These tools should include the use of algorithms to accomplish near optimal traffic flow management with time varying en route and terminal capacities. The development and validation of such tools is a non trivial, but important, undertaking.