Project Report
ATC-341

Wind-Shear System Cost Benefit Analysis Update

R.G. Hallowell
J.Y.N. Cho
S. Huang
M.E. Weber
G. Paull
T. Murphy

13 May 2009

Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS

Prepared for the Federal Aviation Administration,
Washington, D.C. 20591

This document is available to the public through
the National Technical Information Service,
Springfield, Virginia 22161

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
ATC-341		

4. Title and Subtitle	5. Report Date
Wind-Shear System Cost Benefit Analysis Update	13 May 2009
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
R.G. Hallowell, J.Y.N. Cho, S. Huang, M.E. Weber, G. Paull, and T. Murphy	ATC-341
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
MIT Lincoln Laboratory 244 Wood Street Lexington, MA 02420-9108	11. Contract or Grant No. FA8721-05-C-0002
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Department of Transportation Federal Aviation Administration 800 Independence Ave., S.W. Washington, DC 20591	Project Report
	14. Sponsoring Agency Code

15. Supplementary Notes

This report is based on studies performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology, under Air Force Contract FA8721-05-C-0002.

16. Abstract

A series of fatal commercial aviation accidents in the 1970s led to the development of systems and strategies to protect against wind shear. The Terminal Doppler Weather Radar (TDWR), Low Level Wind Shear Alert System (LLWAS), Weather Systems Processor (WSP) for Airport Surveillance Radars (ASR-9), pilot training and on-board wind-shear detection equipment are all key protection components. While these systems have been highly effective, there are substantial costs associated with maintaining and operating ground-based systems. In addition, while over 85% of all major air carrier operations occur at airports protected by one of these ground-based wind-shear systems, the vast majority of smaller operations remain largely unprotected.

This report assesses the technical and operational benefits of current and potential alternative ground-based systems as mitigations for the low-altitude wind-shear hazard. System performance and benefits for all of the current TDWR (46), ASR-9 WSP (35), and LLWAS (40) protected airports are examined, along with 40 currently unprotected airports. We considered in detail several alternatives and/or combinations for existing ground-based systems. These included the option to use data from current WSR-88D (or NEXRAD) and two potential future sensor deployments: (1) a commercially built pulsed-Doppler Lidar and (2) an X-band commercial Doppler weather radar. Wind-shear exposure estimates and simulation models for each wind-shear protection component were developed for each site in order to accurately compare all alternatives.

For the period 2010–32, the current combination of wind-shear protection systems reduces the $3.0 billion unprotected NAS overall wind-shear safety exposure to just $160 million over the entire study period. Overall, there were few alternatives that resulted in higher benefits than the TDWR, TDWR-LLWAS, and WSP configurations that currently exist at 81 airports. However, the cheaper operating costs of NEXRAD make it a potential alternative especially at LLWAS and non-wind-shear protected sites.

17. Key Words	18. Distribution Statement
	This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	186	

FORM DOT F 1700.7 (8-72) Reproduction of completed page authorized

This page intentionally left blank.

ABSTRACT

A series of fatal commercial aviation accidents in the 1970s and 1980s led to the identification of wind-shear as a critical hazard to aviation. In response, the aviation community has developed a number of systems that detect and warn pilots and controllers of low-altitude wind-shear hazards. Pilot training on visual clues to the presence of wind shear, and on avoidance and recovery procedures was the earliest mitigation strategy. The Terminal Doppler Weather Radar (TDWR) was developed as the primary ground-based protection system for 45 of the busiest and most wind-shear exposed airports. In parallel, improved versions of the Low Level Wind Shear Alert System (LLWAS) and a Weather Systems Processor (WSP) modification for existing Airport Surveillance Radars (ASR-9) were developed to detect wind shear at smaller airports. On-board wind shear detection equipment was mandated for Part 121 aircraft. As a result of these steps, there has not been a fatal commercial aircraft accident in the United States attributed to wind shear since 1994.

However, there are substantial costs associated with maintaining and operating TDWR, WSP, and LLWAS systems. In addition, while over 85% of all Part 121 operations are to airports protected by one of these ground based wind shear systems, only half of the Part 135 operations and just over 5% of all Part 91 operations involve these airports. Therefore, the FAA has requested that Lincoln Laboratory reassess the technical and operational benefits of current ground based systems and evaluate the viability of alternative mitigations for the low-altitude wind shear hazard. System performance and benefits for all of the current TDWR (46), ASR-9 WSP (35) and LLWAS (40) protected airports are examined, along with 40 currently-unprotected airports where operations rates are forecast to grow.

We considered in detail several alternatives and/or augmentations for existing ground based systems. These included the option to use data from the WSR-88D (or NEXRAD) to provide wind shear services at airports where its siting is appropriate. Two potential future sensor deployments were also considered: (1) a commercially built pulsed-Doppler Lidar currently being tested at Las Vegas International airport; and (2) an X-band commercial Doppler weather radar that is being promoted as adjunct to the pulsed Lidar. An objective metric for wind shear detection capability was calculated for each system or combination of systems evaluated.

For the period 2010–32 in an unprotected NAS, wind shear would cost over $3.0 billion in wind shear related accidents. Pilot training and airborne systems reduce this exposure to $972 million. The current ground-based wind shear protection systems and in-progress TDWR/WSP upgrades reduce this safety exposure further to just $160 million for the entire study period. Overall, there were few alternatives that resulted in higher benefits than the TDWR, TDWR-LLWAS and WSP configurations that currently exist at 81 airports. Even when system costs are factored in, switching to the optimal alternative at all 161 sites would result in less than 10% in overall net benefits. However, the cheaper operating costs of NEXRAD make it a potential alternative especially at LLWAS and non-wind shear protected sites. Individual sites varied, however, often due to unique siting, wind shear and/or traffic load conditions.

This page intentionally left blank.

TABLE OF CONTENTS

TABLE OF CONTENTS
(CONTINUED)

Page

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (CONTINUED)

LIST OF ILLUSTRATIONS (CONTINUED)

LIST OF ILLUSTRATIONS (CONTINUED)

LIST OF ILLUSTRATIONS (CONTINUED)

This page intentionally left blank.

LIST OF TABLES

LIST OF TABLES (CONTINUED)

1. INTRODUCTION

The Terminal Doppler Weather Radar (TDWR) was developed in response to a series of fatal commercial aircraft wind shear accidents in the 1970s and 1980s. In aggregate, these resulted in over 400 fatalities and pressure on the FAA to develop effective warning technologies. An aggressive development and implementation program led to operational deployment of the TDWR at 46 airports during the 1990s. In parallel, improved versions of the Low Level Wind Shear Alert System (LLWAS) and a Weather Systems Processor (WSP) modification for existing Airport Surveillance Radars (ASR-9) were developed to provide similar warning services at smaller airports.

To date, there has not been a wind shear related accident at an airport where one of these modern wind shear detection systems is in operation. Most experts believe that this reflects a combination of circumstances including, but not confined to, deployment of the ground-based warning systems. Improved pilot awareness of the meteorological conditions in which wind shear occurs and the associated visual cues, as well as extensive pilot training on recovery procedures are clearly factors as well. All Part 121/129 aircraft are now equipped with either "reactive" or "predictive" on-board wind shear detection equipment. These airborne systems assist the pilot in recovery when a wind shear is encountered, and provide short lead-time warnings that the aircraft is approaching wind shear. Finally, deployment of the ground based systems and associated training have enhanced air traffic controller awareness of wind shear and greatly improved their ability to provide proactive advisories to pilots of hazardous conditions.

It has now been more than two decades since the first prototype radar tested the ability of Doppler-radars to detect wind shear, and more than a decade since the first TDWR became operational. While there has been a demonstrable decrease in the number and severity of wind shear and other weather related accidents there are substantial costs associated with operating and maintaining TDWR, WSP, and LLWAS. In addition to recurring costs associated with site- and second-level engineering support, substantial non-recurring costs accrue from hardware, processor, and software upgrades which are necessary to assure long-term operational availability. For example, the FAA is currently executing a multi-year Service Life Extension Program (SLEP) for TDWR that addresses many of its major subsystems, including the antenna drive mechanism, signal- and data-processing computers, and user displays. And, recently, new wind shear detection technology has been developed such as the Lidar and X-band radar that might be useful in complementing or replacing the deployed systems.

In this report, we quantify the effectiveness and associated operational benefits of deployed ground based wind shear detection systems (TDWR, ASR-9 augmented with the Weather Systems Processor (WSP) and LLWAS). In addition, we consider possible complementary or alternative sensors including the WSR-88D (or NEXRAD), a commercially built pulsed-Doppler Lidar and a commercially built 3 cm wavelength (X-Band) Doppler weather radar. Combinations of systems are examined to evaluate the benefits of integration. All of these single-sensor and integrated configurations are evaluated for the 121 US airports that currently have some type of operational, ground-based wind-shear system. Additionally, 40 feeder airports that are not currently protected by ground-based wind-shear systems are examined. Figure 1 shows the location of the airports studied coded by the site's current wind-shear protection systems.

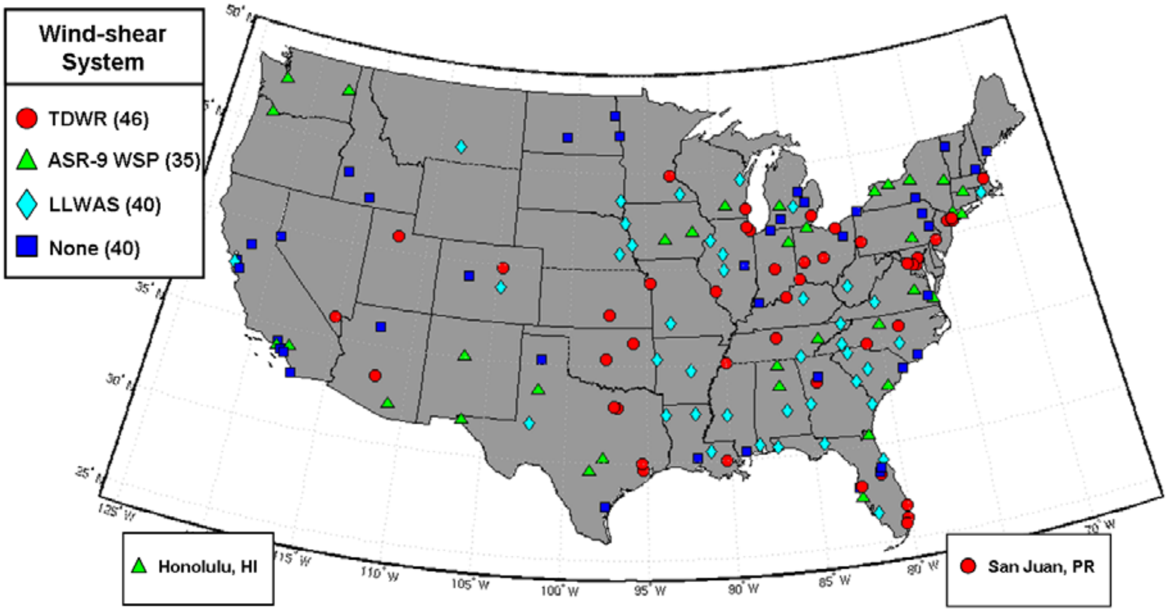

Figure 1. Airports considered in this study. The symbols indicate the wind shear protection system currently operating at each airport. Note that nine of the TDWR airports are also equipped with an integrated network-expansion LLWAS system.

Section 2 provides an estimate of the wind shear accident rate that would occur in the absence of the ground based detection and warning systems. This estimate must of course consider the effect of complementary mitigations (pilot training and airborne wind shear systems) that have been introduced in the last two decades. In Section 3, we evaluate wind shear exposure at each of the studied airports. These are extrapolated from TDWR microburst and gust front measurements at major U.S. airports, using meteorological parameters that are available on a nation-wide basis. Section 4 discusses the modeling of pilot training and airborne wind shear system impacts and the basis for and the results of a technical comparison of the various ground-based wind shear systems. In Section 5, we discuss the methodology for safety and delay benefits estimates and the estimated costs of maintaining and/or implementing current and alternative systems. Section 6 details the total safety-related financial exposure of the NAS to wind shear accidents and the current effectiveness of the current configuration of wind shear mitigation systems. The relative value of safety and delay benefits for current and alternative system configurations is evaluated in Section 7, while Section 8 presents details of the cost-benefit assessment for all alternatives and sites.

This report is an update to the "Integrated Wind Shear Systems Cost-Benefit Analysis" published in 1994 (Martin Marietta, 1994) and a follow-on to recent studies by Weber et al. (2007) and Cho & Martin (2007). While we have largely retained the overall approach to evaluating wind-shear systems benefits that was defined in the 1994 report, we have substantially improved the data going into the analysis. In particular, the accident rate estimates have been updated to consider accidents since 1985 and the likely impact of pilot training and airborne equipage. Ground based system effectiveness estimates are based on an objective, airport-specific model as opposed to the "expert judgment" applied in the earlier report. Wind shear exposure is calculated on an airport-specific basis using relevant measured parameters, as opposed to the subjective, regional exposure estimates provided previously. Finally, delay estimates utilize queuing models as opposed to empirical data to calculate benefits for proactive runway changes as wind-shifts approach an airport.

This page intentionally left blank.

2. WIND SHEAR ACCIDENT RATE ANALYSIS

The **National Transportation Safety Board (NTSB)** is an independent agency responsible for the investigation of accidents involving aviation, highway, marine, pipelines and railroads in the United States (except aircraft of the armed forces and the intelligence agencies). The agency is charged by the U.S. Congress to investigate every civil aviation accident in the United States. The NTSB maintains a database of aviation accidents detailing each accident from raw statistics of injuries, fatalities, aircraft damage and weather conditions, to pilot and eyewitness statements, aircraft type and equipage. Most importantly, the NTSB attempts to assign the probable cause of and contributing factors to each accident. The attribution of cause is important because it enables aviation experts to focus on the safety-critical needs of the aviation system.

In the NTSB database, an event is classified as either an accident or an incident. As defined by the NTSB, "aircraft accident" means an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage. An "incident" is defined as an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations. Accidents are required to be reported and investigated but incidents have some discretion involved with them. This is an important distinction for cost-benefits analyses as only accidents, with their clear reporting criteria, can be relied upon for consistent reporting over time.

2.1 ESTIMATING ACCIDENT RATE

One of the challenges in measuring the benefits of wind shear mitigation systems is that the frequency of accidents is very small compared to the total operations. This means that one accident can have a large impact on the apparent accident rate, especially over short time periods. In addition, reliable records of wind shear related accidents were available only a short time before mitigation techniques started to be employed (see Figure 2). Complicating matters further, the implementation of various mitigation techniques has been ongoing since the early 1980s. However, because we now have over 30 years of measurements we are able to use the underlying variability to measure risk and wind-shear system benefits in a variety of ways. Therefore, we use several accident rate measures in this benefits analysis (see bottom of Figure 2). The **protected accident rate** estimates the rate of accidents that have been occurring since the deployment of all current wind-shear protection systems (LLWAS, PWS, TDWR, and WSP). The **transitional accident rate** is designed to estimate the rate of wind-shear related accidents as pilot awareness was rapidly increasing and initial LLWAS systems were being deployed, but prior to the deployment of widespread automated radar-based wind-shear protection systems. And finally, for a historical perspective, we use the **baseline accident rate** as measured in the original cost-benefits analysis for TDWR (Martin Marietta, 1994). The **baseline** is an estimate of the rate of wind-shear related accidents prior to both the widespread awareness of pilots and the deployment of automated wind-shear protection systems. All of these measures are important in both estimating the benefits of wind-shear protection systems and helping to cross-check the estimated effectiveness of wind shear mitigation measures.

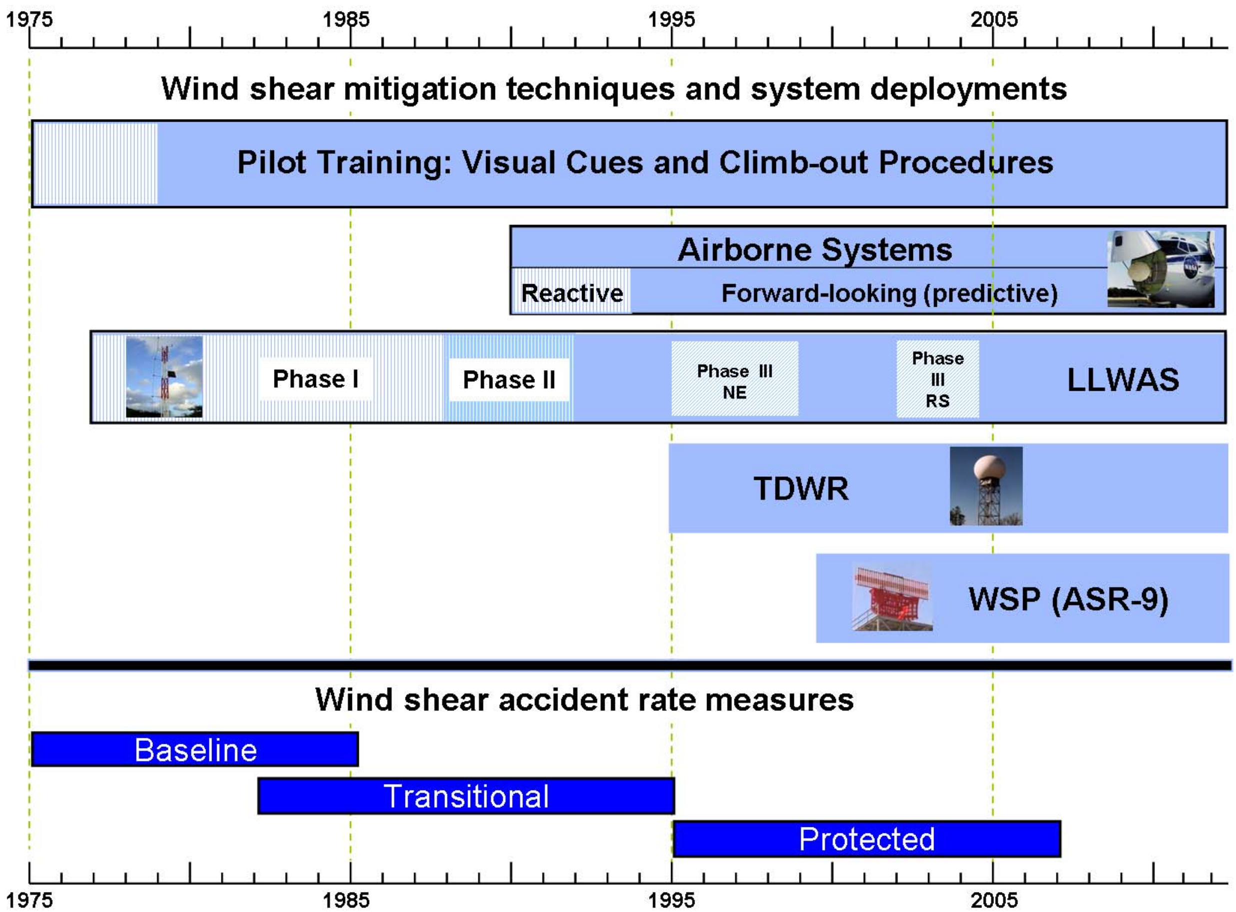

Figure 2. Timeline of wind-shear mitigation techniques and alerting systems as compared to baseline, transitional, and protected wind shear accident rate measures.

The NTSB database of aviation accidents and incidents has been updated and standardized for all accidents since 1982. For accidents after 1981, wind-shear accidents were identified based on entries that specified wind shear as either a cause or factor in the accident. The NTSB has six identified cause/factor codes that are relevant to wind-shear: 2231: WINDSHEAR, 2238: MB/WET, 2239: MB/DRY, 2249: SUDDEN WINDSHIFT and 2244: THUNDERSTORM OUTFLOW. Some accidents were removed after being initially selected because the narrative indicated non-microburst related wind-shear (tropospheric gravity waves for instance). For completeness, we included data from 1975-81 prior to the NTSB standardization because these accidents formed the basis of the original TDWR report and provide the best measure of the unprotected rate of wind shear accidents. Selection criteria were more subjective but roughly equivalent to the later selection criteria for the pre-1982 accident reports.

The breakdown of accident statistics for each measure of the three accident eras defined above is shown in Table 1. The protected accident rate removes the most uncertainty in the follow-on calculations of benefits as estimates of pilot training; PWS and the current ground-based system are all captured by this measure. However, as will be shown later we have calculated estimates of not only the ground-based system effectiveness but also for pilot training and PWS. Therefore, we can obtain estimates of the variability of the accident rate measure by cross-comparing the unprocessed "protected" accident rate with the other accident rate measures.

TABLE 1

Wind-shear accident statistics and rates for baseline, transitional, and protected time periods

		Aircraft Category & Safety Era		
		PART 121/129 1975-85	PART 135/137 1975-85	PART 91 1975-85
Baseline (1975-85)				
# of Accidents		13	19	173
Personal Injury	Fatal	400	35	37
	Serious	131	16	33
	Minor	28	3	14
	None	1037	26	285
	Total Injuries	559	54	84
Aircraft Damage	Destroyed	4	15	28
	Substantial	8	4	82
	Minor	0	0	0
	None	1	0	1

Safety Exposure	Operations (millions)	111.3	79.1	983.4
	Accident Rate (# acc per million ops)	0.1168	0.2402	0.1759
Transition (1982-94)				
# of Accidents		12	16	152
Personal Injury	Fatal	398	16	45
	Serious	125	8	39
	Minor	42	9	54
	None	801	35	219
	Total Injuries	565	33	138
Aircraft Damage	Destroyed	4	11	35
	Substantial	7	5	117
	Minor	1	0	0
	None	0	0	0
Safety Exposure	Operations (millions)	156.9	141.7	1098.2
	Accident Rate (# acc per million ops)	0.0765	0.1129	0.1384
Protected (1995-2007)				
# of Accidents		2	5	83
Personal Injury	Fatal	0	4	26
	Serious	1	3	13
	Minor	0	6	32
	None	279	19	125
	Total Injuries	1	13	71
Aircraft Damage	Destroyed	0	1	20
	Substantial	1	4	63
	Minor	0	0	0
	None	1	0	0
Safety Exposure	Operations (millions)	181.7	187.0	1086.5
	Accident Rate (# acc per million ops)	0.0110	0.0267	0.0764

Table 2 lists the major air carrier accidents that have occurred since 1975 in the United States. Note that none of these accidents has occurred at an airport actively protected by a TDWR or WSP wind shear detection system. Figure 3 shows the timeline of accident occurrences from 1975 to present for all three aircraft categories. There has clearly been a marked decrease in the occurrence of wind shear related accidents even while total operations continue to increase.

TABLE 2

Part 121/9 air carrier wind-shear-related accidents, 1975 to 2006, in the US

Date	Location	Aircraft	Fatalities	Injuries	Uninjured	Aircraft Damage
24 Jun 1975	Jamaica, NY	Boeing 727	112	12	0	Destroyed
7 Aug 1975	Denver, CO	Boeing 727	0	15	119	Substantial
12 Nov 1975	Raleigh, NC	Boeing 727	0	1	138	Substantial
23 Jun 1976	Philadelphia, PA	Douglas DC-9	0	86	20	Destroyed
3 Jun 1977	Tucson, AZ	Boeing 727	0	0	91	Substantial
25 Aug 1981	Miami, FL	Boeing 727	0	20	117	Substantial
9 Jul 1982	New Orleans, LA	Boeing 727	153	9	7	Destroyed
28 Dec 1983	New York, NY	Boeing 727	0	0	127	Substantial
31 May 1984	Denver, CO	Boeing 727	0	0	105	Substantial
13 Jun 1984	Detroit, MI	Douglas DC-9	0	0	56	Substantial
19 Feb 1985	San Francisco, CA	Boeing 747	0	2	271	Substantial
2 Aug. 1985	Dallas/Ft. Worth, TX	Lockheed L-1011	135	28	2	Destroyed
25 Sep 1985	Unalaska, AK	Boeing 737	0	1	20	Substantial
7 Apr 1986	Jamestown, NY	Douglas DC-10	0	12	71	Minor
15 Sep 1987	Tulsa, OK	Boeing 727	0	0	62	Substantial
25 Jan 1990	Cove Neck, NY	Boeing 707	73	85	0	Destroyed
26 Apr 1993	Denver, CO	Douglas DC-9	0	0	90	Substantial
2 Jul 1994	Charlotte, NC	Douglas DC-9	37	20	0	Destroyed
25 Nov 1995	Portland, OR	Boeing 737	0	1	111	None
22 May 1997	Newark , NJ	Boeing 767	0	0	168	Substantial

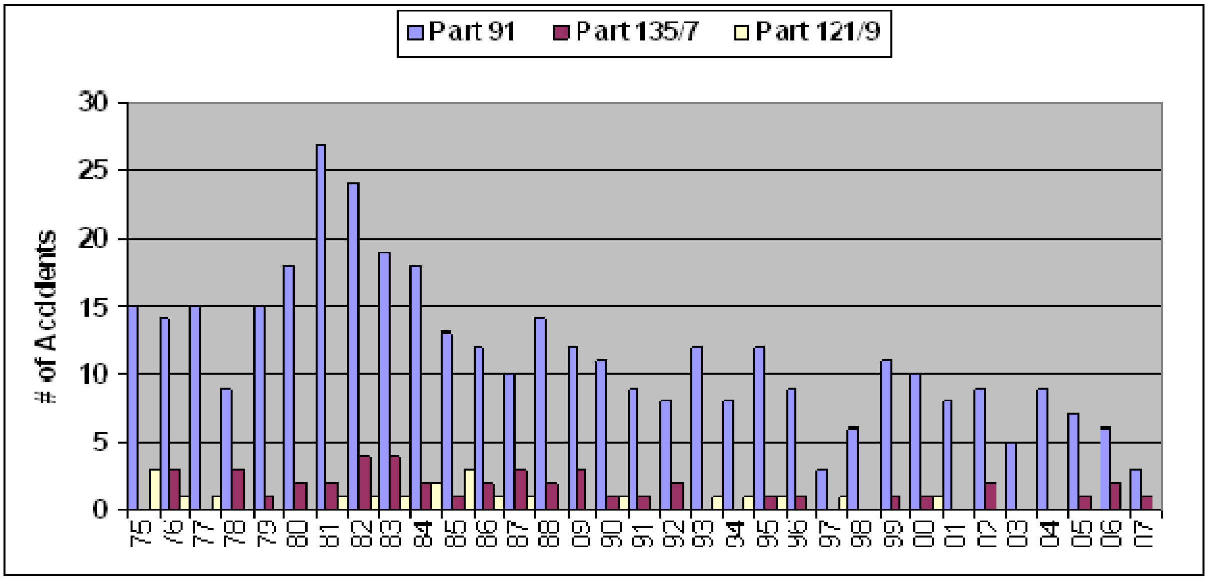

Figure 3. Timeline of wind-shear-related accident occurrences, 1975–2007, by aircraft category.

2.1.1 International Events

Wind shear activity is not restricted to the United States and there have been many reports of aviation accidents where wind shear is cited as a factor. The Aviation Safety Network (http://aviation-safety.net) and the NTSB have recorded over forty wind shear related accidents outside the US starting in the 1950s (Table 3). Accident reporting standards vary widely from country to country and US standards are among the highest in the world. Therefore, the international accidents listed here should be a conservative estimate of the total accidents and fatalities related to wind-shear. In fact, officials from the NTSB estimate that the wind shear accident rate internationally is roughly equivalent to the rates experienced in the US prior to the deployment of ground-based systems. Figure 4 illustrates this point by showing the number of accidents both within the United States and internationally broken down by time periods pre- and post-TDWR deployment in the US. Current estimates are that the total number of commercial aviation operations in the US is about equivalent to that of all the traffic in the rest of the world (NTSB, 2007).

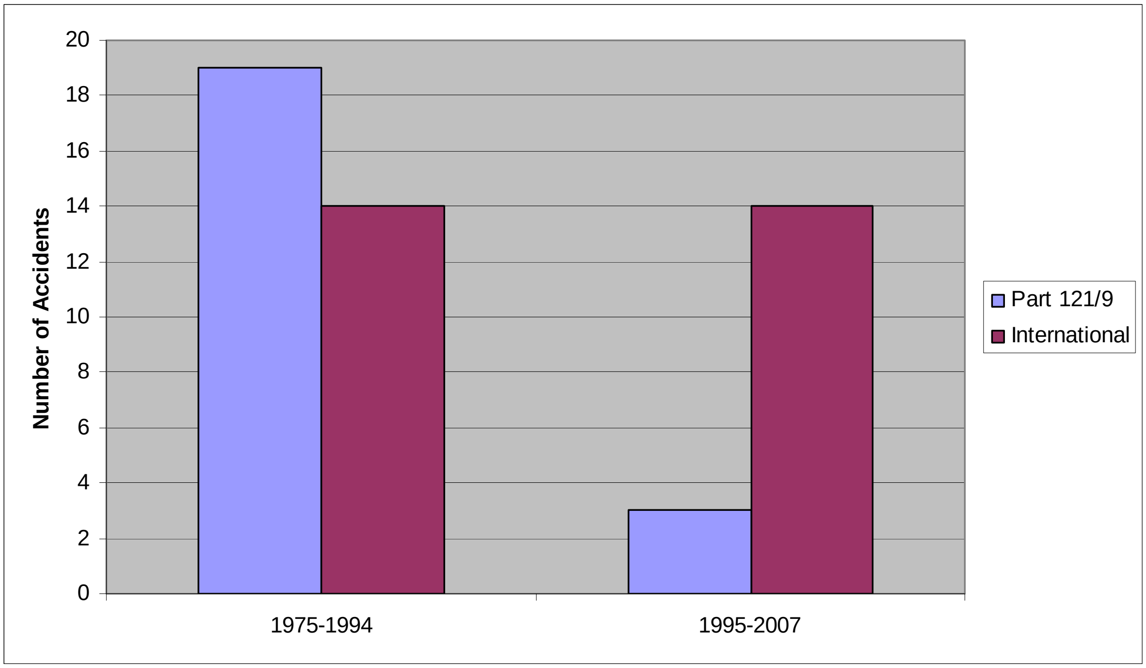

Figure 4. Comparison of major wind-shear-related accidents between accidents occurring inside and outside the US, 1975–2007.

TABLE 3

Known international wind-shear-related aviation accidents, 1975 to present (source Aviation Safety Network, NTSB)

Date	Location	Aircraft	Fatalities	Injuries	Uninjured
15 Nov 1978	Sri Lanka	Douglas DC-8	183	0	0
14 Mar 1979	Qatar	Boeing 727	45	19	0
12 Apr 1980	Brazil	B-727	55	3	0
27 Apr 1980	Thailand	HS-748	44	9	0
7 Jul 1980	Kazakhstan	Tupolev 154B	163	0	0
7 May 1981	Argentina	BAC 111	31	0	0
16 Jun 1981	India	HAL-748	0	0	28
27 Jul 1981	Mexico	DC-9	30	6	0
4 Apr 1987	Indonesia	Douglas DC-9	23	22	0
3 Sep 1989	Cuba	Ilyushin 62M	171*	0	0
24 Jul 1992	Indonesia	Vickers Vicount	70	0	0
21 Dec 1992	Portugal	Douglas DC-10	56	44	240
14 Sep 1993	Poland	Airbus A320	2	0	68
7 Jun 1997	Indonesia	Casa 212	0	0	12
10 Jun 1997	Mongolia	Y-12	7	5	0
10 Mar 1998	Zimbabwe	BAe-146	0	0	66
28 Jan 1999	Italy	MD-82	0	0	84
19 Mar 2000	Congo	Antonev 26B	0	0	10
22 Jun 2000	China	B-3479	42	0	0
7 Feb 2001	Spain	Airbus A320	0	0	143
30 Aug 2002	Brazil	EMB-120	23	8	0
27 Dec 2002	Belize	Cessna`	0	0	14
21 Jul 2004	Mexico	Douglas DC-9	0	0	56
9 Mar 2005	Belize	Cessna	0	0	14
10 Dec 2005	Nigeria	Douglas DC-9	108	1	0
23 Aug 2005	Peru	Boeing 727	31	57	0
15 Apr 2007&	Australia	Boeing 737	0	0	100

* Includes 45 ground casualties
& Preliminary analysis indicates wind shear may have been a factor

2.2 ACCIDENT RATE MODELING

As detailed above, there are three eras of accident rates that were calculated: baseline (1975–85), transitional (1982–94), and protected (1995–2007). Each time period captures a different state of wind shear mitigation, consequently we can use the models of pilot training, airborne systems and ground-based systems to transform accident rates between eras. Figure 5 illustrates this concept for Part 121/9 aircraft, the bars with hatching are the measured accident rates presented in Table 1. Each grouping of accident rates show the accident rate based on corrections for either adding or subtracting the impact of various safety measures. For example, the red hatched bar for 1975–85 represents the measured accident rate for that time period. When we correct this accident rate for the pilot training model discussed in Section 4 we obtain the solid green bar under the heading w/Pilot Training. Adding predictive wind shear systems results in the yellow bar and with the current ground-based constellation of TDWR, WSP, and LLWAS we obtain the blue bar. Conversely, the measured 'protected' accident rate from 1995–2007 can be corrected backwards to remove each mitigation technique.

This manipulation of the accident rates allows us to obtain a better average estimate of the 'unprotected' accident rate that can be used for all benefits calculations. Variability for Part 135/7 and Part 91 aircraft is much larger than for Part 121/9 aircraft in part because the models for pilot training and estimates of impact on aircraft outside ground-based protection are more limited. Table 4 lists the pooled average accident rate and the range of values over the three corrected unprotected rates for each aircraft category.

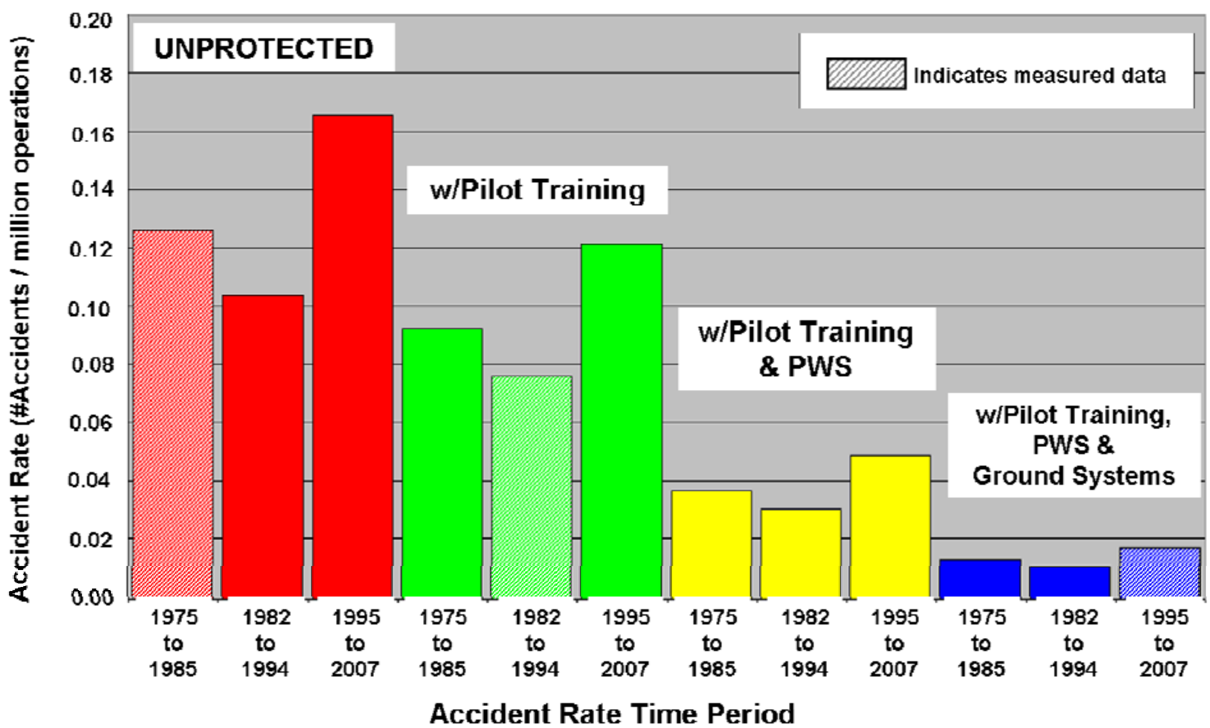

Figure 5. Comparison of measured and mitigation-adjusted accident rates for unprotected (1975–85), transitional (1982–94), and protected (1995–2007) time periods.

TABLE 4

Average and range of wind-shear-related accident rates by category (# of “unprotected” accidents per million operations)

Aircraft Category	Average Rate	Range
Part 121/9	0.1095	0.1045 – 0.1168
Part 135/7	0.2037	0.1299 – 0.2410
Part 91	0.1600	0.1201 – 0.1842

3. MEASURING WIND-SHEAR EXPOSURE

Obviously, knowing each airport's exposure to wind-shear activity is a key factor in determining the relative accident risk at each airport. Each dot on the map shown in Figure 6 represents an airport that requires analysis, there are a total of 161 airports (San Juan, Puerto Rico [SJU] and Honolulu, Hawaii [HNL] are not shown). Details of the sites chosen and their respective wind shear protection systems are given in Appendix A. For a variety of reasons we don't have a record of wind-shear activity at all of these sites (especially in the West and at small airports where we don't have radar coverage). In order to measure wind shear exposure, microburst (MB) and gust front (GF) archive data were gathered from selected TDWR and ITWS installations. In Figure 6, the TDWR archive locations are shown in red, while the ITWS archive airports are shown in green. In some cases a single ITWS serves multiple nearby airports, such as the clustered dots shown near Miami, Houston, and DC. The archives are generally only a year in length and, as such, statistical and climatological analyses were performed to interpolate the record not only spatially but also temporally.

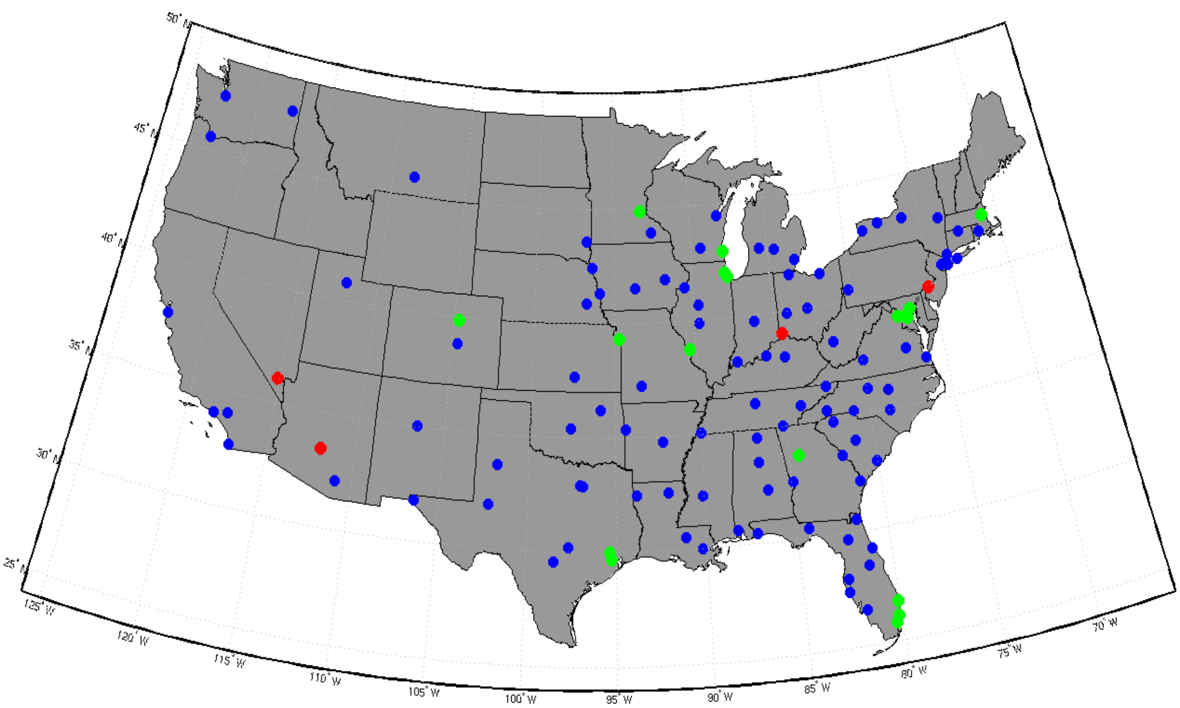

Figure 6. Location of study airports with TDWR (red) and ITWS (green) archive sites identified (San Juan, Puerto Rico, and Honolulu, Hawaii, not shown).

3.1 MICROBURST EXPOSURE

The TDWR and ITWS microburst archive data report the exact location and strength (expected wind shift loss across the alert) for each alert shape generated by either the TDWR or ITWS system, respectively. Each alert shape, however, does not necessarily represent a single microburst. The automated TDWR microburst algorithm (used to derive both TDWR and ITWS alerts) detects a wind shear and then a secondary algorithm (slightly different for TDWR than for ITWS) breaks up the detected region into alerts as a way of minimizing over-warning over the airport. In some cases the TDWR can generate more than a dozen shapes to represent a very large microburst. Because alert shapes may not represent a single wind shear and because TDWR and ITWS algorithms will output sometimes dramatically different numbers of shapes, we can't simply count up all the alerts for each archive site and use this as the number of wind shear events. Instead, we chose to count the number of minutes that each site reported at least one microburst alert. These are called "unique" MB minutes, and Figure 7 shows a map of the unique minutes for each archive site (normalized to a full year and full 360 degree, 30 km radius TDWR scan). Note the exponentially higher levels of microburst activity in the Gulf region, and the strong drop-off in the Northeast and upper Midwest. Next, we needed to interpolate this snapshot of microburst activity over the entire country and at the same time account for climatology for year to year variations.

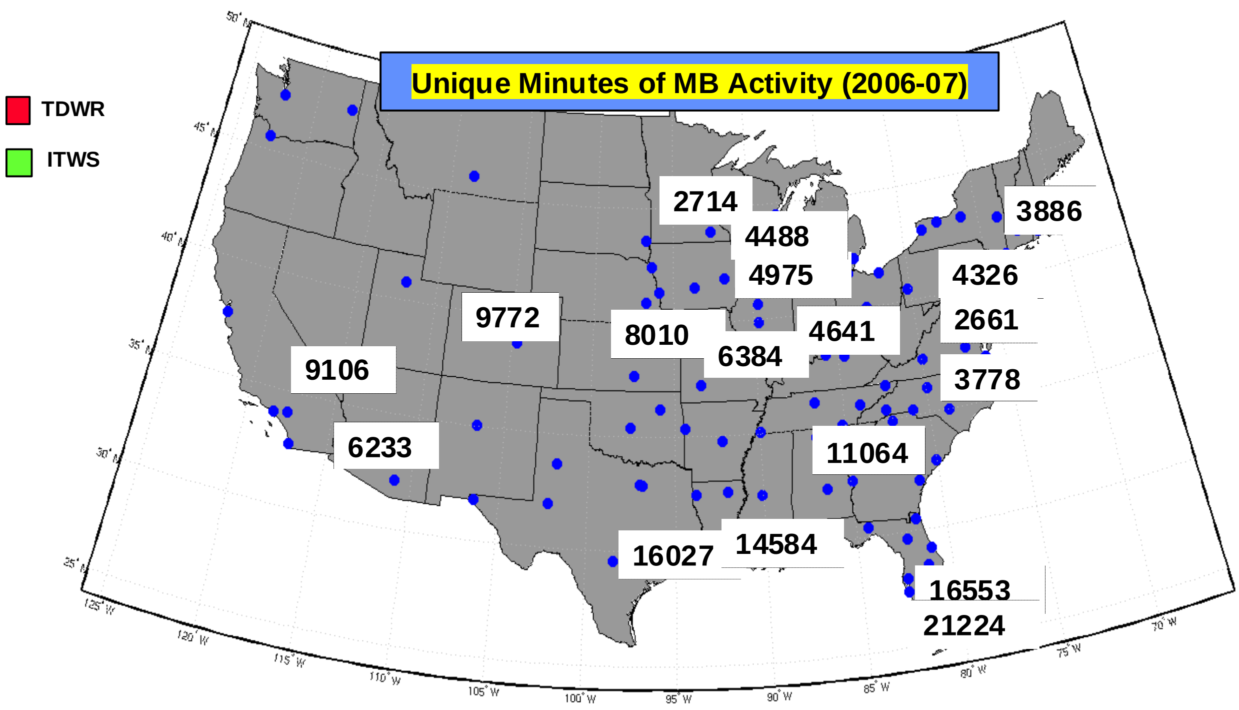

Figure 7. Measured number of minutes per year where at least one microburst was within a 30 km radius of the respective TDWR/ITWS archive site.

There are two types of microbursts: wet and dry. Wet microbursts are driven by thunderstorms and their associated precipitation-driven outflows. As a well-measured surrogate of thunderstorm activity, we obtained a ten year climatology of average annual lightning flash rates over the US. Figure 8 shows the distribution of annual lightning flash rate intensity over the contiguous United States while Figure 9 shows the comparison of lightning flash rates to microburst minutes for all of the archived sites. In addition ceiling height, or the height at which clouds typically begin to form, can be utilized in two ways. For regions with relatively low cloud base heights in the summer (the West coast for example), microburst activity is suppressed. Secondly, dry microbursts are driven by evaporative cooling and that requires the depth through which the cold air falls to be large enough to generate sufficient force to produce a microburst. Cloud base height is a good measure of this depth and we utilized a 20-year climatology of hourly observations to measure average ceiling height over the active summer months (Figure 10). Finally, the elevation of the station is often indicative of the relative exposure to dry microbursts (Wolfson et al., 1988, 1994).

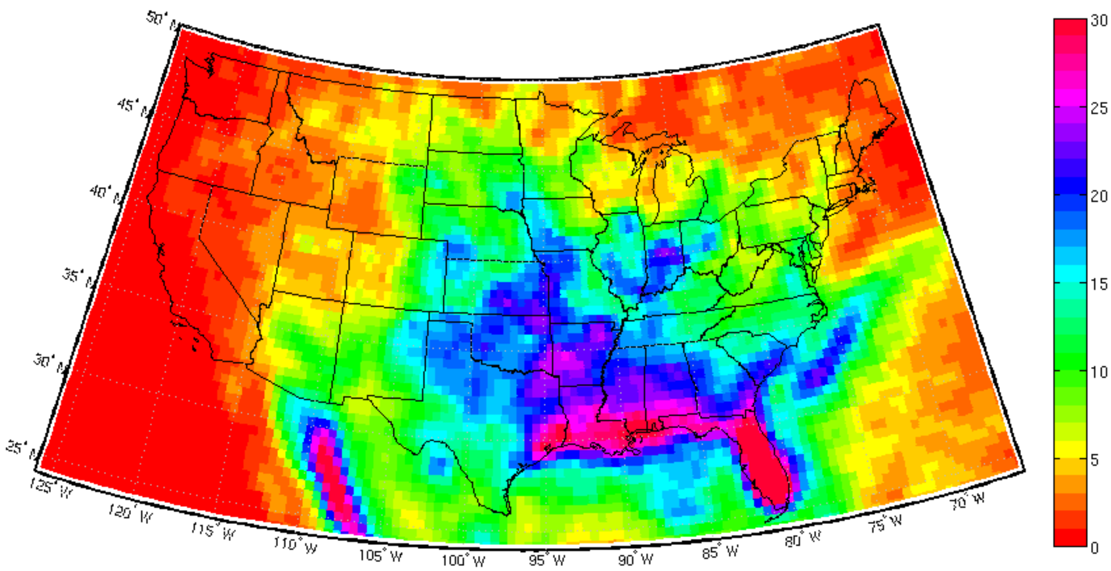

Figure 8. Ten-year lightning flash rate climatology (flashes/km²/year) (NASA, High Resolution Full Climatology Lightning Archive, http://thunder.msfc.nasa.gov/data).

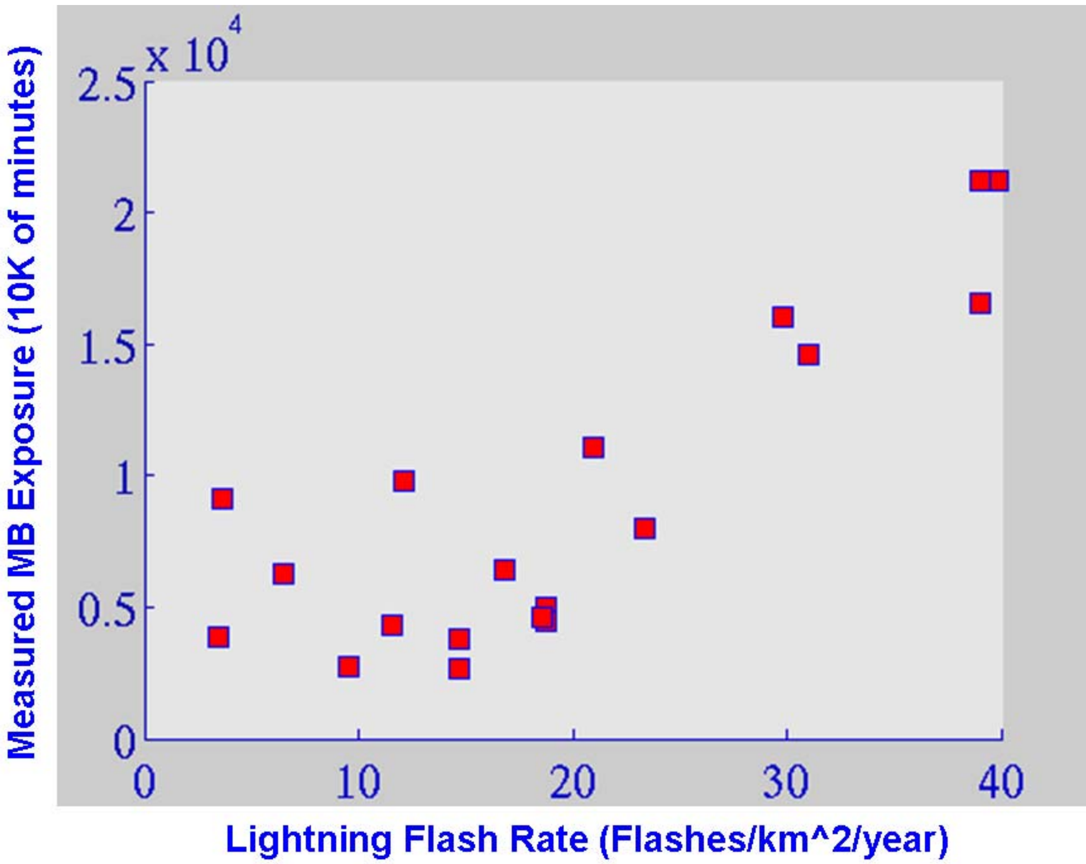

Figure 9. The annual lightning flash rate vs. measured MB minutes.

All of these data were fit via a least squares fit and the resultant wind shear exposure formula is shown in Figure 11. Not unexpectedly, the most important factor in wind shear exposure is the density of the lightning flash rate (**L**) (Weber, 1998). In areas of moderate to high flash rate density, the wind shear exposure is driven by the thunderstorms that the lightning accompanies. The secondary factor of ceiling height is especially important in the high plains region where dry microbursts tend to dominate. Regions with very low lightning flash rates (< 1.0) tend to have very limited wind shear activity (the Pacific Coast region for example). Therefore, the non-lightning related terms in the equation (ceiling height and the constant) are tempered by a factor, **F**, that is simply **L** capped at 1.0.

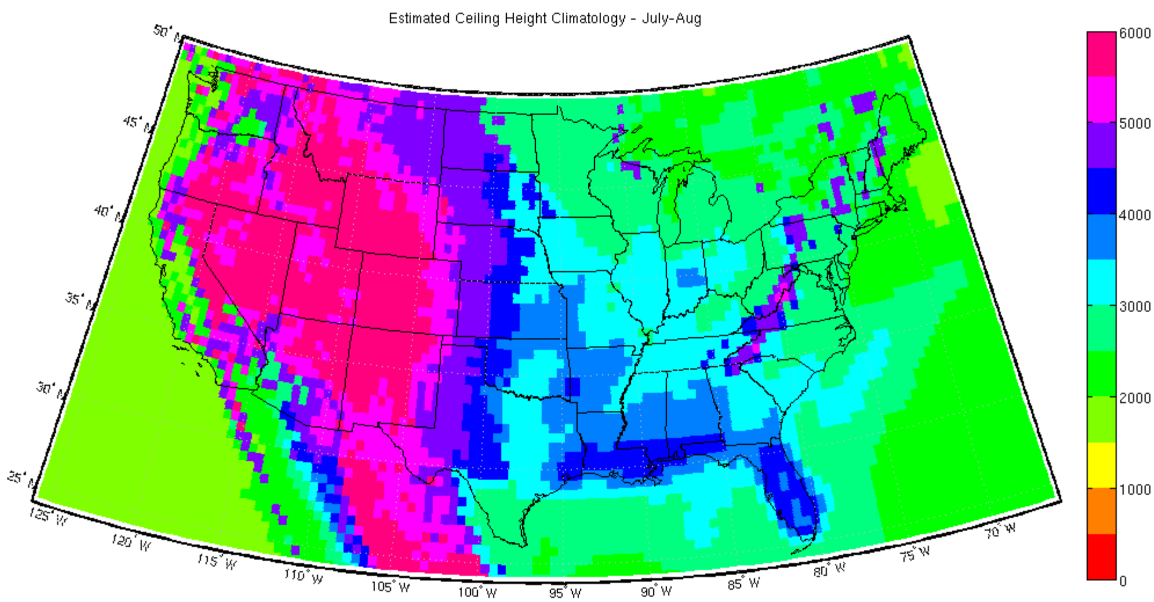

Figure 10. Average summer ceiling height (meters above sea level). Raw data gathered from 20-year dataset of hourly station observations, interpolated to a grid by fitting to lightning and terrain data.

$$\mathbf{MB = -0.7 * L^3 + 52.7 * L^2 - 726 * L + F * (19.6 * C + 499.5)}$$

Where: MB = The annual exposure to microbursts (minutes)
L = Lightning flash rate
F = The low lightning flash rate factor, capped at 1.0
C = The average summer ceiling height (meters)

Figure 11. Microburst exposure model based on TDWR/ITWS archive data.

Overall, the model correlates well (r^2 = 0.93) with the measured archive data (Figure 12). Remember, only one year of archive data was available, so we would not expect a perfect match because the lighting and cloud height climatology are helping to capture longer term averages of exposure risk. A map of the interpolated MB exposure over the entire US is shown in Figure 13.

The model estimates are for the same TDWR 360 degree scan, 30 km footprint around each station. However, the airport specific exposure would be limited by the size of the ARENA (AREas Noted for Attention) at each airport. The ARENA generally depicts the region of highest concern for wind shear detection. The ARENA size is dependent on the number of runways and the arrival and departure route configuration for each runway. The median arena size is 50 sq-km with the smallest being 25 sq-km and the largest 125 sq-km. The exposure for an individual airport then is equal to the MB exposure times the size of the ARENA divided by the TDWR microburst coverage area (2827.4 km^2). Therefore, if we assume a random distribution of events, a median sized airport arena with 10,000 minutes of annual exposure in the TDWR scan area would roughly equate to 175 minutes of ARENA alert activity. Individual station values of MB exposure are shown in Appendix A (along with the gust front exposure counterpart).

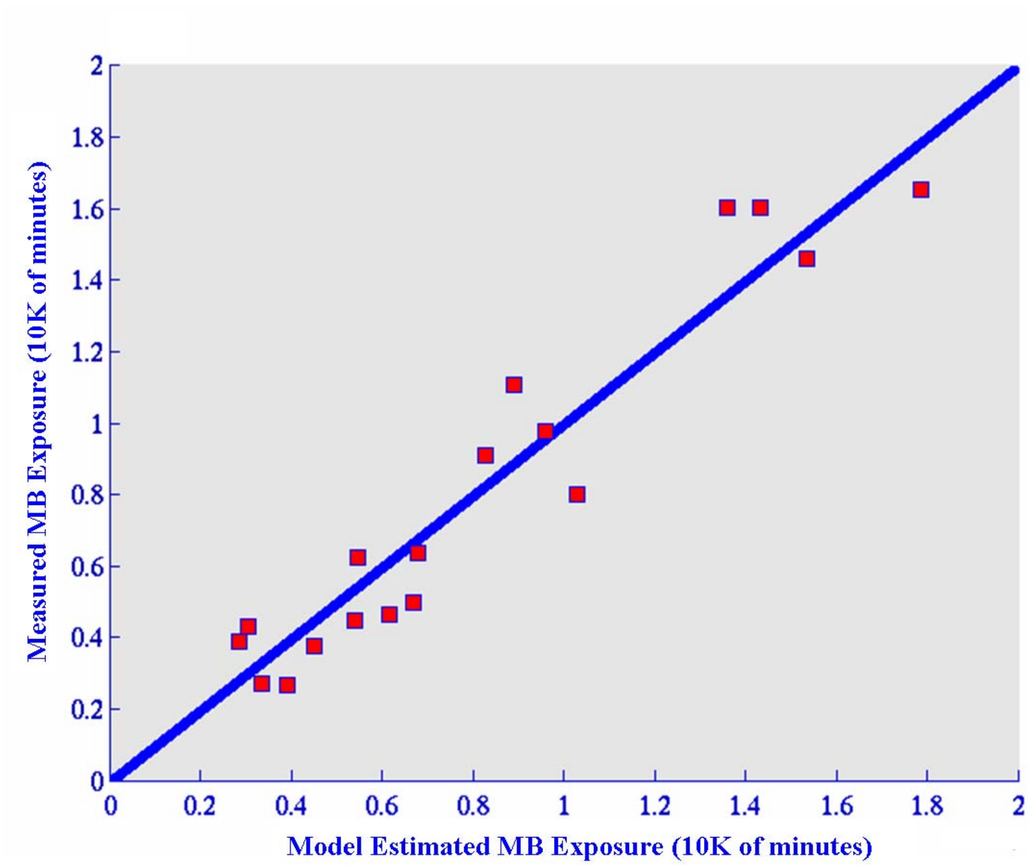

Figure 12. Comparison of MB exposure model estimates to archive measurements (R^2 correlation = 0.93).

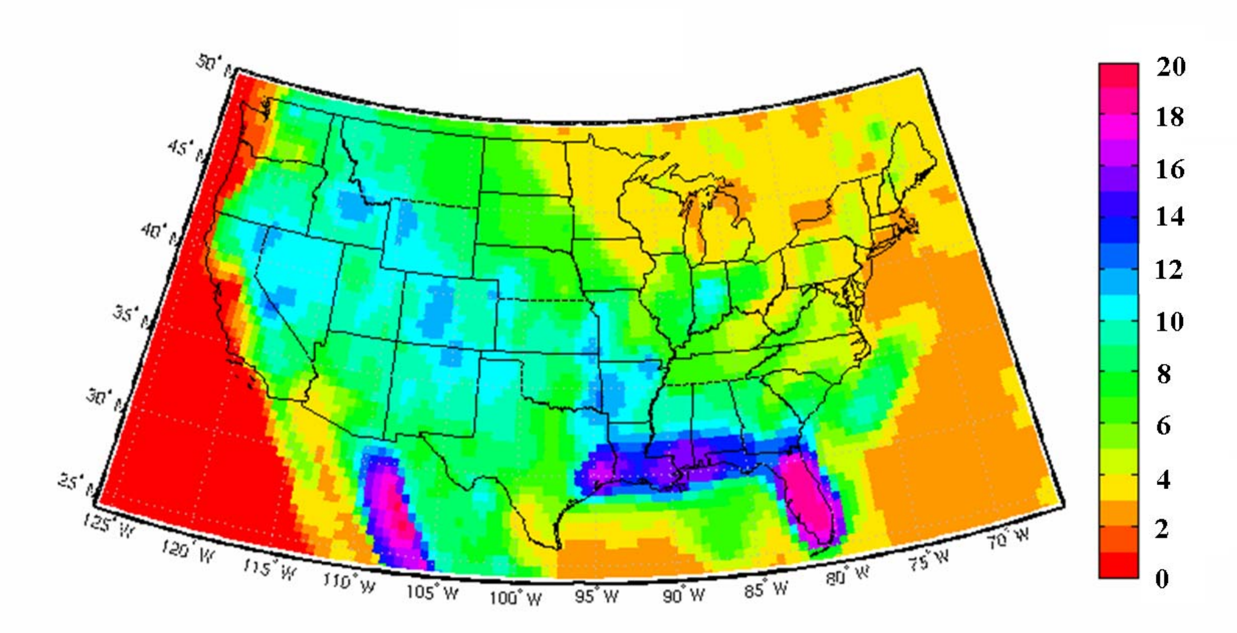

Figure 13. US map of annual microburst exposure based on station archive model (1000s of minutes).

3.2 GUST FRONT EXPOSURE

The analysis of gust front exposure was similar to that of the microburst exposure. Archive data was gathered for a one year period, but only ITWS site data were available. As for microburst exposure, the gust front exposure is based on minute-by-minute activity of gust fronts. Therefore, the exposure is based on the number of minutes that each site reported at least one gust front alert. These are called "unique" GF minutes, and Figure 14 shows a map of the unique minutes for each archive site (normalized to a full year and full 360 degree, 18 km radius around the airport). Note that the gust front activity is far less variable than the microburst activity. Gulf region activity is roughly double that of some other parts of the country as opposed to the ten-fold increase seen in microburst activity. Gust front detections, while designed for thunderstorm outflows, often pick up passing cold-fronts and sea breezes and this may explain some of the reduced variability. Next, we needed to interpolate this snapshot of gust front activity over the entire country and at the same time account for climatology for year to year variations.

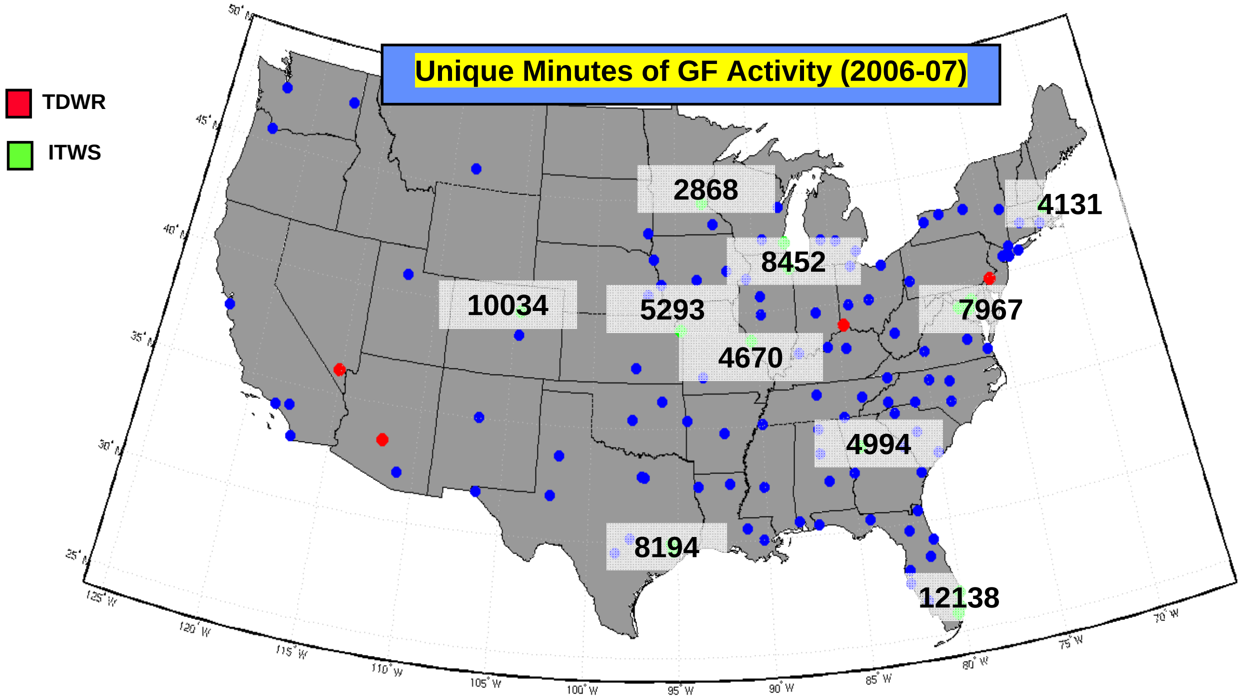

Figure 14. The measured number of minutes per year where at least one gust front was within an 18 km radius of the respective ITWS archive site.

Gust fronts are the leading edge of thunderstorm outflows, typically occurring many kilometers ahead of an approaching thunderstorm. The aviation safety hazard comes from the roll of winds at the leading edge of the outflow. Much like a microburst, crossing a gust front with its changing wind direction and shifting wind speeds can induce a drop in lift for the aircraft very near the ground. Most gust fronts have weak shear that will more likely cause a bumpy ride than an accident, but occasionally strong fronts can result in damage and injuries. As mentioned, the gust front detection algorithm will often find other types of fronts, such as cold fronts and sea breezes. But the predominant driver is the thunderstorm (Klingle-Wilson & Donovan, 1991).

The gust front exposure model developed from the ITWS archive data is shown in Figure 15. As in the microburst model, lightning flash rate is by far the largest contributor; higher ceiling heights also increase the frequency of gust fronts. Gust fronts, like microbursts, are also tempered by an extremely low-lightning factor (flash rates < 1.0), **F**, to reduce exposure in the Pacific Coastal region. Figure 16 shows the comparison of measured archive data to model estimates. The overall correlation for this model was an R^2 of only 0.69, and the ability to estimate regional differences was limited due to the reduced number of station archives that were available. Finally, Figure 17 shows a map of the estimated gust front exposure across the continental US (Appendix A gives a site by site breakdown).

$$GF = 0.7 * L^3 - 38.8 * L^2 + 723 * L + F * (8.3 * C)$$

Where: GF = The annual exposure to gustfronts (minutes)
L = Lightning flash rate
F = The low lightning flash rate factor, capped at 1.0
C = The average summer ceiling height (meters)

Figure 15. Gust front exposure model based on ITWS archive data.

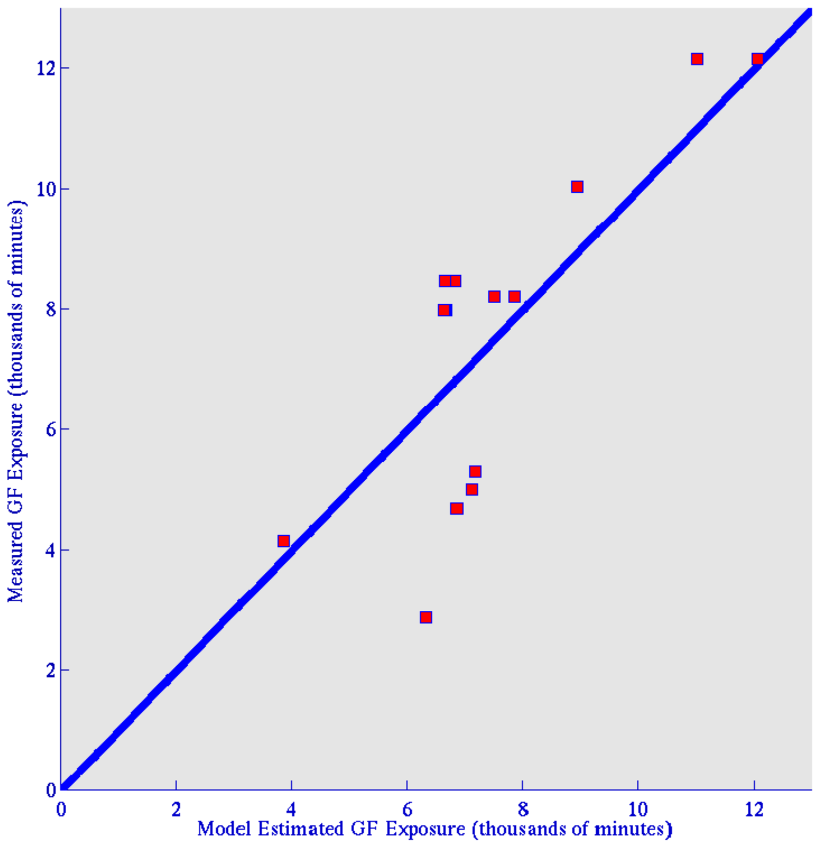

Figure 16. Comparison of GF exposure model estimates to archive measurements (R^2 correlation = 0.69).

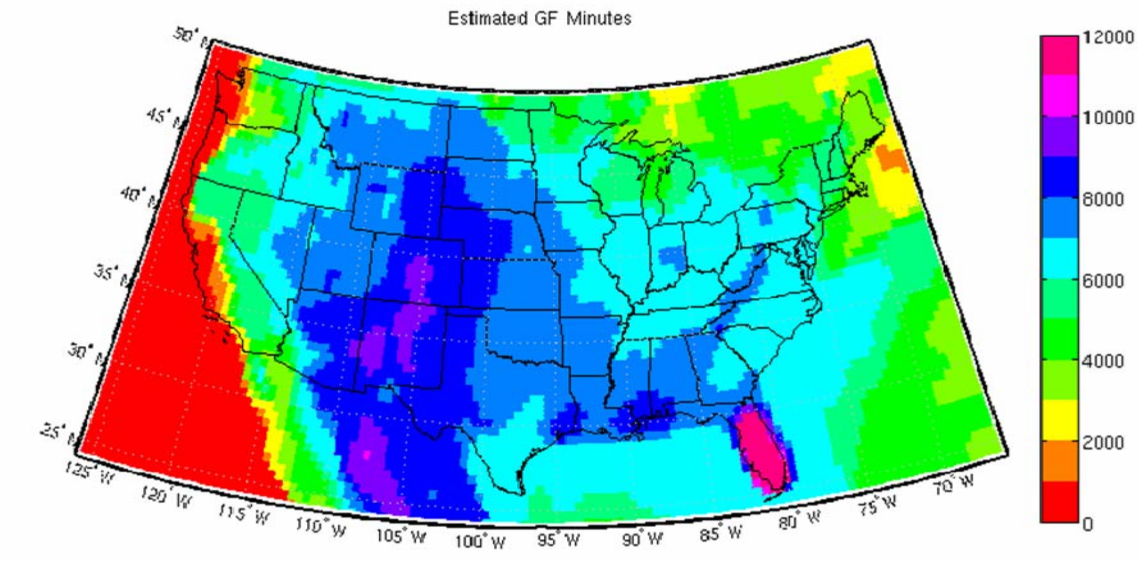

Figure 17. US map of annual gust front exposure based on station archive model (minutes).

3.3 REFLECTIVITY DISTRIBUTIONS AND OUTFLOW HEIGHT

The effectiveness of wind-shear detection systems is partially dependent on the reflectivity embedded within the outflow and the height of overall outflow depth. During the research effort to develop the TDWR system, outflow characteristics were captured at the various test-bed airport installations. From these data we have direct measurements of microburst and gust front relative reflectivity distributions at the time of peak strength for several sites (Weber and Troxel 1994). Figure 18 shows the frequency distribution of reflectivity within microburst events as measured in Denver (red) and Orlando (blue). Denver is dominated by dry microbursts with greater than 80% of the microbursts there associated with reflectivities of less than 30 dBZ (moderate rain). Conversely, Orlando is dominated by wet microbursts with more than 80% of the microburst related reflectivity exceeding 30 dBZ. The microburst-relative reflectivity PDF varies primarily because of the relative frequency of dry and wet microbursts. By using the Orlando and Denver field study data as a reference we were able to generate site-by-site estimates based on ancillary weather archives (Biron, 1991).

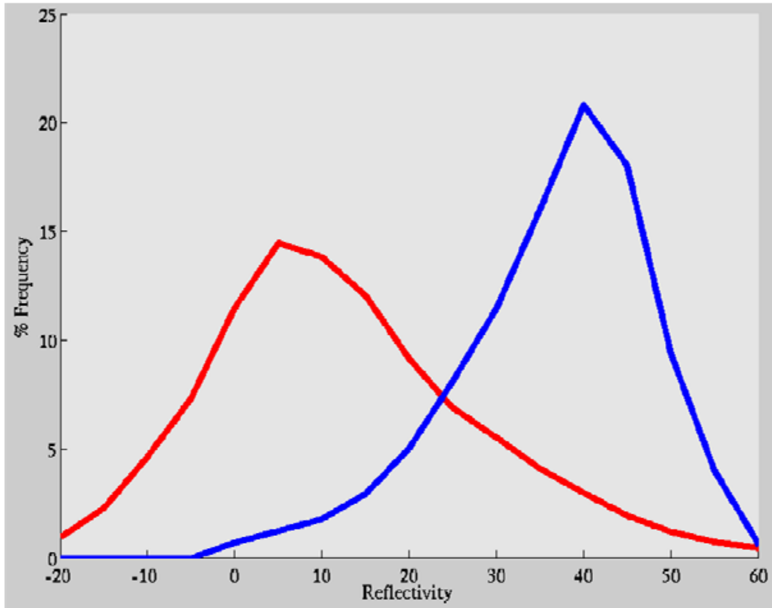

Figure 18. Distribution of peak reflectivity associated with microburst outflows as measured at Denver, CO (red) and Orlando, FL (blue) TDWR field studies.

Unfortunately, even with the TDWR archive records that we were able to obtain, interpolating less than a dozen actual measurements of reflectivity distributions across the country would be impractical. However, we do have an estimate of the overall reflectivity distribution at each site based on a one-year archive of 15-minute NEXRAD composite 2 km data (courtesy Weather Services Incorporated, WSI). A 40 km × 40 km grid of NEXRAD reflectivities was analyzed for each site and the distribution of non-zero maximum reflectivities was utilized as an indicator of overall reflectivity tendency. NEXRAD distributions for Denver and Orlando were then used to normalize the profiles to the dry and wet field study profiles, respectively.

Figure 19 shows the NEXRAD distribution of reflectivity for Denver (dashed red) and Orlando (dashed blue) for time periods when the sites had non-zero reflectivity. The field study curves (**solid lines**) are superimposed for comparison. Note that both sets of curves show a distinct separation in dry and wet site distributions. We then create a scaling by which we can transform the NEXRAD profiles into their respective peak outflow reflectivity curves (i.e., transform the dashed lines into the solid lines). A limiting factor for this scaling is that NEXRAD reflectivity below 5 dBZ is not reported, while TDWR reports reflectivity down to -20 dBZ. To compensate for this lack of sensitivity the NEXRAD frequency curve is continued linearly down from 10 dBZ to -20 dBZ.

For all other sites, we must determine whether the site is more like a wet (MCO) or dry (DEN) site before the proper transformation weighting can be applied. Each site's NEXRAD profile was compared to both the Denver and Orlando NEXRAD profiles and given a factor from 0.0 to 1.0 to represent whether it is a dry (0.0) or wet (1.0) site. The transformation curves are applied to the NEXRAD profile and then weighted according to the calculated dry/wet factor. Figure 20 shows the conglomeration of all 161 airport specific PDF distributions, while Figure 21 shows a map of the dry/wet tendency overlaid on a map of the US. Dry sites are mostly in the high plains, while wet sites are predominantly in the Gulf of Mexico and southeastern US.

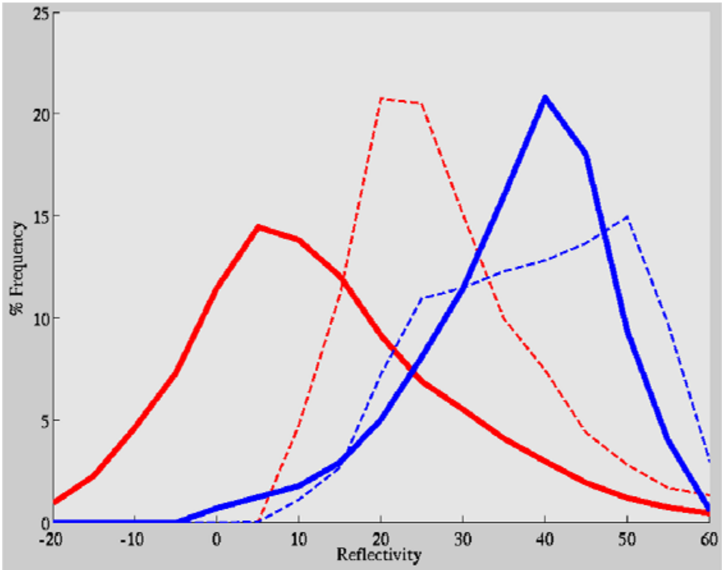

Figure 19. Distribution of NEXRAD reflectivity for Denver, CO (dashed red) and Orlando, FL (dashed blue).

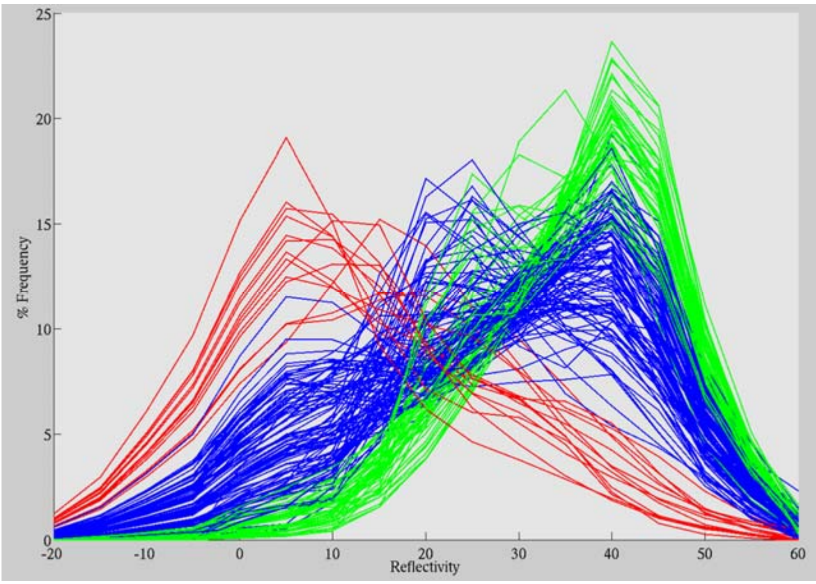

Figure 20. Compilation of wind-shear relative reflectivity distributions for all sites.

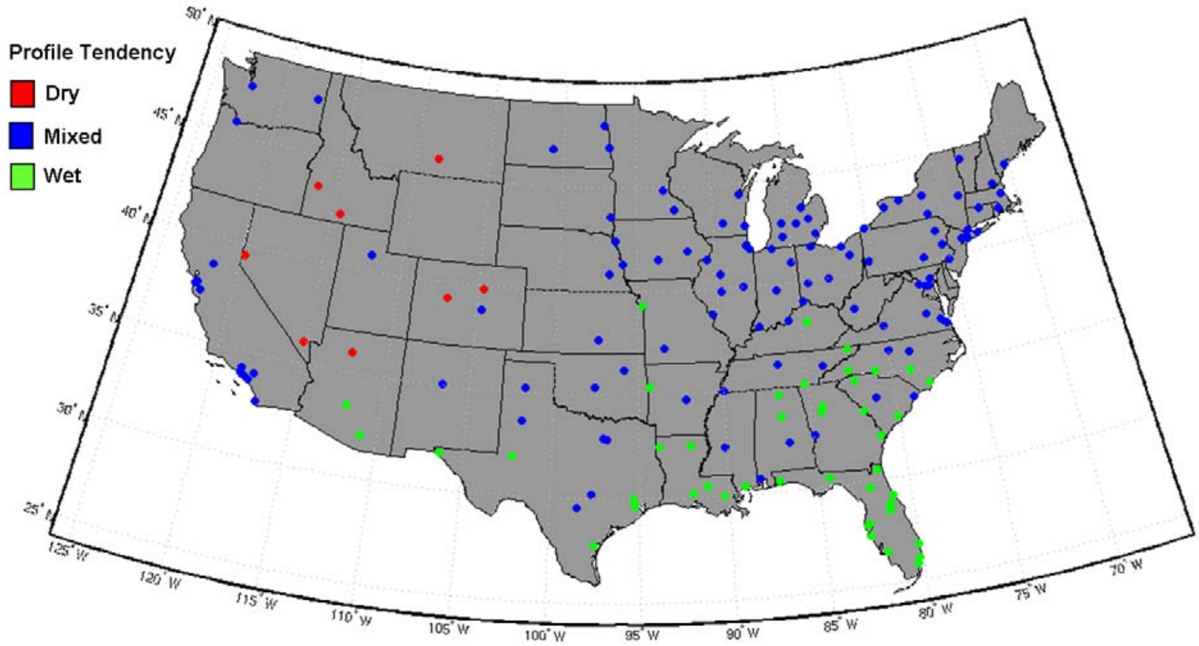

Figure 21. Dry/wet profile tendency by site.

The vertical extent of an outflow is an important factor in determining how well a radar or Lidar system will be at detecting wind shears. Shallow outflows are difficult for radars to see at a distance due primarily to line-of-sight issues. The peak outflow strength occurs in the lowest 100 meters and drops of with height. Wind shear detection systems can often detect outflows at higher elevations despite these weaker signatures. The simulation model for this study assumed that events were detectable up to the point that the outflow strength had dropped to 50% of its peak value. In addition, field study data indicate that the depth of microburst outflows varies depending on the distribution of dry and wet microbursts (Biron, 1991). Figure 22 illustrates the cumulative distribution of outflow depths (the height at which for each of the 161 study airports. The distributions are color-coded by reflectivity tendency (red for dry, blue for mixed and green for wet). Note that wet microbursts tend to be shallower while dry events more frequently begin higher up. However, the upper range for all outflow depths is fairly constant at just over 1 km.

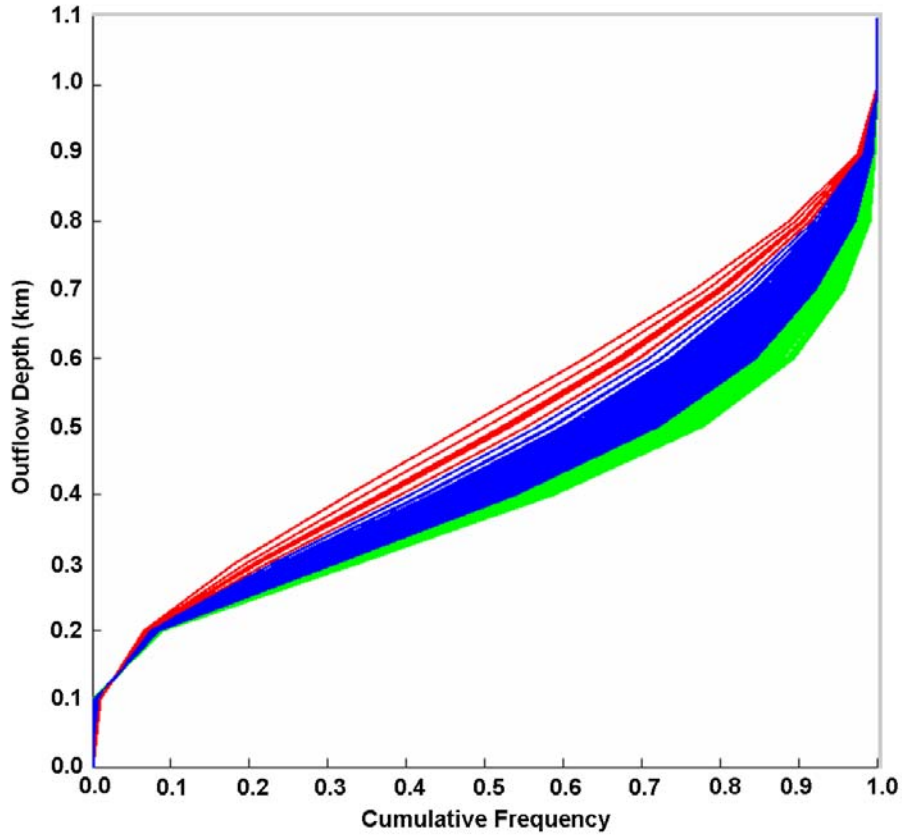

Figure 22. Cumulative frequency of outflow depths for all sites color-coded by reflectivity profile tendency (red-dry, blue-mixed, green-wet).

Gust front characteristics do not vary as greatly with location, so we were able to use average profiles of reflectivity and outflow height based on observations from TDWR field sites (Klingle-Wilson and Donovan 1991). Figure 23(a) displays the observed average gust front reflectivity PDF and (b) the PDF for maximum depth of the gust front velocity signature.

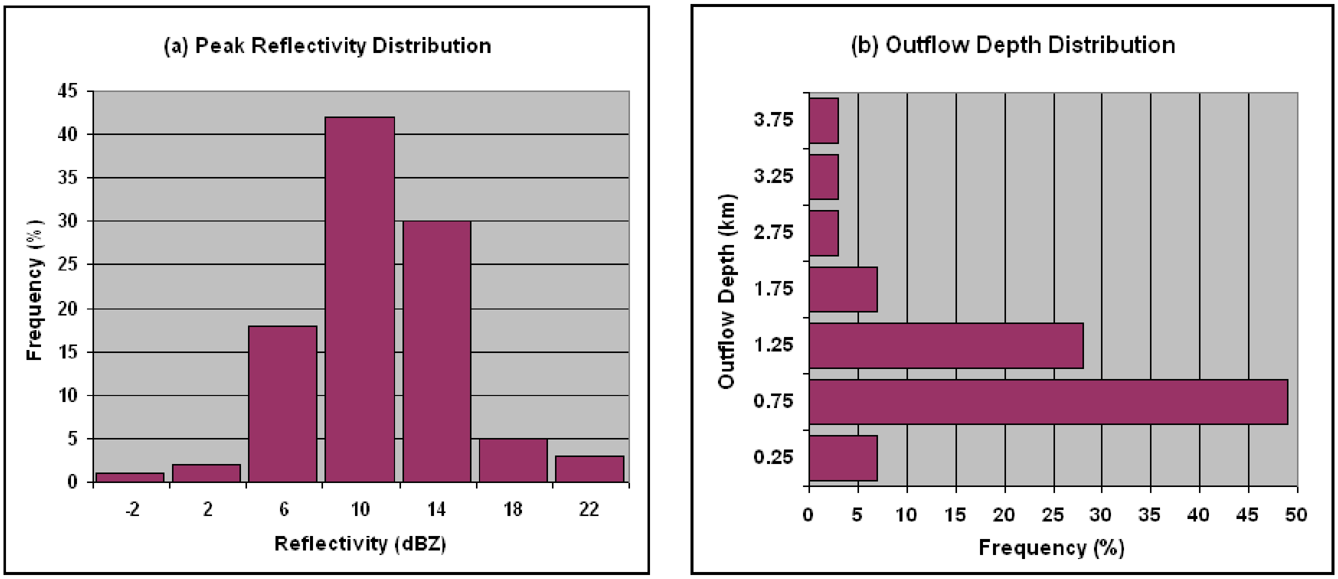

Figure 23. Gust front profiles for (a) peak reflectivity distribution associated with gust front and (b) distribution of maximum outflow depth (peak height of radar-detectable shear) (profile is the same for all sites).

This page intentionally left blank.

4. WIND-SHEAR MITIGATION TECHNIQUES AND DETECTION SYSTEM EFFECTIVENESS

4.1 MODELING PILOT TRAINING IMPACTS

After the 1975 Eastern Airlines crash in New York was attributed to a microburst, pilots were trained in ways to recognize, avoid, and recover from wind-shear encounters. The FAA's wind shear training aid program started in 1987 and it stresses recognition and avoidance of wind-shear hazards. Pilots are told to look for visual clues such as virga (elevated rain shafts), plumes of dust and debris at the surface, and intense rain shafts that could all be indicative of microburst activity. Awareness is always heightened any time thunderstorms are present in the airport region. Once these visual clues are seen, pilots are told to avoid the area under and around such features. However, in the event that the pilot enters the outflow the FAA has defined specific criteria for maneuvering up and out of the hazard. So, there are three parts to the impact of pilot training: How visible are the visual clues that the pilot must see? How effective will a pilot be at recognizing the necessary features and avoiding the hazardous regions? And, what is the likelihood that the pilot can extract the aircraft if it nevertheless enters an outflow region?

Voutflow = %Daylight * (%Dry * %DryView + %Wet * %WetView)

Voutflow = Probability that the pilot can visibly see outflow evidence

%Daylight = The percentage of time that outflows occur at night

%Dry = The percentage of time that peak outflows are associated with reflectivities ≤ 20 dBz

%DryView = The percentage of time that dry outflows are unobscured by cloud cover

%Wet = The percentage of time that peak outflows are associated with reflectivities > 20 dBz

%WetView = The percentage of time that wet outflows are unobscured by cloud cover

Figure 24. Equation for estimating the likelihood that a pilot will observe visual characteristics of an outflow.

4.1.1 Visibility of Outflow Features

Figure 24 illustrates an expression for the ability of pilots to see the visual microburst clues that they were trained to identify. The model concept is based on the method defined in the 1994 TDWR system engineering study, but with significantly more refined inputs (Martin Marietta, 1994). Identifying visual microburst features is dependent on the event being during daylight/twilight hours and the ground being visible through clouds and precipitation. The time of day distribution of microbursts was based on an archive dataset of microburst activity (detailed in Section 3). From this dataset we were able to determine the percent of time that microbursts actually occurred during daylight for a sub-sample of airports. Data ranged from 71% daylight in Twin Falls, ID to a peak of 83% in Fort Lauderdale, FL. Obviously, this factor is highly dependent on the latitude of the site because more daylight hours are available. But, it is also impacted by the frequency and intensity of microburst activity. Figure 25 shows the estimated microburst daylight frequency breakdown across the continental US based on a model fit of the archive data.

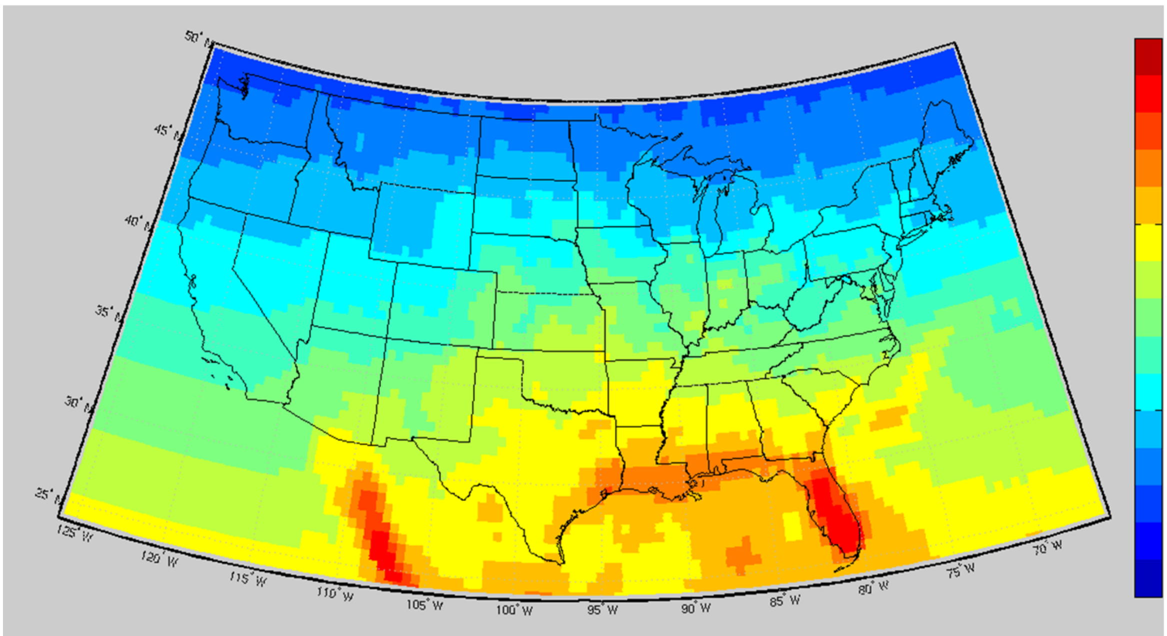

Figure 25. Estimated frequency of daylight microburst activity (%).

Secondly, pilot observations can be restricted by the presence of clouds and precipitation that is blanketing the region around an airport. By utilizing a one-year archive of NEXRAD reflectivity we examined the region within 20 km of all studied airports and calculated a % obscured field. If more than a third of the region had measurable reflectivity it was assumed that the precipitation and clouds in the region would cover the airport region and a pilot would be unable to see most visual cues. The coverage estimates are broken down by times of high and low reflectivity (using 30 dBZ as the divider). High reflectivity, or wet, microburst environments typically have widespread precipitation coverage that makes it more difficult to see outflow events, while low reflectivity (dry) environments have fewer meteorological obstructions. On average, wet environments are obscured about 50% of the time, while dry environments are obscured just 15% of the time.

Finally, we must estimate the human factor that even if a pilot *could* see a hazardous outflow, *would* he recognize it as a hazard? There are very little hard data to generate this number. Even if we were to know how many outflows with visual clues were visible to a pilot we have no way of tracking how many the pilot would actually recognize. Therefore, we are simply using a flat estimate of 50% as was used in the original TDWR study in 1994. Table 5 details the effectiveness factors for pilot observation at a subset of airport locations, the site by site breakdown can be found in Appendix B. In Table 5, the %Human column captures the human factor discussed above (50%) and %Effectiveness is simply %Voutflow (see Figure 24) X %Human.

TABLE 5

Sampling of site-specific pilot observation factors that impact a pilot's ability to visually recognize wind shears

Airport	%Daylight	%Wet	%WetView	%Dry	%DryView	%Human	%Effectiveness
BOS	75	63	28	37	69	50	16
ORD	77	58	36	42	83	50	21
DEN	76	43	35	57	84	50	24
LAS	77	38	70	62	83	50	30
MSY	81	70	72	30	98	50	32
MIA	84	84	71	16	96	50	31

4.2 ESTIMATING AIRBORNE WIND-SHEAR SYSTEM IMPACTS

The Federal Acquisition Rule (FAR) 121.358, issued on 9 May 1990, required that all Part 121 aircraft be equipped with either a "reactive" wind shear warning and flight guidance system or a "predictive" wind shear (PWS) radar. The reactive system technology was developed in the mid-1980s by Boeing and Sperry and certified by the FAA in November 1985 as an enhancement to onboard Performance Management Systems (PMS). Primary inputs are true airspeed, angle of attack, longitudinal acceleration, normal acceleration and pitch. Performance was certified using computer models representing documented wind shear conditions. Table 6 lists the effectiveness probabilities that an aircraft equipped with a reactive system would recover from a wind-shear encounter without coming in contact with the ground (Martin Marietta, 1994). But, the raw accident rate that is used for the basis of this safety analysis already has the recovery of aircraft built into the analysis. Recovery is enhanced, however, as new, higher performing, aircraft are placed in service. The current mix of 2-, 3-, and 4-engine aircraft increases the overall performance expectation of the overall fleet by 10 percentage points over that of the 1975–85 period (FAA, 2008). This 10% increase in performance is taken into consideration when factoring airborne capabilities.

TABLE 6

Estimates for the effectiveness of reactive wind-shear warnings and the overall effectiveness when combined with aircraft performance criteria

	Lowest	Most Likely	Highest
Probability that RWS warning would results in effective recovery	23.6%	37.5%	48.2%
Cumulative probability based on aircraft performance	27.4%	43.8%	58.6%

Predictive wind shear warning systems were developed in the early 1990s by NASA Langley Research Center. Microwave radar, Lidar and passive infrared detection systems were evaluated through simulations and flight testing in conjunction with FAA prototype testing of TDWR in Denver, CO and Orlando, FL. The first microwave PWS radar was certified by FAA in September 1994 and today several systems are available for Part 121 aircraft (e.g., the Rockwell-Collins WXR-700 and the Honeywell, RDR-4B). PWS radars compatible with regional jet size constraints are not available at present. Figure 26 illustrates a wind shear encounter timeline for a PWS. Note that the warning horizon with these systems is extended up to 2 minutes.

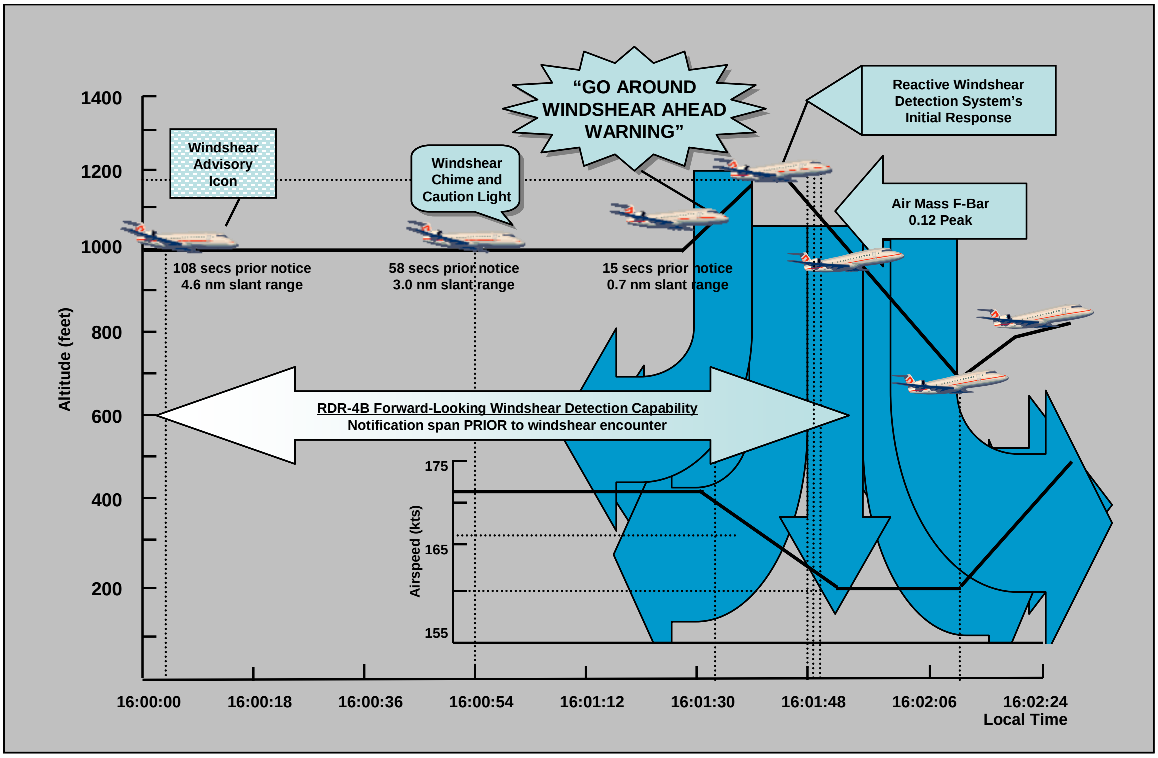

Figure 26. National PWS radar wind-shear encounter scenario.

MIT/LL polled the major airlines to estimate the percentage of the commercial fleet currently equipped with PWS radars, and to obtain feedback on the operational value of both reactive systems and PWS radars. Table 7 shows that approximately 67% of the U.S. commercial part 121 fleet was equipped with and utilized PWS radars at the time of this survey (September 2007). This rate, while above the 1994 report predictions, is increasing at a slower pace as older aircraft are replaced by PWS-equipped new Boeing or Airbus aircraft. Some airlines expressed that with the heavy coverage of ground-based systems, the investment in installing and maintaining airborne PWS systems was less compelling. In addition, foreign air carriers were not surveyed for this analysis but are likely to be less equipped for wind shear protection. For these carriers, representing approximately 25% of aircraft operations, we estimated 50% equipage. Hence, the estimate used for PWS equipage was dropped from 67% to 63%. Finally, although manufacturers are developing regional jet PWS systems, there is no guarantee that this will be technically or economically feasible for this aircraft class (and even less so for General Aviation).

TABLE 7

U.S. Part 121 fleet equipage percentages for PWS radars, based on a telephone poll of industry representatives in September 2007*

Carrier	Total Fleet Size	Fleet with PWS	% Usage
American	685	122	18 %
Southwest	511	511	100 %
United	460	400	87 %
Delta	436	275	63 %
Northwest	375	58	15 %
Continental	348	348	100 %
USAirways	266	266	100 %
AirTran	114	114	100 %
Jet Blue	106	106	100%
Totals	3301	2078	67 %

*While these ten airlines represent the vast majority of major airline traffic in the US, this table does not include foreign carriers that are more likely to be less equipped for wind shear protection.

As noted in Weber & Cho (2005), the field validation of the reactive wind shear systems and PWS radars has not been nearly as extensive as was accomplished for the FAA ground based warning systems. Manufacturers continue to do some flight testing, but certification has been accomplished entirely through computer simulated microburst penetration data. The airline users we spoke with generally felt that the PWS radars were useful, but they uniformly emphasized that these were not a substitute for the ground based systems. Broad-area situational awareness of wind shear – not attainable with the limited range, on-board systems – was felt to be essential for minimizing encounter risk. The reactive wind-shear systems were stated to be ineffective by those users who commented on their performance.

As mentioned, the effectiveness of PWS radars has only been measured in simulated environments where it often exceeds 95% effectiveness (Martin Marietta, 1994). However, based on the known limitations of the PWS in dry environments, effectiveness values are reduced based on the distribution of outflows associated with weak reflectivity. Appendix B lists the estimated effectiveness of PWS at each airport based on the sites reflectivity profile.

4.3 MODELING GROUND-BASED WIND-SHEAR SYSTEM EFFECTIVENESS

One of the key factors in estimating the benefits of a terminal wind-shear detection system is its performance. Thus, it is necessary to quantify the wind-shear detection effectiveness for each sensor, preferably on an airport-by-airport basis. To consider sensors that are not yet deployed models must be developed that take into account the various effects that factor into the detection probability. This section gives a brief summary of the models that were developed. Complete description and technical details are provided in a separate report (Cho and Hallowell, 2008).

The sensors considered in this study are the existing FAA terminal wind-shear detection systems: the Low Altitude Wind Shear Alert System (LLWAS) (Wilson and Gramzow, 1991), the Terminal Doppler Weather Radar (TDWR) (Michelson et al., 1990), and the Airport Surveillance Radar Weather Systems Processor (ASR-9 WSP) (Weber and Stone, 1995). We also included the Weather Surveillance Radar 1988-Doppler (WSR-88D, commonly known as NEXRAD) (Heiss et al., 1990) in this study. Although not specifically deployed to be a terminal wind-shear detection radar, the NEXRAD is a high-performance weather radar that is capable of providing useful wind-shear data if it is located close enough to an airport. Furthermore, we included new sensors in addition to the currently deployed systems. For reasons to be explained later, a Doppler Lidar is expected to be a good complement to radar for wind-shear detection. The Lockheed Martin Coherent Technologies (LMCT) Wind Tracer Lidar is a commercially available product that has been operationally deployed at the Hong Kong International Airport along with a TDWR (Chan et al., 2006). It has likewise been suggested as a complementary sensor at major U.S. airports where radar alone has not been yielding satisfactory wind-shear detection performance. (The FAA has recently decided to purchase one for the Las Vegas airport.) To offer a stand-alone wind-shear detection package, LMCT has proposed an X-band radar to go along with the Lidar, so we included this sensor in our analysis also.

Airports that presently have coverage by TDWR (46), ASR-9 WSP (35), and LLWAS-RS (Relocation/Sustainment) (40) were selected for this study. An additional 40 airports without wind-shear sensors were included, based on a change in FAA policy to also protect non-Part-121 aircraft from wind shear hazards. Table 8 shows which sensors already exist at which airports, and which sensors are considered for new deployment at which airports. We did not consider the possibility of installing new TDWRs or ASR-9s due to prohibitive cost; new WSPs are only considered for already existing ASR-9s. Deploying new or moving existing NEXRADs was not considered.

TABLE 8

Sensors vs. airports included in study

Sensor	Airport (161)			
	TDWR (46)	**WSP (35)**	**LLWAS-RS (40)**	**Other (40)**
TDWR	Existing	N/A	N/A	Existing*
WSP	New	Existing	N/A	Existing*
LLWAS	Existing (9) New (37)	New	Existing	New
NEXRAD	Existing*	Existing*	Existing*	Existing*
LMCT Lidar	New	New	New	New
LMCT X band	New	New	New	New

* Closest to airport.

Wind-shear detection performances of sensor combinations were also analyzed (see Table 9).

TABLE 9

Sensor combination vs. site

Sensor Combination	Site
TDWR + Lidar	TDWR and other airports
TDWR + LLWAS	TDWR and other airports
TDWR + NEXRAD	TDWR and other airports
TDWR + NEXRAD + LIDAR	TDWR and other airports
TDWR + NEXRAD + LLWAS	TDWR and other airports
WSP + Lidar	TDWR, WSP, and other airports
WSP + LLWAS	TDWR, WSP, and other airports
WSP + NEXRAD	TDWR, WSP, and other airports
WSP + NEXRAD + Lidar	TDWR, WSP, and other airports
WSP + NEXRAD + LLWAS	TDWR, WSP, and other airports
NEXRAD + Lidar	All airports
NEXRAD + LLWAS	All airports
X-band + Lidar	All airports
X-band + LLWAS	All airports

Note that, at the present time, NEXRADs are not suitable for microburst detection and warning, because their update rates (~5 minutes) are too slow to meet the FAA requirement. (For gust-front detection and tracking, the update rates are adequate, and the FAA already takes advantage of NEXRAD data for this purpose (Smalley et al., 2005).) Thus, even though the NEXRAD microburst detection probabilities we estimate in this study may, in some cases, appear to be acceptable, actual operational use would require that a substantially faster volume scan strategy be implemented. As a tri-agency radar with the FAA as a minor stakeholder, it may be problematic to prioritize the NEXRAD for terminal microburst detection in this way.

The wind-shear phenomena for which we computed detection probabilities are the microburst and gust front. There are, in fact, other forms of hazardous wind-shear, such as gravity waves, but these are the only ones for which FAA detection requirements exist at this time. The detection coverage areas assumed was the union of the Areas Noted for Attention (ARENAs) for microbursts and an 18-km-radius circle around the airport for gust fronts (Figure 27). An ARENA polygon consists of the runway length plus three nautical miles final on approach and two nautical miles on departure times a width of one nautical mile. The 18-km extent of the gust-front coverage corresponds to the distance a gust front would travel at 15 m s^{-1} for 20 minutes, which is an appropriate metric for gust-front anticipation lead time in the context of airport operations. Gust-front detection is important for delay reduction benefits. (For reference, the TDWR generates gust-front products out to 60 km from the airport.)

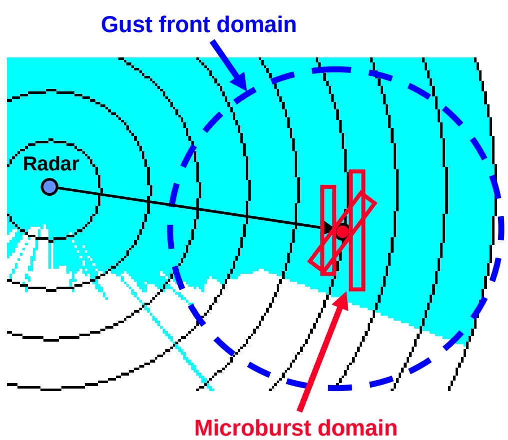

Figure 27. Wind-shear coverage domains used in study. White space illustrates terrain blockage.

4.3.1 Radar Performance Analysis

Of the radar systems considered in this study, the TDWR has the best performance characteristics for terminal wind-shear detection—it has the highest weather sensitivity, the narrowest antenna beam (for clutter avoidance), and its use is 100% dedicated to this mission. It also incurs the highest cost to the FAA, because it is not shared with other agencies or missions, and it is located on its own site away from the airport. The WSP is a signal processing system that is piggybacked onto the ASR-9 terminal aircraft surveillance radar, so the incremental cost is quite low. However, being dependent on the vertical fan beam and rapid scanning rate of the ASR-9, it is far from an ideal system for low-level wind-shear detection. The NEXRAD is only slightly less sensitive to weather compared to the TDWR, has a 1° antenna beam, and its cost is shared by two other agencies besides the FAA. However, it is often not located close enough to the airport, and its volume scanning strategy, which is tailored to wide-area coverage, is too slow for microburst alerting. The proposed LMCT X-band radar should have performance and cost profiles that are somewhere in between the TDWR/NEXRAD and WSP extremes.

The radar system sensitivity was the starting point of our analysis. Shown in Table 10 are some of the relevant system parameters and the minimum detectable dBZ at 50-km range for the four radars studied. Although the latter quantity does not include precipitation attenuation effects, the impact of attenuation was included in the X-band analysis as the impact on performance can be significant.

TABLE 10

Radar System Parameters

Parameter	TDWR	ASR-9 WSP	NEXRAD	LMCT X-band
Peak Power (kW)	250	1,120	750	200
Pulse Length (µs)	1.1	1	1.6	0.4
Antenna Gain (dB)	50	34	45.5	43
Beamwidth (Az x El)	0.55° x 0.55°	1.4° x 4.8°	0.925° x 0.925°	1.4° x 1.4°
Beam Elevation Angle	0.3°	2°	0.5°	0.7°
Wavelength (cm)	5.4	11	10.5	3.3
Max. Clutter Suppression (dB)	57 (60*)	48 (60*)	50 (60*)	50
Rotation Rate (°/s)	~ 20	75	~ 20	~ 20
Pulse Repetition Frequency (Hz)	~ 1600	~ 1100	~ 1000	~ 2500
Min. Detectable dBZ @ 50 km**	-11	7	-10	-3

*After upgrade.
**Without precipitation attenuation.

Radar signal detection can be noise limited or clutter limited. In the latter case, the clutter suppression capability determines the detection performance. All three existing radars (TDWR, NEXRAD, ASR-9) which have klystron transmitters, are undergoing or expected to undergo an upgrade that will bring the maximum possible clutter suppression to about 60 dB. The LMCT X-band radar has a magnetron transmitter with an expected maximum clutter suppression capability of 50 dB. For the results used in the cost-benefit analysis we used the post-upgrade performance figures.

The ability of a radar system to detect low-altitude wind shear depends not only on the radar sensitivity and clutter suppression capability, but also on viewing geometry, clutter environment, signal processing and detection algorithm effectiveness, and the characteristics of the wind shear itself (Figure 28). Thus, although the system characteristics may be invariant with respect to location, there are many site-specific factors that affect the probability of detection (P_d) performance. In this study we tried to objectively account for as many of these factors as possible.

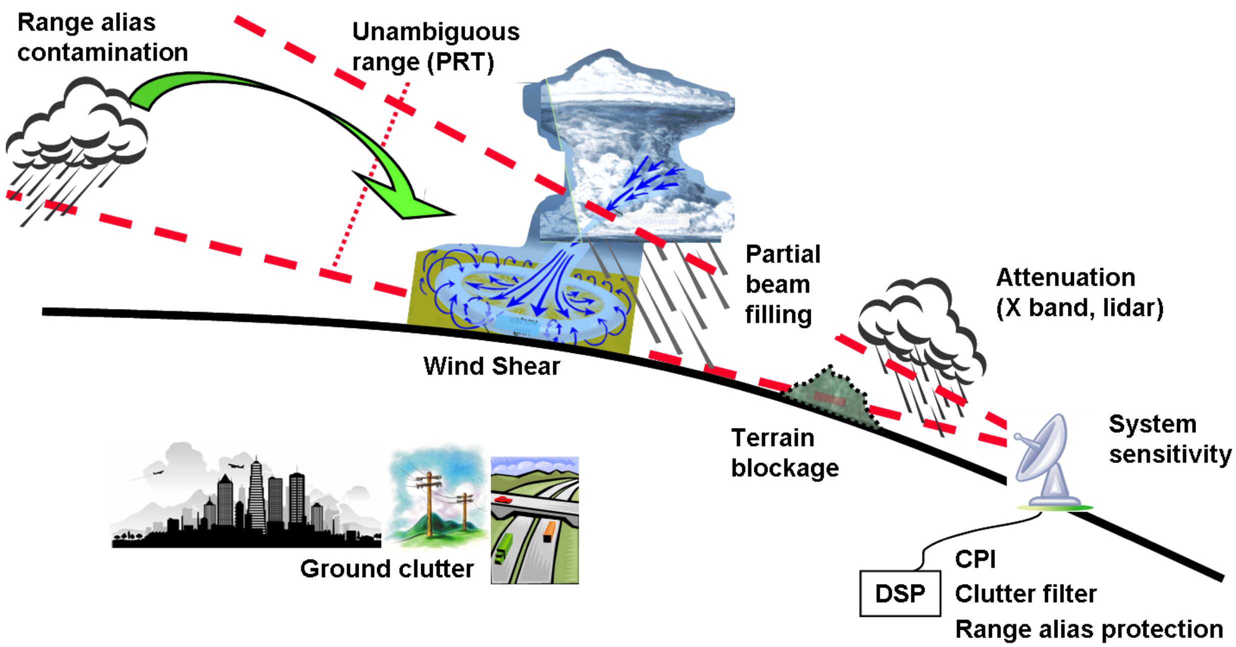

Figure 28. Illustration of various factors that impact radar wind-shear detection probability.

A high-level flow chart of the radar wind-shear P_d performance estimator is shown in Figure 29. For each radar at a given site, a clutter residue map (CREM) was generated using digital terrain elevation data (DTED), digital feature analysis data (DFAD), and radar characteristics. Probability distribution functions (PDFs) of the wind-shear reflectivity, $p(Z_W)$, and outflow depth PDF, $p(h_W)$, were also generated for each radar at a given site. These were produced using a combination of wind-shear data collected during field experiments and modeling based on nationwide proxy parameters. The interest area, as explained previously, was the union of the ARENAs for the microburst case and an 18-km radius circle around the airport for the gust front case.

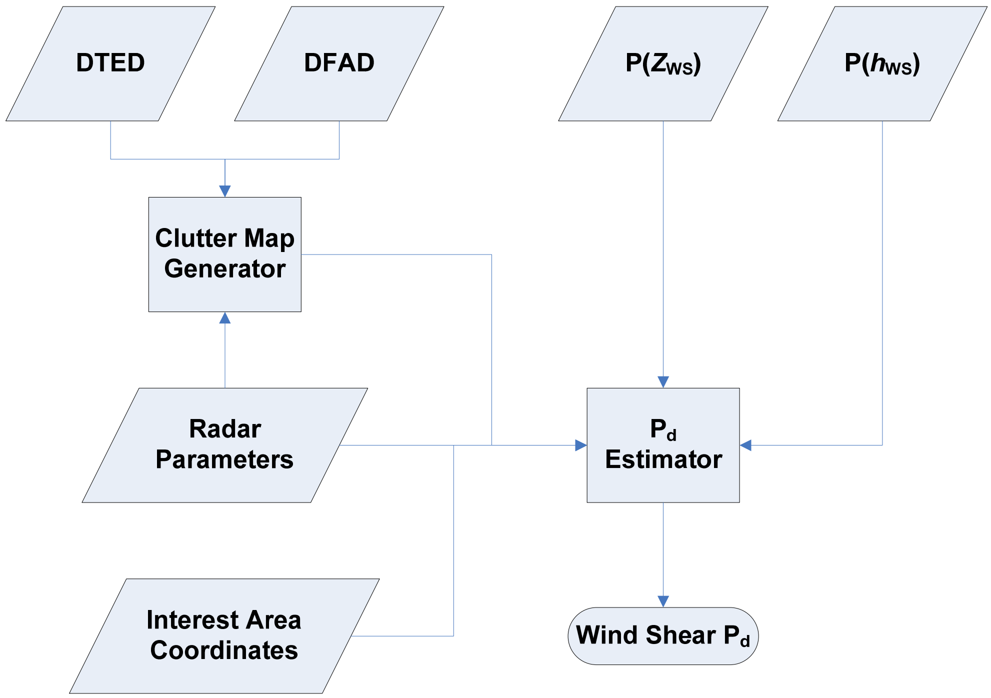

Figure 29. Flow chart of the radar wind-shear P_d performance estimator.

With a range-azimuth grid centered on the radar, for each cell inside the interest area the minimum detectable reflectivity is computed. This calculation involves the factors shown back in Figure 28 as well as others—system sensitivity, terrain blockage, clutter signal and the ability of the system to suppress it, range-alias contamination likelihood and the capacity of the signal processing to mitigate it, signal loss and clutter gain due to partial beam filling, and attenuation due to intervening precipitation. The probability of the wind-shear signal being visible above the noise and clutter in that cell is computed by integrating upward from the minimum detectable reflectivity over the wind-shear reflectivity PDF. The mean over all the cells in the interest area are then calculated with the result from each cell weighted by its area. This overall wind-shear "visibility" is then multiplied by the maximum success rate of the wind-shear detection algorithm, i.e., the best detection rate (for a specified false alarm rate) that the algorithm can yield if given noise-free images of wind-shear, to arrive at the estimate of wind-shear detection probability.

For the X-band radar, it is possible to have a maximum detectable reflectivity in addition to the minimum limit, because highly reflective weather can also attenuate the signal severely at these shorter wavelengths. In this case, the integration over the wind-shear reflectivity PDF is taken from the minimum to the maximum detectable reflectivities. For siting, we arbitrarily placed the X-band radar in the center of the union of the ARENAs on an 8-m tower. Determining whether this would be feasible or optimal was well beyond the scope of this study.

4.3.2 Lidar Performance Analysis

The LMCT Doppler Lidar operates at a wavelength of 1.6 µm with an average transmitted power of 2 W. It has a laser beam diameter of 10 cm, a range resolution of 30 to 50 m, and a maximum scan rate of 20° s^{-1}. For a more detailed description, see Hannon (2005).

Lidars operate at much shorter wavelengths than radars, and the balance between scattering and attenuation relative to particles in the atmosphere is quite different. For a Lidar, the maximum range occurs in the absence of large, attenuating precipitation particles, and in the presence of aerosols that provide effective backscattering. The detection range generally decreases with increasing dBZ along the propagation path. Therefore, the integration over the wind-shear reflectivity PDF in computing the visibility should be computed downward from a maximum detectable reflectivity.

This is a simplified model of the actual physical process, because dBZ is a radar-based quantity that corresponds well to the Lidar attenuation but not the backscattering strength. For our analysis, we were only concerned with two specific meteorological situations—a microburst at close range and a gust front approaching from a distance. Based on a sensitivity model that incorporated field testing data, LMCT provided us with maximum range vs. dBZ curves for the microburst case and for the gust-front case at wet and dry sites (Figure 30). The gust-front detection ranges are enhanced relative to the microburst detection range, because the leading edge of a gust front contains a wealth of scattering sources for the Lidar, while the air mass preceding it is often quite clear. The wet-site gust front tends to have more precipitation in the vicinity of the front, so the range is reduced. A receding gust front would tend to have much more precipitation between it and the Lidar, but this is a situation that is of much less importance to the safety and delay reduction missions of the terminal wind-shear sensor.

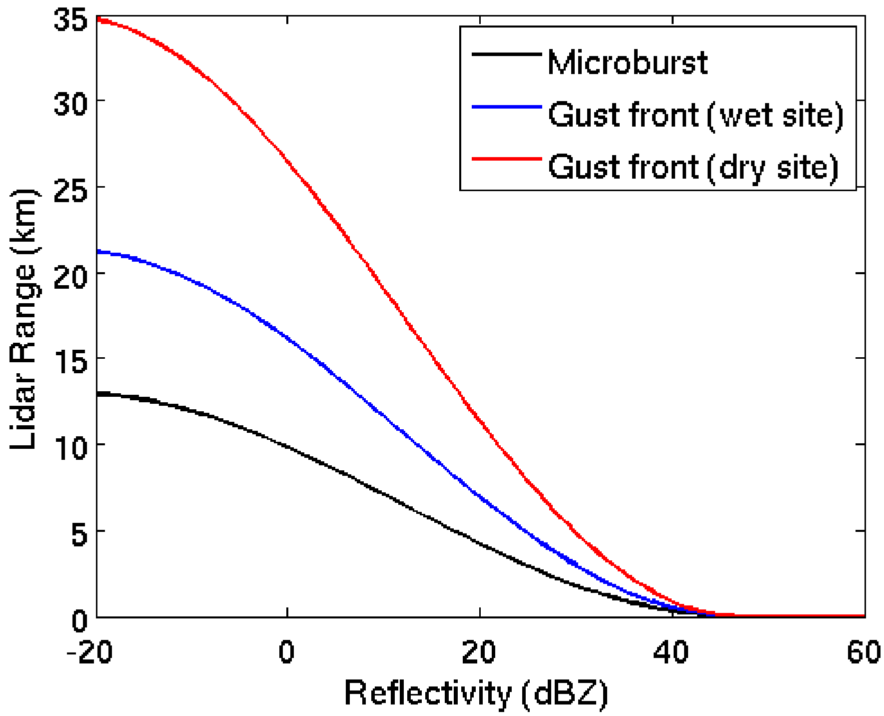

Figure 30. LMCT Doppler Lidar maximum detection range vs. weather radar reflectivity.

The current Lidar obtains samples up to only about 12 km in range due to signal processor limitations. However, according to LMCT, it would be quite feasible to upgrade the processor to allow sampling up to 18 km in range. Therefore, as with the radars, we assumed a post-upgrade capability for the Lidar.

Because the Lidar beam is collimated, we assumed that it successfully avoids ground clutter altogether. (We did include terrain blockage for the 18-km-radius-around-the-airport gust-front case, assuming a beam elevation angle of 0.7°.) Thus, the detection probability estimation scheme, which follows the radar model, becomes much simpler because the clutter effects are removed. These characteristics of the Lidar (maximum sensitivity at low dBZ and not being affected by clutter) make the Lidar an ideal complement to a radar. As with the X-band radar, we assumed that it would be sited in the center of the union of the ARENAs on an 8-m tower.

4.3.3 LLWAS Performance Analysis

The LLWAS obtains its wind measurements from anemometers mounted on towers at multiple locations in the airport vicinity. The wind-shear detection coverage provided is therefore directly dependent on the distribution of the anemometers and is limited to a small area compared to the radars and Lidar. The number of sensors per airport is 6–10 for the LLWAS-RS and 8–32 for the LLWAS-NE++ (network expansion).

The coverage provided at each LLWAS-equipped airport is given in the data base as (nautical) miles final on arrival and departure for each runway. Since the ARENA is a one-mile-wide corridor from three miles final arrival to two miles final departure (runway inclusive), it is simple arithmetic to compute the LLWAS coverage from these numbers. The microburst detection probability is then estimated as the product of the coverage and the LLWAS detection algorithm detection probability, which we took to be 0.97 (for a false alarm probability of 0.1) (Wilson and Cole, 1993). To verify the accuracy of the data base, we ran the NCAR code (courtesy of W. Wilson) originally used in the development of the LLWAS microburst detection algorithm to compute the coverage at Orlando (MCO) with the actual airport configuration file (ACF) ingested by LLWAS. The coverage based on the database numbers yielded 87% while the NCAR code with ACF gave 88% coverage, an excellent agreement.

4.3.4 Sensor Combination Analysis

Fusion of data from multiple sensors has the potential to increase wind-shear detection probability. At the minimum, holes in the coverage of one sensor due to blockage, clutter residue, lack of sensitivity, etc., may be filled in by another sensor with better sensing conditions in those areas. Line-of-sight velocity fields cannot be directly merged for non-collocated sensors, but sophisticated detection algorithms that perform fuzzy logic operations on interest fields would allow merging at that level instead of at the base data level. Therefore, for radar + radar and radar(s) + Lidar combinations, we computed the visibility pixel-by-pixel for each sensor and took the greater value before summing over interest area.

In the case of radar(s) + LLWAS, the detection phenomenologies are independent of each other. The data on which the detection algorithms work are quite different—volumetric base data for the radar and point measurements of surface winds for the LLWAS—so they cannot be fused together in the same way as the radar and Lidar data. In practice, the detection alert is issued after combining the wind-shear message outputs from the two systems (Cole 1992). Thus, we took the detection probability, P_d, for each sensor and combined them as $P_d(\text{combined}) = 1 - [1 - P_d(\text{radar})][1 - P_d(\text{LLWAS})]$. In theory, the false alarm rates also combine to increase in similar fashion. However, clever use of all the available contextual data can reduce false alarms (Cole and Todd 1996) so we assumed that the false alarm rate stayed constant.

4.3.5 Discussion of Performance Results

The complete wind-shear detection probability estimates are tabulated in Appendix C. Note again that post-upgrade performance characteristics were assumed for the TDWR, ASR-9 WSP, and NEXRAD. (For comparison purposes, single-radar results for the “legacy” systems are also given in Cho and Hallowell (2008).) The summary results for each class of system are given below.

The post-upgrade TDWR is expected to meet the microburst detection requirement at all airports, except for Las Vegas (LAS) due to the severe road clutter there. For gust-front coverage within the 18-km-radius interest area, the TDWR also does very well except for Las Vegas, Phoenix (PHX), and Salt Lake City (SLC). Since the gust-front reflectivity PDF used was the same for every airport, the poor performance at these three airports are due to terrain blockage and clutter, and not due to the dryness of the sites. This conclusion is reinforced by the high detection probabilities at Denver (DEN), which is the fourth “dry” site. Preexisting TDWRs are close enough to four non-TDWR airports to provide satisfactory wind-shear detection capability (MCO for ORL and SFB, ATL for PDK, and TPA for PIE).

The ASR-9 WSP, as expected, does not perform as well as the TDWR. The reduction in capability is more pronounced for gust fronts. As a potential replacement for the TDWR, a serious problem is that there is no ASR-9 at five of the TDWR airports (DAL, LGA, MDW, PBI, and SJU) and WSPs installed at the closest ones would not yield adequate capability at those sites. Unlike with the TDWR, the dry-site microburst reflectivity PDFs do have a significant negative impact on detection probability as can be seen from the Denver results. This is due to the much lower sensitivity of the ASR-9.

The NEXRAD would yield performance comparable to the TDWR if located close enough to the airport, which is the case for only 20% of the study airports. (Also, we note again that the current operational NEXRAD scan update rates are not fast enough for microburst detection.)

The performance of the proposed LMCT X-band radar falls between that of the TDWR and WSP in general. Site-specific results for the X-band system should be taken with a grain of salt, since the assumed siting at the center of the union of the ARENAs with a tower height of 8 m is neither optimized nor known to be feasible. Actual siting will have an effect on the P_ds for better or for worse. For example, the extremely poor performance in Pittsburgh (PIT) indicates that a more careful siting analysis is needed before a new radar is placed there.

Clearly, the Lidar by itself is not sufficient for acceptable terminal wind-shear detection performance. However, it is an excellent complement to a radar. In fact, any of the four radars considered, properly sited, is projected to deliver satisfactory wind-shear detection performance, provided that the data from the two sensors are optimally integrated.

Almost all LLWAS systems do not have enough anemometers to cover all of the ARENAs at an airport, hence the fairly low microburst detection rate (gust-front detection out to 18-km is obviously not feasible for an LLWAS). The exception is Denver with its 32 anemometers. Combined with a properly sited radar, the microburst detection performance is expected to be quite good, although not as good as the Lidar + radar combination at the more difficult (dry or heavy road clutter) sites. And, of course, there is no boost to the 18-km gust-front coverage with an LLWAS.

5. METHODOLOGY FOR BENEFITS AND COSTS ASSESSMENT

The time period used for all calculations is from 2010 to 2032; this is primarily driven by the evaluation of potential alternatives. Current configurations of systems are assumed to continue from 2010 to 2012 and then alternative costs and benefits are figured for a 20-year life-cycle (2013–2032). Some alternatives may take longer to implement than others, but the 3-year assumption allows for similar cost comparisons between the various system combinations. Cost and benefits projection require that forecasted values be depreciated back to a constant dollar figure, in this case we use FY08 constant dollars. Therefore, for both benefits and analysis figures an FAA recommended value of 7% is used for this depreciation (FAA, 2007). Note that this is particularly important when it comes to costs of initial implementation, as these costs will be depreciated the least.

5.1 ASSESSING SAFETY BENEFITS

The potential safety benefits for each airport and each category of aircraft for each ground wind shear system configuration is based on five factors as shown below. Accident costs capture the expected societal and actual costs that are expected to occur if an aircraft crashes due to wind shear. Accident Rates estimate the frequency with which accidents would occur, given that no ground-based wind shear systems were present. Forecasted operations and enplanement rates are used to predict future safety exposure based on the number of aircraft and people at risk over the evaluation period (2010–2025). The Safety Weather Exposure Factor (SWEF) is a measure of the relative exposure of an airport's operations to wind shear. Finally, the change in system efficiency measures the difference between the current ground-based wind shear detection system and each alternative.

$$\text{Potential Safety Benefits (\$)} = \text{Accident Costs (\$)} \times \text{Accident Rates (accidents per operation)} \times \text{Forecast Operations \& Enplanements} \times \text{Safety Weather Exposure Factor (SWEF)} \times \text{Change in System Efficiency relative to Baseline}$$

5.1.1 Accident Costs

Accident costs are calculated based on values defined in FAA guidelines for economic analyses (GRA, 2007) and (FAA, 2008). Tables 11 and 12 show the recommended values for personal and infrastructure losses in an aviation accident.

TABLE 11

Actuarial data for personal injury or fatality

Category	Cost ($)
Fatality	$ 5,800,000
Serious Injury	$ 1,087,500
Minor Injury	$ 11,600

TABLE 12

Estimated market values of aircraft repair/replacement

Aircraft Damage	Aircraft Category		
	Air Carrier	Air Taxi	General Aviation
Replacement	$ 11,460,000	$ 1,817,062	$ 361,940
Restoration	$ 3,700,000	$ 85,154	$ 35,070
Investigation	$ 449,000	$ 449,000	$ 35,100

To evaluate the cost of a typical wind shear accident, we must estimate the accident 'structure' based on the breakdown of personal injury and infrastructure losses from previous wind shear accidents. Some of this data was presented in Section 2; the relative infrequency of wind shear related accidents in recent years and concerns that relying on a small sample to be representative demands that we pool all the available accident data when estimating accident structure. However, there is some evidence from the data that wind shear accident severity in the mid-late 1970s was significantly higher than it is today. There are several possible explanations for this: enhanced pilot training, improved aircraft performance, and/or widespread awareness of hazardous conditions (from wind shear radar systems). However, since the evidence for reduced severity is extracted from the relatively few events that occurred during the era where ground-based wind shear systems had already been installed it is difficult to quantify the reduction accurately. Therefore, utilizing an average of all the accident severity data would seem acceptable for evaluating the relative worth of ground-based systems. Table 13 lists the distribution of personal fatalities/injuries and infrastructure losses from all accidents over the period 1975–2007.

TABLE 13

Pooled accident structures, 1975–2007

	Aircraft Category		
	Air Carrier	**Air Taxi**	**General Aviation**
People			
Number of passengers	105.9	2.6	2.5
Load factor	80%	100%	100%
Fatality	22 %	31 %	10 %
Serious	10 %	15 %	9 %
Minor	3 %	12 %	19 %
Aircraft			
Destroyed	30 %	63 %	24 %
Substantial	55 %	38 %	76 %
Minor	5 %	0 %	0 %

Utilizing the tables above, the average safety costs associated with a wind shear accident can be calculated as shown in Table 14.

TABLE 14

Estimated average wind-shear-related accident costs

Costs (2008 $$)	**Aircraft Category**		
	Air Carrier	**Air Taxi**	**General Aviation**
People	$ 117,345,503	$ 5,086,966	$ 1,714,929
Aircraft	$ 5,922,000	$ 1,626,108	$ 148,620
Totals	**$ 123,267,503**	**$ 6,713,073**	**$ 1,863,548**

5.1.2 Accident Rate

As detailed in Section 2, the final accident rate breakdowns used for the safety analysis are shown in Table 15.

TABLE 15

Average and range of wind-shear-related accident rates by category (# of "unprotected" accidents per million operations)

Aircraft Category	Average Rate	Range
Part 121/9	0.1095	0.1045 – 0.1168
Part 135/7	0.2037	0.1299 – 0.2410
Part 91	0.1600	0.1201 – 0.1842

5.1.3 Forecasted Operations and Enplanements

The number of operations for each aircraft type and each airport are obtained from the FAA Terminal Area Forecasts (FAA, 2007). Table 16 shows the number of operations (2008) for each class of wind shear study airport and the remaining NAS traffic. Over 94% of the major air carrier traffic is covered by the study airports chosen, with almost 90% of the overall traffic protected by some active wind shear system. The percentage of the total US operations covered by the 161 study airports is roughly 94%, 59%, and 10% for air carrier, air taxi and GA operations, respectively. While a large portion of GA traffic and therefore total traffic are non-study airports, these GA operations are spread out over hundreds of small airports and GA traffic is the most difficult class of aircraft to reach for wind shear warnings.

TABLE 16

Breakdown of aircraft operations by airport type (millions of operations, 2008)

Airport Type	Air Carrier	Air Taxi	General Aviation	Total
TDWR	9.3	5.4	1.5	16.2
WSP	2.2	1.5	1.8	5.5
LLWAS	1.1	0.9	3.2	5.2
Unprotected	0.7	0.9	1.8	3.4
Non-study Airports (unprotected)	0.8	6.1	74.4	81.3
TOTALS	14.1	14.8	82.7	111.6

Growth rates vary from airport to airport but the overall trends for operations are projected to have an average increase of 2% per year for both Air Carrier and Air Taxi traffic operations, with slightly slower growth rates for General Aviation. By 2032, Air Taxi operations at the study airports increase to 63%, while Air Carrier and General Aviation coverage rates stay essentially flat. Figure 31 illustrates the breakdown of operation types grouped by the type of wind shear protection. The disparity in the percentage of air carrier types is not unexpected because large airports with heavy aircraft are less desirable for small aircraft and recreational users.

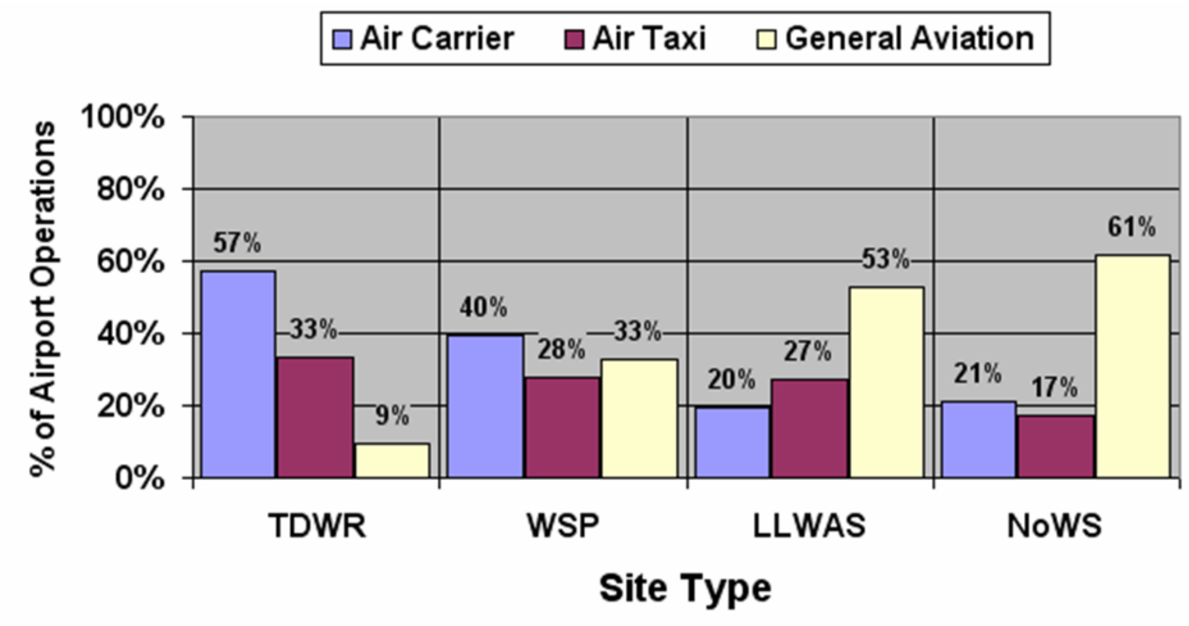

Figure 31. Breakdown of aircraft operations by study airport wind-shear protection coverage (2008).

5.1.4 Safety Weather Exposure Factor (SWEF)

Safety weather exposure factor (SWEF) is used to weight the risk of each operation at individual airports in terms of exposure to wind shear. As discussed in Section 3, wind shear exposure for safety comes primarily from microburst outflows but some gust fronts are strong enough to cause additional concern. The SWEF number combines the two risks by weighting microburst exposure at 90% and gust front exposure at 10%. Microburst exposure is determined by calculating the average microburst-related wind shear exposure factor over all of the 161 airports being analyzed. An implicit assumption is made that the 161 airports are sufficiently dispersed that they represent the average exposure over the entire country. The relative MB exposure for each airport is then the airport exposure divided by the average. An exposure factor of 1.0, therefore, represents an airport risk that is exactly the average. If the ratio is higher (lower) than 1.0 then the exposure is higher (lower) than average. The same calculations are made for gust front exposure and then the two values are combined together (90% MB + 10% GF) to obtain the SWEF. Appendix A lists the overall SWEF value for each site.

5.2 ASSESSING DELAY BENEFITS

Ground-based systems add an important aspect to the benefits equation: delay savings. The ability of many of the radar based systems to detect and predict the location of precipitation, wind shear and gust fronts allows the NAS to be aware of and in some cases plan for disruptive weather events. These benefits are often difficult to quantify, but several reports have detailed both qualitatively and quantitatively the benefits of wide area weather awareness and planning as it relates to TDWR and WSP and the ITWS and

CIWS systems that incorporate these radars (Allan and Evans, 2005 & Robinson, et al., 2004). For this report we focused only on wind shift prediction because it was a potential delay benefit that was directly related to the mission of wind shear protection.

$$\textit{Potential Delay Benefits (\$)} = \textit{Delay Costs (\$)} \times \textit{Annual Number of Strong Windshifts During Operational Day} \times \textit{(Minutes of Runway Outage)}^2 \times \textit{(Capacity X Demand) / (Demand - Capacity)}$$

Estimated benefits of reducing airline delays by detection of wind shift using current ground wind shear systems are calculated according to a standard queuing model [Evans et al. (1999) and Allan & Evans (2005)]. The inputs of this model are airport-specific demand, capacity, and an estimate of the time period when the capacity is reduced due to an adverse weather event. The model outputs are the total delay time for all the aircraft affected by the event. Accepted airport capacity estimates were obtained for the 35 Operational Evolution Partnership (OEP) airports (FAA, 2004) which are also the primary drivers of delay in the NAS. Estimates for non-OEP airports assumed that only the flights directly impacted by the runway outage would incur delay and that no queue would be built-up.

To estimate airport demand, we used hourly rates calculated from TAFs scheduled operations in 2007 based on assumptions of 365 days per year and 18 operational hours per day. Adjustments were made for two airports, LAS and LAX where this methodology resulted in artificially high demand values. Based on a benefit study of runway wind forecast at Boston Logan International Airport (Rasmussen and Robasky, 1995, 1996), we estimated that runway reconfiguration following an unanticipated wind shift would cost ATC 10 min for arrivals and 15 min for departures on average. If the wind shift was anticipated, this reconfiguration time could be reduced to approximately 5 minutes. Therefore, we use an average value, 12.5 min, for the duration of the runway capacity loss for a wind shift event that is not detected by the airport's ground based wind shear detection system. The arrival and departure delays are assumed to be evenly distributed. For events that are detected by the wind shear system, we use 5 min as the duration of the capacity gain that would be achieved due to advance warning of wind shifts.

While even weak gust fronts could potentially force an airport to shift runways, our analysis focuses only on strong windshifts where the wind direction was shown to shift by more than 45 degrees and the wind speed maintained greater than 10 knots throughout the shift. Hourly observations from 1977–96 for the study airports were examined to estimate the annual frequency of strong windshifts for each airport. Appendix A lists the windshift frequency result for each airport.

Delay costs are calculated by multiplying total delay hours with hourly delay costs adapted from FAA economic analysis guidelines, GRA (2007). Table 17 shows the breakdown of delay costs as derived from the economic guidelines.

TABLE 17

Breakdown of delay costs for passenger and aircraft time (including crew) as adapted from GRA, 2007

FY08$	Variable Cost			Passenger Costs per Hour			Total Per Delay Hour Cost ($/hour)
	Per Airborne Hour	Per Ground Hour	Per Delay Hour	# of passengers	Time costs ($/hour)	Total Passenger Cost ($)	
Air Carrier	$3,948	$1,932	$2,940	95.4	$ 28.60	$2,728	$5,668
Air Taxi	$1,125	$ 550	$ 838	3.7	$ 37.20	$ 138	$ 975
General Aviation	N/A	N/A	$ 526	3.7	$37.20	$ 138	$ 663

To estimate the delay benefits, we first calculate the total delay costs for each airport assuming there is no capability for advance detection of an impending airport wind shift. We then repeat the calculation taking into account the detection capability of each evaluated airport wind shear detection system. The differences between these two delay costs represent the delay reduction benefits associated with each system.

5.3 ESTIMATING SYSTEM COSTS

Both the currently implemented and alternative wind shear systems evaluated in this report have operating and/or building costs associated with them. In assessing the relative value of wind shear system value one must reduce the overall benefit of the system by its associated cost. Therefore, each alternative was examined to estimate the cost of operating existing systems and implementing and then operating alternative systems and/or configurations.

Cost data were gathered by MCR Federal, Inc. using both actual cost data (for existing systems like TDWR, WSP and LLWAS) and estimated costs obtained from vendors and FAA staff for alternatives (X-band, NEXRAD and Lidar-based systems). All costs for the wind shear study were estimated using Base Year 2008 (BY08) constant year dollars within the ACE-IT, version 7.1, cost model. Costs for all systems, both existing and new, were estimated for the years 2010 through the year 2032. This timeframe was based on the simplifying assumption that all new systems (where applicable) would be procured, implemented and commissioned by the year 2013 and remain in the NAS for a 20 year life cycle (through 2032). Present value costs for purposes of economic analysis were calculated by applying an annual 7% discount factor to the BY08 calculated costs. The following table summarizes the average cost per system. Any Tech Refresh or SLEP costs associated with the existing legacy systems (TDWR, WSP, and LLWAS) were included in the "In-Service Management" costs. Where applicable, these costs were included in the implementation costs for the newer systems.

Cost estimates for the existing weather systems (TDWR, WSP, and LLWAS) were based on current and recent cost baselines. TDWR costs, including SLEP activities, were based primarily on the TDWR SLEP baseline estimate conducted in FY07. This estimate was augmented by the 2006 O&M Study conducted by ATO-F for those WBS elements not addressed by the SLEP. WSP costs were estimated using the 2006 WSP Tech Refresh Baseline estimate and LLWAS costs were estimated using inputs from subject matter experts such as the Logistics Center, the Second Level Engineering organization (AJW-144), and ATO-F Workforce Planning.

The cost estimates for the new weather systems (WSP, LLWAS, LIDAR, and X-Band Radar) and for modifying the existing NEXRAD system were based on analogies to existing costs and engineering assessments. However, only incremental costs associated with new systems or new functionality were included in the estimate. For example, Second Level Engineering costs only included additional staffing required to support the new systems. NEXRAD modifications were based on analogies to current algorithm upgrades and telecommunications requirements, as well as engineering assessments for studies and testing. Implementation cost for new WSP systems were based on engineering assessments and ROM hardware costs provided by AJW-144. In-Service Management costs of the WSP systems were based on analogies to the current WSP Tech Refresh Baseline. Similarly, LLWAS new system costs were based on analogies to the existing system costs. LIDAR implementation costs were based on current costs to implement and maintain the Las Vegas LIDAR system, adjusted to reflect some savings due to economies of scale. Finally, the estimated costs of developing, implementing, and maintaining a new X-Band Radar system were based on an analogy to the ASDE-X program, assuming a radar-only configuration.

Table 18 lists each of the wind shear system configurations and their startup and operating costs. Existing systems have no cost associated with startup as the system is already installed. In the case of WSP, startup costs refer to installation of a new system since that alternative was evaluated for TDWR airports. Figure 32 shows the comparison of life-cycle cost grouped by system type. Note from Table 18 that system costs are spread out over different numbers of sites depending on the system installation.

TABLE 18

Breakdown of site costs for wind-shear systems, 2010–2032 (from MCR Systems)

Wind-Shear System	Estimated Number of Costed Systems	One-time Implementation Costs Per Site (in Base Year 2008 $M)	Per Site Life-Cycle In-Service Management Costs (2010-32 in Base Year 2008 $M)	Per Site Total Base Year Costs (2010-32 in Base Year 2008 $M)	Per Site Total Costs (2010-32 in Present Value FY08 $M)*
Existing TDWR	46	N/A	$ 5.009	$ 5.009	$ 2.507
Existing WSP	35	N/A	$ 1.953	$ 1.953	$ 0.947
Existing LLWAS	40	N/A	$ 1.321	$ 1.321	$ 0.605
Existing NEXRAD (w/Updated Algorithms/Scanning)	74	$ 0.178	$ 0.266	$ 0.444	$ 0.242
New WSP	80	$ 4.104	$ 1.255	$ 5.359	$ 3.574
New LLWAS	121	$ 0.843	$ 1.698	$ 2.541	$ 1.366
New LIDAR & Algorithms	161	$ 2.461	$ 1.979	$ 4.440	$ 2.656
New X-Band Radar & Algorithms	161	$ 7.356	$ 1.972	$ 9.328	$ 6.350

* As noted in the text above, Present Value is used to take into account inflation, thereby discounting benefits that are achieved in later years relative to current year dollars.

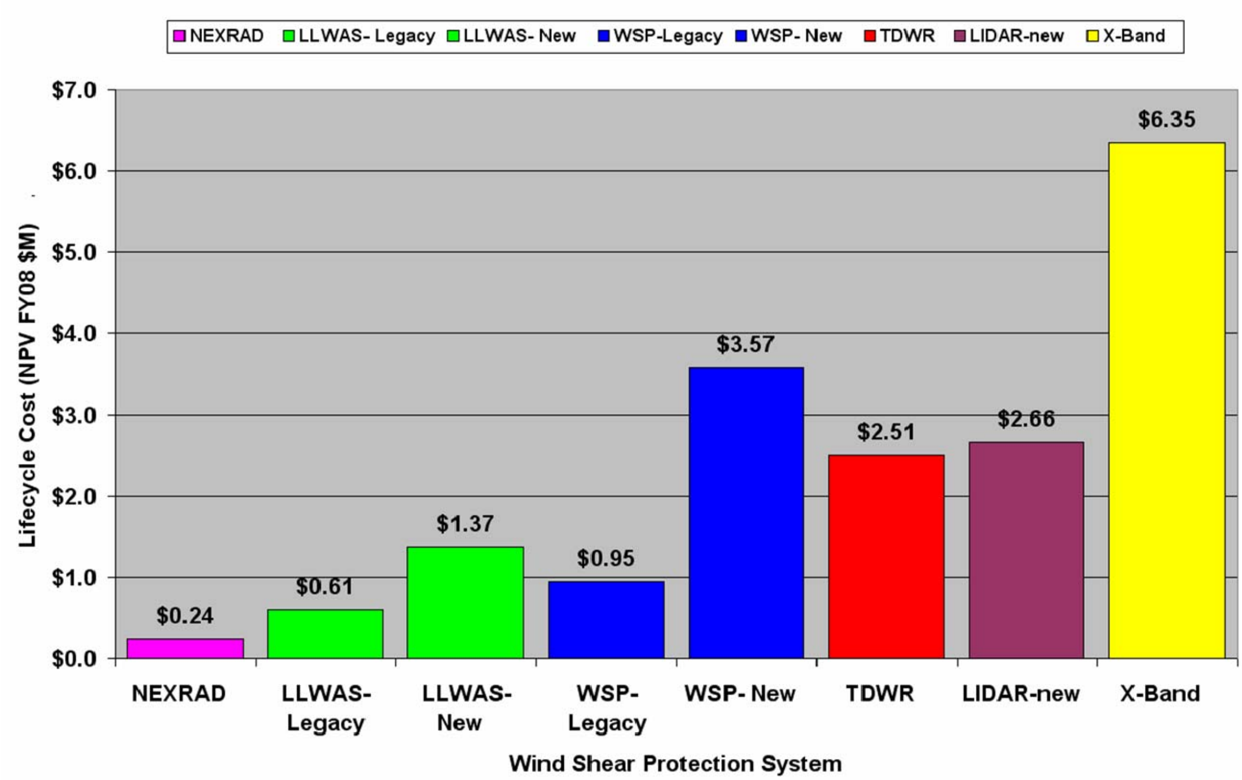

Figure 32. Total life-cycle system costs (2010–2032) per airport for wind-shear protection systems (present value FY08 $M).

6. CURRENT AIRPORT-SPECIFIC SAFETY AND DELAY MITIGATION

There are several layers of wind shear mitigation that are in present use, this section details the current situation by examining (1) the assessment of the NAS completely unprotected for wind shear, (2) pilot training benefits, (3) airborne systems benefits, and (4) the current and near-term baseline ground-based benefits. Figure 33 shows the relative safety exposure based on the level of wind shear protection that is applied. The red vertical bars show the variation in this exposure based on the estimated variability of accident rate estimates (as given in Table 15).

Results throughout this section are typically given as an overall total and an annual liability or benefit over the period 2010–2032 with charts showing the breakdown by current site configuration and individual airports where necessary. These values are given in present value FY08$ which attempts to account for the depreciation of dollars as you move forward in time. Therefore annual figures correspond to the base year FY08 dollars that would represent the total present value if that cost occurred each year. Consequently, this figure is significantly higher than just dividing the total present value cost by the total number of years.

Only safety liability is discussed for items (1) through (3), while delay measures are considered for the current and near-term ground-based coverage. Alternative systems benefit changes were modeled to begin in 2013 (allowing 3 years for the modification to take place); the existing benefits were assumed to stay in effect from 2010–2012. The implementation cost assumptions and risks of the various alternatives are discussed on Section 5. Appendix D covers safety benefits for unprotected, pilot training only, pilot plus PWS, current ground-based systems, and TDWR/WSP upgraded current configuration. The data contains a complete tabulation of airport specific safety (and delay) benefits at each of the 161 airports.

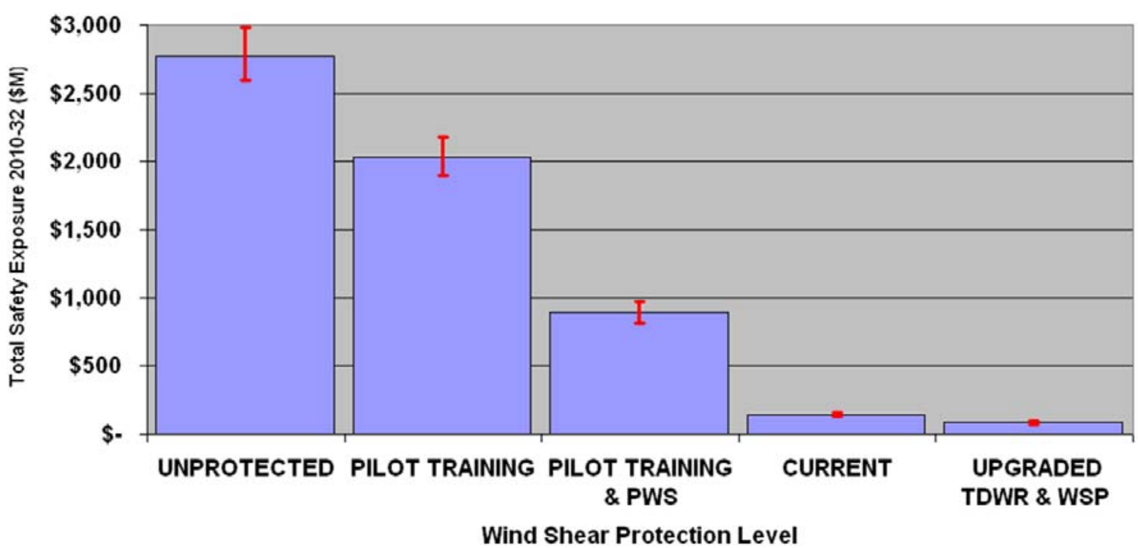

Figure 33. Total annual safety-related financial exposure from wind-shear accidents based on the levels and types of protection applied (present value FY08 $M). Error bars show the range of values based on minimum/maximu estimates of accident rates given in Table 15.

6.1 NO WIND-SHEAR MITIGATION

The very rawest form of the safety exposure starts with all airports and aircraft being unprotected by any wind shear mitigation system. The only aircraft factor taken into account is the increased performance ability of aircraft since the 1970s that allows pilots an approximately 10% better chance to power the aircraft out of a wind shear once they have entered the hazard. Based on all the factors presented above, if all of the 161 airports in the NAS were unprotected from 2010 to 2032 the total expenses for wind shear related accidents would be $2.8 billion in present value (2008) dollars or $265 million annually. In addition, if we include all of the air traffic operations that are not covered by the 161 study airports, we would add $250 million to the total, or an additional $23.7 million annually.

The unprotected financial exposure based on an airport's ground-based wind shear protection system is shown in Figure 34. Not unexpectedly, the TDWR sites, chosen for their high volume of air carrier traffic and exposure to wind shear have by far the largest financial liability. Many of the remaining sites typically have lower volumes of traffic (even if they might have significant wind-shear activity) thereby reducing the potential financial exposure to wind shear.

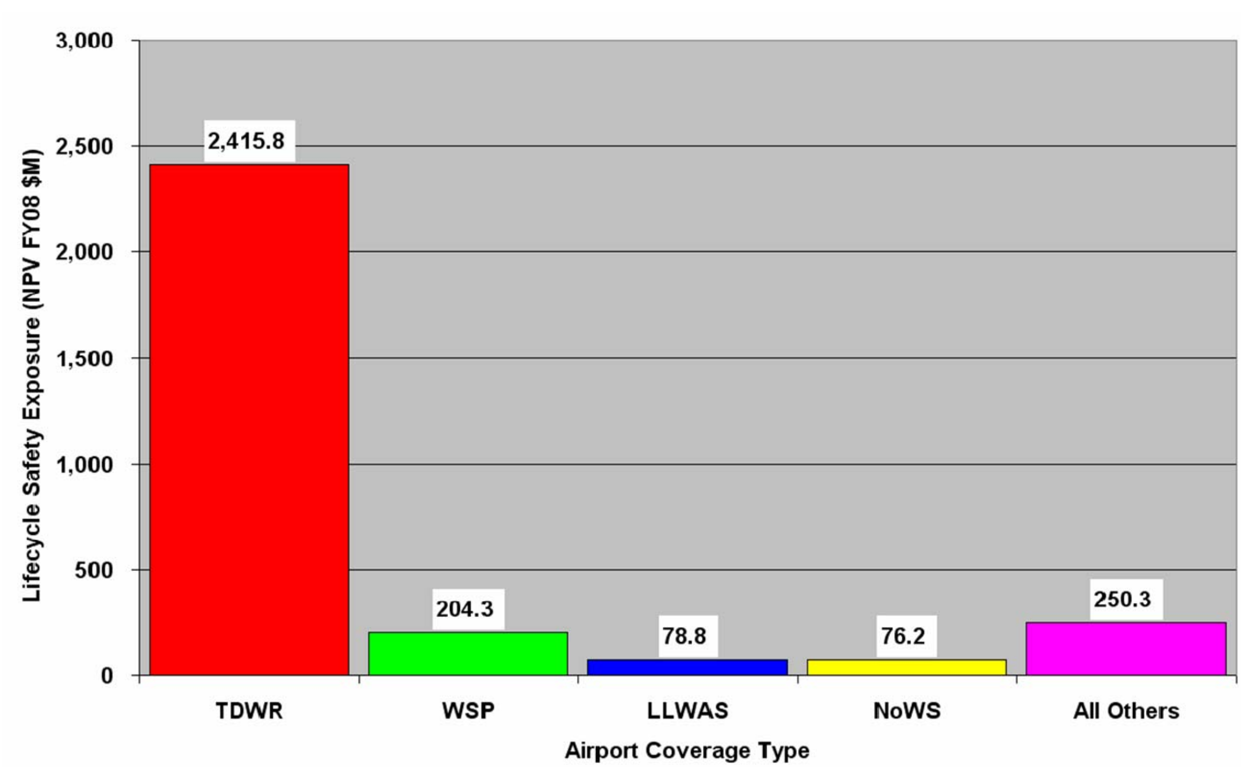

Figure 34. Total (2010–2032 in billions of dollars) safety-related financial exposure from wind-shear accidents based on an unprotected NAS broken down by the current protection system at each site.

Figures 35 through 38 show the distribution of unprotected safety-related exposure for each type of airport studied: TDWR, WSP, LLWAS, and No shear system. The annual exposure given for each site uses present value FY08 dollars as described in Section 5.

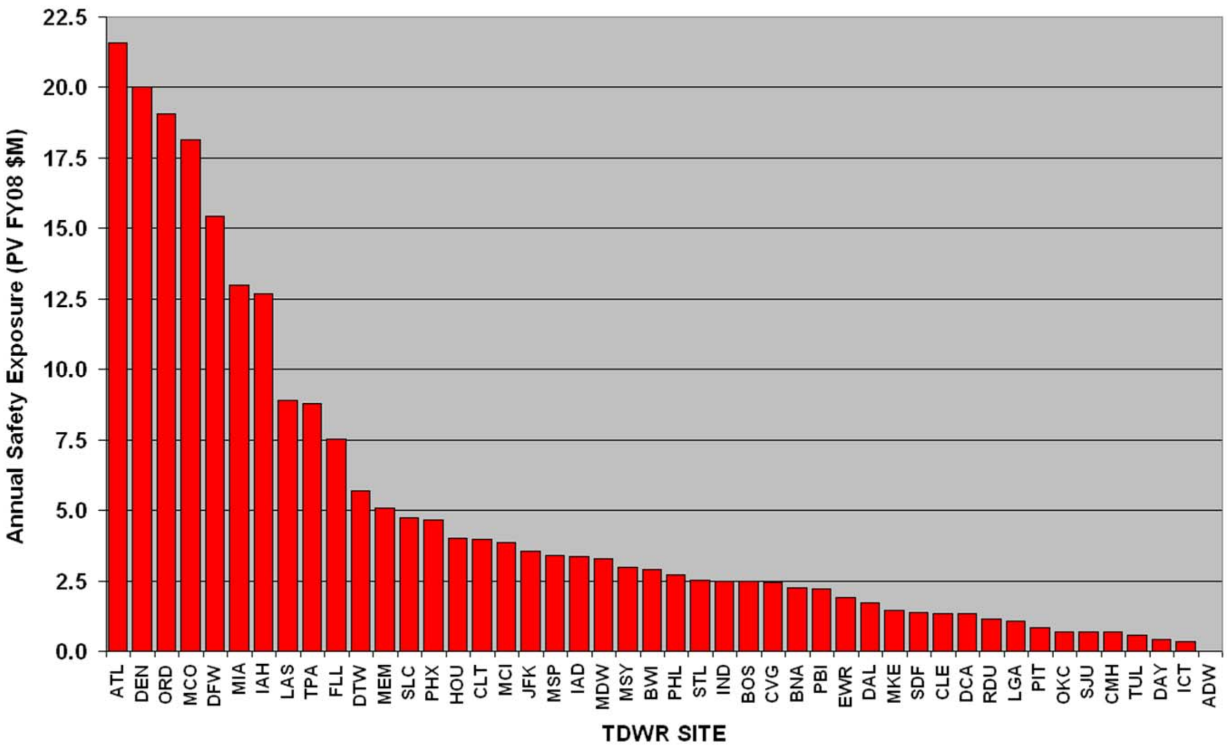

Figure 35. Annual safety-related financial safety exposure from wind shear for each TDWR (or TDWR-LLWAS) protected airport (present value FY08 $M) based on an unprotected NAS.

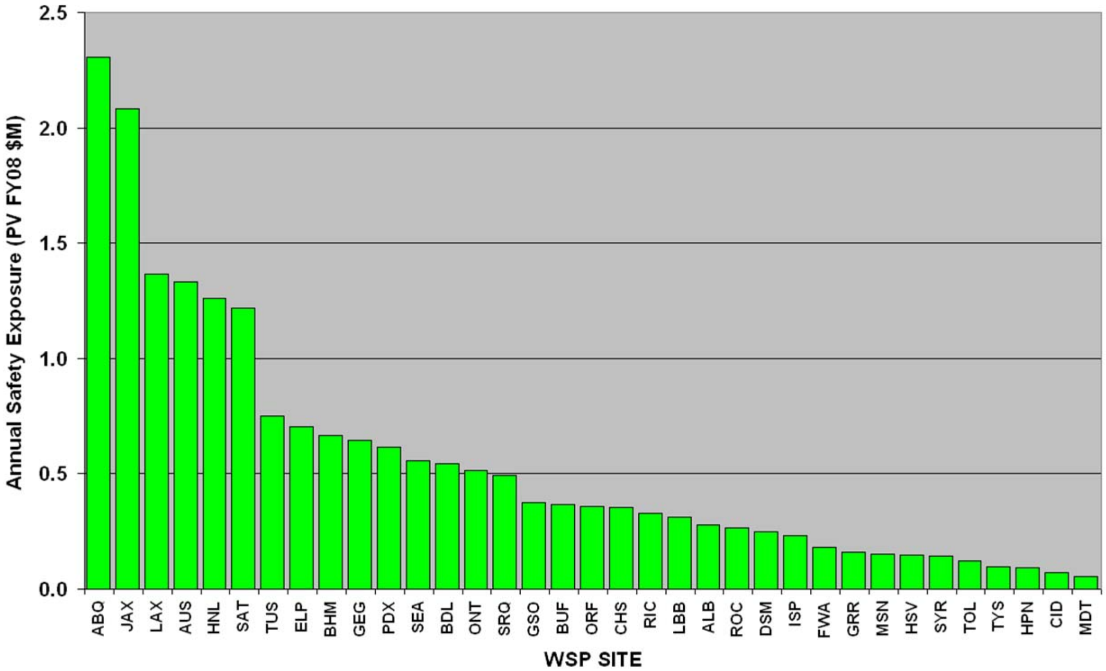

Figure 36. Annual safety-related financial safety exposure from wind shear for each WSP protected airport (present value FY08 $M) based on an unprotected NAS.

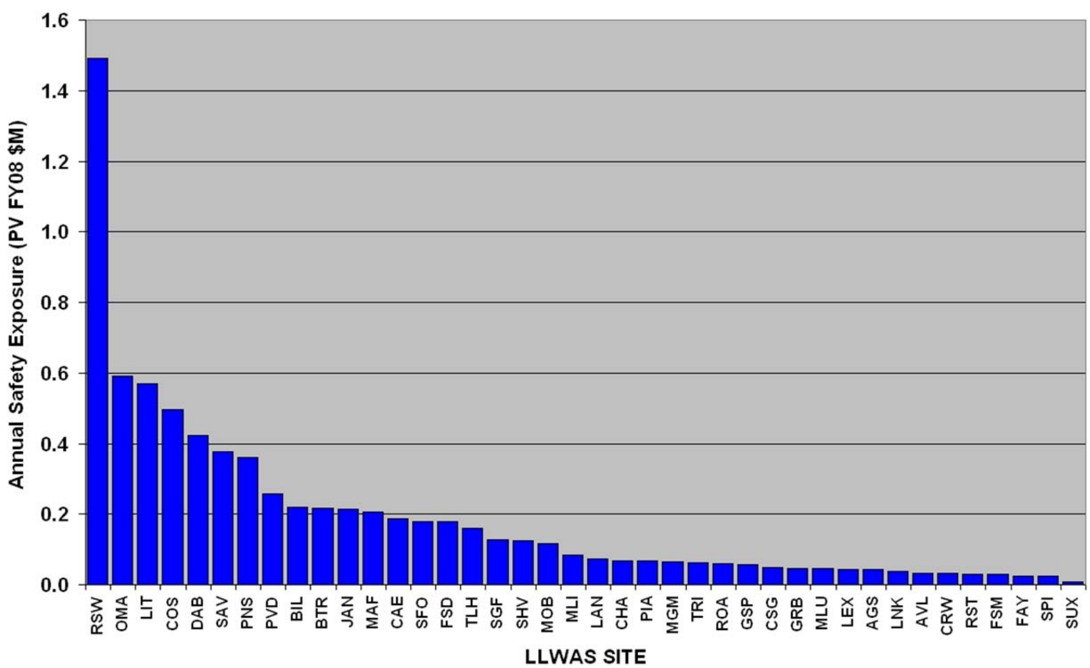

Figure 37. Annual safety-related financial safety exposure from wind shear for each LLWAS protected airport (present value FY08 $M) based on an unprotected NAS.

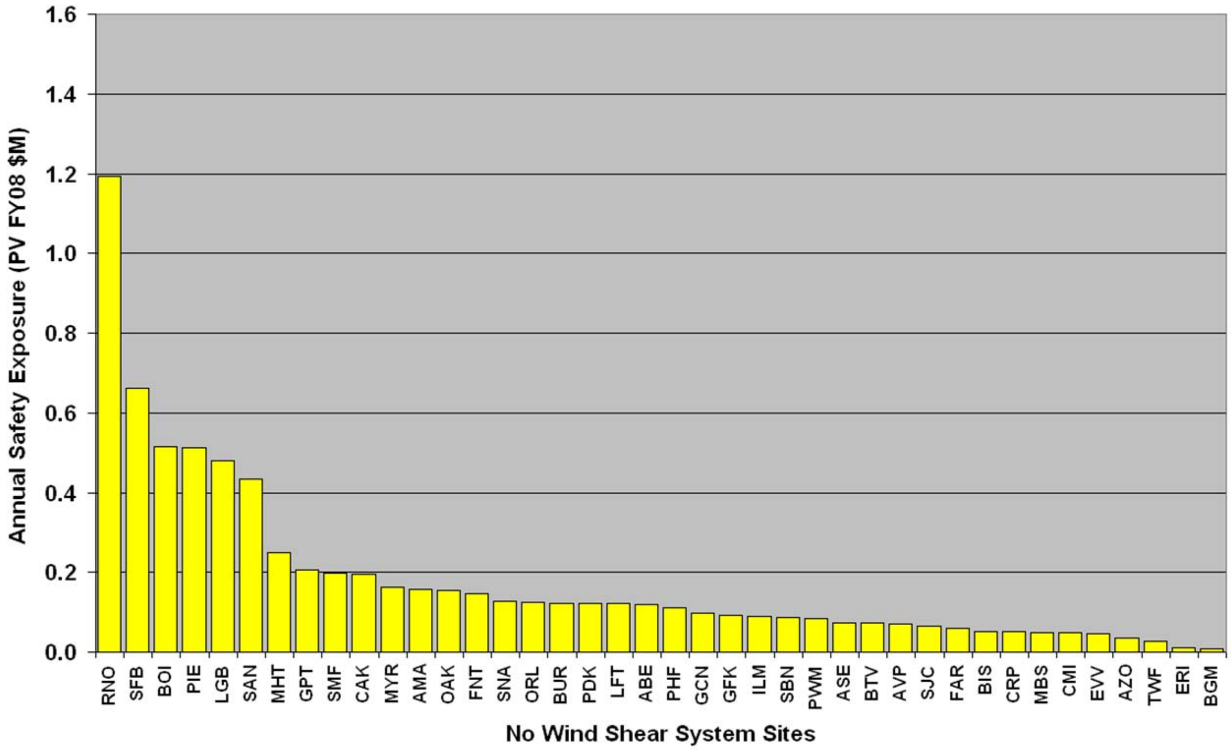

Figure 38. Annual safety-related financial safety exposure from wind shear for each unprotected study airport (present value FY08 $M) based on an unprotected NAS.

6.2 PILOT TRAINING ASSESSMENT

Pilot training is the first mitigation technique and the effectiveness of this training is applied to all forms of air traffic equally (air carrier, air taxi, and GA). Therefore, it is the strategy with the most widespread impact. As shown in Figure 33 above, the total safety exposure reduction for study airports due to pilot training is $728.7 million or 26% ($69.2 million annually). The rank order of sites changes only slightly as some airports have environments that are easier for pilots to identify visual cues. For example, MCO and ORD swap places in the top 10 exposure list as ORD's pilot observability effectiveness is 21% but MCO's is 29%.

As shown in the accident rate analysis discussed in Section 1, the measured Part 121 (Air Carrier) accident rate in the period where pilot training was the primary mitigation technique was within 10% of either of the transformed measurements from the other two accident rate eras. There was a similar comparison for General Aviation accident rates. Conversely, the measured 'pilot training' accident rate for Air Taxi (part 135/7) was much lower than the rate as transformed from the measured unprotected era (1975–85). This may indicate that the financial estimates for air taxi operations may be overstated. However, pilot training was implemented over many years and the class of airplanes utilized for Air Taxi services has changed dramatically over the years so the variability for this class of aircraft is not surprising. In addition, the averaging of accident rate eras is designed to reduce such errors. Figure 39 shows the estimated life-cycle safety-related expenses in a NAS protected only by pilot training broken down by airport coverage type.

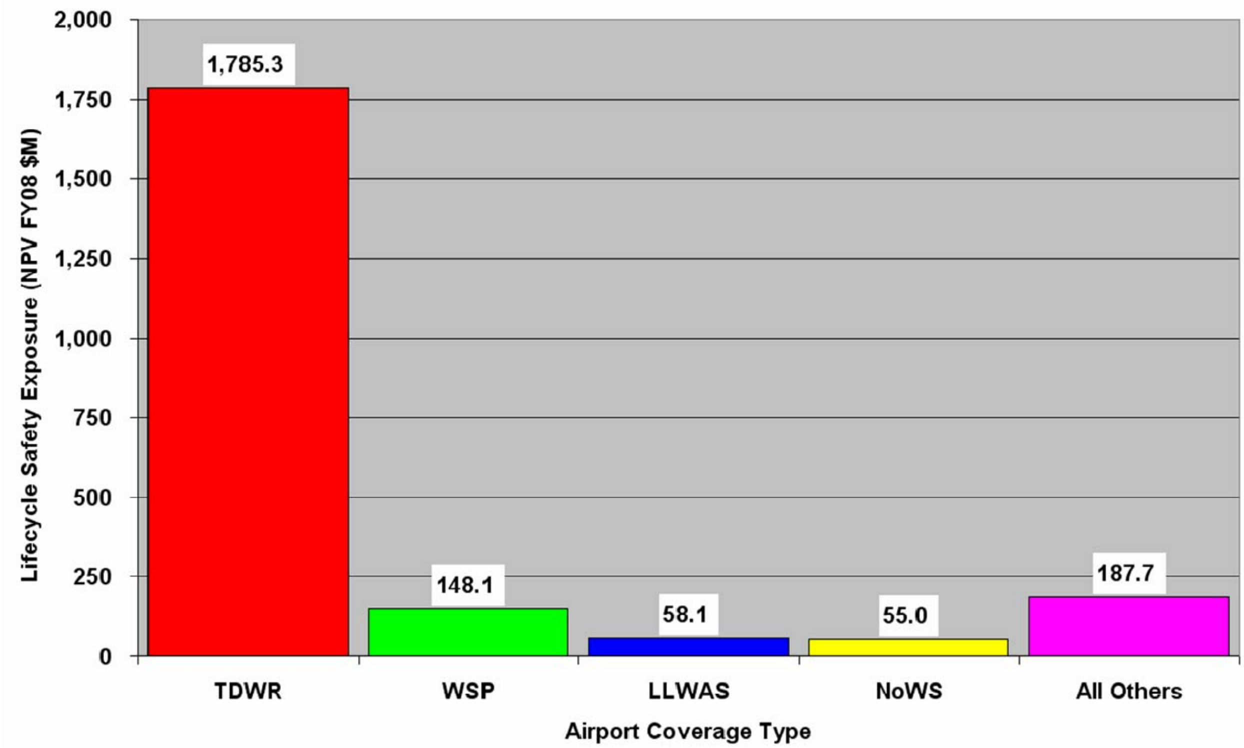

Figure 39. Total safety-related financial safety exposure from wind shear for each by class of airport (present value FY08 $B) based on a NAS protected by pilot training only.

6.3 AIRBORNE MITIGATION SYSTEMS

On-board systems include both reactive and predictive wind shear systems. These systems are not routinely available on general aviation or Part 135/7 aircraft. Predictive systems are available on approximately 63% of the air carrier fleet and for this analysis we assume that those aircraft are randomly distributed throughout the country. While outside the scope of this study, variability in equipped aircraft between airports could impact the financial exposure of individual airports. The overall reduction in safety exposure from 2010–2032 relative to pilot training estimates is $1.1 billion or 56% ($109 million annually). The combined reduction from both pilot training and airborne systems relative to unprotected airspace is $1.9 billion or 68% ($178 million annually). This estimate assumes that the equipage rate stays constant throughout the period. If the equipage rate were 100% for air carriers the safety exposure would be reduced by nearly $2.5 billion or a 91% reduction in safety liability ($240 million annually). Figure 40 shows the resultant remaining safety-related financial exposure for each class of airport based on a NAS protected by both pilot training and PWS. This number represents the baseline for comparisons of current and alternative ground-based wind shear systems.

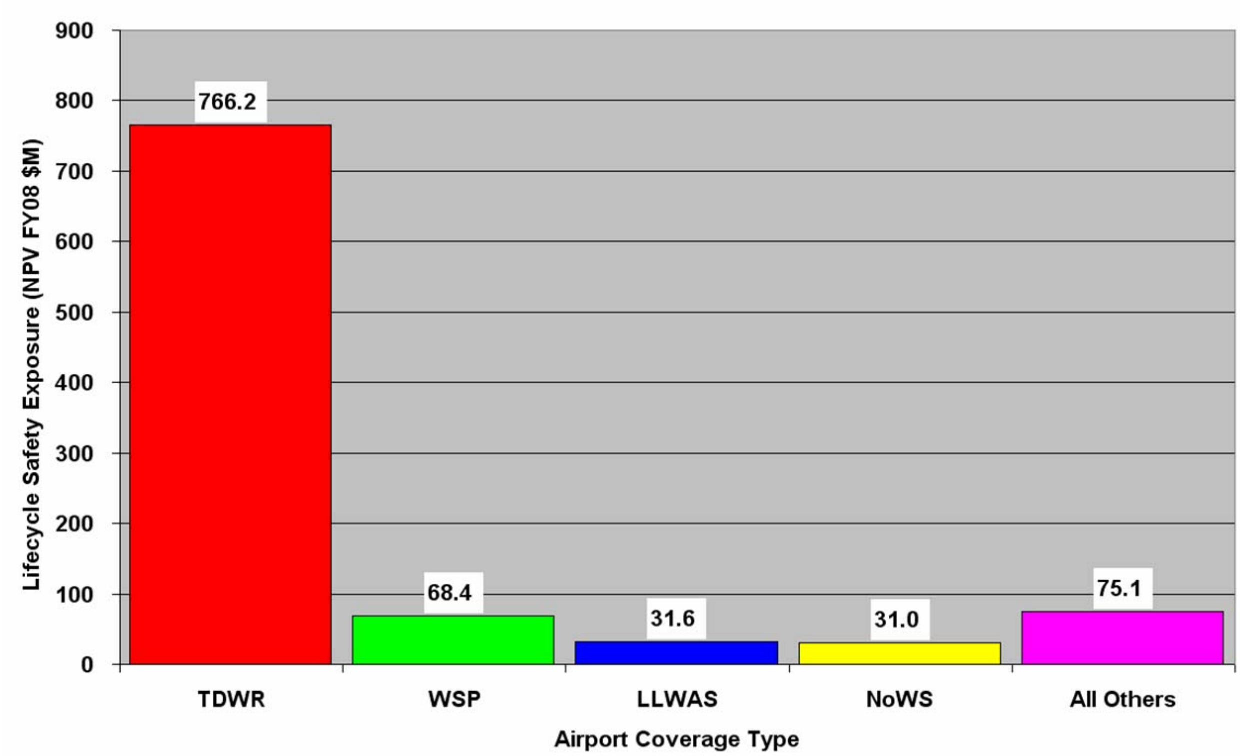

Figure 40. Total safety-related financial safety exposure from wind shear for each by class of airport (present value FY08 $B) based on a NAS protected by pilot training and airborne PWS only.

6.4 BASELINE GROUND-BASED COVERAGE

The current constellation of ground-based wind shear protection systems comprises four configurations: TDWR, TDWR+LLWAS, WSP, and LLWAS. For the TDWR and WSP systems, upgrades to the algorithms and processors are already making their way through the system (reference). The current configuration, without upgrades, reduces safety-related wind shear exposure by 84% ($752M) over that of pilot training and PWS, and results in an overall reduction from an unprotected NAS of 95% ($2.63B) (Figure 41). Systems upgrades reduce the safety exposure at WSP sites by an additional $4.3M and by $56.1M at TDWR sites (Figure 42).

The remaining safety exposure in the system of about $160M from 2010–2032 roughly equates to 1–2 major air carrier accident for the entire NAS over the 22 year period. About 47% of that safety exposure lies in the hundreds of smaller airports that were outside of the 161 airports included in this study. Individually, however, the hundreds of small airports that make up those outside operations have extremely low financial exposure making investments in protection systems uneconomical.

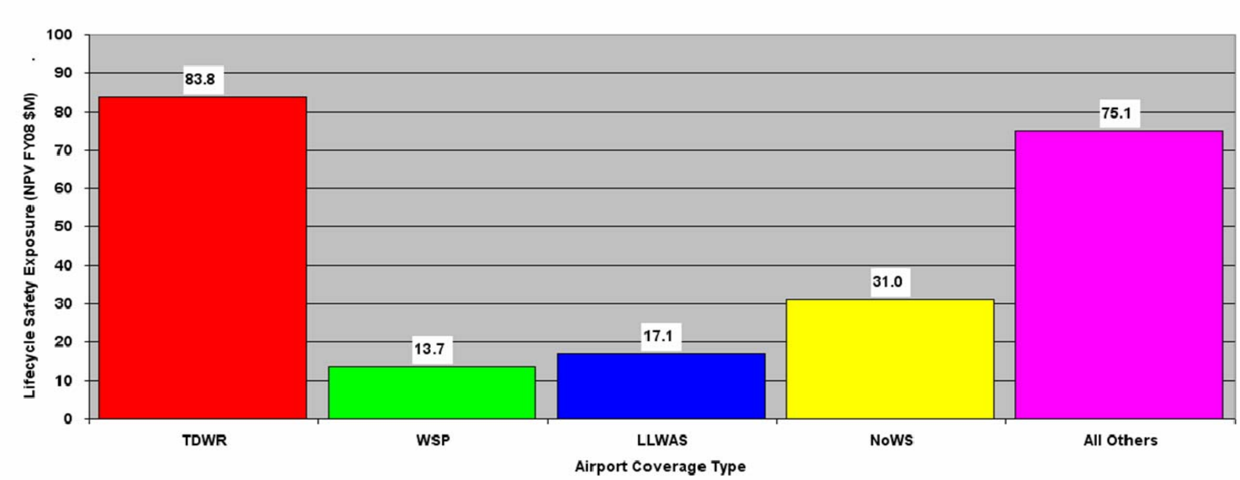

Figure 41. Total safety-related financial safety exposure from wind shear for each by class of airport (present value FY08 $B) based on a NAS protected by pilot training and airborne PWS and current configuration of ground-based wind-shear systems.

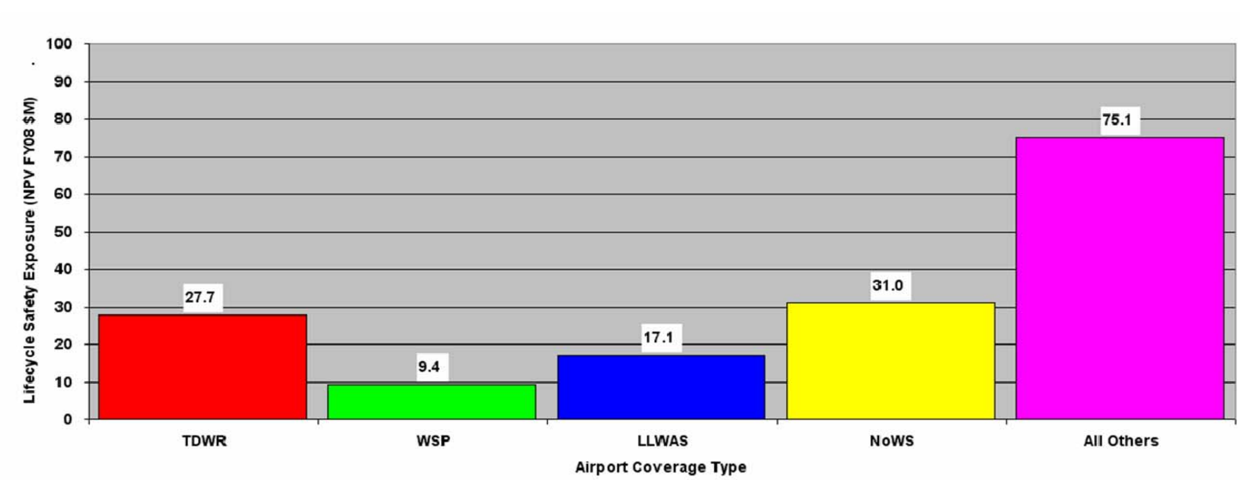

Figure 42. Total safety-related financial safety exposure from wind shear for each by class of airport (present value FY08 $B) based on a NAS protected by pilot training and airborne PWS and current configuration of ground-based wind-shear systems with TDWR and WSP upgrades.

Delay savings due to wind shift prediction and planning from gust front detection, as discussed in section 4.2, are significant for ground-based systems. The total estimated delay savings due to the upgrade of TDWR and WSP relative to the current baseline is estimated at $40 million over the 2010–32 life cycle. The safety and delay savings for the current and upgraded ground-based wind shear detection systems is shown in Figure 43. Figure 44, shows the breakdown of safety and delay savings for the top 50 highest benefit sites. The TDWR upgrade includes enhancements to reduce range-aliased obscuration of the interest region which allows more wind shears and gust fronts to be detected. The WSP upgrade improves the maximum clutter suppression enhancing WSP's ability to detect weaker wind shears and gust fronts in general.

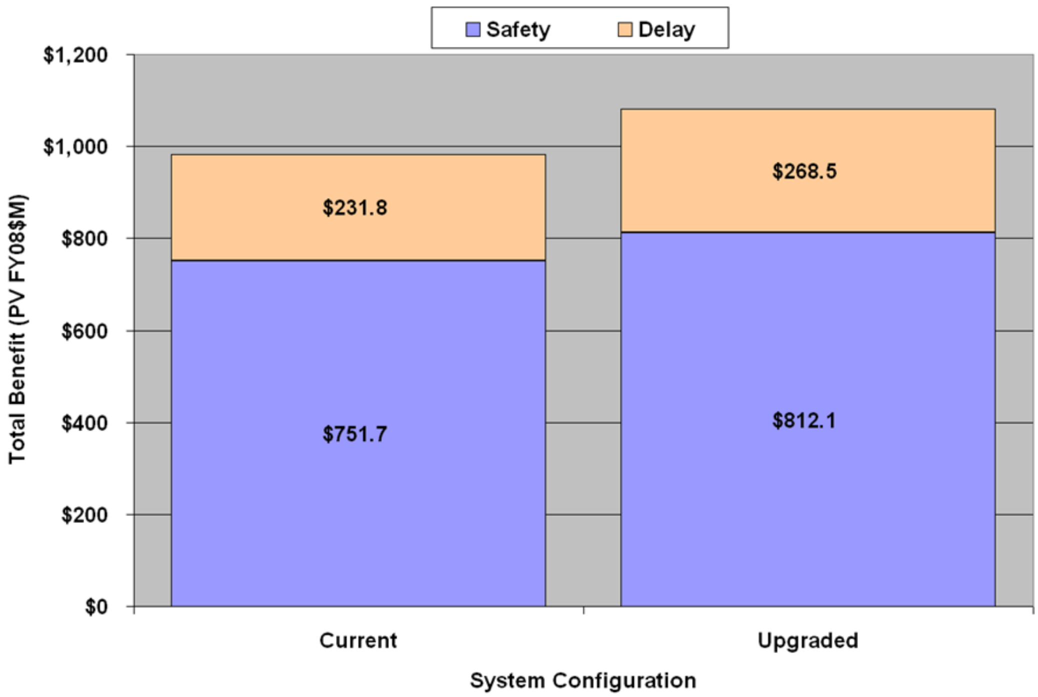

Figure 43. Safety-related savings relative to coverage by pilot training and PWS only and wind-shift delay benefits from gust front detection and forecasting for current and TDWR/WSP upgraded system configuration 2010–32 (present value FY08 $B).

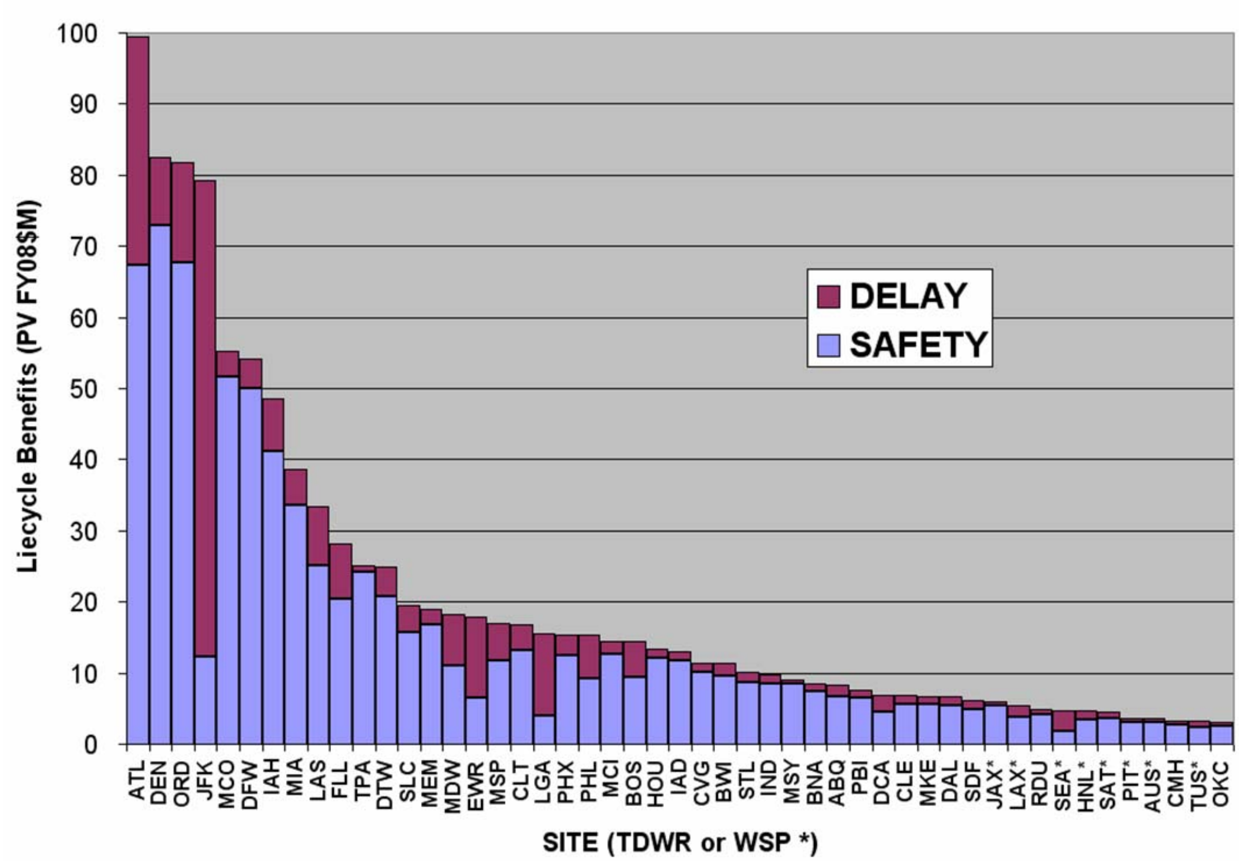

Figure 44. Top 50 sites in terms of total benefits (safety and delay) relative to the NAS as protected by pilot training and PWS for the baseline upgraded wind-shear system configuration (pilot training + PWS + current ground-based + planned upgrades).

7. AIRPORT SPECIFIC COST-BENEFIT RESULTS

The final goal of this report is to determine which of the twenty wind shear system alternatives is the optimal wind shear solution for each site. To make this assessment we utilize an FAA-recommended analysis of Net Present Value (NPV) (FAA, 2008) based on the system costs and overall safety and delay benefits for each site. NPV is calculated by subtracting the cost of the alternative's development and/or operational costs from the estimated benefits of the system. Positive NPV means that a system's benefits outweigh its costs and that therefore safety improvements and/or delay reductions are worth implementing. This analysis also produces the best system configuration to optimize the safety and safety+delay without regard to cost at each site. Table 19 summarizes the study results for each site by showing: (a) the current wind shear protection system (b) the optimal (largest positive NPV) alternative based solely on safety benefits (c) the optiumal (largest positive NPV) alternative based on safety+delay (d) the alternative that maximizes the safety benefit irrespective of cost and (e) the alternative that maximizes the safety+delay benefit irrespective of cost. Detailed summaries by current site configuration and by sensor type are given in the subsections that follow. Complete results of safety and delay benefits for each airport are shown in Appendix D. In addition, the NPV calculations are given in Appendix E (based on safety + delay) and Appendix F (based on safety only) and summarized in this section.

TABLE 19

Study results summary showing optimal alternatives and maximum coverage alternatives for safety and safety+delay (* indicates different system chosen between safety and safety+delay choice)

Site Name	Current System	Optimal System Based on Safety Only	Optimal System Based on Safety+Delay		Best Alternative Based on Maximum Safety Coverage	Best Alternative Based on Maximum Safety&Delay Coverage	
ABE	NoWS	None	None		X-Band & LLWAS	X-Band & LLWAS	
ABQ	WSP	NEXRAD	NEXRAD		WSP, NEXRAD, LLWAS	WSP, NEXRAD, LIDAR	*
ADW	TDWR	None	None		TDWR,NEXRAD,LIDAR	TDWR,NEXRAD,LIDAR	
AGS	LLWAS	None	None		X-Band & LLWAS	X-Band & LLWAS	
ALB	WSP	WSP	WSP		WSP & LIDAR	X-Band & LLWAS	*
AMA	NoWS	NEXRAD	NEXRAD		NEXRAD & LLWAS	NEXRAD & LLWAS	
ASE	NoWS	None	None		X-Band & LIDAR	X-Band & LIDAR	
ATL	TDWR&LLWAS	NEXRAD & LLWAS	NEXRAD & LLWAS		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
AUS	WSP	WSP	WSP		X-Band & LLWAS	X-Band & LLWAS	
AVL	LLWAS	None	None		X-Band & LLWAS	X-Band & LLWAS	

Site Name	Current System	Optimal System Based on Safety Only	Optimal System Based on Safety+Delay		Best Alternative Based on Maximum Safety Coverage	Best Alternative Based on Maximum Safety&Delay Coverage	
AVP	NoWS	None	None		X-Band & LLWAS	X-Band & LLWAS	
AZO	NoWS	None	None		X-Band & LLWAS	X-Band & LLWAS	
BDL	WSP	WSP	WSP		WSP & LIDAR	WSP & LIDAR	
BGM	NoWS	None	None		NEXRAD & LLWAS	NEXRAD & LLWAS	
BHM	WSP	NEXRAD	NEXRAD		WSP, NEXRAD, LLWAS	WSP, NEXRAD, LLWAS	
BIL	LLWAS	NEXRAD	NEXRAD		NEXRAD & LIDAR	NEXRAD & LIDAR	
BIS	NoWS	None	None		X-Band & LIDAR	X-Band & LIDAR	
BNA	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
BOI	NoWS	NEXRAD	NEXRAD		NEXRAD & LLWAS	NEXRAD & LLWAS	
BOS	TDWR	NEXRAD	TDWR	*	TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
BTR	LLWAS	None	None		X-Band & LLWAS	X-Band & LLWAS	
BTV	NoWS	NEXRAD	NEXRAD		NEXRAD & LLWAS	NEXRAD & LLWAS	
BUF	WSP	NEXRAD	NEXRAD		WSP, NEXRAD, LLWAS	X-Band & LLWAS	*
BUR	NoWS	None	None		WSP & LIDAR	WSP & LIDAR	
BWI	TDWR	TDWR	TDWR		TDWR,NEXRAD,LIDAR	TDWR,NEXRAD,LIDAR	
CAE	LLWAS	NEXRAD	NEXRAD		NEXRAD & LLWAS	NEXRAD & LLWAS	
CAK	NoWS	TDWR	TDWR		TDWR,NEXRAD,LIDAR	TDWR,NEXRAD,LIDAR	
CHA	LLWAS	None	None		X-Band & LLWAS	X-Band & LLWAS	
CHS	WSP	WSP	WSP		X-Band & LLWAS	X-Band & LLWAS	
CID	WSP	None	None		X-Band & LLWAS	X-Band & LLWAS	
CLE	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
CLT	TDWR	TDWR	TDWR		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
CMH	TDWR	TDWR	TDWR		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
CMI	NoWS	None	None		X-Band & LLWAS	X-Band & LLWAS	
COS	LLWAS	NEXRAD	NEXRAD		X-Band & LLWAS	X-Band & LLWAS	
CRP	NoWS	None	NEXRAD	*	NEXRAD & LLWAS	X-Band & LLWAS	*
CRW	LLWAS	None	None		NEXRAD & LLWAS	NEXRAD & LLWAS	
CSG	LLWAS	None	None		X-Band & LIDAR	X-Band & LIDAR	
CVG	TDWR	TDWR	TDWR		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
DAB	LLWAS	LLWAS	LLWAS		X-Band & LLWAS	X-Band & LLWAS	
DAL	TDWR	NEXRAD	TDWR	*	TDWR, NEXRAD, LLWAS	TDWR,NEXRAD,LIDAR	*

Site Name	Current System	Optimal System Based on Safety Only	Optimal System Based on Safety+Delay		Best Alternative Based on Maximum Safety Coverage	Best Alternative Based on Maximum Safety&Delay Coverage	
DAY	TDWR	None	None		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
DCA	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
DEN	TDWR&LLWAS	NEXRAD & LLWAS	NEXRAD & LLWAS		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
DFW	TDWR&LLWAS	NEXRAD & LLWAS	NEXRAD & LLWAS		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
DSM	WSP	NEXRAD	NEXRAD		WSP, NEXRAD, LLWAS	WSP, NEXRAD, LIDAR	*
DTW	TDWR	TDWR	TDWR		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
ELP	WSP	WSP	WSP		X-Band & LLWAS	WSP, NEXRAD, LIDAR	*
ERI	NoWS	None	None		X-Band & LIDAR	X-Band & LIDAR	
EVV	NoWS	None	None		X-Band & LLWAS	X-Band & LLWAS	
EWR	TDWR	TDWR	TDWR		X-Band & LLWAS	X-Band & LLWAS	
FAR	NoWS	None	None		X-Band & LIDAR	X-Band & LIDAR	
FAY	LLWAS	None	None		X-Band & LIDAR	X-Band & LIDAR	
FLL	TDWR	NEXRAD	TDWR & NEXRAD	*	TDWR, NEXRAD, LLWAS	TDWR,NEXRAD,LIDAR	*
FNT	NoWS	NEXRAD	NEXRAD		X-Band & LLWAS	X-Band & LLWAS	
FSD	LLWAS	NEXRAD	NEXRAD		X-Band & LIDAR	X-Band & LIDAR	
FSM	LLWAS	None	None		NEXRAD & LLWAS	NEXRAD & LLWAS	
FWA	WSP	None	None		X-Band & LIDAR	X-Band & LIDAR	
GCN	NoWS	None	None		X-Band & LIDAR	X-Band & LIDAR	
GEG	WSP	NEXRAD	NEXRAD		WSP, NEXRAD, LIDAR	WSP, NEXRAD, LIDAR	
GFK	NoWS	None	NEXRAD	*	X-Band & LLWAS	X-Band & LLWAS	
GPT	NoWS	None	None		X-Band & LLWAS	X-Band & LLWAS	
GRB	LLWAS	None	None		NEXRAD & LIDAR	X-Band & LIDAR	*
GRR	WSP	NEXRAD	NEXRAD		WSP, NEXRAD, LLWAS	NEXRAD & LLWAS	*
GSO	WSP	WSP	WSP		WSP & LIDAR	WSP & LIDAR	
GSP	LLWAS	None	None		NEXRAD & LLWAS	X-Band & LLWAS	*
HNL	WSP	WSP	WSP		WSP & LIDAR	WSP & LIDAR	
HOU	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
HPN	WSP	None	WSP	*	WSP, NEXRAD, LIDAR	X-Band & LLWAS	*
HSV	WSP	None	None		WSP & LIDAR	X-Band & LLWAS	*

Site Name	Current System	Optimal System Based on Safety Only	Optimal System Based on Safety+Delay		Best Alternative Based on Maximum Safety Coverage	Best Alternative Based on Maximum Safety&Delay Coverage	
IAD	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
IAH	TDWR	TDWR & NEXRAD	TDWR & NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
ICT	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
ILM	NoWS	NEXRAD	NEXRAD		X-Band & LLWAS	X-Band & LLWAS	
IND	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
ISP	WSP	NEXRAD	NEXRAD		WSP, NEXRAD, LIDAR	WSP, NEXRAD, LIDAR	
JAN	LLWAS	NEXRAD	NEXRAD		NEXRAD & LLWAS	NEXRAD & LLWAS	
JAX	WSP	NEXRAD	NEXRAD		WSP, NEXRAD, LLWAS	NEXRAD & LLWAS	*
JFK	TDWR	TDWR	TDWR		TDWR, NEXRAD, LLWAS	X-Band & LLWAS	*
LAN	LLWAS	None	None		X-Band & LIDAR	X-Band & LIDAR	
LAS	TDWR	TDWR & LIDAR	WSP & LIDAR	*	WSP & LIDAR	WSP & LIDAR	
LAX	WSP	WSP	WSP		X-Band & LIDAR	X-Band & LIDAR	
LBB	WSP	NEXRAD	NEXRAD		WSP, NEXRAD, LLWAS	X-Band & LLWAS	*
LEX	LLWAS	None	None		X-Band & LLWAS	X-Band & LLWAS	
LFT	NoWS	None	None		X-Band & LLWAS	X-Band & LLWAS	
LGA	TDWR&LLWAS	LLWAS	TDWR	*	TDWR, NEXRAD, LLWAS	TDWR & LIDAR	*
LGB	NoWS	None	None		X-Band & LLWAS	X-Band & LLWAS	
LIT	LLWAS	NEXRAD	NEXRAD		NEXRAD & LLWAS	NEXRAD & LLWAS	
LNK	LLWAS	None	None		X-Band & LLWAS	X-Band & LLWAS	
MAF	LLWAS	NEXRAD	NEXRAD		NEXRAD & LLWAS	X-Band & LLWAS	*
MBS	NoWS	None	None		X-Band & LLWAS	X-Band & LLWAS	
MCI	TDWR	TDWR	TDWR		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
MCO	TDWR&LLWAS	TDWR & LLWAS	TDWR & LLWAS		X-Band & LLWAS	X-Band & LLWAS	
MDT	WSP	None	None		WSP & LIDAR	WSP & LIDAR	
MDW	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
MEM	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
MGM	LLWAS	None	None		X-Band & LLWAS	X-Band & LLWAS	

Site Name	Current System	Optimal System Based on Safety Only	Optimal System Based on Safety+Delay		Best Alternative Based on Maximum Safety Coverage	Best Alternative Based on Maximum Safety&Delay Coverage	
MHT	NoWS	None	None		WSP & LIDAR	WSP & LIDAR	
MIA	TDWR	NEXRAD	NEXRAD & LLWAS	*	TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
MKE	TDWR	TDWR	TDWR		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
MLI	LLWAS	None	NEXRAD	*	NEXRAD & LIDAR	NEXRAD & LIDAR	
MLU	LLWAS	None	None		X-Band & LLWAS	X-Band & LLWAS	
MOB	LLWAS	NEXRAD	NEXRAD		NEXRAD & LLWAS	X-Band & LLWAS	*
MSN	WSP	None	None		X-Band & LLWAS	X-Band & LLWAS	
MSP	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
MSY	TDWR&LLWAS	TDWR	TDWR		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
MYR	NoWS	NEXRAD	NEXRAD		X-Band & LIDAR	X-Band & LIDAR	
OAK	NoWS	None	None		WSP & LIDAR	WSP & LIDAR	
OKC	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
OMA	LLWAS	NEXRAD	NEXRAD		NEXRAD & LIDAR	NEXRAD & LIDAR	
ONT	WSP	WSP	WSP		WSP & LIDAR	X-Band & LLWAS	*
ORD	TDWR&LLWAS	TDWR & LLWAS	TDWR, NEXRAD, LLWAS	*	TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
ORF	WSP	WSP	WSP		X-Band & LIDAR	X-Band & LIDAR	
ORL	NoWS	TDWR	TDWR		TDWR, NEXRAD, LLWAS	TDWR,NEXRAD,LIDAR	*
PBI	TDWR	TDWR	TDWR		X-Band & LLWAS	X-Band & LLWAS	
PDK	NoWS	TDWR	TDWR		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
PDX	WSP	WSP	WSP		WSP & LIDAR	WSP & LIDAR	
PHF	NoWS	NEXRAD	NEXRAD		NEXRAD & LIDAR	X-Band & LIDAR	*
PHL	TDWR	TDWR	TDWR		TDWR,NEXRAD,LIDAR	TDWR,NEXRAD,LIDAR	
PHX	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	WSP, NEXRAD, LIDAR	*
PIA	LLWAS	None	None		X-Band & LIDAR	X-Band & LIDAR	
PIE	NoWS	TDWR	TDWR		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
PIT	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
PNS	LLWAS	None	None		X-Band & LLWAS	X-Band & LLWAS	
PVD	LLWAS	NEXRAD	NEXRAD		NEXRAD & LIDAR	NEXRAD & LIDAR	

Site Name	Current System	Optimal System Based on Safety Only	Optimal System Based on Safety+Delay		Best Alternative Based on Maximum Safety Coverage	Best Alternative Based on Maximum Safety&Delay Coverage	
PWM	NoWS	None	NEXRAD	*	WSP, NEXRAD, LIDAR	WSP, NEXRAD, LIDAR	
RDU	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
RIC	WSP	NEXRAD	NEXRAD		WSP, NEXRAD, LIDAR	X-Band & LIDAR	*
RNO	NoWS	LLWAS	NEXRAD & LLWAS	*	X-Band & LIDAR	X-Band & LIDAR	
ROA	LLWAS	None	None		X-Band & LLWAS	X-Band & LLWAS	
ROC	WSP	WSP	WSP		X-Band & LLWAS	X-Band & LLWAS	
RST	LLWAS	None	None		X-Band & LLWAS	X-Band & LLWAS	
RSW	LLWAS	LLWAS	NEXRAD & LLWAS	*	X-Band & LLWAS	X-Band & LLWAS	
SAN	NoWS	None	None		X-Band & LLWAS	WSP & LIDAR	*
SAT	WSP	NEXRAD	NEXRAD		WSP, NEXRAD, LIDAR	WSP, NEXRAD, LIDAR	
SAV	LLWAS	LLWAS	NEXRAD & LLWAS	*	X-Band & LIDAR	X-Band & LIDAR	
SBN	NoWS	None	None		X-Band & LIDAR	X-Band & LIDAR	
SDF	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
SEA	WSP	WSP	WSP		X-Band & LLWAS	X-Band & LLWAS	
SFB	NoWS	TDWR	TDWR		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
SFO	LLWAS	None	NEXRAD & LLWAS	*	X-Band & LLWAS	X-Band & LLWAS	
SGF	LLWAS	NEXRAD	NEXRAD		NEXRAD & LLWAS	NEXRAD & LLWAS	
SHV	LLWAS	NEXRAD	NEXRAD		NEXRAD & LLWAS	X-Band & LLWAS	*
SJC	NoWS	None	None		WSP & LIDAR	WSP & LIDAR	
SJU	TDWR	None	TDWR	*	TDWR, NEXRAD, LLWAS	TDWR & LIDAR	*
SLC	TDWR	TDWR	TDWR		TDWR & LIDAR	TDWR & LIDAR	
SMF	NoWS	NEXRAD	NEXRAD		WSP, NEXRAD, LLWAS	WSP, NEXRAD, LIDAR	*
SNA	NoWS	None	None		X-Band & LIDAR	X-Band & LIDAR	
SPI	LLWAS	None	None		X-Band & LLWAS	X-Band & LLWAS	
SRQ	WSP	NEXRAD	NEXRAD		WSP, NEXRAD, LLWAS	WSP, NEXRAD, LLWAS	
STL	TDWR&LLWAS	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
SUX	LLWAS	None	None		X-Band & LIDAR	X-Band & LIDAR	
SYR	WSP	None	None		X-Band & LIDAR	X-Band & LIDAR	
TLH	LLWAS	NEXRAD	NEXRAD		X-Band & LIDAR	X-Band & LIDAR	

Site Name	Current System	Optimal System Based on Safety Only	Optimal System Based on Safety+Delay		Best Alternative Based on Maximum Safety Coverage	Best Alternative Based on Maximum Safety&Delay Coverage	
TOL	WSP	None	None		WSP & LIDAR	X-Band & LIDAR	*
TPA	TDWR&LLWAS	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
TRI	LLWAS	None	None		X-Band & LLWAS	X-Band & LLWAS	
TUL	TDWR	NEXRAD	NEXRAD		TDWR, NEXRAD, LLWAS	TDWR, NEXRAD, LLWAS	
TUS	WSP	WSP	WSP		X-Band & LLWAS	X-Band & LLWAS	
TWF	NoWS	None	None		X-Band & LIDAR	X-Band & LIDAR	
TYS	WSP	None	None		WSP & LIDAR	WSP & LIDAR	

Note that only existing TDWR installations are utilized for TDWR alternatives, therefore, benefits for this class of alternative were not calculated for sites that did not have a TDWR available (these sites appear as N/A in Appendix C through F). New WSP installations, are only considered where an ASR-9 currently exists (most TDWR locations) and also show as N/A in the Appendices. Similarly, new LLWAS installations are conisderd at non-LLWAS sites. Conversely, X-band and LIDAR alternatives assume that a new system will be installed at all sites. NEXRAD systems were evaluated everywhere, even in cases where the nearest NEXRAD turned out to be too far away. So, NEXRAD based alternatives have entries in the Appendices which may default to the secondary sensor's effectiveness if NEXRAD is too far away to add value or zero if we are considering just NEXRAD.

Additionally, when the optimal solution is "None" this means that none of the alternatives were considered cost effective (NPV > 0). This doesn't mean that the alternative didn't provide safety and/or delay benefits only that the cost of operations was higher than those benefits.

In evaluating the various combinations of alternatives, most comparisons are made relative to the NAS as protected by pilot training and PWS (see Section 6.3) or as protected by the upgraded ground-based system configuration, called "baseline" henceforth (see Section 6.4), although other comparisons may be made where appropriate. As noted above, the upgraded ground-based coverage yields a total safety-related benefit for the 161 study airports of $812 million and a wind shift delay savings benefit of $269 million from 2010–32, or $ 77.1 and $ 25.5 million annually, respectively.

While each optimal alternative yields an increase in the benefits relative to the upgraded baseline, the total increase in the benefits stream if every alternative listed were to be employed is approximately $76 million ($7.3 million annually), or roughly a 7% increase from the baseline 2010–32 benefits.

7.1 ALTERNATIVE SYSTEM ASSESSMENT BY CURRENT SITE CONFIGURATION

As described above, the availability of some alternatives such as TDWR and WSP are limited by the current configuration. Therefore, it is instructive to examine the relative worth of system alternatives grouped by site type. The contingency tables shown in Tables 20 and 21 shows the number of times a particular wind shear system alternative was chosen as the optimal solution for each airport protection configuration. Table 20 is based on only the safety benefits value, while Table 21 uses both safety and delay savings. Alternatives that aren't shown didn't have any sites where they were the optimal system.

TABLE 20

Frequency table of optimal systems by current airport protection based on NPV calculations that consider only safety

Optimal System	Current Configuration					
	TDWR&LLWAS	TDWR	WSP	LLWAS	NoWS	Total
TDWR & LLWAS	2					2
TDWR	1	12			5	18
TDWR & NEXRAD		1				1
TDWR, NEXRAD, LLWAS						0
TDWR & LIDAR		1				1
WSP			14			14
WSP & LIDAR						0
LLWAS	1			3	1	5
NEXRAD & LLWAS	3					3
NEXRAD	2	20	12	13	8	55
None		3	9	24	26	62
Total	9	37	35	40	40	161

TABLE 21

Frequency table of optimal systems by current airport protection based on NPV calculations that consider both safety and delay benefits

Optimal System	Current Configuration					
	TDWR&LLWAS	TDWR	WSP	LLWAS	NoWS	Total
TDWR & LLWAS	1					1
TDWR	2	15			5	22
TDWR & NEXRAD		2				2
TDWR, NEXRAD, LLWAS	1					1
TDWR & LIDAR						0
WSP			15			15
WSP & LIDAR		1				1
LLWAS				1		1
NEXRAD & LLWAS	3	1		3	1	8
NEXRAD	2	16	12	14	11	55
None		2	8	22	23	55
Total	9	37	35	40	40	161

7.1.1 Safety Only Analysis

Looking strictly at the safety benefits of the system without implementation and operating costs allows us to examine the systems that could potentially provide the highest safety improvements at each site. Table 19 shows the individual site results for the best safety improvement alternative at each site, but there are general trends that are summarized here. Figures 45 through 48 show the ranking of alternative systems by changes in safety benefit for each grouping of ground-based sites: TDWR, WSP, LLWAS and unprotected. All alternatives are measured against the baseline configuration, so the entry for UPGRADED will always show zero. Alternatives to the right of UPGRADED provide increased safety improvements from the baseline and those to the left indicate reductions. In addition, for these safety charts the top of the chart reflects the maximum safety benefit that could be achieved (zero accidents).

Looking at Figure 45, the TDWR sites have few options that can provide overall safety improvements. However, integrating sensors to the TDWR is beneficial over the current system and all the positive options include the TDWR as a base sensor. Figure 46 shows the ranking for WSP sites, and like TDWR, adding a sensor to complement the WSP is beneficial. But, in addition, X-band combinations also yield improved safety benefits. LLWAS sites, shown in Figure 47, have far fewer options because no TDWR or WSP radars are co-located with these sites. However, NEXRAD based systems provide significant safety benefits and an on-airport X-band weather radars are by far the best alternative.

Finally, unprotected sites are shown in Figure 48, and here every alternative shows some benefit. TDWR offers some benefits to this class of site as five unprotected sites are near enough to an existing TDWR to be partially covered if upgrades were made for processing and displays (CAK, ORL, PDK, PIE, and SFB). WSP also has coverage through the potential to upgrade existing ASR-9s at BUR, LGB, MHT, OAK, ORL, PDK, PIE, PWM, SAN, SJC, SMF, and SNA. NEXRAD based system with LLWAS or LIDAR gain almost half of the remaining potential safety benefit. X-band combinations are again the best performers for these unprotected sites, but that is primarily because the system is 'available' at all sites.

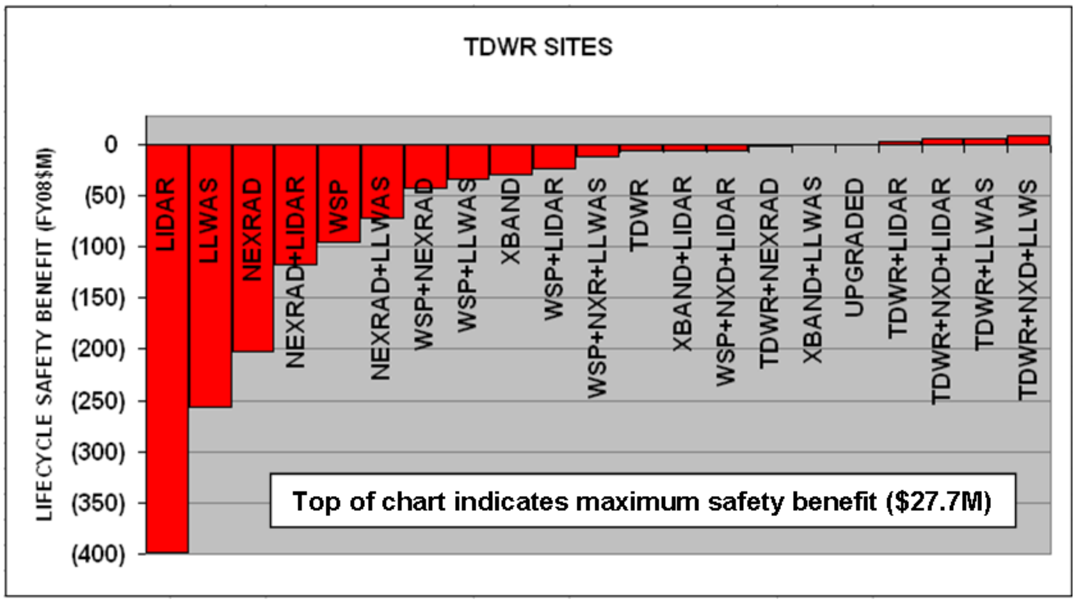

Figure 45. Annual benefit gain or loss relative to baseline (UPGRADED) for alternatives being deployed at all TDWR and TDWR-LLWAS study airports.

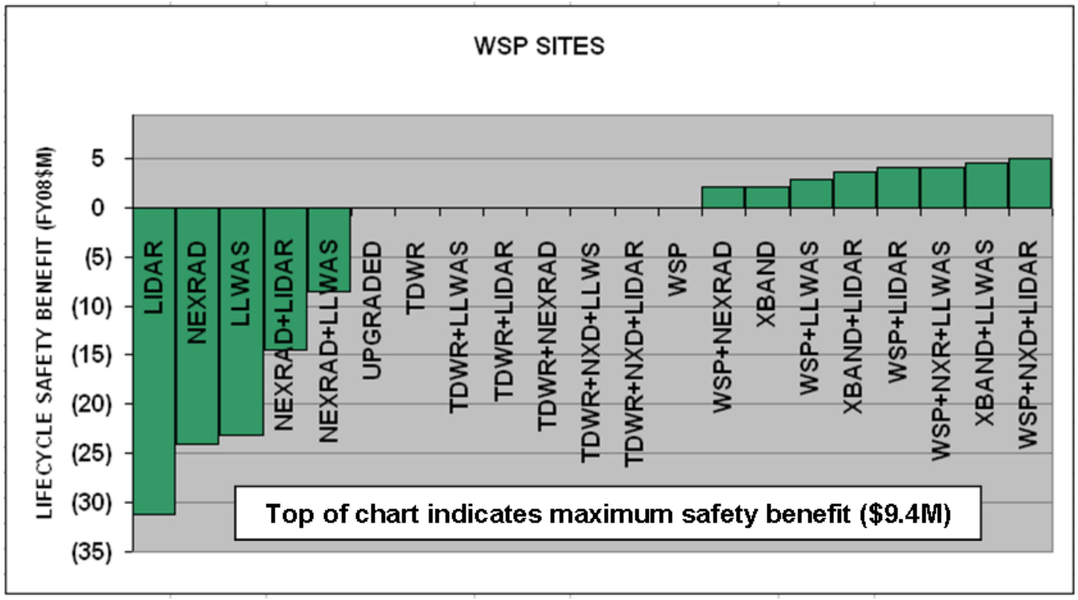

Figure 46. Annual safety benefit gain or loss relative to baseline (UPGRADED) for alternatives being deployed at all WSP study airports.

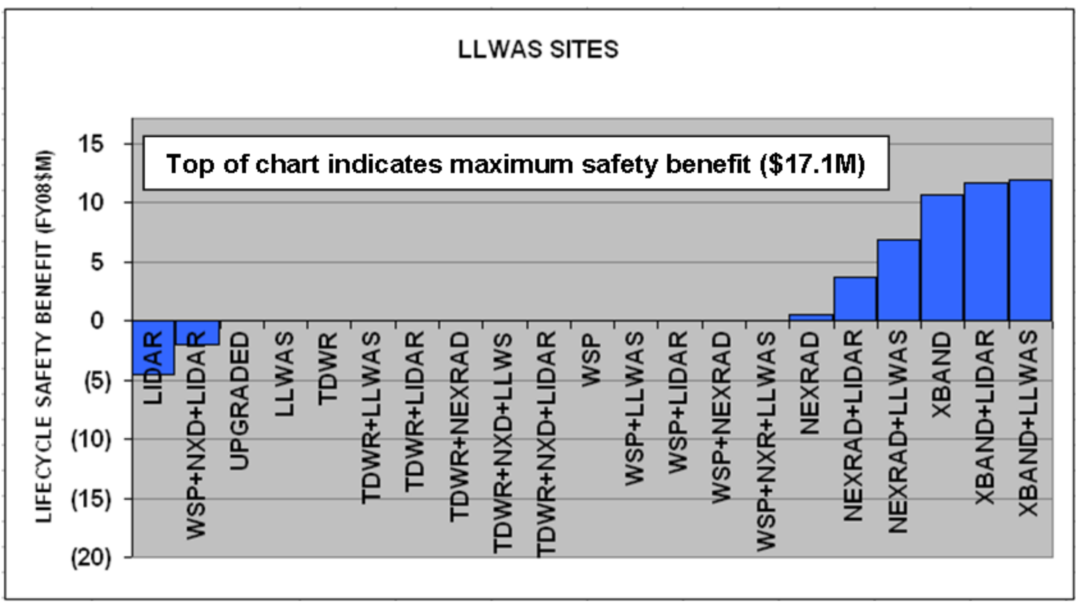

Figure 47. Annual safety benefit gain or loss relative to baseline (UPGRADED) for alternatives being deployed at all LLWAS study airports.

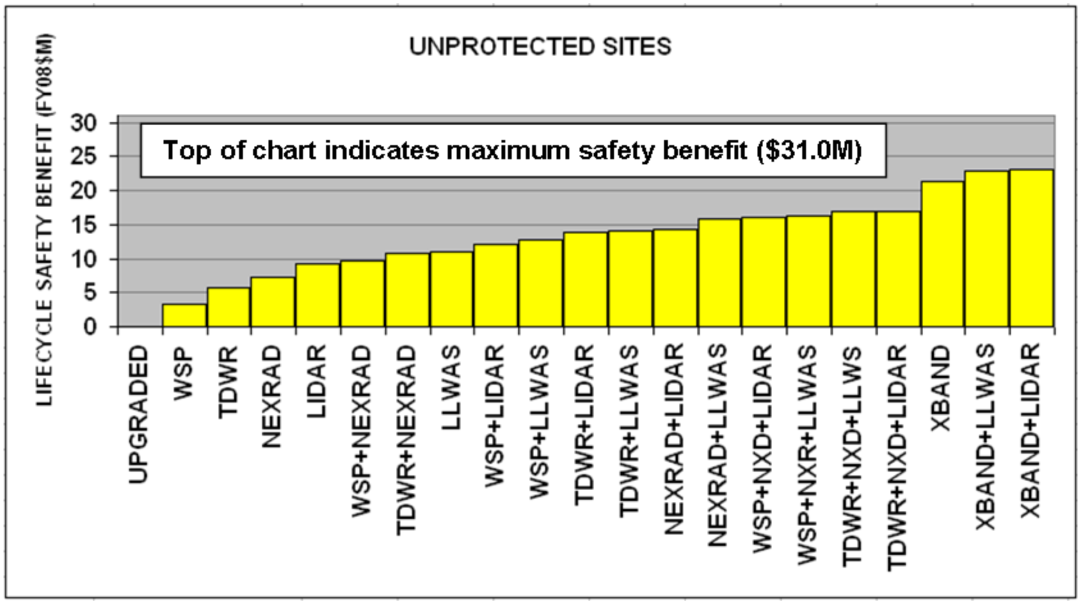

Figure 48. Annual safety benefit gain or loss relative to baseline (UPGRADED) for alternatives being deployed at all study airports with no current ground-based wind-shear system.

7.1.2 TDWR-LLWAS Sites

There are currently nine TDWR sites that have an integrated wind shear system that is enhanced by LLWAS sensors. Table 22 shows the optimal alternative chosen and the corresponding NPV for safety and delay. In addition, the table compares the optimal NPV to the current TDWR-LLWAS NPV. Note that the overall benefit gained by choosing the optimal installation at each site yields a 3% increase in overall benefits ($10.9 million). The high value of these busy sites is underscored by the fact that all but two of the 20 alternatives assessed at all 9 sites had positive NPV values.

The predominance of NEXRAD in the mix of optimal alternatives is common throughout all sites. This is discussed further in Section 8.3 that summarizes results by sensor type.

TABLE 22

Comparison of optimal alternative vs. current wind-shear protection system for TDWR-LLWAS sites (safety + delay)

Site	Optimal Configuration	TDWR-LLWAS Life Cycle NPV (FY08$M)	Optimal Life Cycle NPV (FY08$M)
ATL	NEXRAD&LLWAS	$ 96.4	$ 99.2
DEN	NEXRAD&LLWAS	$ 79.4	$ 81.1
DFW	NEXRAD&LLWAS	$ 51.1	$ 52.0
LGA	TDWR	$ 12.4	$ 12.8
MCO	TDWR&LLWAS	$ 52.1	$ 52.1
MSY	TDWR	$ 5.9	$ 6.3
ORD	TDWR,NEXRAD,LLWAS	$ 78.8	$ 79.0
STL	NEXRAD	$ 6.9	$ 9.0
TPA	NEXRAD	$ 22.0	$ 24.4
TOTAL		$ 405.0	$ 415.9

7.1.3 TDWR Sites

There are 37 sites with TDWR-only installations; of these there are 15 where the optimal configuration is a single sensor TDWR. In addition, 3 sites have the TDWR enhanced with an additional sensor (NEXRAD or LIDAR). Table 23 shows the optimal alternative chosen and the corresponding NPV for safety and delay for each site that did not have TDWR as the optimal choice. The increased net benefit from choosing the optimal system for each site increases the total overall benefit at these sites by approximately $32.6 million.

TABLE 23

Comparison of optimal alternative vs. current wind-shear protection system for TDWR sites (safety + delay)

Site	Optimal Configuration	TDWR Life Cycle NPV (FY08$M)	Optimal Life Cycle NPV (FY08$M)
IAH	TDWR&NEXRAD	$ 46.06	$ 46.34
MIA	NEXRAD&LLWAS	$ 36.04	$ 37.31
LAS	WSP&LIDAR	$ 30.87	$ 33.54
FLL	TDWR&NEXRAD	$ 25.56	$ 25.83
MEM	NEXRAD	$ 16.36	$ 17.88
MDW	NEXRAD	$ 15.72	$ 17.21
PHX	NEXRAD	$ 12.85	$ 16.27
MSP	NEXRAD	$ 14.45	$ 15.95
HOU	NEXRAD	$ 10.78	$ 12.36
IAD	NEXRAD	$ 10.50	$ 10.90
IND	NEXRAD	$ 7.27	$ 8.93
BNA	NEXRAD	$ 5.88	$ 7.37
CLE	NEXRAD	$ 4.36	$ 6.02
DCA	NEXRAD	$ 4.41	$ 5.49
SDF	NEXRAD	$ 3.60	$ 5.26
RDU	NEXRAD	$ 2.44	$ 3.95
PIT	NEXRAD	$ 1.16	$ 2.94
OKC	NEXRAD	$ 0.59	$ 2.32
TUL	NEXRAD	$ 0.13	$ 1.90
ICT	NEXRAD	$ (0.32)	$ 1.34
DAY	None	$ (0.53)	$ (0.13)
ADW	None	$ (2.49)	$ (0.71)
TOTAL		$ 460.3	$ 492.9

Two sites (ADW and DAY) have no alternatives that produce a positive NPV; an additional site drops out (SJU) if we only consider safety benefits. Andrews AFB (ADW) is protected by a TDWR due almost entirely to its military importance. Dayton, Ohio (DAY) has relatively low air traffic operations for a TDWR site and its exposure to wind shear is also limited. SJU has a relatively low volume of traffic and low wind shear frequency (note however that the climatology of wind shear for SJU was sparse). Of the remaining 22 sites, 16 have NEXRAD as the optimal system.

7.1.4 WSP Sites

There are 35 WSP protected airports in the NAS and the optimal alternatives analysis yielded 15 sites where WSP was chosen as the best option while 12 sites had NEXRAD as the most cost-beneficial system. There were also eight sites where no cost beneficial system could be found (CID, FWA, HPN, HSV, MSN, SYR, TOL, and TYS). However, the least negative NPV for these sites were either WSP (4) or NEXRAD (4). The NPV for the 20 sites where WSP was *not* chosen as the optimal alternative are shown in Table 24.

TABLE 24

Life Cycle NPV comparisons for WSP sites with non-WSP optimal alternatives (safety + delay)

Site	Optimal Alternative	WSP Life Cycle NPV (FY08$M)	Optimal Life Cycle NPV (FY08$M)
ABQ	NEXRAD	$7.34	8.29
JAX	NEXRAD	$5.06	6.51
SAT	NEXRAD	$3.60	4.30
BHM	NEXRAD	$1.47	2.28
GEG	NEXRAD	$1.53	2.27
SRQ	NEXRAD	$1.42	2.08
BUF	NEXRAD	$0.94	1.63
LBB	NEXRAD	$0.59	1.23
ISP	NEXRAD	$0.27	1.01
DSM	NEXRAD	$0.30	0.95
GRR	NEXRAD	($0.06)	0.56
RIC	NEXRAD	$0.41	0.49
Totals		$22.87	$31.60

7.1.5 LLWAS Sites

Unlike TDWR and to some extent WSP sites, there are only up to 3 alternatives that yielded positive NPV at LLWAS sites: LLWAS, NEXRAD, or a combination of the two. Of the 40 LLWAS protected sites, 22 do not have a cost beneficial alternative and just one has an LLWAS only system. NEXRAD is the only effective alternative at the remaining 17 sites and LLWAS is used as a complementary system at three of those sites. The NPV for the 18 sites where an optimal alternative was found are shown in Table 25.

TABLE 25

Comparison of optimal alternative vs. current wind-shear protection system for LLWAS sites (safety + delay)

Site	Optimal Alternative	LLWAS Life Cycle NPV (FY08$M)	Optimal Life Cycle NPV (FY08$M)
OMA	NEXRAD	$ 0.43	$ 1.97
RSW	NEXRAD&LLWAS	$ 1.32	$ 1.93
LIT	NEXRAD	$ 0.57	$ 1.78
COS	NEXRAD	$ 0.34	$ 1.49
PVD	NEXRAD	$ -	$ 1.16
BIL	NEXRAD	$ -	$ 0.90
SFO	NEXRAD&LLWAS	$ -	$ 0.73
MAF	NEXRAD	$ -	$ 0.57
DAB	LLWAS	$ 0.56	$ 0.56
CAE	NEXRAD	$ -	$ 0.46
FSD	NEXRAD	$ -	$ 0.45
JAN	NEXRAD	$ -	$ 0.42
TLH	NEXRAD	$ -	$ 0.32
SGF	NEXRAD	$ -	$ 0.27
SHV	NEXRAD	$ -	$ 0.25
MOB	NEXRAD	$ -	$ 0.15
SAV	NEXRAD&LLWAS	$ 0.06	$ 0.09
MLI	NEXRAD	$ -	$ 0.05
Totals		$ 3.29	$ 13.56

7.1.6 Unprotected Sites

There were 40 feeder airport sites examined that are currently unprotected from wind shear. The optimal alternative analysis showed that 22 of those sites indeed do not have a cost beneficial alternative. Interestingly, 5 sites are able to use a nearby existing TDWR installation to provide positive benefits. NEXRAD based alternatives, due primarily to the estimated inexpensive implementation costs, are the optimal alternative at the remaining 12 sites. The NPV and alternative for the 17 sites where an optimal alternative was found are shown in Table 26, along with the corresponding TDWR site location, where appropriate.

TABLE 26

Comparison of optimal alternative vs. current wind-shear protection system for unprotected sites (safety + delay)

Site	Optimal Alternative	Optimal Life Cycle NPV (FY08$M)
SFB	TDWR (MCO)	$ 3.46
PIE	TDWR (TPA)	$ 2.40
BOI	NEXRAD	$ 1.78
PDK	TDWR (ATL)	$ 1.22
SMF	NEXRAD	$ 1.11
ORL	TDWR (MCO)	$ 1.07
CAK	TDWR (CLE)	$ 0.64
AMA	NEXRAD	$ 0.51
PHF	NEXRAD	$ 0.44
RNO	NEXRAD&LLWAS	$ 0.28
GFK	NEXRAD	$ 0.20
FNT	NEXRAD	$ 0.18
BTV	NEXRAD	$ 0.17
MYR	NEXRAD	$ 0.15
PWM	NEXRAD	$ 0.15
ILM	NEXRAD	$ 0.08
CRP	NEXRAD	$ 0.04
Total		$ 13.87

7.2 ALTERNATIVE SYSTEM ASSESSMENT BY SENSOR TYPE

7.2.1 LLWAS Alternatives

LLWAS can be an effective enhancement at sites where microburst detection is difficult from ground-based radar (clutter for example) or where traffic volume is high and the exposure to wind shear is above average. In fact, nine TDWR locations are already enhanced with an expanded LLWAS for exactly these reasons. However, even the expanded LLWAS (NE) configuration typically covers only half of the ARENA coverage area at a typical airport. In addition, because gust front detection is critical in a region much larger than the LLWAS coverage area and requires dense data coverage for reliable detection, LLWAS installations do not add gust front detection capability beyond the airport vicinity. Therefore, LLWAS upgrades also have no impact on delay calculations as wind shift prediction is driven by gust front capability.

For all these reasons, replacing all the current ground-based systems with LLWAS only coverage would result in a significant decrease in safety and delay benefits relative to the baseline upgraded ground-based systems. However, adding LLWAS as a complementary system at some installations can be beneficial. Of the 161 sites, just 10 have optimal alternatives that utilize LLWAS (Table 27).

TABLE 27

Sites where LLWAS is used as a complementary or primary sensor

Site	Current	Complementary optimal LLWAS configuration
ATL	TDWR-LLWAS	NEXRAD & LLWAS
DEN	TDWR-LLWAS	NEXRAD & LLWAS
DFW	TDWR-LLWAS	NEXRAD & LLWAS
MCO	TDWR-LLWAS	TDWR & LLWAS
ORD	TDWR-LLWAS	TDWR, NEXRAD & LLWAS
MIA	TDWR	NEXRAD & LLWAS
DAB	LLWAS	LLWAS
RSW	LLWAS	NEXRAD & LLWAS
SFO	LLWAS	NEXRAD & LLWAS
SAV	LLWAS	NEXRAD & LLWAS

7.2.2 LIDAR Alternatives

LIDAR, by itself, can provide some benefit at all sites, but it is among the lowest performing of the single-senor systems and the implementation expenses make it cost effective only at Las Vegas (LAS). This cost benefit analysis attempts to optimize the net benefits of each alternative. If the focus were increasing the effectiveness of the system, LIDAR based alternatives would be more appropriate alternatives. In fact, from Table 19 we see that alternatives with LIDAR as a complementary system are selected at 53 of the sites when only improved safety coverage is considered. The difference in the choice of LIDAR complemented systems is primarily driven by the relative cost of the LIDAR system rather than by the ability of the system to enhance protection against wind shear.

7.2.3 TDWR Alternatives

Because the TDWR radar was designed and sited specifically for wind shear detection it is generally the best or next best alternative at the sites where it is installed. No new TDWR installations were considered for this analysis. When comparing TDWR, or any other alternatives, to the baseline it should be noted that nine TDWR locations are integrated with LLWAS-NE installations and these are all high benefit sites. Therefore, alternatives such as TDWR + NEXRAD show a loss relative to the baseline because of the loss of the LLWAS integration at those high value sites.

WSP is one potential alternative to the existing TDWR installations; however, in all cases WSP performance would result in a performance degradation compared to the TDWR. Replacing all 45 TDWR or TDWR-LLWAS installations with WSP or WSP-LLWAS configurations, respectively, would result in a loss of $179 million in total life cycle safety and delay benefits ($17 million annually). Figure 49 shows the breakdown of benefit loss by TDWR site location.

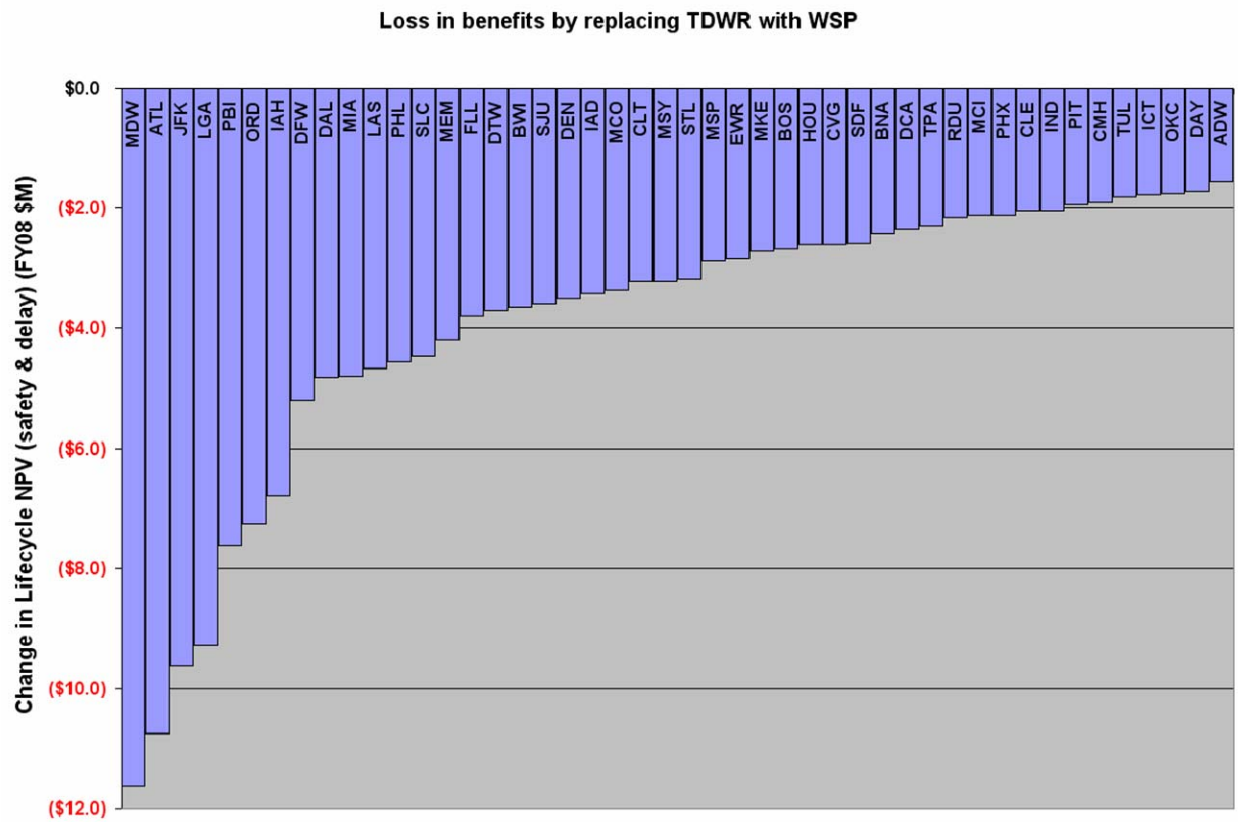

Figure 49. Resulting life cycle benefit loss (safety + delay) from replacing TDWR and TDWR-LLWAS sites with WSP and WSP-LLWAS.

A potential benefit exists at five unprotected study airports that are close enough to be covered by existing TDWR installations (CAK, ORL, PDK, PIE, and SFB). All of these airports currently have no ground-based coverage and the total added benefit would be $8.79 million, as shown in Table 28. No TDWRs are close enough to LLWAS-only sites to provide wind shear benefits.

TABLE 28

Unprotected sites that would benefit from coverage of an existing TDWR

Site	Corresponding TDWR Site	TDWR Life Cycle NPV (FY08 $M)
CAK	CLE	$ 3.46
ORL	MCO	$ 2.40
PDK	ATL	$ 1.22
PIE	TPA	$ 1.07
SFB	MCO	$ 0.64
Total Net Benefit		$ 8.79

7.2.4 WSP Alternatives

WSP is available only at sites where an ASR-9 currently exists but not all ASR-9s have WSP upgrades. As shown in the previous section, WSP by itself does not provide superior benefits to TDWR based systems. In fact, there is only one WSP combination that exceeded its TDWR counterpart and that was combining the WSP and LIDAR at LAS. According to our performance model, the on airport location of WSP allows it to detect gust fronts better than the TDWR or TDWR+LIDAR) increasing delay savings at LAS. When only safety is considered, however, the TDWR+LIDAR combination provides the optimal benefits. No LLWAS locations have existing ASR-9s that could be upgraded.

There are 12 unprotected sites, however, that could be upgraded to WSP. None of the WSP combinations evaluated resulted in positive NPV values at any of these sites, but each provided some level of additional wind shear protection. Table 29 lists the sites and their associated safety benefits for WSP and WSP&LIDAR alternatives (not considering delay or the costs of implementation). Each alternative is also measured against the total possible safety benefit at that site (relative to the NAS protected by pilot training and PWS).

TABLE 29

WSP safety benefits at currently unprotected sites

SITE	Residual Life Cycle Safety Exposure After Pilot and PWS (FY08 $M)	Life Cycle WSP Safety Reduction (FY08 $M)	% of Residual	Life Cycle WSP&LIDAR Safety Reduction (FY08 $M)	% of Residual
BUR	0.432	0.316	73%	0.393	91%
LGB	1.803	0.899	50%	1.277	71%
MHT	0.985	0.405	41%	0.805	82%
OAK	0.581	0.469	81%	0.542	93%
ORL*	0.929	0.420	45%	0.568	61%
PDK*	0.946	0.044	5%	0.245	26%
PIE*	2.139	1.016	47%	1.333	62%
PWM	0.402	0.012	3%	0.201	50%
SAN	1.308	0.160	12%	0.537	41%
SJC	0.231	0.122	53%	0.186	80%
SMF	0.719	0.153	21%	0.416	58%
SNA	0.453	0.080	18%	0.287	63%

* indicates existing TDWR is also available at this site

7.2.5 NEXRAD Alternatives

NEXRAD is an attractive alternative to other radar-based systems as it is a multi-agency radar (DoD, NWS, FAA) and because of that the expected additional costs for adding operational microburst and gust front capability is much smaller than competing systems (see Figure 32). In fact, gust front detection algorithms (MIGFA) are already part of the NEXRAD ORPG. However, the radar siting is primarily based on coverage of population centers and not on airport locations. Effectivity estimates from the MIT/LL simulation study indicate that despite location issues a significant number of sites are covered adequately. As shown in Table 30, NEXRAD provides coverage for wind shear at 74 of the 161 airports studied. And, 53 of those sites achieve wind shear PODs greater than 90%. In addition, about one third of the high POD sites are non-WSP and/or non-TDWR sites.

TABLE 30

Breakdown of NEXRAD coverage sites by current site type and NEXRAD performance

NEXRAD MB POD	Site Type				
	TDWR	WSP	LLWAS	NoWS	Total
Greater than 90%	21	10	14	8	53
50 – 90 %	8	1	6	6	21
Poor or No Coverage	17	24	20	26	87

A note of caution in interpreting these results, TDWR and WSP simulation results were compared against measured results from field studies but NEXRAD has never been used for microburst detection. The effectivity simulation attempts to measure the potential for a system to detect microbursts and gust fronts based on several metrics of wind shear characteristics (wet/dry frequency, outflow depth, strength, etc). The NEXRAD system with combined wider beam widths and longer distances may be more sensitive to some of these characteristics than either TDWR or WSP.

Having said that, sites with high PODs combined with the relatively inexpensive implementation costs overwhelmingly have NEXRAD based alternatives as their optimal choices. A total of 63 airports have NEXRAD or NEXRAD+LLWAS as the optimal choice (three additional sites recommend NEXRAD in addition to TDWR).

7.2.6 X-band Alternatives

The X-band radar and alternatives that combine with it are routinely the best performing alternative at almost all sites. Certainly that is true at the LLWAS and unprotected sites where TDWR and WSP alternatives were not even considered. But, even in high value airports this radar scored consistently high. Indeed, referring to Table 19, you see that X-band based alternatives are chosen for highest safety coverage at 61 sites. That number increases to 77 if you consider both safety and delay.

However, the X-band radar is not a finished system and implementation costs are estimated to be the highest of all alternatives. Because of this no X-band system is chosen as an optimal system at any site. In addition, actual performance (many of the radar parameters were based on theoretical design) may be highly variable and there may also be issues related to radar placement especially at congested airports.

8. SUMMARY AND CONCLUSIONS

In this report, we quantified the effectiveness and associated operational benefits of deployed ground based wind shear detection systems (TDWR, ASR-9 augmented with the Weather Systems Processor (WSP) and LLWAS). In addition, we considered complementary or alternative sensors including the WSR-88D (or NEXRAD), Lidar and X-Band based wind shear systems, and various integrated systems that combine multiple sensors. All 20 of these single-sensor and integrated configurations were evaluated for the 121 US airports that currently have some type of operational, ground-based wind shear system. Additionally, 40 smaller airports that are not currently protected by ground based wind shear systems were also examined.

Wind shear phenomena are still a potent hazard to aircraft in the United States and around the world. This analysis presents a thorough review of the wind shear hazards to aircraft and the estimated exposure throughout the country based on recent archive data from TDWR and ITWS and climatological surrogates for wet and dry microburst exposure. A complete review and update of the expected wind shear related accident rate was performed, including the use of the now 25+ year safety record to cross-check measured accident rates against models of pilot training, airborne PWS, and ground based wind shear protection methods. Updated accident profiles were also used to calculate the anticipated costs of life and property in wind shear accidents.

The current state of protection from wind shear is high, with some 95% of the estimated safety-related financial exposure being removed from the system by a combination of pilot training, airborne wind shear systems and ground-based detection and prediction systems. In addition, ground-based systems provide wide-area warnings of wind shear and gust fronts that aid in the reduction of delay. A conservative approach for considering delay was taken by restricting delay reduction estimates to the algorithm directly related to wind shear detection. Delay benefit assessments were based on the wind shift prediction ability of ground-based systems and the associated reduction in runway closures for unplanned runway change operations.

The effectiveness of the various wind shear system configurations to detect wind shear was estimated by simulating the radar or other system characteristics (clutter, range-folding, beam widths/heights, etc). These system models were then used to estimate how well the system would detect the specific profile of microburst and gust front activity at that airport. In addition, life cycle cost data were approximated from FAA and industry estimates for the various systems.

Each airport's wind shear exposure and projected operations from 2010–32 were combined with the modeled performance expectation of each alternative to estimate the safety savings (from accident reduction) and decreased delay (from reduced runway down time) for each of the study airports. Safety benefits were the primary focus for benefits, delay reduction benefits were deliberately conservative and focused on the direct benefit of wind shift prediction from wind shear related algorithms. The overall goal was to determine the optimal wind shear detection system at each site taking into account not just the benefits of the system but also its costs. Figure 50 summarizes the overall results of this analysis. While many of the existing systems of today are often not the optimal solution chosen, replacing current systems with the alternatives chosen at all sites results in a net benefits increase of only 7%.

Evaluating the multitude of system choices for an optimal alternative based on costs and benefits must be done with consideration of the variability of projected system costs and timelines. Existing systems like LLWAS, WSP and TDWR have better known operating costs than their prospective counterparts (NEXRAD, Lidar, and X-band). In addition, new systems were assumed for this analysis to begin in 2013, therefore extended timelines for implementation and siting of new systems would significantly reduce system benefits over competing systems. Finally, costs are distributed based on assumptions about how many sites would be fitted with each system. Therefore, making decisions to replace only a few systems with an alternative would require updated cost data to verify the investment decision.

Most notable in the list of most chosen alternatives, is the NEXRAD radar. NEXRAD would require new microburst detection algorithms and a rapid (1–2 minute) surface scan strategy. But, the NEXRAD’s reduced cost of operations makes it an attractive alternative to pursue. TDWR and TDWR-LLWAS locations are fairly well optimized with few better alternatives being found. Many of the WSP sites have the highest NPV with WSP, but at a significant number of sites NEXRAD is the optimal alternative. LLWAS sites have limited options for alternatives as there are no nearby TDWR or WSP sensors. Therefore, NEXRAD is again chosen as a frequent alternative. Unprotected sites frequently benefit from NEXRAD but five sites are close enough to existing TDWR sites that satellite operations at the airport are the optimal choice.

New Airport weather radars, such as X-band systems, were among the best performing based on model simulations, but the large expense of a new program and radar kept this sensor from being chosen an optimal alternative at any site. Finally, systems with LIDAR were only chosen at one site (LAS). This system also suffered from high expenses but also from the wind shear exposure research that showed dry western environments generally had fewer events than had previously been estimated. However, when alternative selection is optimized by safety, without regard for costs, alternatives that include LIDAR as a complimentary system are frequently selected.

Finally, the meteorological, accident investigation and radar simulation methodologies performed for this study may prove a valuable asset in the future investigation of optimizing wind shear system investments.

Site Name	Current System	Optimal System Based on Safety+Delay	Site Name	Current System	Optimal System Based on Safety+Delay	Site Name	Current System	Optimal System Based on Safety+Delay	Site Name	Current System	Optimal System Based on Safety+Delay	Site Name	Current System	Optimal System Based on Safety+Delay
ABE	NoWS	None	CMI	NoWS	None	HNL	WSP	WSP	MKE	TDWR	TDWR	RSW	LLWAS	NEXRAD & LLWAS
ABQ	WSP	NEXRAD	COS	LLWAS	NEXRAD	HOU	TDWR	NEXRAD	MLI	LLWAS	NEXRAD	SAN	NoWS	None
ADW	TDWR	None	CRP	NoWS	NEXRAD	HPN	WSP	WSP	MLU	LLWAS	None	SAT	WSP	NEXRAD
AGS	LLWAS	None	CRW	LLWAS	None	HSV	WSP	None	MOB	LLWAS	NEXRAD	SAV	LLWAS	NEXRAD & LLWAS
ALB	WSP	WSP	CSG	LLWAS	None	IAD	TDWR	NEXRAD	MSN	WSP	None	SBN	NoWS	None
AMA	NoWS	NEXRAD	CVG	TDWR	TDWR	IAH	TDWR	TDWR & NEXRAD	MSP	TDWR	NEXRAD	SDF	TDWR	NEXRAD
ASE	NoWS	None	DAB	LLWAS	LLWAS	ICT	TDWR	NEXRAD	MSY	TDWR & LLWAS	TDWR	SEA	WSP	WSP
ATL	TDWR & LLWAS	NEXRAD & LLWAS	DAL	TDWR	TDWR	ILM	NoWS	NEXRAD	MYR	NoWS	NEXRAD	SFB	NoWS	TDWR
AUS	WSP	WSP	DAY	TDWR	None	IND	TDWR	NEXRAD	OAK	NoWS	None	SFO	LLWAS	NEXRAD & LLWAS
AVL	LLWAS	None	DCA	TDWR	NEXRAD	ISP	WSP	NEXRAD	OKC	TDWR	NEXRAD	SGF	LLWAS	NEXRAD
AVP	NoWS	None	DEN	TDWR & LLWAS	NEXRAD & LLWAS	JAN	LLWAS	NEXRAD	OMA	LLWAS	NEXRAD	SHV	LLWAS	NEXRAD
AZO	NoWS	None	DFW	TDWR & LLWAS	NEXRAD & LLWAS	JAX	WSP	NEXRAD	ONT	WSP	WSP	SJC	NoWS	None
BDL	WSP	WSP	DSM	WSP	NEXRAD	JFK	TDWR	TDWR	ORD	TDWR & LLWAS	TDWR,LLWAS, NEXRAD	SJU	TDWR	TDWR
BGM	NoWS	None	DTW	TDWR	TDWR	LAN	LLWAS	None	ORF	WSP	WSP	SLC	TDWR	TDWR
BHM	WSP	NEXRAD	ELP	WSP	WSP	LAS	TDWR	WSP & LIDAR	ORL	NoWS	TDWR	SMF	NoWS	NEXRAD
BIL	LLWAS	NEXRAD	ERI	NoWS	None	LAX	WSP	WSP	PBI	TDWR	TDWR	SNA	NoWS	None
BIS	NoWS	None	EVV	NoWS	None	LBB	WSP	NEXRAD	PDK	NoWS	TDWR	SPI	LLWAS	None
BNA	TDWR	NEXRAD	EWR	TDWR	TDWR	LEX	LLWAS	None	PDX	WSP	WSP	SRQ	WSP	NEXRAD
BOI	NoWS	NEXRAD	FAR	NoWS	None	LFT	NoWS	None	PHF	NoWS	NEXRAD	STL	TDWR & LLWAS	NEXRAD
BOS	TDWR	TDWR	FAY	LLWAS	None	LGA	TDWR & LLWAS	TDWR	PHL	TDWR	TDWR	SUX	LLWAS	None
BTR	LLWAS	None	FLL	TDWR	TDWR & NEXRAD	LGB	NoWS	None	PHX	TDWR	NEXRAD	SYR	WSP	None
BTV	NoWS	NEXRAD	FNT	NoWS	NEXRAD	LIT	LLWAS	NEXRAD	PIA	LLWAS	None	TLH	LLWAS	NEXRAD
BUF	WSP	NEXRAD	FSD	LLWAS	NEXRAD	LNK	LLWAS	None	PIE	NoWS	TDWR	TOL	WSP	None
BUR	NoWS	None	FSM	LLWAS	None	MAF	LLWAS	NEXRAD	PIT	TDWR	NEXRAD	TPA	TDWR & LLWAS	NEXRAD
BWI	TDWR	TDWR	FWA	WSP	None	MBS	NoWS	None	PNS	LLWAS	None	TRI	LLWAS	None
CAE	LLWAS	NEXRAD	GCN	NoWS	None	MCI	TDWR	TDWR	PVD	LLWAS	NEXRAD	TUL	TDWR	NEXRAD
CAK	NoWS	TDWR	GEG	WSP	NEXRAD	MCO	TDWR&LLWAS	TDWR&LLWAS	PWM	NoWS	NEXRAD	TUS	WSP	WSP
CHA	LLWAS	None	GFK	NoWS	NEXRAD	MDT	WSP	None	RDU	TDWR	NEXRAD	TWF	NoWS	None
CHS	WSP	WSP	GPT	NoWS	None	MDW	TDWR	NEXRAD	RIC	WSP	NEXRAD	TYS	WSP	None
CID	WSP	None	GRB	LLWAS	None	MEM	TDWR	NEXRAD	RNO	NoWS	NEXRAD & LLWAS			
CLE	TDWR	NEXRAD	GRR	WSP	NEXRAD	MGM	LLWAS	None	ROA	LLWAS	None			
CLT	TDWR	TDWR	GSO	WSP	WSP	MHT	NoWS	None	ROC	WSP	WSP			
CMH	TDWR	TDWR	GSP	LLWAS	None	MIA	TDWR	NEXRAD & LLWAS	RST	LLWAS	None			

Figure 50. Summary of optimal alternatives for all 161 study sites.

This page intentionally left blank.

GLOSSARY

ARENAs	Areas Noted for Attention
ASR9	Airport Surveillance Radar-9
CREM	Clutter Residue Map
DFAD	Digital Feature Analysis Data
FAA	Federal Aviation Administration
GF	Gust Front
LLWAS-RS	Low Altitude Wind Shear Alert System Relocation/Sustainment
LMCT	Lockheed Martin Coherent Technologies
MB	Microburst
MIGFA	Machine Intelligent Gust Front Algorithm
MPAR	Multi-mission Phased Array Radar
NAS	National Airspace System
NCAR	National Center for Atmospheric Research
NEXRADs	Next Generation Weather Radar
NTSB	National Transportation Safety Board
PDF	Probability Distribution Function
SLEPs	Service Life Extension Programs
TDWR	Terminal Doppler Weather Radar
WSI	Weather Services Incorporated
WSP	Weather Systems Processor
WSR-88D	Weather Surveillance Radar-1988 Doppler

This page intentionally left blank.

REFERENCES

Allan, S. S., and J. E. Evans, 2005: "Operational Benefits of the Integrated Terminal Weather System (ITWS) at Atlanta," Project Report ATC-320, MIT Lincoln Laboratory, Lexington, MA.

Biron, P. J., and M. A. Isaminger, 1991: "High Resolution Microburst Outflow Vertical Profile Data from Huntsville, Alabama and Denver, Colorado," Project Report ATC-163, MIT Lincoln Laboratory, Lexington, MA.

Chan, P. W., C. M. Shun, and K. C. Wu, 2006: "Operational LIDAR-based system for automatic windshear alerting at the Hong Kong International Airport," preprint, *12th Conf. on Aviation, Range, and Aerospace Meteorology*, Atlanta, GA, Amer. Meteor. Soc., http://ams.confex.com/ams/pdfpapers/100601.pdf.

Cho, J. Y. N. and R. G. Hallowell, 2008: "Detection Probability Modeling for Airport Wind-Shear Sensors," Project Report ATC-340, MIT Lincoln Laboratory, Lexington, MA.

Cho, J. Y. N., R. G. Hallowell, and M. E. Weber, 2008: "Comparative Analysis of Terminal Wind-shear Detection Systems," *13th Conf. on Aviation, Range, and Aerospace Meteorology*, New Orleans, LA.

Cho, J. Y. N., and B. D. Martin, 2007: "Technical Assessment of the Impact of Decommissioning the TDWR on Terminal Weather Services," Project Report ATC-331, MIT Lincoln Laboratory, Lexington, MA.

Cole, R. E., 1992: "Terminal Doppler Weather Radar/Low-Level Wind Shear Alert System Integration Algorithm Specification Version 1.1," Project Report ATC-187, MIT Lincoln Laboratory, Lexington, MA.

Cole, R. E., and R. F. Todd, 1996: "A comparative performance study of TDWR/LLWAS 3 integration algorithms for wind shear detection," preprints, *Workshop on Wind shear and Wind Shear Alert Systems*, Amer. Meteor. Soc., Oklahoma City, OK, 43–52.

Cullen, J. A., and M. M. Wolfson, 1990: "Predicting Summer Microburst Hazard from Thunderstorm Day Statistics," *16th Conf. on Severe Local Storms/Conf. on Atmospheric Electricity*, Kananaskis Park, Alta., Canada, pp. 383–387.

FAA, 2008: Revised Department Guidelines: Treatment of the Value of Preventing Fatalities and Injuries in Preparing Economic Analyses.

GRA, Incorporated, 2007: "Economic Values for FAA Investment and Regulatory Decisions, A Guide," Final Report, October 3, 2007.

Hannon, S. M., 2004: "Pulsed Doppler lidar for terminal weather area monitoring of wind and wake hazards," preprints, *11th Conf. on Aviation, Range, and Aerospace Meteorology*, Amer. Meteor. Soc., Hyannis, MA, P4.21, http://ams.confex.com/ams/pdfpapers/87757.pdf.

Heiss, W. D., D. L. McGrew, and D. Sirmans, 1990: "NEXRAD: Next Generation Weather Radar (WSR-88D)," *Microwave J.*, 33, 79–98.

Klingle-Wilson, D., and M. F. Donovan, 1991: "Characteristics of gust fronts," preprints, *4th Int. Conf. on Aviation Weather Systems*, Paris, France, Amer. Meteor. Soc., 387–392.

Martin Marietta, 1994: "Wind shear systems cost-benefit and deployment study: System engineering and integration contract for implementation of the National Airspace System plan," ATC-92-1201, Martin Marietta Air Traffic Systems, 91 pp.

NOAA, 1989: Microbursts A Handbook for Visual Identification, U.S. Department of Commerce.

NTSB, 2007: Notes from meeting with Don Eich, NTSB, December 20, 2007.

Rasmussen, R. G., and F. M. Robasky, 1995: "The ITWS Runway Wind Nowcast Product," *6th Conf. on Aviation Weather Systems*, Dallas, TX.

Robinson, M., J. E. Evans, B. A. Crowe, D. L. Klingle-Wilson, and S. S. Allan, 2004: "Corridor Integrated Weather System Operational Benefits 2002–2003: Initial Estimates of Convective Weather Delay Reduction," Project Report ATC-313, MIT Lincoln Laboratory, Lexington, MA.

Smalley, D. J., B. J. Bennett, and R. Frankel, 2005: "MIGFA: The machine intelligent gust front algorithm for NEXRAD," preprints, *32nd Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc., http://ams.confex.com/ams/pdfpapers/96098.pdf.

Weber, M. E., J. Y. N. Cho, M. Robinson, and J. E. Evans, 2007: "Analysis of Operational Alternatives to the Terminal Doppler Weather Radar (TDWR)," Project Report ATC-332, MIT Lincoln Laboratory, Lexington, MA.

Weber, M. E., J. E. Evans, W. R. Moser II, and O. J. Newell, 2007: "Air Traffic Management Decision Support During Convective Weather," *MIT Lincoln Laboratory Journal*, Volume 16, pp. 263–276, Number 2.

Weber, M. E., E. R. Williams, M. M. Wolfson, and S. Goodman, 1998: "An Assessment of the Operational Utility of a GOES Lightning Mapping Sensor," Project Report NOAA-18, MIT Lincoln Laboratory, Lexington, MA.

Weber, M. E., J. A. Cullen, S. W. Troxel, and C. A. Meuse, 1996: "ASR-9 Weather System Processor (WSP): Wind Shear Algorithms Performance Assessment," Project Report ATC-247, MIT Lincoln Laboratory, Lexington, MA.

Weber, M. E., and M. L. Stone, 1995: "Low altitude wind shear detection using airport surveillance radars," *IEEE Aerosp. Electron. Syst. Mag.*, 1, 3–9.

Weber, M. E., and S. W. Troxel, 1994: "Assessment of the Weather Detection Capability of an Airport Surveillance Radar with Solid-State Transmitter," Project Report ATC-209, MIT Lincoln Laboratory, Lexington, MA.

Wilson, F. W., and R. E. Cole, 1993: "LLWAS II and LLWAS III performance evaluation," preprints, *5th Conf. on Aviation Weather Systems*, Amer. Meteor. Soc., Vienna, VA, 204–208.

Wilson, F. W., and R. H. Gramzow, 1991: "The Redesigned Low Level Wind Shear Alert System," preprints, *4th Int. Conf. on Aviation Weather Systems*, Paris, France, 370.

Wolfson, M. M., R. L. Delanoy, B. E. Forman, R. G. Hallowell, M. L. Pawlak, and P. D. Smith, 1994: "Automated Microburst Wind-Shear Prediction," *Lincoln Laboratory Journal*, Volume 7, Number 2, p. 399.

Wolfson, M. M., et al., 1990: "Characteristics of Thunderstorm-Generated Low Altitude Wind Shear: A Survey Based on Nationwide Terminal Doppler Weather Radar Testbed Measurements," *29th IEEE Conference on Decision and Control*, Honolulu, HI.

This page intentionally left blank.

APPENDIX A
WIND-SHEAR AND WIND-SHIFT EXPOSURE ASSESSMENT

Airport Info			Microbursts		Gust Fronts		SWEF	Wind Shifts
Site	Type	Airport ARENA Coverage (sq-km)	Microbursts in the ARENA (mb/year)	Mbexp	Gust Fronts in the ARENA (gf/year)	Gfexp	(0.1*GF+0.9*MB)	Annual Number of Strong Wind Shifts
ABE	NoWS	45.1	58	0.41	6498	0.97	**0.46**	**60**
ABQ	WSP	86.3	289	2.02	8978	1.34	**1.95**	**129**
ADW	TDWR	34.8	55	0.39	6668	1.00	**0.45**	**25**
AGS	LLWAS	45.6	127	0.89	6832	1.02	**0.90**	**38**
ALB	WSP	45.2	71	0.50	6016	0.90	**0.54**	**61**
AMA	NoWS	49.8	183	1.28	8164	1.22	**1.27**	**133**
ASE	NoWS	24.5	97	0.68	8455	1.26	**0.74**	**189**
ATL	TDWR-LLWAS	91.6	289	2.02	7125	1.07	**1.93**	**62**
AUS	WSP	53.2	115	0.81	6871	1.03	**0.83**	**44**
AVL	LLWAS	25.1	60	0.42	7983	1.19	**0.49**	**32**
AVP	NoWS	43.8	56	0.39	6316	0.94	**0.45**	**61**
AZO	NoWS	58.9	99	0.69	6772	1.01	**0.72**	**94**
BDL	WSP	63.0	67	0.47	4917	0.74	**0.49**	**49**
BGM	NoWS	44.1	55	0.38	5434	0.81	**0.43**	**58**
BHM	WSP	46.6	159	1.11	7121	1.06	**1.11**	**53**
BIL	LLWAS	48.3	138	0.96	7438	1.11	**0.98**	**110**
BIS	NoWS	46.4	108	0.76	7755	1.16	**0.80**	**41**
BNA	TDWR	84.4	201	1.40	6979	1.04	**1.37**	**44**
BOI	NoWS	29.9	96	0.67	6008	0.90	**0.69**	**67**
BOS	TDWR	103.5	105	0.73	3863	0.58	**0.72**	**93**
BTR	LLWAS	47.8	260	1.82	8189	1.22	**1.76**	**41**
BTV	NoWS	42.6	52	0.36	5571	0.83	**0.41**	**57**

Airport Info			Microbursts		Gust Fronts		SWEF	Wind Shifts
Site	Type	Airport ARENA Coverage (sq-km)	Microbursts in the ARENA (mb/year)	Mbexp	Gust Fronts in the ARENA (gf/year)	Gfexp	(0.1*GF+0.9*MB)	Annual Number of Strong Wind Shifts
BUF	WSP	45.3	61	0.43	6306	0.94	**0.48**	**63**
BUR	NoWS	44.8	19	0.13	797	0.12	**0.13**	**44**
BWI	TDWR	78.5	109	0.76	6643	0.99	**0.79**	**48**
CAE	LLWAS	46.6	130	0.91	6832	1.02	**0.92**	**46**
CAK	NoWS	44.9	79	0.55	6754	1.01	**0.60**	**57**
CHA	LLWAS	43.8	110	0.77	7049	1.05	**0.80**	**28**
CHS	WSP	46.1	139	0.97	6889	1.03	**0.98**	**65**
CID	WSP	44.4	61	0.43	6658	1.00	**0.48**	**47**
CLE	TDWR	67.6	130	0.91	6821	1.02	**0.92**	**66**
CLT	TDWR	68.8	119	0.83	6794	1.02	**0.85**	**43**
CMH	TDWR	38.2	99	0.69	6836	1.02	**0.72**	**42**
CMI	NoWS	64.5	168	1.18	6877	1.03	**1.16**	**123**
COS	LLWAS	70.5	252	1.76	9066	1.36	**1.72**	**153**
CRP	NoWS	43.8	78	0.54	6739	1.01	**0.59**	**67**
CRW	LLWAS	44.0	63	0.44	6518	0.97	**0.50**	**23**
CSG	LLWAS	43.8	165	1.15	7146	1.07	**1.14**	**42**
CVG	TDWR	88.4	193	1.35	6793	1.02	**1.32**	**52**
DAB	LLWAS	52.2	339	2.37	11991	1.79	**2.31**	**49**
DAL	TDWR	55.2	142	0.99	7015	1.05	**1.00**	**58**
DAY	TDWR	67.1	171	1.20	6911	1.03	**1.18**	**47**
DCA	TDWR	53.1	85	0.59	6668	1.00	**0.63**	**56**
DEN	TDWR-LLWAS	125.8	427	2.99	8946	1.34	**2.82**	**105**
DFW	TDWR-LLWAS	117.1	301	2.11	7015	1.05	**2.00**	**52**
DSM	WSP	47.8	121	0.85	7050	1.05	**0.87**	**52**
DTW	TDWR	98.3	190	1.33	6809	1.02	**1.30**	**76**
ELP	WSP	54.6	154	1.08	7911	1.18	**1.09**	**80**
ERI	NoWS	41.9	49	0.34	6246	0.93	**0.40**	**78**

Airport Info			Microbursts		Gust Fronts		SWEF	Wind Shifts
Site	Type	Airport ARENA Coverage (sq-km)	Microbursts in the ARENA (mb/year)	Mbexp	Gust Fronts in the ARENA (gf/year)	Gfexp	(0.1*GF+0.9*MB)	Annual Number of Strong Wind Shifts
EVV	NoWS	61.2	149	1.04	6936	1.04	**1.04**	**45**
EWR	TDWR	54.7	49	0.35	5667	0.85	**0.40**	**71**
FAR	NoWS	60.3	72	0.50	6190	0.93	**0.55**	**59**
FAY	LLWAS	44.3	100	0.70	6815	1.02	**0.73**	**35**
FLL	TDWR	57.6	343	2.40	11016	1.65	**2.32**	**74**
FNT	NoWS	61.8	92	0.64	6741	1.01	**0.68**	**57**
FSD	LLWAS	63.0	148	1.03	7113	1.06	**1.04**	**66**
FSM	LLWAS	44.5	183	1.28	7251	1.08	**1.26**	**52**
FWA	WSP	64.5	163	1.14	6898	1.03	**1.13**	**41**
GCN	NoWS	25.7	82	0.58	8778	1.31	**0.65**	**128**
GEG	WSP	46.0	137	0.96	5230	0.78	**0.94**	**63**
GFK	NoWS	56.0	61	0.43	5808	0.87	**0.47**	**60**
GPT	NoWS	44.2	247	1.73	8428	1.26	**1.68**	**57**
GRB	LLWAS	46.5	50	0.35	5155	0.77	**0.39**	**62**
GRR	WSP	62.4	67	0.47	5521	0.83	**0.51**	**48**
GSO	WSP	47.0	76	0.53	6814	1.02	**0.58**	**32**
GSP	LLWAS	26.8	50	0.35	6870	1.03	**0.42**	**36**
HNL	WSP	70.2	63	0.44	1647	0.25	**0.42**	**58**
HOU	TDWR	71.5	344	2.41	7506	1.12	**2.28**	**48**
HPN	WSP	42.7	40	0.28	5626	0.84	**0.34**	**87**
HSV	WSP	49.3	152	1.06	7058	1.06	**1.06**	**60**
IAD	TDWR	73.4	117	0.82	6679	1.00	**0.84**	**30**
IAH	TDWR	73.9	374	2.62	7866	1.18	**2.48**	**48**
ICT	TDWR	60.9	193	1.35	7286	1.09	**1.33**	**76**
ILM	NoWS	46.0	103	0.72	6776	1.01	**0.75**	**43**
IND	TDWR	66.6	213	1.49	6961	1.04	**1.44**	**48**
ISP	WSP	63.5	59	0.41	4863	0.73	**0.45**	**62**
JAN	LLWAS	41.2	169	1.18	7241	1.08	**1.17**	**40**
JAX	WSP	47.2	287	2.00	9743	1.46	**1.95**	**57**

Airport Info			Microbursts		Gust Fronts		SWEF	Wind Shifts
Site	Type	Airport ARENA Coverage (sq-km)	Microbursts in the ARENA (mb/year)	Mbexp	Gust Fronts in the ARENA (gf/year)	Gfexp	(0.1*GF+0.9*MB)	Annual Number of Strong Wind Shifts
JFK	TDWR	84.2	76	0.53	5667	0.85	**0.56**	**70**
LAN	LLWAS	46.8	58	0.41	6477	0.97	**0.46**	**50**
LAS	TDWR	58.0	170	1.19	6471	0.97	**1.17**	**161**
LAX	WSP	54.0	23	0.16	797	0.12	**0.16**	**25**
LBB	WSP	59.7	205	1.44	8195	1.23	**1.41**	**122**
LEX	LLWAS	41.6	66	0.46	6783	1.01	**0.52**	**42**
LFT	NoWS	48.1	232	1.62	7671	1.15	**1.57**	**43**
LGA	TDWR-LLWAS	45.7	44	0.31	5804	0.87	**0.36**	**101**
LGB	NoWS	79.0	122	0.86	2332	0.35	**0.80**	**47**
LIT	LLWAS	58.8	211	1.47	7114	1.06	**1.43**	**40**
LNK	LLWAS	56.2	119	0.83	6998	1.05	**0.85**	**58**
MAF	LLWAS	70.4	205	1.43	8160	1.22	**1.41**	**124**
MBS	NoWS	45.9	51	0.35	6289	0.94	**0.41**	**66**
MCI	TDWR	73.8	269	1.88	7177	1.07	**1.80**	**63**
MCO	TDWR-LLWAS	86.8	569	3.98	12988	1.94	**3.78**	**70**
MDT	WSP	25.9	35	0.25	6587	0.99	**0.32**	**81**
MDW	TDWR	52.2	124	0.87	6833	1.02	**0.88**	**82**
MEM	TDWR	65.7	213	1.49	6958	1.04	**1.45**	**53**
MGM	LLWAS	44.7	187	1.31	7240	1.08	**1.28**	**33**
MHT	NoWS	46.7	49	0.34	5200	0.78	**0.39**	**49**
MIA	TDWR	66.9	423	2.96	12061	1.80	**2.84**	**85**
MKE	TDWR	85.0	162	1.14	6663	1.00	**1.12**	**61**
MLI	LLWAS	62.5	103	0.72	6825	1.02	**0.75**	**53**
MLU	LLWAS	61.0	250	1.75	7232	1.08	**1.68**	**45**
MOB	LLWAS	42.6	239	1.67	8480	1.27	**1.63**	**57**
MSN	WSP	61.0	92	0.64	6718	1.00	**0.68**	**53**
MSP	TDWR	86.5	103	0.72	6339	0.95	**0.74**	**58**

Airport Info			Microbursts		Gust Fronts		SWEF	Wind Shifts
Site	Type	Airport ARENA Coverage (sq-km)	Microbursts in the ARENA (mb/year)	Mbexp	Gust Fronts in the ARENA (gf/year)	Gfexp	(0.1*GF+0.9*MB)	Annual Number of Strong Wind Shifts
MSY	TDWR-LLWAS	63.2	343	2.40	8189	1.22	**2.28**	**37**
MYR	NoWS	25.9	70	0.49	6838	1.02	**0.54**	**16**
OAK	NoWS	60.3	7	0.05	231	0.03	**0.05**	**76**
OKC	TDWR	69.5	188	1.31	7153	1.07	**1.29**	**68**
OMA	LLWAS	49.1	123	0.86	7037	1.05	**0.88**	**48**
ONT	WSP	30.5	59	0.41	2682	0.40	**0.41**	**49**
ORD	TDWR-LLWAS	117.7	279	1.95	6833	1.02	**1.86**	**53**
ORF	WSP	45.6	60	0.42	6541	0.98	**0.47**	**83**
ORL	NoWS	43.4	284	1.99	12988	1.94	**1.98**	**78**
PBI	TDWR	46.6	295	2.06	12061	1.80	**2.04**	**77**
PDK	NoWS	61.2	188	1.32	7057	1.06	**1.29**	**72**
PDX	WSP	59.5	39	0.27	1040	0.16	**0.26**	**49**
PHF	NoWS	44.5	62	0.43	6624	0.99	**0.49**	**90**
PHL	TDWR	64.4	69	0.49	6320	0.95	**0.53**	**54**
PHX	TDWR	46.2	89	0.63	6658	1.00	**0.66**	**39**
PIA	LLWAS	47.9	120	0.84	6893	1.03	**0.86**	**40**
PIE	NoWS	64.5	394	2.76	10557	1.58	**2.64**	**83**
PIT	TDWR	69.7	93	0.65	6257	0.94	**0.68**	**49**
PNS	LLWAS	45.6	245	1.71	8121	1.21	**1.66**	**76**
PVD	LLWAS	45.0	46	0.32	3819	0.57	**0.35**	**84**
PWM	NoWS	44.3	51	0.35	3755	0.56	**0.37**	**52**
RDU	TDWR	66.8	108	0.75	6760	1.01	**0.78**	**39**
RIC	WSP	50.0	91	0.64	6716	1.00	**0.68**	**46**
RNO	NoWS	49.9	188	1.32	5649	0.84	**1.27**	**158**
ROA	LLWAS	44.8	91	0.64	7780	1.16	**0.69**	**60**
ROC	WSP	61.2	80	0.56	5741	0.86	**0.59**	**53**
RST	LLWAS	46.8	57	0.40	6193	0.93	**0.45**	**84**

Airport Info			Microbursts		Gust Fronts		SWEF	Wind Shifts
Site	Type	Airport ARENA Coverage (sq-km)	Microbursts in the ARENA (mb/year)	Mbexp	Gust Fronts in the ARENA (gf/year)	Gfexp	(0.1*GF+0.9*MB)	Annual Number of Strong Wind Shifts
RSW	LLWAS	27.4	167	1.17	11215	1.68	**1.22**	**110**
SAN	NoWS	25.9	22	0.15	1198	0.18	**0.16**	**39**
SAT	WSP	50.1	98	0.69	6851	1.02	**0.72**	**51**
SAV	LLWAS	47.0	178	1.25	7064	1.06	**1.23**	**44**
SBN	NoWS	57.8	142	0.99	6717	1.00	**1.00**	**51**
SDF	TDWR	65.1	122	0.86	6802	1.02	**0.87**	**57**
SEA	WSP	30.7	18	0.13	815	0.12	**0.13**	**43**
SFB	NoWS	60.5	393	2.75	11991	1.79	**2.65**	**84**
SFO	LLWAS	54.7	6	0.04	199	0.03	**0.04**	**55**
SGF	LLWAS	45.7	156	1.09	7196	1.08	**1.09**	**47**
SHV	LLWAS	45.9	188	1.31	7150	1.07	**1.29**	**58**
SJC	NoWS	32.5	4	0.03	231	0.03	**0.03**	**59**
SJU	TDWR	42.6	53	0.37	6396	0.96	**0.43**	**25**
SLC	TDWR	81.4	246	1.72	7454	1.11	**1.66**	**126**
SMF	NoWS	50.6	14	0.10	502	0.08	**0.10**	**44**
SNA	NoWS	25.6	11	0.08	797	0.12	**0.08**	**98**
SPI	LLWAS	63.3	167	1.17	6982	1.04	**1.16**	**54**
SRQ	WSP	44.5	261	1.82	9620	1.44	**1.79**	**116**
STL	TDWR-LLWAS	72.9	175	1.22	6860	1.03	**1.20**	**61**
SUX	LLWAS	45.1	102	0.71	7027	1.05	**0.75**	**62**
SYR	WSP	45.7	56	0.39	4757	0.71	**0.42**	**55**
TLH	LLWAS	45.7	211	1.47	7517	1.12	**1.44**	**32**
TOL	WSP	46.9	113	0.79	6823	1.02	**0.81**	**43**
TPA	TDWR-LLWAS	77.5	473	3.31	10557	1.58	**3.14**	**33**
TRI	LLWAS	43.4	93	0.65	7936	1.19	**0.70**	**24**
TUL	TDWR	64.7	187	1.31	7032	1.05	**1.28**	**52**
TUS	WSP	50.4	149	1.04	8254	1.23	**1.06**	**109**

Airport Info				Microbursts		Gust Fronts		SWEF		Wind Shifts
Site	Type	Airport ARENA Coverage (sq-km)		Microbursts in the ARENA (mb/year)	Mbexp	Gust Fronts in the ARENA (gf/year)	Gfexp	(0.1*GF+0.9*MB)		Annual Number of Strong Wind Shifts
TWF	NoWS	43.0		150	1.05	6641	0.99	**1.04**		**219**
TYS	WSP	31.9		63	0.44	6951	1.04	**0.50**		**32**
Average		**55**		**143**	**1**	**6687**	**1**	**161**		**64**

This page intentionally left blank.

APPENDIX B
PILOT OBSERVABILITY AND PWS AIRBORNE SYSTEM EFECTIVENESS

		Pilot Observability						Airborne	
Site	Type	% of Time High Reflectivity	Estimated Visibility of High Refl MB Events	% of Time Low Reflectivity	Estimated Visibility of Low Refl MB Events	% of Time MB/GF Occur During Daylight	% of Time a Pilot Can See Through Wx to See MB	PWS Effectiveness	Airborne % Effectiveness
ABE	NoWS	66	33	34	73	76	**17.7**	90.0	**60%**
ABQ	WSP	70	73	30	95	78	**31.0**	91.2	**61%**
ADW	TDWR	61	46	39	83	77	**23.3**	88.5	**59%**
AGS	LLWAS	77	59	23	94	79	**26.5**	93.2	**62%**
ALB	WSP	65	29	35	74	75	**16.8**	89.7	**60%**
AMA	NoWS	57	48	43	88	79	**25.8**	87.4	**59%**
ASE	NoWS	45	54	55	80	76	**26.0**	83.8	**57%**
ATL	TDWR-LLWAS	71	56	29	93	79	**26.4**	91.5	**61%**
AUS	WSP	64	63	36	94	79	**29.3**	89.4	**60%**
AVL	LLWAS	70	67	30	90	78	**28.8**	91.2	**61%**
AVP	NoWS	67	39	33	73	75	**18.8**	90.3	**61%**
AZO	NoWS	59	32	41	78	76	**19.3**	87.9	**59%**
BDL	WSP	66	32	34	76	75	**17.6**	90.0	**60%**
BGM	NoWS	66	36	34	81	75	**19.2**	90.0	**60%**
BHM	WSP	72	65	28	90	79	**28.4**	91.8	**62%**
BIL	LLWAS	43	49	57	85	74	**25.7**	83.2	**56%**
BIS	NoWS	49	45	51	88	75	**25.1**	85.0	**57%**
BNA	TDWR	58	62	42	97	78	**29.9**	87.6	**59%**
BOI	NoWS	36	61	64	95	74	**30.6**	81.2	**55%**
BOS	TDWR	63	28	37	69	75	**16.2**	89.1	**60%**
BTR	LLWAS	78	60	22	95	81	**27.4**	93.5	**63%**
BTV	NoWS	53	32	47	76	75	**19.8**	86.2	**58%**

		Pilot Observability							Airborne	
Site	**Type**	**% of Time High Reflectivity**	**Estimated Visibility of High Refl MB Events**	**% of Time Low Reflectivity**	**Estimated Visibility of Low Refl MB Events**	**% of Time MB/GF Occur During Daylight**	**% of Time a Pilot Can See Through Wx to See MB**		**PWS Effectiveness**	**Airborne % Effectiveness**
BUF	WSP	52	48	48	84	76	**24.8**		85.9	**58%**
BUR	NoWS	49	70	51	88	77	**30.5**		85.0	**57%**
BWI	TDWR	58	46	42	81	77	**23.4**		87.6	**59%**
CAE	LLWAS	64	61	36	94	79	**28.8**		89.4	**60%**
CAK	NoWS	72	46	28	80	76	**21.1**		91.8	**62%**
CHA	LLWAS	75	59	25	89	79	**26.3**		92.6	**62%**
CHS	WSP	81	57	19	91	80	**25.4**		94.4	**63%**
CID	WSP	65	31	35	74	76	**17.5**		89.7	**60%**
CLE	TDWR	56	40	44	79	77	**22.0**		87.1	**59%**
CLT	TDWR	72	52	28	88	78	**24.2**		91.8	**62%**
CMH	TDWR	67	47	33	79	77	**22.2**		90.3	**61%**
CMI	NoWS	66	42	34	77	77	**20.8**		90.0	**60%**
COS	LLWAS	68	61	32	90	77	**27.1**		90.6	**61%**
CRP	NoWS	66	63	34	96	80	**29.7**		90.0	**60%**
CRW	LLWAS	60	51	40	85	77	**24.9**		88.2	**59%**
CSG	LLWAS	70	63	30	94	80	**28.9**		91.2	**61%**
CVG	TDWR	64	45	36	82	77	**22.5**		89.4	**60%**
DAB	LLWAS	75	66	25	85	83	**29.4**		92.6	**62%**
DAL	TDWR	66	60	34	92	79	**28.0**		90.0	**60%**
DAY	TDWR	68	46	32	81	77	**22.0**		90.6	**61%**
DCA	TDWR	60	46	40	84	77	**23.6**		88.2	**59%**
DEN	TDWR-LLWAS	43	35	57	84	76	**23.9**		83.2	**56%**
DFW	TDWR-LLWAS	66	53	34	91	79	**26.0**		90.0	**60%**
DSM	WSP	49	42	51	89	77	**25.4**		85.0	**57%**
DTW	TDWR	64	36	36	77	76	**19.3**		89.4	**60%**
ELP	WSP	71	73	29	96	78	**31.1**		91.5	**61%**
ERI	NoWS	61	35	39	75	76	**19.2**		88.5	**59%**

		Pilot Observability						Airborne	
Site	Type	% of Time High Reflectivity	Estimated Visibility of High Refl MB Events	% of Time Low Reflectivity	Estimated Visibility of Low Refl MB Events	% of Time MB/GF Occur During Daylight	% of Time a Pilot Can See Through Wx to See MB	PWS Effectiveness	Airborne % Effectiveness
EVV	NoWS	56	45	44	91	78	**25.4**	87.1	**59%**
EWR	TDWR	63	39	37	78	76	**20.3**	89.1	**60%**
FAR	NoWS	60	29	40	75	74	**17.5**	88.2	**59%**
FAY	LLWAS	72	51	28	88	78	**23.9**	91.8	**62%**
FLL	TDWR	83	71	17	92	82	**30.6**	95.0	**64%**
FNT	NoWS	60	35	40	77	76	**19.7**	88.2	**59%**
FSD	LLWAS	42	56	58	94	76	**29.7**	82.9	**56%**
FSM	LLWAS	67	54	33	91	79	**26.2**	90.3	**61%**
FWA	WSP	64	40	36	81	77	**21.1**	89.4	**60%**
GCN	NoWS	45	54	55	77	77	**25.7**	83.8	**57%**
GEG	WSP	50	59	50	91	73	**27.4**	85.3	**57%**
GFK	NoWS	58	41	42	83	74	**21.7**	87.6	**59%**
GPT	NoWS	74	69	26	96	82	**31.2**	92.4	**62%**
GRB	LLWAS	46	43	54	87	74	**24.7**	84.1	**57%**
GRR	WSP	50	37	50	82	75	**22.3**	85.3	**57%**
GSO	WSP	70	53	30	87	78	**24.6**	91.2	**61%**
GSP	LLWAS	67	69	33	95	78	**30.3**	90.3	**61%**
HNL	WSP	64	68	36	97	80	**31.4**	89.4	**60%**
HOU	TDWR	77	60	23	96	81	**27.7**	93.2	**62%**
HPN	WSP	60	33	40	73	75	**18.4**	88.2	**59%**
HSV	WSP	73	62	27	93	79	**27.8**	92.1	**62%**
IAD	TDWR	51	49	49	88	77	**26.2**	85.6	**58%**
IAH	TDWR	74	56	26	95	82	**27.1**	92.4	**62%**
ICT	TDWR	58	38	42	88	78	**23.0**	87.6	**59%**
ILM	NoWS	76	57	24	88	79	**25.5**	92.9	**62%**
IND	TDWR	55	43	45	91	78	**25.2**	86.8	**58%**
ISP	WSP	55	31	45	79	75	**19.7**	86.8	**58%**
JAN	LLWAS	58	70	42	97	80	**32.5**	87.6	**59%**

		Pilot Observability							Airborne	
Site	**Type**	**% of Time High Reflectivity**	**Estimated Visibility of High Refl MB Events**	**% of Time Low Reflectivity**	**Estimated Visibility of Low Refl MB Events**	**% of Time MB/GF Occur During Daylight**	**% of Time a Pilot Can See Through Wx to See MB**		**PWS Effectiveness**	**Airborne % Effectiveness**
JAX	WSP	64	68	36	97	81	**31.8**		89.4	**60%**
JFK	TDWR	58	38	42	76	76	**20.5**		87.6	**59%**
LAN	LLWAS	61	37	39	81	75	**20.3**		88.5	**59%**
LAS	TDWR	38	70	62	83	77	**30.1**		81.8	**55%**
LAX	WSP	46	61	54	90	77	**29.5**		84.1	**57%**
LBB	WSP	61	54	39	95	79	**27.6**		88.5	**59%**
LEX	LLWAS	73	48	27	84	77	**22.2**		92.1	**62%**
LFT	NoWS	78	62	22	94	81	**28.0**		93.5	**63%**
LGA	TDWR-LLWAS	61	37	39	75	76	**19.7**		88.5	**59%**
LGB	NoWS	64	83	36	89	77	**32.8**		89.4	**60%**
LIT	LLWAS	55	53	45	90	79	**27.5**		86.8	**58%**
LNK	LLWAS	63	37	37	86	76	**20.9**		89.1	**60%**
MAF	LLWAS	66	59	34	97	79	**28.4**		90.0	**60%**
MBS	NoWS	63	39	37	76	75	**19.8**		89.1	**60%**
MCI	TDWR	71	43	29	88	78	**21.9**		91.5	**61%**
MCO	TDWR-LLWAS	78	63	22	92	83	**28.8**		93.5	**63%**
MDT	WSP	69	42	31	76	76	**20.0**		90.9	**61%**
MDW	TDWR	59	37	41	87	77	**22.1**		87.9	**59%**
MEM	TDWR	48	57	52	93	79	**29.9**		84.7	**57%**
MGM	LLWAS	61	64	39	95	80	**30.4**		88.5	**59%**
MHT	NoWS	62	28	38	71	75	**16.6**		88.8	**60%**
MIA	TDWR	84	71	16	96	84	**31.5**		95.3	**64%**
MKE	TDWR	60	38	40	82	76	**21.1**		88.2	**59%**
MLI	LLWAS	50	42	50	87	76	**24.5**		85.3	**57%**
MLU	LLWAS	75	59	25	93	80	**27.0**		92.6	**62%**
MOB	LLWAS	64	66	36	96	82	**31.5**		89.4	**60%**
MSN	WSP	66	37	34	78	76	**19.4**		90.0	**60%**

		Pilot Observability						Airborne	
Site	Type	% of Time High Reflectivity	Estimated Visibility of High Refl MB Events	% of Time Low Reflectivity	Estimated Visibility of Low Refl MB Events	% of Time MB/GF Occur During Daylight	% of Time a Pilot Can See Through Wx to See MB	PWS Effectiveness	Airborne % Effectiveness
MSP	TDWR	65	43	35	87	75	**21.9**	89.7	**60%**
MSY	TDWR-LLWAS	70	72	30	98	81	**32.3**	91.2	**61%**
MYR	NoWS	70	53	30	94	79	**25.8**	91.2	**61%**
OAK	NoWS	41	42	59	72	76	**22.7**	82.6	**56%**
OKC	TDWR	61	48	39	92	78	**25.4**	88.5	**59%**
OMA	LLWAS	60	34	40	89	77	**21.6**	88.2	**59%**
ONT	WSP	46	73	54	90	77	**31.6**	84.1	**57%**
ORD	TDWR-LLWAS	58	36	42	83	77	**21.5**	87.6	**59%**
ORF	WSP	68	52	32	84	77	**24.0**	90.6	**61%**
ORL	NoWS	80	64	20	93	83	**29.0**	94.1	**63%**
PBI	TDWR	82	72	18	87	83	**31.0**	94.7	**63%**
PDK	NoWS	74	59	26	90	79	**26.5**	92.4	**62%**
PDX	WSP	56	40	44	73	74	**20.2**	87.1	**59%**
PHF	NoWS	68	45	32	85	78	**22.5**	90.6	**61%**
PHL	TDWR	64	40	36	81	76	**20.8**	89.4	**60%**
PHX	TDWR	77	68	23	95	77	**28.6**	93.2	**62%**
PIA	LLWAS	62	45	38	80	77	**22.4**	88.8	**60%**
PIE	NoWS	74	72	26	95	81	**31.6**	92.4	**62%**
PIT	TDWR	55	43	45	83	76	**23.2**	86.8	**58%**
PNS	LLWAS	73	71	27	96	82	**31.9**	92.1	**62%**
PVD	LLWAS	61	33	39	79	75	**19.1**	88.5	**59%**
PWM	NoWS	59	28	41	74	74	**17.3**	87.9	**59%**
RDU	TDWR	64	52	36	92	78	**25.9**	89.4	**60%**
RIC	WSP	65	49	35	83	77	**23.4**	89.7	**60%**
RNO	NoWS	45	81	55	88	75	**31.8**	83.8	**57%**
ROA	LLWAS	68	58	32	86	77	**25.8**	90.6	**61%**

		Pilot Observability						Airborne	
Site	Type	% of Time High Reflectivity	Estimated Visibility of High Refl MB Events	% of Time Low Reflectivity	Estimated Visibility of Low Refl MB Events	% of Time MB/GF Occur During Daylight	% of Time a Pilot Can See Through Wx to See MB	PWS Effectiveness	Airborne % Effectiveness
ROC	WSP	65	38	35	78	75	**19.5**	89.7	**60%**
RST	LLWAS	69	43	31	79	75	**20.3**	90.9	**61%**
RSW	LLWAS	85	55	15	88	81	**24.3**	95.6	**64%**
SAN	NoWS	55	88	45	91	77	**34.4**	86.8	**58%**
SAT	WSP	64	56	36	94	80	**27.9**	89.4	**60%**
SAV	LLWAS	76	61	24	93	80	**27.5**	92.9	**62%**
SBN	NoWS	63	35	37	78	76	**19.3**	89.1	**60%**
SDF	TDWR	62	40	38	87	77	**22.3**	88.8	**60%**
SEA	WSP	47	36	53	70	73	**19.7**	84.4	**57%**
SFB	NoWS	80	65	20	91	83	**29.1**	94.1	**63%**
SFO	LLWAS	38	45	62	73	76	**23.7**	81.8	**55%**
SGF	LLWAS	64	48	36	88	78	**24.3**	89.4	**60%**
SHV	LLWAS	59	57	41	94	80	**28.9**	87.9	**59%**
SJC	NoWS	36	51	64	92	76	**29.4**	81.2	**55%**
SJU	TDWR	64	68	36	97	82	**32.2**	89.4	**60%**
SLC	TDWR	49	60	51	92	75	**28.6**	85.0	**57%**
SMF	NoWS	36	38	64	84	75	**25.3**	81.2	**55%**
SNA	NoWS	42	58	58	88	77	**29.0**	82.9	**56%**
SPI	LLWAS	59	43	41	82	78	**23.0**	87.9	**59%**
SRQ	WSP	69	70	31	93	81	**31.2**	90.9	**61%**
STL	TDWR-LLWAS	62	53	38	91	77	**26.0**	88.8	**60%**
SUX	LLWAS	63	36	37	85	76	**20.6**	89.1	**60%**
SYR	WSP	65	32	35	76	75	**17.8**	89.7	**60%**
TLH	LLWAS	65	64	35	98	81	**30.7**	89.7	**60%**
TOL	WSP	61	41	39	75	76	**20.6**	88.5	**59%**
TPA	TDWR-LLWAS	76	73	24	95	81	**31.7**	92.9	**62%**
TRI	LLWAS	72	53	28	88	77	**24.2**	91.8	**62%**

		Pilot Observability							Airborne	
Site	**Type**	**% of Time High Reflectivity**	**Estimated Visibility of High Refl MB Events**	**% of Time Low Reflectivity**	**Estimated Visibility of Low Refl MB Events**	**% of Time MB/GF Occur During Daylight**	**% of Time a Pilot Can See Through Wx to See MB**		**PWS Effectiveness**	**Airborne % Effectiveness**
TUL	TDWR	65	46	35	91	78	**24.1**		89.7	**60%**
TUS	WSP	61	58	39	89	79	**27.7**		88.5	**59%**
TWF	NoWS	32	31	68	72	75	**22.1**		80.0	**54%**
TYS	WSP	70	57	30	90	78	**26.1**		91.2	**61%**
Average		**62**	**51**	**38**	**86**	**78**	**25**		**89**	**1**

This page intentionally left blank.

APPENDIX C
WIND-SHEAR SYSTEM EFFECTIVITY BY SITE AND SYSTEM (POD MB & GF)

	Site	ABE	ABQ	ADW	AGS	ALB	AMA	ASE	ATL	AUS	AVL	AVP	AZO	BDL	BGM	BHM
	Type	NoWS	WSP	TDWR	LLWAS	WSP	NoWS	NoWS	TDWR-LLWAS	WSP	LLWAS	NoWS	NoWS	WSP	NoWS	WSP
"Current"	MB	0.0%	89.6%	89.3%	45.8%	82.8%	0.0%	0.0%	90.9%	69.6%	43.3%	0.0%	0.0%	85.9%	0.0%	79.4%
	GF	0.0%	61.5%	79.4%	1.3%	74.4%	0.0%	0.0%	78.6%	41.8%	0.7%	0.0%	0.0%	76.5%	0.0%	57.7%
"Upgraded" TDWR/WSP	MB	0.0%	93.1%	95.1%	45.8%	88.2%	0.0%	0.0%	98.7%	72.5%	43.3%	0.0%	0.0%	89.9%	0.0%	90.7%
	GF	0.0%	68.1%	91.9%	1.3%	78.2%	0.0%	0.0%	91.0%	53.1%	0.7%	0.0%	0.0%	79.6%	0.0%	66.0%
XBAND	MB	95.4%	95.9%	87.1%	90.8%	93.3%	95.1%	49.5%	94.3%	95.2%	87.9%	74.2%	95.3%	93.2%	95.8%	48.2%
	GF	83.0%	75.6%	88.7%	70.5%	90.5%	92.3%	2.7%	87.9%	90.4%	32.2%	29.1%	94.3%	77.2%	93.9%	15.9%
XBAND + LIDAR	MB	96.7%	97.0%	96.1%	94.2%	96.3%	96.0%	79.9%	96.2%	97.0%	93.4%	83.0%	97.1%	95.3%	96.9%	57.2%
	GF	90.0%	81.5%	94.3%	87.3%	93.7%	94.5%	3.5%	93.3%	93.7%	47.5%	41.9%	94.9%	87.9%	94.6%	30.5%
XBAND + LLWAS	MB	97.6%	97.9%	93.4%	95.3%	96.6%	97.5%	74.3%	97.9%	97.5%	93.9%	86.8%	97.6%	96.5%	97.9%	73.6%
	GF	90.0%	81.5%	94.3%	87.3%	93.7%	94.5%	3.5%	93.3%	93.7%	47.5%	41.9%	94.9%	87.9%	94.6%	30.5%
Lidar Only	MB	37.2%	19.2%	38.6%	15.7%	40.8%	21.8%	63.0%	16.3%	23.1%	22.6%	35.4%	48.6%	37.3%	31.6%	17.8%
	GF	58.3%	50.2%	65.1%	46.9%	64.0%	56.9%	2.9%	53.2%	56.6%	22.8%	22.4%	71.8%	54.6%	60.7%	11.9%
LLWAS Only	MB	48.8%	48.8%	48.8%	45.8%	48.8%	48.8%	48.8%	61.9%	48.8%	43.3%	48.8%	48.8%	48.8%	48.8%	48.8%
	GF	1.4%	1.4%	1.4%	1.3%	1.4%	1.4%	1.4%	5.4%	1.4%	0.7%	1.4%	1.4%	1.4%	1.4%	1.4%
NEXRAD	MB	0.0%	96.8%	75.4%	0.0%	0.0%	97.2%	0.0%	97.1%	0.0%	0.0%	0.0%	0.0%	0.0%	97.5%	95.7%
	GF	0.0%	76.7%	63.5%	0.0%	0.0%	87.6%	0.0%	93.0%	18.1%	0.0%	0.0%	18.4%	0.0%	92.9%	94.0%
NEXRAD + Lidar	MB	37.2%	97.9%	97.0%	15.7%	40.8%	97.5%	63.0%	97.8%	23.1%	22.6%	35.4%	48.6%	37.3%	97.8%	98.0%
	GF	58.3%	78.4%	82.7%	46.9%	64.0%	93.0%	2.9%	94.0%	67.8%	22.8%	22.4%	79.1%	54.6%	94.1%	94.0%
NEXRAD + LLWAS	MB	49.0%	98.4%	87.5%	49.0%	49.0%	98.6%	49.0%	98.9%	49.0%	49.0%	49.0%	49.0%	49.0%	98.7%	97.8%
	GF	58.3%	78.4%	82.7%	46.9%	64.0%	93.0%	2.9%	94.0%	67.8%	22.8%	22.4%	79.1%	54.6%	94.1%	94.0%
TDWR	MB	0.0%	NA	95.1%	NA	NA	0.0%	0.0%	96.5%	NA	NA	0.0%	0.0%	NA	0.0%	NA
	GF	0.0%	NA	91.9%	NA	NA	0.0%	0.0%	91.0%	NA	NA	0.0%	0.0%	NA	0.0%	NA
TDWR + LLWAS	MB	49.0%	NA	97.5%	NA	NA	49.0%	49.0%	98.7%	NA	NA	49.0%	49.0%	NA	49.0%	NA
	GF	0.0%	NA	91.9%	NA	NA	0.0%	0.0%	91.0%	NA	NA	0.0%	0.0%	NA	0.0%	NA
TDWR +LIDAR	MB	37.2%	NA	97.5%	NA	NA	21.8%	63.0%	97.1%	NA	NA	35.4%	48.6%	NA	31.6%	NA
	GF	58.3%	NA	94.5%	NA	NA	56.9%	2.9%	93.6%	NA	NA	22.4%	71.8%	NA	60.7%	NA
TDWR + NEXRAD	MB	0.0%	NA	95.8%	NA	NA	97.2%	0.0%	97.8%	NA	NA	0.0%	0.0%	NA	97.5%	NA
	GF	0.0%	NA	94.0%	NA	NA	87.6%	0.0%	94.7%	NA	NA	0.0%	18.4%	NA	92.9%	NA
TDWR + NXRAD + LLWAS	MB	49.0%	NA	97.8%	NA	NA	98.6%	49.0%	99.2%	NA	NA	49.0%	49.0%	NA	98.7%	NA
	GF	0.0%	NA	94.0%	NA	NA	87.6%	0.0%	94.7%	NA	NA	0.0%	18.4%	NA	92.9%	NA
TDWR + NEXRAD + LIDAR	MB	37.2%	NA	98.0%	NA	NA	97.5%	63.0%	98.0%	NA	NA	35.4%	48.6%	NA	97.8%	NA
	GF	58.3%	NA	94.7%	NA	NA	93.0%	2.9%	94.8%	NA	NA	22.4%	79.1%	NA	94.1%	NA
TDWR	MB	0.0%	NA	95.1%	NA	NA	0.0%	0.0%	96.5%	NA	NA	0.0%	0.0%	NA	0.0%	NA
	GF	0.0%	NA	91.9%	NA	NA	0.0%	0.0%	91.0%	NA	NA	0.0%	0.0%	NA	0.0%	NA
WSP	MB	0.0%	93.1%	81.4%	NA	88.2%	0.0%	0.0%	90.6%	72.5%	NA	0.0%	0.0%	89.9%	0.0%	90.7%
	GF	0.0%	68.1%	72.0%	NA	78.2%	0.0%	0.0%	65.8%	53.1%	NA	0.0%	0.0%	79.6%	0.0%	66.0%
WSP + LLWAS	MB	49.0%	96.5%	90.5%	NA	94.0%	49.0%	49.0%	96.4%	86.0%	NA	49.0%	49.0%	94.9%	49.0%	95.3%
	GF	0.0%	68.1%	72.0%	NA	78.2%	0.0%	0.0%	65.8%	53.1%	NA	0.0%	0.0%	79.6%	0.0%	66.0%
WSP + LIDAR	MB	37.2%	97.0%	96.8%	NA	97.6%	21.8%	63.0%	95.2%	85.9%	NA	35.4%	48.6%	97.6%	31.6%	95.8%
	GF	58.3%	79.7%	88.6%	NA	89.6%	56.9%	2.9%	82.9%	76.3%	NA	22.4%	71.8%	89.5%	60.7%	71.7%
WSP + NEXRAD	MB	0.0%	97.0%	84.9%	NA	88.2%	97.2%	0.0%	97.3%	72.5%	NA	0.0%	0.0%	89.9%	97.5%	96.5%
	GF	0.0%	86.0%	85.8%	NA	78.2%	87.6%	0.0%	93.9%	66.4%	NA	0.0%	18.4%	79.6%	92.9%	94.1%
WSP + NEXRAD + LLWAS	MB	49.0%	98.5%	92.3%	NA	94.0%	98.6%	49.0%	99.0%	86.0%	NA	49.0%	49.0%	94.9%	98.7%	98.2%
	GF	0.0%	86.0%	85.8%	NA	78.2%	87.6%	0.0%	93.9%	66.4%	NA	0.0%	18.4%	79.6%	92.9%	94.1%
MOD-XBAND	MB	95.4%	95.9%	87.1%	90.8%	93.3%	95.1%	49.5%	97.9%	95.2%	87.9%	74.2%	95.3%	93.2%	95.8%	48.2%
	GF	83.0%	75.6%	88.7%	70.5%	90.5%	92.3%	2.7%	93.3%	90.4%	32.2%	29.1%	94.3%	77.2%	93.9%	15.9%
WSP + NEXRAD + LIDAR	MB	37.2%	98.0%	97.8%	NA	97.6%	97.5%	63.0%	98.0%	85.9%	NA	35.4%	48.6%	97.6%	97.8%	98.0%
	GF	58.3%	88.0%	91.9%	NA	89.6%	93.0%	2.9%	94.5%	84.2%	NA	22.4%	79.1%	89.5%	94.1%	94.5%

	Site	BIL	BIS	BNA	BOI	BOS	BTR	BTV	BUF	BUR	BWI	CAE	CAK	CHA	CHS	CID
	Type	LLWAS	NoWS	TDWR	NoWS	TDWR	LLWAS	NoWS	WSP	NoWS	TDWR	LLWAS	NoWS	LLWAS	WSP	WSP
"Current"	MB	62.5%	0.0%	92.0%	0.0%	90.8%	42.9%	0.0%	85.8%	0.0%	90.4%	47.5%	0.0%	52.7%	83.6%	89.1%
	GF	1.9%	0.0%	79.7%	0.0%	79.8%	1.4%	0.0%	74.9%	0.0%	77.7%	1.3%	0.0%	1.5%	24.3%	72.4%
"Upgraded" TDWR/WSP	MB	62.5%	0.0%	97.7%	0.0%	96.5%	42.9%	0.0%	90.5%	0.0%	96.0%	47.5%	0.0%	52.7%	93.4%	92.3%
	GF	1.9%	0.0%	92.9%	0.0%	92.5%	1.4%	0.0%	79.4%	0.0%	89.8%	1.3%	0.0%	1.5%	49.2%	76.7%
XBAND	MB	65.7%	92.1%	95.2%	88.3%	93.6%	94.4%	92.3%	95.5%	78.4%	83.5%	50.5%	96.0%	79.2%	93.9%	95.3%
	GF	78.8%	88.4%	90.6%	55.6%	91.1%	80.4%	73.1%	93.6%	37.8%	85.1%	42.4%	91.9%	44.5%	75.2%	92.3%
XBAND + LIDAR	MB	85.8%	96.7%	96.7%	96.3%	95.6%	96.0%	95.6%	97.0%	87.2%	96.8%	64.3%	96.9%	83.2%	95.9%	96.5%
	GF	92.5%	93.7%	93.9%	67.0%	93.9%	90.5%	82.8%	94.7%	51.5%	94.4%	55.6%	94.1%	62.8%	87.7%	94.4%
XBAND + LLWAS	MB	82.5%	96.0%	97.5%	94.0%	96.7%	97.1%	96.1%	97.7%	89.0%	91.6%	74.7%	97.9%	89.4%	96.9%	97.6%
	GF	92.5%	93.7%	93.9%	67.0%	93.9%	90.5%	82.8%	94.7%	51.5%	94.4%	55.6%	94.1%	62.8%	87.7%	94.4%
Lidar Only	MB	65.6%	41.9%	24.1%	63.5%	34.8%	14.6%	51.0%	42.9%	36.8%	47.7%	22.3%	24.7%	17.1%	12.4%	31.0%
	GF	68.3%	65.3%	57.8%	52.4%	63.3%	49.9%	59.4%	68.4%	33.4%	73.0%	26.4%	56.5%	28.2%	48.6%	61.0%
LLWAS Only	MB	62.5%	48.8%	48.8%	48.8%	48.8%	42.9%	48.8%	48.8%	48.8%	48.8%	47.5%	48.8%	52.7%	48.8%	48.8%
	GF	1.9%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.3%	1.4%	1.5%	1.4%	1.4%
NEXRAD	MB	91.7%	92.3%	94.4%	97.8%	80.1%	0.0%	94.4%	96.7%	0.0%	0.0%	91.5%	32.2%	0.0%	0.0%	0.0%
	GF	88.1%	84.4%	85.2%	75.0%	77.1%	0.0%	69.5%	89.1%	0.0%	0.5%	71.6%	42.2%	0.0%	0.0%	0.0%
NEXRAD + Lidar	MB	97.0%	96.4%	97.0%	98.0%	97.9%	14.6%	96.7%	97.5%	36.8%	47.7%	94.6%	53.4%	17.1%	12.4%	31.0%
	GF	92.3%	92.9%	92.8%	87.7%	85.7%	49.9%	82.5%	93.5%	33.4%	73.4%	79.5%	74.0%	28.2%	48.6%	61.0%
NEXRAD + LLWAS	MB	95.8%	96.1%	97.2%	98.9%	89.9%	49.0%	97.1%	98.3%	49.0%	49.0%	95.7%	65.4%	49.0%	49.0%	49.0%
	GF	92.3%	92.9%	92.8%	87.7%	85.7%	49.9%	82.5%	93.5%	33.4%	73.4%	79.5%	74.0%	28.2%	48.6%	61.0%
TDWR	MB	NA	0.0%	97.7%	0.0%	96.5%	NA	0.0%	NA	0.0%	96.0%	NA	75.2%	NA	NA	NA
	GF	NA	0.0%	92.9%	0.0%	92.5%	NA	0.0%	NA	0.0%	89.8%	NA	51.8%	NA	NA	NA
TDWR + LLWAS	MB	NA	49.0%	98.8%	49.0%	98.2%	NA	49.0%	NA	49.0%	98.0%	NA	87.4%	NA	NA	NA
	GF	NA	0.0%	92.9%	0.0%	92.5%	NA	0.0%	NA	0.0%	89.8%	NA	51.8%	NA	NA	NA
TDWR +LIDAR	MB	NA	41.9%	97.9%	63.5%	97.8%	NA	51.0%	NA	36.8%	97.6%	NA	86.4%	NA	NA	NA
	GF	NA	65.3%	94.1%	52.4%	93.9%	NA	59.4%	NA	33.4%	94.2%	NA	75.9%	NA	NA	NA
TDWR + NEXRAD	MB	NA	92.3%	97.8%	97.8%	96.8%	NA	94.4%	NA	0.0%	96.0%	NA	75.2%	NA	NA	NA
	GF	NA	84.4%	94.2%	75.0%	94.4%	NA	69.5%	NA	0.0%	89.8%	NA	52.9%	NA	NA	NA
TDWR + NXRAD + LLWAS	MB	NA	96.1%	98.9%	98.9%	98.4%	NA	97.1%	NA	49.0%	98.0%	NA	87.4%	NA	NA	NA
	GF	NA	84.4%	94.2%	75.0%	94.4%	NA	69.5%	NA	0.0%	89.8%	NA	52.9%	NA	NA	NA
TDWR + NEXRAD + LIDAR	MB	NA	96.4%	98.0%	98.0%	98.0%	NA	96.7%	NA	36.8%	97.6%	NA	86.4%	NA	NA	NA
	GF	NA	92.9%	94.8%	87.7%	94.6%	NA	82.5%	NA	33.4%	94.3%	NA	76.2%	NA	NA	NA
TDWR	MB	NA	0.0%	97.7%	0.0%	96.5%	NA	0.0%	NA	0.0%	96.0%	NA	75.2%	NA	NA	NA
	GF	NA	0.0%	92.9%	0.0%	92.5%	NA	0.0%	NA	0.0%	89.8%	NA	51.8%	NA	NA	NA
WSP	MB	NA	0.0%	88.9%	0.0%	88.8%	NA	0.0%	90.5%	76.6%	74.3%	NA	0.0%	NA	93.4%	92.3%
	GF	NA	0.0%	66.7%	0.0%	80.4%	NA	0.0%	79.4%	41.9%	68.1%	NA	0.0%	NA	49.2%	76.7%
WSP + LLWAS	MB	NA	49.0%	94.4%	49.0%	94.3%	NA	49.0%	95.2%	88.1%	86.9%	NA	49.0%	NA	96.6%	96.1%
	GF	NA	0.0%	66.7%	0.0%	80.4%	NA	0.0%	79.4%	41.9%	68.1%	NA	0.0%	NA	49.2%	76.7%
WSP + LIDAR	MB	NA	41.9%	95.5%	63.5%	97.6%	NA	51.0%	97.4%	94.7%	96.5%	NA	24.7%	NA	96.0%	97.5%
	GF	NA	65.3%	85.0%	52.4%	90.5%	NA	59.4%	91.0%	56.0%	92.5%	NA	56.5%	NA	71.8%	87.4%
WSP + NEXRAD	MB	NA	92.3%	96.2%	97.8%	89.4%	NA	94.4%	97.4%	76.6%	74.3%	NA	32.2%	NA	93.4%	92.3%
	GF	NA	84.4%	90.6%	75.0%	89.2%	NA	69.5%	92.3%	41.9%	68.3%	NA	42.2%	NA	49.2%	76.7%
WSP + NEXRAD + LLWAS	MB	NA	96.1%	98.0%	98.9%	94.6%	NA	97.1%	98.7%	88.1%	86.9%	NA	65.4%	NA	96.6%	96.1%
	GF	NA	84.4%	90.6%	75.0%	89.2%	NA	69.5%	92.3%	41.9%	68.3%	NA	42.2%	NA	49.2%	76.7%
MOD-XBAND	MB	65.7%	92.1%	95.2%	88.3%	93.6%	94.4%	92.3%	95.5%	78.4%	83.5%	50.5%	96.0%	79.2%	93.9%	95.3%
	GF	78.8%	88.4%	90.6%	55.6%	91.1%	80.4%	73.1%	93.6%	37.8%	85.1%	42.4%	91.9%	44.5%	75.2%	92.3%
WSP + NEXRAD + LIDAR	MB	NA	96.4%	97.8%	98.0%	98.0%	NA	96.7%	97.8%	94.7%	96.5%	NA	53.4%	NA	96.0%	97.5%
	GF	NA	92.9%	94.1%	87.7%	93.5%	NA	82.5%	94.4%	56.0%	92.5%	NA	74.0%	NA	71.8%	87.4%

	Site	CLE	CLT	CMH	COS	CRP	CRW	CSG	CVG	DAB	DAL	DAY	DCA	DEN	DFW	DSM
	Type	TDWR	TDWR	TDWR	LLWAS	NoWS	LLWAS	LLWAS	TDWR	LLWAS	TDWR	TDWR	TDWR	TDWR-LLWAS	TDWR-LLWAS	WSP
"Current"	MB	91.2%	91.8%	92.0%	51.9%	0.0%	43.6%	63.7%	91.6%	57.1%	90.4%	91.4%	90.9%	90.5%	91.3%	79.8%
	GF	80.3%	78.8%	80.3%	1.6%	0.0%	1.3%	2.0%	80.5%	1.9%	78.7%	79.9%	77.5%	80.6%	79.4%	69.7%
"Upgraded" TDWR/WSP	MB	96.9%	97.5%	97.9%	51.9%	0.0%	43.6%	63.7%	97.3%	57.1%	95.9%	97.1%	96.7%	99.9%	98.9%	88.5%
	GF	94.0%	91.5%	93.9%	1.6%	0.0%	1.3%	2.0%	93.8%	1.9%	91.3%	92.8%	89.9%	94.6%	92.9%	75.2%
XBAND	MB	95.8%	90.8%	93.9%	82.3%	96.2%	64.4%	87.9%	94.0%	94.3%	93.9%	95.7%	88.0%	92.7%	96.0%	94.3%
	GF	93.6%	90.0%	90.5%	64.5%	94.2%	56.4%	82.7%	92.1%	87.0%	90.6%	91.7%	68.8%	93.9%	91.3%	93.9%
XBAND + LIDAR	MB	97.1%	95.9%	96.6%	85.4%	97.0%	74.0%	95.7%	97.0%	96.3%	96.9%	96.9%	94.9%	97.1%	97.2%	96.9%
	GF	94.8%	94.1%	94.6%	71.1%	94.9%	67.2%	93.2%	94.7%	93.3%	94.2%	94.0%	86.7%	94.9%	93.5%	94.9%
XBAND + LLWAS	MB	97.9%	95.3%	96.9%	91.0%	98.0%	81.8%	93.9%	97.0%	97.1%	96.9%	97.8%	93.9%	99.8%	98.5%	97.1%
	GF	94.8%	94.1%	94.6%	71.1%	94.9%	67.2%	93.2%	94.7%	93.3%	94.2%	94.0%	86.7%	94.9%	93.5%	94.9%
Lidar Only	MB	36.8%	18.8%	31.0%	21.8%	22.4%	29.9%	25.6%	30.4%	15.7%	27.8%	23.6%	37.8%	62.3%	20.7%	35.8%
	GF	65.7%	52.8%	60.2%	43.8%	53.2%	36.4%	56.6%	62.3%	50.7%	59.4%	57.2%	50.4%	83.8%	57.7%	64.3%
LLWAS Only	MB	48.8%	48.8%	48.8%	51.9%	48.8%	43.6%	63.7%	48.8%	57.1%	48.8%	48.8%	48.8%	97.0%	61.8%	48.8%
	GF	1.4%	1.4%	1.4%	1.6%	1.4%	1.3%	2.0%	1.4%	1.9%	1.4%	1.4%	1.4%	11.6%	6.9%	1.4%
NEXRAD	MB	96.0%	0.0%	0.0%	78.7%	97.2%	96.0%	0.0%	0.0%	0.0%	68.3%	4.9%	86.6%	92.7%	91.0%	95.4%
	GF	89.0%	0.0%	0.0%	56.6%	90.3%	86.7%	0.0%	0.0%	0.0%	49.6%	29.6%	74.4%	91.9%	90.6%	89.0%
NEXRAD + Lidar	MB	97.0%	18.8%	31.0%	89.6%	97.4%	97.4%	25.6%	30.4%	15.7%	84.9%	28.7%	97.9%	97.6%	97.8%	97.5%
	GF	93.7%	52.8%	60.2%	64.0%	93.5%	91.5%	56.6%	62.3%	50.7%	76.8%	71.1%	84.6%	94.7%	92.2%	93.8%
NEXRAD + LLWAS	MB	98.0%	49.0%	49.0%	89.1%	98.6%	98.0%	49.0%	49.0%	49.0%	83.8%	51.5%	93.2%	99.8%	96.6%	97.7%
	GF	93.7%	52.8%	60.2%	64.0%	93.5%	91.5%	56.6%	62.3%	50.7%	76.8%	71.1%	84.6%	94.7%	92.2%	93.8%
TDWR	MB	96.9%	97.5%	97.9%	NA	0.0%	NA	NA	97.3%	NA	95.9%	97.1%	96.7%	96.1%	97.0%	NA
	GF	94.0%	91.5%	93.9%	NA	0.0%	NA	NA	93.8%	NA	91.3%	92.8%	89.9%	94.6%	92.9%	NA
TDWR + LLWAS	MB	98.4%	98.7%	98.9%	NA	49.0%	NA	NA	98.6%	NA	97.9%	98.5%	98.3%	99.9%	98.9%	NA
	GF	94.0%	91.5%	93.9%	NA	0.0%	NA	NA	93.8%	NA	91.3%	92.8%	89.9%	94.6%	92.9%	NA
TDWR +LIDAR	MB	97.8%	97.8%	98.0%	NA	22.4%	NA	NA	97.9%	NA	97.4%	97.7%	97.7%	98.0%	97.7%	NA
	GF	94.7%	93.4%	94.5%	NA	53.2%	NA	NA	94.7%	NA	94.2%	94.3%	92.4%	95.0%	94.3%	NA
TDWR + NEXRAD	MB	97.8%	97.5%	97.9%	NA	97.2%	NA	NA	97.3%	NA	96.4%	97.1%	97.4%	96.3%	97.3%	NA
	GF	94.5%	91.5%	93.9%	NA	90.3%	NA	NA	93.8%	NA	93.1%	93.0%	93.8%	94.7%	94.8%	NA
TDWR + NXRAD + LLWAS	MB	98.9%	98.7%	98.9%	NA	98.6%	NA	NA	98.6%	NA	98.2%	98.5%	98.7%	99.9%	99.0%	NA
	GF	94.5%	91.5%	93.9%	NA	90.3%	NA	NA	93.8%	NA	93.1%	93.0%	93.8%	94.7%	94.8%	NA
TDWR + NEXRAD + LIDAR	MB	97.9%	97.8%	98.0%	NA	97.4%	NA	NA	97.9%	NA	97.8%	97.7%	98.0%	98.0%	98.0%	NA
	GF	94.9%	93.4%	94.5%	NA	93.5%	NA	NA	94.7%	NA	94.7%	94.4%	94.6%	95.0%	94.9%	NA
TDWR	MB	96.9%	97.5%	97.9%	NA	0.0%	NA	NA	97.3%	NA	95.9%	97.1%	96.7%	96.1%	97.0%	NA
	GF	94.0%	91.5%	93.9%	NA	0.0%	NA	NA	93.8%	NA	91.3%	92.8%	89.9%	94.6%	92.9%	NA
WSP	MB	90.3%	90.3%	88.7%	NA	0.0%	NA	NA	87.8%	NA	40.8%	90.9%	83.7%	59.8%	87.9%	88.5%
	GF	79.1%	67.8%	69.2%	NA	0.0%	NA	NA	75.9%	NA	31.8%	69.3%	74.5%	75.4%	66.5%	75.2%
WSP + LLWAS	MB	95.1%	95.1%	94.3%	NA	49.0%	NA	NA	93.8%	NA	69.8%	95.4%	91.7%	98.8%	95.4%	94.1%
	GF	79.1%	67.8%	69.2%	NA	0.0%	NA	NA	75.9%	NA	31.8%	69.3%	74.5%	75.4%	66.5%	75.2%
WSP + LIDAR	MB	97.2%	96.5%	97.0%	NA	22.4%	NA	NA	96.8%	NA	68.2%	97.2%	96.4%	91.8%	95.2%	96.6%
	GF	90.0%	81.9%	86.0%	NA	53.2%	NA	NA	88.6%	NA	72.6%	84.6%	87.2%	93.4%	82.6%	88.9%
WSP + NEXRAD	MB	97.1%	90.3%	88.7%	NA	97.2%	NA	NA	87.8%	NA	74.4%	90.9%	90.4%	93.6%	93.2%	96.4%
	GF	92.7%	67.8%	69.2%	NA	90.3%	NA	NA	75.9%	NA	56.7%	77.6%	91.1%	93.6%	93.1%	92.8%
WSP + NEXRAD + LLWAS	MB	98.5%	95.1%	94.3%	NA	98.6%	NA	NA	93.8%	NA	86.9%	95.4%	95.1%	99.8%	97.4%	98.2%
	GF	92.7%	67.8%	69.2%	NA	90.3%	NA	NA	75.9%	NA	56.7%	77.6%	91.1%	93.6%	93.1%	92.8%
MOD-XBAND	MB	95.8%	90.8%	93.9%	82.3%	96.2%	64.4%	87.9%	94.0%	94.3%	93.9%	95.7%	88.0%	99.8%	98.5%	94.3%
	GF	93.6%	90.0%	90.5%	64.5%	94.2%	56.4%	82.7%	92.1%	87.0%	90.6%	91.7%	68.8%	94.9%	93.5%	93.9%
WSP + NEXRAD + LIDAR	MB	97.6%	96.5%	97.0%	NA	97.4%	NA	NA	96.8%	NA	91.0%	97.3%	97.9%	97.8%	97.9%	97.9%
	GF	94.5%	81.9%	86.0%	NA	93.5%	NA	NA	88.6%	NA	80.8%	89.0%	92.9%	94.9%	94.1%	94.5%

	Site	DTW	ELP	ERI	EVV	EWR	FAR	FAY	FLL	FNT	FSD	FSM	FWA	GCN	GEG	GFK
	Type	TDWR	WSP	NoWS	NoWS	TDWR	NoWS	LLWAS	TDWR	NoWS	LLWAS	LLWAS	WSP	NoWS	WSP	NoWS
"Current"	**MB**	91.9%	90.1%	0.0%	0.0%	90.2%	0.0%	44.7%	91.5%	0.0%	46.7%	49.1%	79.5%	0.0%	81.1%	0.0%
	GF	80.7%	64.7%	0.0%	0.0%	72.4%	0.0%	1.3%	75.8%	0.0%	1.8%	1.4%	63.3%	0.0%	73.3%	0.0%
"Upgraded" TDWR/WSP	**MB**	97.7%	94.1%	0.0%	0.0%	95.8%	0.0%	44.7%	97.0%	0.0%	46.7%	49.1%	88.3%	0.0%	85.9%	0.0%
	GF	94.3%	69.4%	0.0%	0.0%	84.6%	0.0%	1.3%	86.7%	0.0%	1.8%	1.4%	73.6%	0.0%	76.6%	0.0%
XBAND	**MB**	96.3%	95.8%	83.9%	95.3%	94.7%	89.5%	93.0%	96.2%	94.8%	91.7%	93.3%	93.7%	92.3%	93.5%	95.2%
	GF	94.7%	78.7%	66.7%	94.5%	86.9%	91.6%	81.5%	84.5%	92.6%	93.1%	68.0%	91.1%	78.4%	86.0%	94.1%
XBAND + LIDAR	**MB**	97.2%	96.6%	94.6%	96.8%	96.8%	97.2%	96.5%	96.8%	96.8%	97.1%	95.8%	96.9%	96.6%	97.1%	97.3%
	GF	95.0%	85.8%	78.4%	94.9%	91.4%	94.8%	90.4%	92.8%	94.7%	95.0%	83.0%	94.4%	81.9%	92.7%	94.9%
XBAND + LLWAS	**MB**	98.1%	97.9%	91.8%	97.6%	97.3%	94.6%	96.4%	98.0%	97.4%	95.8%	96.6%	96.8%	96.1%	96.7%	97.5%
	GF	95.0%	85.8%	78.4%	94.9%	91.4%	94.8%	90.4%	92.8%	94.7%	95.0%	83.0%	94.4%	81.9%	92.7%	94.9%
Lidar Only	**MB**	29.0%	17.7%	46.6%	35.5%	39.4%	43.7%	20.7%	9.5%	41.9%	51.9%	21.9%	29.6%	61.2%	47.0%	45.3%
	GF	62.0%	47.3%	53.1%	64.3%	63.6%	69.9%	54.0%	47.1%	68.4%	75.4%	39.3%	60.7%	68.5%	69.3%	69.9%
LLWAS Only	**MB**	48.8%	48.8%	48.8%	48.8%	48.8%	48.8%	44.7%	48.8%	48.8%	46.7%	49.1%	48.8%	48.8%	48.8%	48.8%
	GF	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.3%	1.4%	1.4%	1.8%	1.4%	1.4%	1.4%	1.4%	1.4%
NEXRAD	**MB**	0.0%	3.2%	0.0%	0.0%	0.0%	0.0%	0.0%	94.3%	52.3%	88.0%	97.1%	6.9%	0.0%	93.4%	38.4%
	GF	0.0%	31.7%	0.0%	0.0%	0.0%	0.0%	0.0%	57.2%	72.4%	89.7%	87.4%	29.5%	0.0%	85.4%	68.6%
NEXRAD + Lidar	**MB**	29.0%	20.4%	46.6%	35.5%	39.4%	43.7%	20.7%	96.7%	90.2%	96.7%	97.5%	36.7%	61.2%	97.6%	82.0%
	GF	62.0%	70.2%	53.1%	64.3%	63.6%	69.9%	54.0%	73.5%	85.2%	94.8%	90.3%	73.3%	68.5%	92.9%	85.1%
NEXRAD + LLWAS	**MB**	49.0%	50.6%	49.0%	49.0%	49.0%	49.0%	49.0%	97.1%	75.7%	93.9%	98.5%	52.5%	49.0%	96.6%	68.6%
	GF	62.0%	70.2%	53.1%	64.3%	63.6%	69.9%	54.0%	73.5%	85.2%	94.8%	90.3%	73.3%	68.5%	92.9%	85.1%
TDWR	**MB**	97.7%	NA	0.0%	0.0%	95.8%	0.0%	NA	97.0%	0.0%	NA	NA	NA	0.0%	NA	0.0%
	GF	94.3%	NA	0.0%	0.0%	84.6%	0.0%	NA	86.7%	0.0%	NA	NA	NA	0.0%	NA	0.0%
TDWR + LLWAS	**MB**	98.8%	NA	49.0%	49.0%	97.9%	49.0%	NA	98.5%	49.0%	NA	NA	NA	49.0%	NA	49.0%
	GF	94.3%	NA	0.0%	0.0%	84.6%	0.0%	NA	86.7%	0.0%	NA	NA	NA	0.0%	NA	0.0%
TDWR +LIDAR	**MB**	98.0%	NA	46.6%	35.5%	97.4%	43.7%	NA	97.1%	41.9%	NA	NA	NA	61.2%	NA	45.3%
	GF	94.7%	NA	53.1%	64.3%	90.1%	69.9%	NA	92.4%	68.4%	NA	NA	NA	68.5%	NA	69.9%
TDWR + NEXRAD	**MB**	97.7%	NA	0.0%	0.0%	95.8%	0.0%	NA	97.9%	52.3%	NA	NA	NA	0.0%	NA	38.4%
	GF	94.3%	NA	0.0%	0.0%	84.6%	0.0%	NA	91.1%	72.4%	NA	NA	NA	0.0%	NA	68.6%
TDWR + NXRAD + LLWAS	**MB**	98.8%	NA	49.0%	49.0%	97.9%	49.0%	NA	98.9%	75.7%	NA	NA	NA	49.0%	NA	68.6%
	GF	94.3%	NA	0.0%	0.0%	84.6%	0.0%	NA	91.1%	72.4%	NA	NA	NA	0.0%	NA	68.6%
TDWR + NEXRAD + LIDAR	**MB**	98.0%	NA	46.6%	35.5%	97.4%	43.7%	NA	98.0%	90.2%	NA	NA	NA	61.2%	NA	82.0%
	GF	94.7%	NA	53.1%	64.3%	90.1%	69.9%	NA	93.8%	85.2%	NA	NA	NA	68.5%	NA	85.1%
TDWR	**MB**	97.7%	NA	0.0%	0.0%	95.8%	0.0%	NA	97.0%	0.0%	NA	NA	NA	0.0%	NA	0.0%
	GF	94.3%	NA	0.0%	0.0%	84.6%	0.0%	NA	86.7%	0.0%	NA	NA	NA	0.0%	NA	0.0%
WSP	**MB**	88.8%	94.1%	0.0%	0.0%	85.2%	0.0%	NA	96.1%	0.0%	NA	NA	88.3%	0.0%	85.9%	0.0%
	GF	78.7%	69.4%	0.0%	0.0%	77.6%	0.0%	NA	61.8%	0.0%	NA	NA	73.6%	0.0%	76.6%	0.0%
WSP + LLWAS	**MB**	94.3%	97.0%	49.0%	49.0%	92.5%	49.0%	NA	98.0%	49.0%	NA	NA	94.0%	49.0%	92.8%	49.0%
	GF	78.7%	69.4%	0.0%	0.0%	77.6%	0.0%	NA	61.8%	0.0%	NA	NA	73.6%	0.0%	76.6%	0.0%
WSP + LIDAR	**MB**	96.5%	96.6%	46.6%	35.5%	96.7%	43.7%	NA	97.1%	41.9%	NA	NA	97.0%	61.2%	97.5%	45.3%
	GF	88.7%	81.6%	53.1%	64.3%	90.1%	69.9%	NA	81.4%	68.4%	NA	NA	87.7%	68.5%	91.5%	69.9%
WSP + NEXRAD	**MB**	88.8%	94.4%	0.0%	0.0%	85.2%	0.0%	NA	97.3%	52.3%	NA	NA	88.3%	0.0%	96.2%	38.4%
	GF	78.7%	79.0%	0.0%	0.0%	77.6%	0.0%	NA	80.6%	72.4%	NA	NA	77.7%	0.0%	90.8%	68.6%
WSP + NEXRAD + LLWAS	**MB**	94.3%	97.1%	49.0%	49.0%	92.5%	49.0%	NA	98.6%	75.7%	NA	NA	94.1%	49.0%	98.1%	68.6%
	GF	78.7%	79.0%	0.0%	0.0%	77.6%	0.0%	NA	80.6%	72.4%	NA	NA	77.7%	0.0%	90.8%	68.6%
MOD-XBAND	**MB**	96.3%	95.8%	83.9%	95.3%	94.7%	89.5%	93.0%	96.2%	94.8%	91.7%	93.3%	93.7%	92.3%	93.5%	95.2%
	GF	94.7%	78.7%	66.7%	94.5%	86.9%	91.6%	81.5%	84.5%	92.6%	93.1%	68.0%	91.1%	78.4%	86.0%	94.1%
WSP + NEXRAD + LIDAR	**MB**	96.5%	96.8%	46.6%	35.5%	96.7%	43.7%	NA	98.0%	90.2%	NA	NA	97.0%	61.2%	97.9%	82.0%
	GF	88.7%	88.7%	53.1%	64.3%	90.1%	69.9%	NA	88.2%	85.2%	NA	NA	89.9%	68.5%	93.9%	85.1%

	Site	GPT	GRB	GRR	GSO	GSP	HNL	HPN	HSV	IAD	IAH	ICT	ILM	IND	ISP	JAN
	Type	NoWS	LLWAS	WSP	WSP	LLWAS	WSP	WSP	WSP	TDWR	TDWR	TDWR	NoWS	TDWR	WSP	LLWAS
"Current"	**MB**	0.0%	47.4%	86.7%	85.9%	47.2%	87.4%	87.2%	89.2%	91.1%	91.5%	91.4%	0.0%	90.5%	71.9%	59.1%
	GF	0.0%	1.3%	77.6%	59.0%	0.6%	34.9%	78.6%	62.6%	78.2%	79.1%	79.2%	0.0%	80.3%	70.2%	1.5%
"Upgraded" TDWR/WSP	**MB**	0.0%	47.4%	90.2%	91.7%	47.2%	95.7%	89.8%	93.9%	96.7%	97.0%	97.2%	0.0%	96.2%	79.0%	59.1%
	GF	0.0%	1.3%	80.2%	70.3%	0.6%	55.8%	80.5%	71.5%	90.9%	89.1%	92.4%	0.0%	93.6%	76.8%	1.5%
XBAND	**MB**	94.7%	90.4%	95.8%	72.1%	93.8%	92.3%	92.5%	91.8%	87.9%	92.6%	93.6%	92.8%	95.9%	94.1%	88.4%
	GF	81.5%	90.1%	94.6%	75.4%	88.8%	61.0%	84.9%	87.4%	85.6%	72.4%	89.2%	71.9%	93.7%	92.0%	86.6%
XBAND + LIDAR	**MB**	96.5%	96.6%	97.1%	78.8%	96.3%	92.8%	95.3%	93.6%	96.2%	95.6%	96.5%	96.3%	96.8%	97.4%	95.8%
	GF	91.1%	94.6%	95.0%	88.3%	93.2%	65.9%	91.5%	92.1%	94.2%	87.4%	94.4%	88.0%	94.5%	94.7%	94.0%
XBAND + LLWAS	**MB**	97.3%	95.1%	97.8%	85.8%	96.9%	96.1%	96.2%	95.8%	93.8%	96.2%	96.7%	96.3%	97.9%	97.0%	94.1%
	GF	91.1%	94.6%	95.0%	88.3%	93.2%	65.9%	91.5%	92.1%	94.2%	87.4%	94.4%	88.0%	94.5%	94.7%	94.0%
Lidar Only	**MB**	16.2%	49.7%	44.4%	23.8%	21.7%	13.7%	44.6%	18.8%	34.8%	12.1%	29.7%	16.7%	24.9%	54.0%	29.6%
	GF	51.4%	73.2%	71.0%	56.1%	51.9%	39.0%	44.0%	50.8%	67.0%	50.5%	61.0%	51.4%	58.0%	77.0%	58.8%
LLWAS Only	**MB**	48.8%	47.4%	48.8%	48.8%	47.2%	48.8%	48.8%	48.8%	48.8%	48.8%	48.8%	48.8%	48.8%	48.8%	59.1%
	GF	1.4%	1.3%	1.4%	1.4%	0.6%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.5%
NEXRAD	**MB**	0.0%	93.4%	97.2%	0.0%	97.1%	0.0%	0.0%	0.0%	85.2%	76.2%	92.7%	76.0%	96.0%	94.8%	95.2%
	GF	6.1%	79.7%	92.7%	0.0%	81.6%	0.0%	15.2%	0.0%	75.4%	52.2%	79.9%	54.7%	87.8%	90.5%	84.0%
NEXRAD + Lidar	**MB**	16.2%	97.3%	97.7%	23.8%	97.5%	13.7%	44.6%	18.8%	94.7%	80.7%	96.4%	83.5%	96.4%	98.0%	96.8%
	GF	57.1%	92.4%	94.7%	56.1%	89.3%	39.0%	74.0%	50.8%	92.2%	73.6%	92.5%	74.5%	92.1%	94.0%	91.4%
NEXRAD + LLWAS	**MB**	49.0%	96.6%	98.6%	49.0%	98.5%	49.0%	49.0%	49.0%	92.4%	87.9%	96.3%	87.8%	97.9%	97.3%	97.5%
	GF	57.1%	92.4%	94.7%	56.1%	89.3%	39.0%	74.0%	50.8%	92.2%	73.6%	92.5%	74.5%	92.1%	94.0%	91.4%
TDWR	**MB**	0.0%	NA	NA	NA	NA	NA	NA	NA	96.7%	97.0%	97.2%	0.0%	96.2%	NA	NA
	GF	0.0%	NA	NA	NA	NA	NA	NA	NA	90.9%	89.1%	92.4%	0.0%	93.6%	NA	NA
TDWR + LLWAS	**MB**	49.0%	NA	NA	NA	NA	NA	NA	NA	98.3%	98.5%	98.6%	49.0%	98.0%	NA	NA
	GF	0.0%	NA	NA	NA	NA	NA	NA	NA	90.9%	89.1%	92.4%	0.0%	93.6%	NA	NA
TDWR +LIDAR	**MB**	16.2%	NA	NA	NA	NA	NA	NA	NA	97.7%	97.3%	97.8%	16.7%	97.4%	NA	NA
	GF	51.4%	NA	NA	NA	NA	NA	NA	NA	94.0%	92.4%	94.4%	51.4%	94.6%	NA	NA
TDWR + NEXRAD	**MB**	0.0%	NA	NA	NA	NA	NA	NA	NA	97.0%	97.7%	97.6%	76.0%	97.9%	NA	NA
	GF	6.1%	NA	NA	NA	NA	NA	NA	NA	92.3%	92.1%	93.7%	54.7%	94.5%	NA	NA
TDWR + NXRAD + LLWAS	**MB**	49.0%	NA	NA	NA	NA	NA	NA	NA	98.5%	98.8%	98.8%	87.8%	98.9%	NA	NA
	GF	6.1%	NA	NA	NA	NA	NA	NA	NA	92.3%	92.1%	93.7%	54.7%	94.5%	NA	NA
TDWR + NEXRAD + LIDAR	**MB**	16.2%	NA	NA	NA	NA	NA	NA	NA	97.7%	97.9%	97.9%	83.5%	98.0%	NA	NA
	GF	57.1%	NA	NA	NA	NA	NA	NA	NA	94.6%	93.4%	94.7%	74.5%	94.8%	NA	NA
TDWR	**MB**	0.0%	NA	NA	NA	NA	NA	NA	NA	96.7%	97.0%	97.2%	0.0%	96.2%	NA	NA
	GF	0.0%	NA	NA	NA	NA	NA	NA	NA	90.9%	89.1%	92.4%	0.0%	93.6%	NA	NA
WSP	**MB**	0.0%	NA	90.2%	91.7%	NA	95.7%	89.8%	93.9%	81.2%	91.8%	88.6%	0.0%	92.6%	79.0%	NA
	GF	0.0%	NA	80.2%	70.3%	NA	55.8%	80.5%	71.5%	68.6%	52.0%	70.2%	0.0%	77.3%	76.8%	NA
WSP + LLWAS	**MB**	49.0%	NA	95.0%	95.8%	NA	97.8%	94.8%	96.9%	90.4%	95.8%	94.2%	49.0%	96.2%	89.3%	NA
	GF	0.0%	NA	80.2%	70.3%	NA	55.8%	80.5%	71.5%	68.6%	52.0%	70.2%	0.0%	77.3%	76.8%	NA
WSP + LIDAR	**MB**	16.2%	NA	97.7%	97.0%	NA	96.7%	97.7%	97.1%	95.1%	94.3%	96.6%	16.7%	95.7%	97.1%	NA
	GF	51.4%	NA	92.7%	85.5%	NA	67.2%	86.5%	83.7%	89.9%	73.9%	87.2%	51.4%	86.9%	93.9%	NA
WSP + NEXRAD	**MB**	0.0%	NA	97.6%	91.7%	NA	95.7%	89.8%	93.9%	90.7%	95.7%	95.1%	76.0%	96.7%	94.8%	NA
	GF	6.1%	NA	94.1%	70.3%	NA	55.8%	83.8%	71.5%	84.5%	75.6%	87.6%	54.7%	91.2%	93.0%	NA
WSP + NEXRAD + LLWAS	**MB**	49.0%	NA	98.8%	95.8%	NA	97.8%	94.8%	96.9%	95.3%	97.8%	97.5%	87.8%	98.3%	97.3%	NA
	GF	6.1%	NA	94.1%	70.3%	NA	55.8%	83.8%	71.5%	84.5%	75.6%	87.6%	54.7%	91.2%	93.0%	NA
MOD-XBAND	**MB**	94.7%	90.4%	95.8%	72.1%	93.8%	92.3%	92.5%	91.8%	87.9%	92.6%	93.6%	92.8%	95.9%	94.1%	88.4%
	GF	81.5%	90.1%	94.6%	75.4%	88.8%	61.0%	84.9%	87.4%	85.6%	72.4%	89.2%	71.9%	93.7%	92.0%	86.6%
WSP + NEXRAD + LIDAR	**MB**	16.2%	NA	97.9%	97.0%	NA	96.7%	97.7%	97.1%	97.3%	97.5%	97.6%	83.5%	97.1%	98.0%	NA
	GF	57.1%	NA	94.9%	85.5%	NA	67.2%	89.4%	83.7%	94.1%	83.8%	93.8%	74.5%	93.4%	94.8%	NA

	Site	JAX	JFK	LAN	LAS	LAX	LBB	LEX	LFT	LGA	LGB	LIT	LNK	MAF	MBS	MCI	MCO
	Type	WSP	TDWR	LLWAS	TDWR	WSP	WSP	LLWAS	NoWS	TDWR-LLWAS	NoWS	LLWAS	LLWAS	LLWAS	NoWS	TDWR	TDWR-LLWAS
"Current"	**MB**	84.3%	91.4%	47.8%	78.4%	70.4%	88.2%	47.4%	0.0%	91.5%	0.0%	57.8%	62.1%	53.3%	0.0%	91.8%	91.9%
	GF	64.7%	80.2%	1.5%	48.6%	41.0%	69.3%	1.3%	0.0%	80.3%	0.0%	2.1%	1.8%	2.3%	0.0%	80.7%	78.3%
"Upgraded" TDWR/WSP	**MB**	84.5%	97.0%	47.8%	84.6%	84.7%	92.1%	47.4%	0.0%	98.4%	0.0%	57.8%	62.1%	53.3%	0.0%	97.6%	99.6%
	GF	67.1%	92.4%	1.5%	57.2%	60.4%	73.9%	1.3%	0.0%	94.0%	0.0%	2.1%	1.8%	2.3%	0.0%	94.5%	90.6%
XBAND	**MB**	96.3%	95.2%	92.4%	61.6%	92.5%	95.6%	95.2%	94.9%	94.7%	87.6%	91.5%	94.8%	94.7%	93.8%	96.5%	96.5%
	GF	94.5%	94.2%	92.8%	58.1%	78.2%	94.2%	93.6%	86.5%	93.2%	69.1%	87.0%	94.3%	90.1%	87.9%	94.8%	91.7%
XBAND + LIDAR	**MB**	96.8%	97.2%	96.9%	83.2%	97.3%	96.4%	96.5%	96.2%	96.8%	92.7%	96.2%	96.9%	96.3%	96.8%	96.9%	97.1%
	GF	94.9%	95.0%	94.8%	76.9%	88.6%	94.9%	94.9%	93.6%	94.6%	85.4%	94.0%	94.9%	93.5%	92.8%	95.0%	93.9%
XBAND + LLWAS	**MB**	98.1%	97.6%	96.1%	80.4%	96.2%	97.7%	97.6%	97.4%	96.8%	93.7%	95.7%	97.4%	97.3%	96.8%	98.2%	99.5%
	GF	94.9%	95.0%	94.8%	76.9%	88.6%	94.9%	94.9%	93.6%	94.6%	85.4%	94.0%	94.9%	93.5%	92.8%	95.0%	93.9%
Lidar Only	**MB**	17.6%	40.3%	44.5%	59.3%	32.0%	25.7%	21.2%	15.0%	42.2%	22.4%	29.7%	30.5%	19.1%	37.1%	19.5%	11.7%
	GF	52.4%	69.7%	69.9%	60.0%	61.5%	58.0%	53.8%	49.9%	66.7%	47.6%	61.0%	62.0%	53.2%	64.3%	54.6%	50.1%
LLWAS Only	**MB**	48.8%	48.8%	47.8%	48.8%	48.8%	48.8%	47.4%	48.8%	40.5%	48.8%	57.8%	62.1%	53.3%	48.8%	48.8%	84.6%
	GF	1.4%	1.4%	1.5%	1.4%	1.4%	1.4%	1.3%	1.4%	1.8%	1.4%	2.1%	1.8%	2.3%	1.4%	1.4%	7.0%
NEXRAD	**MB**	97.4%	0.0%	0.0%	0.0%	0.0%	96.0%	0.0%	0.0%	0.0%	0.0%	96.6%	58.2%	96.0%	0.0%	13.3%	0.0%
	GF	90.3%	0.0%	4.3%	0.0%	0.0%	85.8%	0.0%	0.0%	0.0%	0.0%	87.9%	51.3%	82.6%	0.0%	31.8%	17.9%
NEXRAD + Lidar	**MB**	97.5%	40.3%	44.5%	59.3%	32.0%	97.3%	21.2%	15.0%	42.2%	22.4%	97.4%	79.7%	96.9%	37.1%	32.2%	11.7%
	GF	93.2%	69.7%	72.4%	60.0%	61.5%	92.2%	53.8%	49.9%	66.7%	47.6%	92.7%	78.9%	90.4%	64.3%	70.1%	62.8%
NEXRAD + LLWAS	**MB**	98.7%	49.0%	49.0%	49.0%	49.0%	98.0%	49.0%	49.0%	40.0%	49.0%	98.3%	78.7%	98.0%	49.0%	55.8%	85.0%
	GF	93.2%	69.7%	72.4%	60.0%	61.5%	92.2%	53.8%	49.9%	66.7%	47.6%	92.7%	78.9%	90.4%	64.3%	70.1%	62.8%
TDWR	**MB**	NA	97.0%	NA	84.6%	NA	NA	NA	0.0%	97.3%	0.0%	NA	NA	NA	0.0%	97.6%	97.5%
	GF	NA	92.4%	NA	57.2%	NA	NA	NA	0.0%	94.0%	0.0%	NA	NA	NA	0.0%	94.5%	90.6%
TDWR + LLWAS	**MB**	NA	98.5%	NA	92.1%	NA	NA	NA	49.0%	98.4%	49.0%	NA	NA	NA	49.0%	98.8%	99.6%
	GF	NA	92.4%	NA	57.2%	NA	NA	NA	0.0%	94.0%	0.0%	NA	NA	NA	0.0%	94.5%	90.6%
TDWR +LIDAR	**MB**	NA	97.6%	NA	95.8%	NA	NA	NA	15.0%	98.0%	22.4%	NA	NA	NA	37.1%	97.9%	97.7%
	GF	NA	94.4%	NA	65.5%	NA	NA	NA	49.9%	94.7%	47.6%	NA	NA	NA	64.3%	94.9%	93.2%
TDWR + NEXRAD	**MB**	NA	97.0%	NA	84.6%	NA	NA	NA	0.0%	97.3%	0.0%	NA	NA	NA	0.0%	97.6%	97.5%
	GF	NA	92.4%	NA	57.2%	NA	NA	NA	0.0%	94.0%	0.0%	NA	NA	NA	0.0%	94.6%	90.9%
TDWR + NXRAD + LLWAS	**MB**	NA	98.5%	NA	92.1%	NA	NA	NA	49.0%	98.4%	49.0%	NA	NA	NA	49.0%	98.8%	99.6%
	GF	NA	92.4%	NA	57.2%	NA	NA	NA	0.0%	94.0%	0.0%	NA	NA	NA	0.0%	94.6%	90.9%
TDWR + NEXRAD + LIDAR	**MB**	NA	97.6%	NA	95.8%	NA	NA	NA	15.0%	98.0%	22.4%	NA	NA	NA	37.1%	97.9%	97.7%
	GF	NA	94.4%	NA	65.5%	NA	NA	NA	49.9%	94.7%	47.6%	NA	NA	NA	64.3%	94.9%	93.4%
TDWR	**MB**	NA	97.0%	NA	84.6%	NA	NA	NA	0.0%	97.3%	0.0%	NA	NA	NA	0.0%	97.6%	97.5%
	GF	NA	92.4%	NA	57.2%	NA	NA	NA	0.0%	94.0%	0.0%	NA	NA	NA	0.0%	94.5%	90.6%
WSP	**MB**	84.5%	86.4%	NA	69.5%	84.7%	92.1%	NA	0.0%	27.1%	52.0%	NA	NA	NA	0.0%	94.9%	95.7%
	GF	67.1%	79.9%	NA	59.5%	60.4%	73.9%	NA	0.0%	38.8%	30.7%	NA	NA	NA	0.0%	81.6%	69.8%
WSP + LLWAS	**MB**	92.1%	93.1%	NA	84.4%	92.2%	96.0%	NA	49.0%	56.3%	75.5%	NA	NA	NA	49.0%	97.4%	99.4%
	GF	67.1%	79.9%	NA	59.5%	60.4%	73.9%	NA	0.0%	38.8%	30.7%	NA	NA	NA	0.0%	81.6%	69.8%
WSP + LIDAR	**MB**	89.4%	96.7%	NA	95.4%	95.0%	96.9%	NA	15.0%	69.0%	73.4%	NA	NA	NA	37.1%	97.2%	97.3%
	GF	79.3%	92.1%	NA	78.8%	83.1%	86.5%	NA	49.9%	78.4%	47.6%	NA	NA	NA	64.3%	88.0%	81.8%
WSP + NEXRAD	**MB**	97.6%	86.4%	NA	69.5%	84.7%	97.2%	NA	0.0%	27.1%	52.0%	NA	NA	NA	0.0%	94.9%	95.7%
	GF	92.7%	79.9%	NA	59.5%	60.4%	90.8%	NA	0.0%	38.8%	30.7%	NA	NA	NA	0.0%	85.2%	72.1%
WSP + NEXRAD + LLWAS	**MB**	98.8%	93.1%	NA	84.4%	92.2%	98.6%	NA	49.0%	56.3%	75.5%	NA	NA	NA	49.0%	97.4%	99.4%
	GF	92.7%	79.9%	NA	59.5%	60.4%	90.8%	NA	0.0%	38.8%	30.7%	NA	NA	NA	0.0%	85.2%	72.1%
MOD-XBAND	**MB**	96.3%	95.2%	92.4%	61.6%	92.5%	95.6%	95.2%	94.9%	96.8%	87.6%	91.5%	94.8%	94.7%	93.8%	96.5%	99.5%
	GF	94.5%	94.2%	92.8%	58.1%	78.2%	94.2%	93.6%	86.5%	94.6%	69.1%	87.0%	94.3%	90.1%	87.9%	94.8%	93.9%
WSP + NEXRAD + LIDAR	**MB**	97.7%	96.7%	NA	95.4%	95.0%	97.8%	NA	15.0%	69.0%	73.4%	NA	NA	NA	37.1%	97.2%	97.3%
	GF	94.1%	92.1%	NA	78.8%	83.1%	93.7%	NA	49.9%	78.4%	47.6%	NA	NA	NA	64.3%	90.7%	83.3%

	Site	MDT	MDW	MEM	MGM	MHT	MIA	MKE	MLI	MLU	MOB	MSN	MSP	MSY	MYR	OAK
	Type	WSP	TDWR	TDWR	LLWAS	NoWS	TDWR	TDWR	LLWAS	LLWAS	LLWAS	WSP	TDWR	TDWR-LLWAS	NoWS	NoWS
"Current"	**MB**	81.8%	92.0%	91.9%	41.1%	0.0%	90.2%	91.2%	55.0%	53.6%	49.0%	75.8%	91.6%	91.0%	0.0%	0.0%
	GF	55.8%	80.7%	79.4%	1.2%	0.0%	75.7%	80.4%	2.0%	2.1%	1.3%	62.5%	80.7%	78.4%	0.0%	0.0%
"Upgraded" TDWR/WSP	**MB**	81.8%	97.8%	97.6%	41.1%	0.0%	95.4%	96.9%	55.0%	53.6%	49.0%	86.4%	97.5%	97.4%	0.0%	0.0%
	GF	60.9%	94.0%	91.9%	1.2%	0.0%	85.7%	93.8%	2.0%	2.1%	1.3%	70.9%	94.6%	89.3%	0.0%	0.0%
XBAND	**MB**	84.8%	95.6%	92.3%	93.1%	94.7%	95.7%	91.1%	83.9%	94.4%	93.9%	92.2%	95.7%	93.5%	87.0%	91.5%
	GF	28.5%	94.2%	89.1%	89.0%	76.3%	82.1%	92.8%	67.9%	73.7%	88.5%	91.8%	93.8%	87.0%	71.9%	64.0%
XBAND + LIDAR	**MB**	88.7%	96.8%	95.6%	96.3%	97.0%	96.3%	97.0%	91.9%	96.2%	96.0%	95.7%	97.0%	95.8%	95.5%	96.9%
	GF	37.6%	94.9%	94.5%	93.8%	85.2%	91.6%	94.9%	79.9%	88.5%	93.8%	94.4%	94.9%	93.7%	88.8%	71.3%
XBAND + LLWAS	**MB**	92.2%	97.8%	96.1%	96.5%	97.3%	97.8%	95.5%	91.8%	97.1%	96.9%	96.0%	97.8%	95.5%	93.4%	95.7%
	GF	37.6%	94.9%	94.5%	93.8%	85.2%	91.6%	94.9%	79.9%	88.5%	93.8%	94.4%	94.9%	93.7%	88.8%	71.3%
Lidar Only	**MB**	32.8%	36.9%	26.7%	32.5%	43.6%	8.4%	39.6%	35.9%	15.8%	22.2%	28.2%	27.5%	14.6%	23.4%	39.9%
	GF	19.2%	64.3%	62.0%	61.7%	59.2%	47.0%	67.6%	49.2%	51.1%	55.0%	59.4%	60.1%	51.4%	55.0%	51.0%
LLWAS Only	**MB**	48.8%	48.8%	48.8%	41.1%	48.8%	48.8%	48.8%	55.0%	53.6%	49.0%	48.8%	48.8%	30.5%	48.8%	48.8%
	GF	1.4%	1.4%	1.4%	1.2%	1.4%	1.4%	1.4%	2.0%	2.1%	1.3%	1.4%	1.4%	1.8%	1.4%	1.4%
NEXRAD	**MB**	0.0%	93.4%	96.1%	0.0%	0.0%	96.1%	13.8%	93.4%	0.0%	95.3%	0.0%	95.0%	60.5%	81.6%	0.0%
	GF	0.0%	95.0%	89.4%	9.0%	0.0%	75.6%	41.1%	83.7%	0.0%	79.7%	22.3%	93.3%	49.7%	54.5%	0.0%
NEXRAD + Lidar	**MB**	32.8%	98.0%	97.4%	32.5%	43.6%	96.4%	53.0%	96.9%	15.8%	96.8%	28.2%	97.7%	67.0%	93.4%	39.9%
	GF	19.2%	95.0%	93.9%	67.9%	59.2%	88.5%	79.5%	84.4%	51.1%	90.3%	70.7%	94.4%	72.9%	76.2%	51.0%
NEXRAD + LLWAS	**MB**	49.0%	96.7%	98.0%	49.0%	49.0%	98.0%	56.0%	96.7%	49.0%	97.6%	49.0%	97.4%	72.7%	90.6%	49.0%
	GF	19.2%	95.0%	93.9%	67.9%	59.2%	88.5%	79.5%	84.4%	51.1%	90.3%	70.7%	94.4%	72.9%	76.2%	51.0%
TDWR	**MB**	NA	97.8%	97.6%	NA	0.0%	95.4%	96.9%	NA	NA	NA	NA	97.5%	96.2%	0.0%	0.0%
	GF	NA	94.0%	91.9%	NA	0.0%	85.7%	93.8%	NA	NA	NA	NA	94.6%	89.3%	0.0%	0.0%
TDWR + LLWAS	**MB**	NA	98.9%	98.8%	NA	49.0%	97.7%	98.4%	NA	NA	NA	NA	98.7%	97.4%	49.0%	49.0%
	GF	NA	94.0%	91.9%	NA	0.0%	85.7%	93.8%	NA	NA	NA	NA	94.6%	89.3%	0.0%	0.0%
TDWR +LIDAR	**MB**	NA	98.0%	97.7%	NA	43.6%	96.0%	97.9%	NA	NA	NA	NA	98.0%	96.6%	23.4%	39.9%
	GF	NA	94.7%	94.3%	NA	59.2%	91.9%	94.7%	NA	NA	NA	NA	94.9%	93.2%	55.0%	51.0%
TDWR + NEXRAD	**MB**	NA	97.8%	97.8%	NA	0.0%	97.7%	96.9%	NA	NA	NA	NA	97.5%	97.3%	81.6%	0.0%
	GF	NA	95.0%	94.2%	NA	0.0%	91.0%	94.6%	NA	NA	NA	NA	95.0%	92.3%	54.5%	0.0%
TDWR + NXRAD + LLWAS	**MB**	NA	98.9%	98.9%	NA	49.0%	98.8%	98.4%	NA	NA	NA	NA	98.7%	98.1%	90.6%	49.0%
	GF	NA	95.0%	94.2%	NA	0.0%	91.0%	94.6%	NA	NA	NA	NA	95.0%	92.3%	54.5%	0.0%
TDWR + NEXRAD + LIDAR	**MB**	NA	98.0%	97.9%	NA	43.6%	97.7%	97.9%	NA	NA	NA	NA	98.0%	97.6%	93.4%	39.9%
	GF	NA	95.0%	94.9%	NA	59.2%	94.0%	94.9%	NA	NA	NA	NA	95.0%	94.0%	76.2%	51.0%
TDWR	**MB**	NA	97.8%	97.6%	NA	0.0%	95.4%	96.9%	NA	NA	NA	NA	97.5%	96.2%	0.0%	0.0%
	GF	NA	94.0%	91.9%	NA	0.0%	85.7%	93.8%	NA	NA	NA	NA	94.6%	89.3%	0.0%	0.0%
WSP	**MB**	81.8%	23.1%	84.1%	NA	40.3%	92.3%	78.8%	NA	NA	NA	86.4%	91.5%	92.8%	0.0%	83.3%
	GF	60.9%	36.9%	60.9%	NA	49.1%	52.3%	65.4%	NA	NA	NA	70.9%	79.0%	57.9%	0.0%	58.3%
WSP + LLWAS	**MB**	90.7%	60.8%	91.9%	NA	69.6%	96.1%	89.2%	NA	NA	NA	93.1%	95.7%	95.1%	49.0%	91.5%
	GF	60.9%	36.9%	60.9%	NA	49.1%	52.3%	65.4%	NA	NA	NA	70.9%	79.0%	57.9%	0.0%	58.3%
WSP + LIDAR	**MB**	94.1%	59.5%	92.7%	NA	81.9%	93.6%	96.5%	NA	NA	NA	96.2%	97.2%	95.5%	23.4%	95.2%
	GF	64.7%	76.9%	86.6%	NA	81.0%	77.2%	87.9%	NA	NA	NA	86.8%	88.5%	79.3%	55.0%	76.8%
WSP + NEXRAD	**MB**	81.8%	93.4%	96.9%	NA	40.3%	97.5%	78.9%	NA	NA	NA	86.4%	95.6%	95.5%	81.6%	83.3%
	GF	60.9%	95.0%	92.4%	NA	49.1%	83.3%	76.7%	NA	NA	NA	75.3%	94.4%	76.7%	54.5%	58.3%
WSP + NEXRAD + LLWAS	**MB**	90.7%	96.7%	98.4%	NA	69.6%	98.7%	89.2%	NA	NA	NA	93.1%	97.8%	96.9%	90.6%	91.5%
	GF	60.9%	95.0%	92.4%	NA	49.1%	83.3%	76.7%	NA	NA	NA	75.3%	94.4%	76.7%	54.5%	58.3%
MOD-XBAND	**MB**	84.8%	95.6%	92.3%	93.1%	94.7%	95.7%	91.1%	83.9%	94.4%	93.9%	92.2%	95.7%	95.5%	87.0%	91.5%
	GF	28.5%	94.2%	89.1%	89.0%	76.3%	82.1%	92.8%	67.9%	73.7%	88.5%	91.8%	93.8%	93.7%	71.9%	64.0%
WSP + NEXRAD + LIDAR	**MB**	94.1%	98.0%	97.9%	NA	81.9%	97.7%	96.7%	NA	NA	NA	96.2%	97.9%	97.3%	93.4%	95.2%
	GF	64.7%	95.0%	94.5%	NA	81.0%	91.7%	89.9%	NA	NA	NA	89.1%	94.8%	87.0%	76.2%	76.8%

	Site	OKC	OMA	ONT	ORD	ORF	ORL	PBI	PDK	PDX	PHF	PHL	PHX	PIA	PIE	PNS
	Type	TDWR	LLWAS	WSP	TDWR-LLWAS	WSP	NoWS	TDWR	NoWS	WSP	NoWS	TDWR	TDWR	LLWAS	NoWS	LLWAS
"Current"	MB	91.6%	46.8%	82.9%	90.7%	68.4%	0.0%	89.5%	0.0%	80.9%	0.0%	87.7%	88.8%	48.4%	0.0%	45.8%
	GF	78.7%	1.2%	51.9%	80.0%	26.5%	0.0%	78.4%	0.0%	63.4%	0.0%	74.6%	48.9%	1.3%	0.0%	1.3%
"Upgraded" TDWR/WSP	MB	97.3%	46.8%	90.7%	99.1%	82.9%	0.0%	94.6%	0.0%	91.0%	0.0%	93.2%	94.0%	48.4%	0.0%	45.8%
	GF	92.2%	1.2%	59.8%	92.2%	52.2%	0.0%	89.4%	0.0%	69.2%	0.0%	86.3%	57.8%	1.3%	0.0%	1.3%
XBAND	MB	95.6%	94.3%	94.0%	91.9%	88.8%	92.6%	95.9%	94.7%	80.4%	86.3%	89.6%	94.0%	91.2%	95.7%	94.6%
	GF	92.2%	63.6%	65.5%	88.9%	81.8%	83.5%	85.3%	88.4%	32.4%	81.5%	79.8%	62.9%	88.6%	82.8%	82.7%
XBAND + LIDAR	MB	96.8%	96.2%	96.4%	96.5%	96.0%	95.6%	96.7%	96.6%	84.8%	96.2%	96.6%	95.7%	96.7%	96.8%	95.7%
	GF	94.5%	65.6%	77.4%	94.3%	92.8%	92.7%	93.0%	94.1%	46.4%	93.0%	92.3%	76.6%	93.4%	91.1%	83.2%
XBAND + LLWAS	MB	97.8%	97.1%	96.9%	98.1%	94.3%	96.2%	97.9%	97.3%	90.0%	93.0%	94.7%	97.0%	95.5%	97.8%	97.2%
	GF	94.5%	65.6%	77.4%	94.3%	92.8%	92.7%	93.0%	94.1%	46.4%	93.0%	92.3%	76.6%	93.4%	91.1%	83.2%
Lidar Only	MB	24.1%	32.1%	34.0%	36.9%	29.9%	14.6%	10.8%	18.2%	24.6%	28.8%	35.6%	19.6%	36.9%	13.8%	17.9%
	GF	58.7%	43.0%	47.2%	68.4%	58.8%	49.3%	47.8%	52.4%	26.0%	58.8%	65.0%	42.5%	62.3%	49.9%	45.7%
LLWAS Only	MB	48.8%	46.8%	48.8%	76.0%	48.8%	48.8%	48.8%	48.8%	48.8%	48.8%	48.8%	48.8%	48.4%	48.8%	45.8%
	GF	1.4%	1.2%	1.4%	8.5%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.3%	1.4%	1.3%
NEXRAD	MB	96.0%	89.7%	0.0%	73.1%	0.0%	0.0%	0.0%	77.4%	0.0%	85.3%	0.0%	94.9%	23.1%	97.5%	0.0%
	GF	87.9%	87.9%	0.0%	94.1%	4.3%	0.7%	0.0%	53.6%	0.0%	77.0%	5.3%	88.9%	37.6%	94.3%	0.0%
NEXRAD + Lidar	MB	97.5%	98.0%	34.0%	90.8%	29.9%	14.6%	10.8%	86.6%	24.6%	97.6%	35.6%	97.6%	58.4%	98.0%	17.9%
	GF	93.4%	87.9%	47.2%	95.0%	63.1%	50.1%	47.8%	74.9%	26.0%	84.0%	69.1%	93.0%	77.7%	94.5%	45.7%
NEXRAD + LLWAS	MB	97.9%	94.7%	49.0%	93.5%	49.0%	49.0%	49.0%	88.5%	49.0%	92.5%	49.0%	97.4%	60.8%	98.8%	49.0%
	GF	93.4%	87.9%	47.2%	95.0%	63.1%	50.1%	47.8%	74.9%	26.0%	84.0%	69.1%	93.0%	77.7%	94.5%	45.7%
TDWR	MB	97.3%	NA	NA	96.4%	NA	95.2%	94.6%	97.9%	NA	0.0%	93.2%	94.0%	NA	96.7%	NA
	GF	92.2%	NA	NA	92.2%	NA	91.3%	89.4%	92.5%	NA	0.0%	86.3%	57.8%	NA	87.9%	NA
TDWR + LLWAS	MB	98.6%	NA	NA	99.1%	NA	97.5%	97.2%	98.9%	NA	49.0%	96.5%	96.9%	NA	98.3%	NA
	GF	92.2%	NA	NA	92.2%	NA	91.3%	89.4%	92.5%	NA	0.0%	86.3%	57.8%	NA	87.9%	NA
TDWR +LIDAR	MB	97.8%	NA	NA	97.6%	NA	96.3%	95.9%	98.0%	NA	28.8%	96.9%	95.8%	NA	97.3%	NA
	GF	94.4%	NA	NA	94.4%	NA	94.1%	93.5%	93.7%	NA	58.8%	93.3%	72.5%	NA	92.2%	NA
TDWR + NEXRAD	MB	97.6%	NA	NA	96.8%	NA	95.2%	94.6%	97.9%	NA	85.3%	93.2%	97.0%	NA	97.9%	NA
	GF	93.3%	NA	NA	94.9%	NA	91.3%	89.4%	94.5%	NA	77.0%	86.6%	91.7%	NA	94.7%	NA
TDWR + NXRAD + LLWAS	MB	98.8%	NA	NA	99.2%	NA	97.5%	97.2%	98.9%	NA	92.5%	96.5%	98.5%	NA	98.9%	NA
	GF	93.3%	NA	NA	94.9%	NA	91.3%	89.4%	94.5%	NA	77.0%	86.6%	91.7%	NA	94.7%	NA
TDWR + NEXRAD + LIDAR	MB	97.8%	NA	NA	97.9%	NA	96.3%	95.9%	98.0%	NA	97.6%	96.9%	98.0%	NA	98.0%	NA
	GF	94.6%	NA	NA	95.0%	NA	94.2%	93.5%	94.8%	NA	84.0%	93.6%	93.8%	NA	94.7%	NA
TDWR	MB	97.3%	NA	NA	96.4%	NA	95.2%	94.6%	97.9%	NA	0.0%	93.2%	94.0%	NA	96.7%	NA
	GF	92.2%	NA	NA	92.2%	NA	91.3%	89.4%	92.5%	NA	0.0%	86.3%	57.8%	NA	87.9%	NA
WSP	MB	92.0%	NA	90.7%	82.2%	82.9%	46.1%	0.0%	4.1%	91.0%	0.4%	77.6%	88.9%	NA	48.0%	NA
	GF	75.7%	NA	59.8%	66.1%	52.2%	36.7%	0.0%	9.4%	69.2%	1.1%	56.6%	56.8%	NA	42.6%	NA
WSP + LLWAS	MB	95.9%	NA	95.3%	95.7%	91.3%	72.5%	49.0%	51.1%	95.4%	49.2%	88.6%	94.3%	NA	73.5%	NA
	GF	75.7%	NA	59.8%	66.1%	52.2%	36.7%	0.0%	9.4%	69.2%	1.1%	56.6%	56.8%	NA	42.6%	NA
WSP + LIDAR	MB	97.2%	NA	97.0%	95.1%	95.5%	60.4%	10.8%	22.1%	95.8%	28.8%	94.8%	93.6%	NA	61.5%	NA
	GF	87.8%	NA	77.0%	88.2%	79.7%	67.9%	47.8%	60.0%	75.6%	60.1%	85.8%	75.8%	NA	69.4%	NA
WSP + NEXRAD	MB	96.9%	NA	90.7%	84.9%	82.9%	46.1%	0.0%	77.4%	91.0%	85.3%	77.6%	95.7%	NA	97.5%	NA
	GF	92.8%	NA	59.8%	94.2%	54.5%	36.8%	0.0%	53.7%	69.2%	77.2%	60.0%	92.2%	NA	94.4%	NA
WSP + NEXRAD + LLWAS	MB	98.4%	NA	95.3%	96.4%	91.3%	72.5%	49.0%	88.5%	95.4%	92.5%	88.6%	97.8%	NA	98.8%	NA
	GF	92.8%	NA	59.8%	94.2%	54.5%	36.8%	0.0%	53.7%	69.2%	77.2%	60.0%	92.2%	NA	94.4%	NA
MOD-XBAND	MB	95.6%	94.3%	94.0%	98.1%	88.8%	92.6%	95.9%	94.7%	80.4%	86.3%	89.6%	94.0%	91.2%	95.7%	94.6%
	GF	92.2%	63.6%	65.5%	94.3%	81.8%	83.5%	85.3%	88.4%	32.4%	81.5%	79.8%	62.9%	88.6%	82.8%	82.7%
WSP + NEXRAD + LIDAR	MB	97.9%	NA	97.0%	96.1%	95.5%	60.4%	10.8%	86.6%	95.8%	97.6%	94.8%	97.9%	NA	98.0%	NA
	GF	94.5%	NA	77.0%	95.0%	81.3%	67.9%	47.8%	75.1%	75.6%	84.8%	88.3%	93.9%	NA	94.7%	NA

	Site	PVD	PWM	RDU	RIC	RNO	ROA	ROC	RST	RSW	SAN	SAT	SAV	SBN	SDF	SEA
	Type	LLWAS	NoWS	TDWR	WSP	NoWS	LLWAS	WSP	LLWAS	LLWAS	NoWS	WSP	LLWAS	NoWS	TDWR	WSP
"Current"	MB	53.2%	0.0%	91.5%	68.4%	0.0%	52.8%	91.3%	43.5%	48.3%	0.0%	89.5%	51.1%	0.0%	91.7%	76.9%
	GF	1.5%	0.0%	78.9%	40.1%	0.0%	1.5%	79.9%	1.2%	0.6%	0.0%	74.3%	1.4%	0.0%	79.3%	64.6%
"Upgraded" TDWR/WSP	MB	53.2%	0.0%	97.4%	82.6%	0.0%	52.8%	92.7%	43.5%	48.3%	0.0%	91.6%	51.1%	0.0%	97.4%	87.0%
	GF	1.5%	0.0%	91.7%	55.9%	0.0%	1.5%	81.1%	1.2%	0.6%	0.0%	77.4%	1.4%	0.0%	92.2%	71.9%
XBAND	MB	95.2%	95.4%	86.6%	87.4%	65.2%	80.2%	95.7%	95.5%	95.2%	89.5%	95.9%	90.7%	93.0%	88.9%	93.8%
	GF	94.0%	94.4%	87.7%	77.7%	16.3%	36.1%	94.5%	93.2%	93.7%	52.5%	93.9%	70.8%	88.1%	77.3%	83.6%
XBAND + LIDAR	MB	97.1%	97.1%	94.3%	96.2%	90.1%	84.6%	96.9%	96.7%	95.8%	94.1%	97.0%	95.8%	97.1%	95.9%	96.7%
	GF	94.9%	95.0%	94.2%	90.7%	25.3%	55.5%	95.0%	94.6%	94.9%	60.3%	94.8%	87.2%	93.9%	89.8%	90.0%
XBAND + LLWAS	MB	97.6%	97.7%	93.2%	93.6%	82.2%	89.9%	97.8%	97.7%	97.6%	94.6%	97.9%	95.3%	96.4%	94.3%	96.9%
	GF	94.9%	95.0%	94.2%	90.7%	25.3%	55.5%	95.0%	94.6%	94.9%	60.3%	94.8%	87.2%	93.9%	89.8%	90.0%
Lidar Only	MB	41.5%	46.9%	25.0%	29.8%	65.7%	25.6%	30.9%	29.8%	12.2%	27.8%	28.6%	15.5%	36.6%	30.0%	38.7%
	GF	67.3%	70.7%	56.9%	60.6%	19.8%	30.7%	61.3%	59.5%	47.8%	35.1%	58.8%	50.7%	64.3%	58.1%	59.4%
LLWAS Only	MB	53.2%	48.8%	48.8%	48.8%	48.8%	52.8%	48.8%	43.5%	48.3%	48.8%	48.8%	51.1%	48.8%	48.8%	48.8%
	GF	1.5%	1.4%	1.4%	1.4%	1.4%	1.5%	1.4%	1.2%	0.6%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%
NEXRAD	MB	89.4%	64.8%	91.0%	42.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	89.3%	15.8%	0.0%	95.3%	0.0%
	GF	94.6%	94.7%	84.8%	42.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	93.8%	36.5%	14.0%	88.9%	0.0%
NEXRAD + Lidar	MB	97.6%	96.2%	95.2%	67.2%	65.7%	25.6%	30.9%	29.8%	12.2%	27.8%	97.9%	31.2%	36.6%	97.9%	38.7%
	GF	94.9%	94.9%	91.3%	76.3%	19.8%	30.7%	61.3%	59.5%	47.8%	35.1%	95.0%	68.8%	71.9%	93.1%	59.4%
NEXRAD + LLWAS	MB	94.6%	82.0%	95.4%	70.6%	49.0%	49.0%	49.0%	49.0%	49.0%	49.0%	94.6%	57.1%	49.0%	97.6%	49.0%
	GF	94.9%	94.9%	91.3%	76.3%	19.8%	30.7%	61.3%	59.5%	47.8%	35.1%	95.0%	68.8%	71.9%	93.1%	59.4%
TDWR	MB	NA	0.0%	97.4%	NA	0.0%	NA	NA	NA	NA	0.0%	NA	NA	0.0%	97.4%	NA
	GF	NA	0.0%	91.7%	NA	0.0%	NA	NA	NA	NA	0.0%	NA	NA	0.0%	92.2%	NA
TDWR + LLWAS	MB	NA	49.0%	98.7%	NA	49.0%	NA	NA	NA	NA	49.0%	NA	NA	49.0%	98.7%	NA
	GF	NA	0.0%	91.7%	NA	0.0%	NA	NA	NA	NA	0.0%	NA	NA	0.0%	92.2%	NA
TDWR +LIDAR	MB	NA	46.9%	97.8%	NA	65.7%	NA	NA	NA	NA	27.8%	NA	NA	36.6%	97.8%	NA
	GF	NA	70.7%	93.8%	NA	19.8%	NA	NA	NA	NA	35.1%	NA	NA	64.3%	94.1%	NA
TDWR + NEXRAD	MB	NA	64.8%	97.6%	NA	0.0%	NA	NA	NA	NA	0.0%	NA	NA	0.0%	97.7%	NA
	GF	NA	94.7%	94.2%	NA	0.0%	NA	NA	NA	NA	0.0%	NA	NA	14.0%	94.3%	NA
TDWR + NXRAD + LLWAS	MB	NA	82.0%	98.8%	NA	49.0%	NA	NA	NA	NA	49.0%	NA	NA	49.0%	98.8%	NA
	GF	NA	94.7%	94.2%	NA	0.0%	NA	NA	NA	NA	0.0%	NA	NA	14.0%	94.3%	NA
TDWR + NEXRAD + LIDAR	MB	NA	96.2%	97.9%	NA	65.7%	NA	NA	NA	NA	27.8%	NA	NA	36.6%	98.0%	NA
	GF	NA	94.9%	94.8%	NA	19.8%	NA	NA	NA	NA	35.1%	NA	NA	71.9%	94.7%	NA
TDWR	MB	NA	0.0%	97.4%	NA	0.0%	NA	NA	NA	NA	0.0%	NA	NA	0.0%	97.4%	NA
	GF	NA	0.0%	91.7%	NA	0.0%	NA	NA	NA	NA	0.0%	NA	NA	0.0%	92.2%	NA
WSP	MB	NA	0.4%	86.8%	82.6%	0.0%	NA	92.7%	NA	NA	10.7%	91.6%	NA	0.0%	81.6%	87.0%
	GF	NA	26.7%	65.0%	55.9%	0.0%	NA	81.1%	NA	NA	26.4%	77.4%	NA	0.0%	59.7%	71.9%
WSP + LLWAS	MB	NA	49.2%	93.2%	91.1%	49.0%	NA	96.3%	NA	NA	54.5%	95.7%	NA	49.0%	90.6%	93.4%
	GF	NA	26.7%	65.0%	55.9%	0.0%	NA	81.1%	NA	NA	26.4%	77.4%	NA	0.0%	59.7%	71.9%
WSP + LIDAR	MB	NA	46.9%	96.4%	95.7%	65.7%	NA	97.5%	NA	NA	38.0%	97.4%	NA	36.6%	94.9%	96.3%
	GF	NA	79.0%	84.3%	80.9%	19.8%	NA	88.8%	NA	NA	68.5%	87.5%	NA	64.3%	83.7%	85.5%
WSP + NEXRAD	MB	NA	64.8%	94.5%	84.7%	0.0%	NA	92.7%	NA	NA	10.7%	92.9%	NA	0.0%	95.4%	87.0%
	GF	NA	94.8%	90.8%	72.4%	0.0%	NA	81.1%	NA	NA	26.4%	93.9%	NA	14.0%	91.6%	71.9%
WSP + NEXRAD + LLWAS	MB	NA	82.0%	97.2%	92.2%	49.0%	NA	96.3%	NA	NA	54.5%	96.4%	NA	49.0%	97.7%	93.4%
	GF	NA	94.8%	90.8%	72.4%	0.0%	NA	81.1%	NA	NA	26.4%	93.9%	NA	14.0%	91.6%	71.9%
MOD-XBAND	MB	95.2%	95.4%	86.6%	87.4%	65.2%	80.2%	95.7%	95.5%	95.2%	89.5%	95.9%	90.7%	93.0%	88.9%	93.8%
	GF	94.0%	94.4%	87.7%	77.7%	16.3%	36.1%	94.5%	93.2%	93.7%	52.5%	93.9%	70.8%	88.1%	77.3%	83.6%
WSP + NEXRAD + LIDAR	MB	NA	96.2%	97.8%	97.0%	65.7%	NA	97.5%	NA	NA	38.0%	98.0%	NA	36.6%	98.0%	96.3%
	GF	NA	94.9%	93.7%	87.4%	19.8%	NA	88.8%	NA	NA	68.5%	95.0%	NA	71.9%	93.8%	85.5%

	Site	SFB	SFO	SGF	SHV	SJC	SJU	SLC	SMF	SNA	SPI	SRQ	STL	SUX	SYR	TLH
	Type	NoWS	LLWAS	LLWAS	LLWAS	NoWS	TDWR	TDWR	NoWS	NoWS	LLWAS	WSP	TDWR-LLWAS	LLWAS	WSP	LLWAS
"Current"	**MB**	0.0%	54.7%	42.5%	50.0%	0.0%	91.3%	87.7%	0.0%	0.0%	44.1%	95.8%	91.4%	58.4%	76.9%	49.7%
	GF	0.0%	1.6%	1.2%	1.4%	0.0%	73.6%	56.0%	0.0%	0.0%	1.7%	77.8%	80.5%	1.5%	66.6%	1.4%
"Upgraded" TDWR/WSP	**MB**	0.0%	54.7%	42.5%	50.0%	0.0%	96.8%	93.1%	0.0%	0.0%	44.1%	97.0%	98.4%	58.4%	84.0%	49.7%
	GF	0.0%	1.6%	1.2%	1.4%	0.0%	84.5%	64.9%	0.0%	0.0%	1.7%	80.9%	94.2%	1.5%	72.0%	1.4%
XBAND	**MB**	96.1%	78.7%	94.9%	93.2%	88.5%	94.0%	89.4%	95.6%	87.1%	95.7%	96.3%	95.5%	91.7%	91.5%	90.7%
	GF	75.8%	47.7%	93.3%	91.6%	56.4%	73.8%	69.4%	89.4%	65.3%	94.3%	94.0%	94.6%	89.6%	88.7%	77.9%
XBAND + LIDAR	**MB**	96.9%	87.7%	96.8%	96.1%	96.4%	95.5%	97.0%	97.2%	96.7%	97.1%	96.8%	96.7%	96.7%	96.7%	96.0%
	GF	88.2%	63.0%	94.6%	94.8%	72.8%	85.9%	79.1%	94.0%	83.1%	94.9%	94.8%	95.0%	94.1%	92.8%	91.9%
XBAND + LLWAS	**MB**	98.0%	89.1%	97.4%	96.5%	94.1%	96.9%	94.6%	97.7%	93.4%	97.8%	98.1%	97.5%	95.8%	95.6%	95.3%
	GF	88.2%	63.0%	94.6%	94.8%	72.8%	85.9%	79.1%	94.0%	83.1%	94.9%	94.8%	95.0%	94.1%	92.8%	91.9%
Lidar Only	**MB**	12.0%	40.4%	26.1%	23.1%	44.2%	19.0%	48.1%	36.5%	48.0%	40.3%	18.1%	27.3%	36.3%	39.5%	18.4%
	GF	48.6%	38.6%	57.3%	54.6%	58.8%	49.5%	63.8%	63.6%	58.0%	67.2%	51.9%	59.3%	64.3%	65.8%	53.2%
LLWAS Only	**MB**	48.8%	54.7%	42.5%	50.0%	48.8%	48.8%	48.8%	48.8%	48.8%	44.1%	48.8%	44.3%	58.4%	48.8%	49.7%
	GF	1.4%	1.6%	1.2%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.7%	1.4%	3.1%	1.5%	1.4%	1.4%
NEXRAD	**MB**	0.0%	0.0%	96.7%	96.2%	0.0%	0.0%	0.0%	95.8%	0.0%	59.7%	97.3%	95.8%	0.0%	0.0%	92.8%
	GF	0.0%	0.0%	84.4%	78.7%	0.0%	0.0%	0.0%	85.4%	0.0%	91.0%	94.8%	94.3%	0.0%	0.0%	61.7%
NEXRAD + Lidar	**MB**	12.0%	40.4%	97.5%	96.8%	44.2%	19.0%	48.1%	97.3%	48.0%	89.8%	98.0%	97.8%	36.3%	39.5%	95.3%
	GF	48.6%	38.6%	91.9%	88.4%	58.8%	49.5%	63.8%	91.9%	58.0%	92.5%	95.0%	94.8%	64.3%	65.8%	83.5%
NEXRAD + LLWAS	**MB**	49.0%	49.0%	98.3%	98.1%	49.0%	49.0%	49.0%	97.9%	49.0%	79.5%	98.6%	97.7%	49.0%	49.0%	96.3%
	GF	48.6%	38.6%	91.9%	88.4%	58.8%	49.5%	63.8%	91.9%	58.0%	92.5%	95.0%	94.8%	64.3%	65.8%	83.5%
TDWR	**MB**	97.7%	NA	NA	NA	0.0%	96.8%	93.1%	0.0%	0.0%	NA	NA	97.2%	NA	NA	NA
	GF	82.2%	NA	NA	NA	0.0%	84.5%	64.9%	0.0%	0.0%	NA	NA	94.2%	NA	NA	NA
TDWR + LLWAS	**MB**	98.8%	NA	NA	NA	49.0%	98.4%	96.5%	49.0%	49.0%	NA	NA	98.4%	NA	NA	NA
	GF	82.2%	NA	NA	NA	0.0%	84.5%	64.9%	0.0%	0.0%	NA	NA	94.2%	NA	NA	NA
TDWR +LIDAR	**MB**	98.0%	NA	NA	NA	44.2%	97.1%	96.7%	36.5%	48.0%	NA	NA	97.6%	NA	NA	NA
	GF	83.9%	NA	NA	NA	58.8%	88.2%	85.7%	63.6%	58.0%	NA	NA	94.8%	NA	NA	NA
TDWR + NEXRAD	**MB**	97.7%	NA	NA	NA	0.0%	96.8%	93.1%	95.8%	0.0%	NA	NA	97.9%	NA	NA	NA
	GF	82.2%	NA	NA	NA	0.0%	84.5%	64.9%	85.4%	0.0%	NA	NA	94.9%	NA	NA	NA
TDWR + NXRAD + LLWAS	**MB**	98.8%	NA	NA	NA	49.0%	98.4%	96.5%	97.9%	49.0%	NA	NA	98.8%	NA	NA	NA
	GF	82.2%	NA	NA	NA	0.0%	84.5%	64.9%	85.4%	0.0%	NA	NA	94.9%	NA	NA	NA
TDWR + NEXRAD + LIDAR	**MB**	98.0%	NA	NA	NA	44.2%	97.1%	96.7%	97.3%	48.0%	NA	NA	98.0%	NA	NA	NA
	GF	83.9%	NA	NA	NA	58.8%	88.2%	85.7%	91.9%	58.0%	NA	NA	95.0%	NA	NA	NA
TDWR	**MB**	97.7%	NA	NA	NA	0.0%	96.8%	93.1%	0.0%	0.0%	NA	NA	97.2%	NA	NA	NA
	GF	82.2%	NA	NA	NA	0.0%	84.5%	64.9%	0.0%	0.0%	NA	NA	94.2%	NA	NA	NA
WSP	**MB**	0.0%	NA	NA	NA	54.3%	0.0%	74.3%	20.0%	16.5%	NA	97.0%	89.9%	NA	84.0%	NA
	GF	0.2%	NA	NA	NA	37.2%	0.0%	55.2%	32.7%	27.1%	NA	80.9%	80.6%	NA	72.0%	NA
WSP + LLWAS	**MB**	49.0%	NA	NA	NA	76.7%	49.0%	86.9%	59.2%	57.4%	NA	98.4%	94.3%	NA	91.9%	NA
	GF	0.2%	NA	NA	NA	37.2%	0.0%	55.2%	32.7%	27.1%	NA	80.9%	80.6%	NA	72.0%	NA
WSP + LIDAR	**MB**	12.0%	NA	NA	NA	82.7%	19.0%	95.4%	56.0%	63.9%	NA	97.5%	95.5%	NA	97.1%	NA
	GF	48.7%	NA	NA	NA	58.8%	49.5%	78.1%	74.7%	58.0%	NA	86.6%	88.7%	NA	88.2%	NA
WSP + NEXRAD	**MB**	0.0%	NA	NA	NA	54.3%	0.0%	74.3%	95.8%	16.5%	NA	97.8%	96.5%	NA	84.0%	NA
	GF	0.2%	NA	NA	NA	37.2%	0.0%	55.2%	88.4%	27.1%	NA	94.8%	94.8%	NA	72.0%	NA
WSP + NEXRAD + LLWAS	**MB**	49.0%	NA	NA	NA	76.7%	49.0%	86.9%	97.9%	57.4%	NA	98.9%	98.0%	NA	91.9%	NA
	GF	0.2%	NA	NA	NA	37.2%	0.0%	55.2%	88.4%	27.1%	NA	94.8%	94.8%	NA	72.0%	NA
MOD-XBAND	**MB**	96.1%	78.7%	94.9%	93.2%	88.5%	94.0%	89.4%	95.6%	87.1%	95.7%	96.3%	97.5%	91.7%	91.5%	90.7%
	GF	75.8%	47.7%	93.3%	91.6%	56.4%	73.8%	69.4%	89.4%	65.3%	94.3%	94.0%	95.0%	89.6%	88.7%	77.9%
WSP + NEXRAD + LIDAR	**MB**	12.0%	NA	NA	NA	82.7%	19.0%	95.4%	97.3%	63.9%	NA	98.0%	98.0%	NA	97.1%	NA
	GF	48.7%	NA	NA	NA	58.8%	49.5%	78.1%	93.0%	58.0%	NA	95.0%	94.9%	NA	88.2%	NA

	Site	TOL	TPA	TRI	TUL	TWF	TYS
	Type	WSP	TDWR-LLWAS	LLWAS	TDWR	NoWS	WSP
"Current"	**MB**	65.9%	90.5%	48.7%	91.6%	0.0%	88.0%
	GF	45.8%	75.1%	1.4%	79.2%	0.0%	68.3%
"Upgraded" TDWR/WSP	**MB**	79.1%	98.3%	48.7%	97.4%	0.0%	92.9%
	GF	64.1%	85.2%	1.4%	92.3%	0.0%	73.5%
XBAND	**MB**	87.3%	96.8%	76.3%	93.1%	89.2%	26.7%
	GF	86.3%	93.3%	57.0%	87.8%	74.1%	36.3%
XBAND + LIDAR	**MB**	96.3%	97.1%	81.3%	96.4%	97.3%	46.0%
	GF	94.1%	94.6%	76.3%	94.3%	88.7%	68.1%
XBAND + LLWAS	**MB**	93.5%	98.7%	87.9%	96.5%	94.5%	62.6%
	GF	94.1%	94.6%	76.3%	94.3%	88.7%	68.1%
Lidar Only	**MB**	42.8%	12.2%	21.6%	25.1%	78.5%	24.2%
	GF	68.4%	49.3%	35.1%	58.0%	70.5%	45.8%
LLWAS Only	**MB**	48.8%	60.3%	48.7%	48.8%	48.8%	48.8%
	GF	1.4%	4.5%	1.4%	1.4%	1.4%	1.4%
NEXRAD	**MB**	0.0%	97.7%	0.0%	96.6%	0.0%	0.0%
	GF	0.0%	93.3%	0.0%	92.8%	0.0%	0.0%
NEXRAD + Lidar	**MB**	42.8%	98.0%	21.6%	98.0%	78.5%	24.2%
	GF	68.4%	94.0%	35.1%	94.1%	70.5%	45.8%
NEXRAD + LLWAS	**MB**	49.0%	99.1%	49.0%	98.3%	49.0%	49.0%
	GF	68.4%	94.0%	35.1%	94.1%	70.5%	45.8%
TDWR	**MB**	NA	95.6%	NA	97.4%	0.0%	NA
	GF	NA	85.2%	NA	92.3%	0.0%	NA
TDWR + LLWAS	**MB**	NA	98.3%	NA	98.7%	49.0%	NA
	GF	NA	85.2%	NA	92.3%	0.0%	NA
TDWR +LIDAR	**MB**	NA	96.6%	NA	97.8%	78.5%	NA
	GF	NA	91.4%	NA	94.3%	70.5%	NA
TDWR + NEXRAD	**MB**	NA	97.9%	NA	97.8%	0.0%	NA
	GF	NA	94.3%	NA	94.9%	0.0%	NA
TDWR + NXRAD + LLWAS	**MB**	NA	99.2%	NA	98.9%	49.0%	NA
	GF	NA	94.3%	NA	94.9%	0.0%	NA
TDWR + NEXRAD + LIDAR	**MB**	NA	98.0%	NA	98.0%	78.5%	NA
	GF	NA	94.6%	NA	95.0%	70.5%	NA
TDWR	**MB**	NA	95.6%	NA	97.4%	0.0%	NA
	GF	NA	85.2%	NA	92.3%	0.0%	NA
WSP	**MB**	79.1%	96.3%	NA	89.2%	0.0%	92.9%
	GF	64.1%	79.8%	NA	69.2%	0.0%	73.5%
WSP + LLWAS	**MB**	89.4%	98.5%	NA	94.5%	49.0%	96.4%
	GF	64.1%	79.8%	NA	69.2%	0.0%	73.5%
WSP + LIDAR	**MB**	97.1%	96.9%	NA	96.8%	78.5%	97.4%
	GF	87.9%	85.7%	NA	86.5%	70.5%	84.2%
WSP + NEXRAD	**MB**	79.1%	97.9%	NA	96.7%	0.0%	92.9%
	GF	64.1%	94.3%	NA	93.9%	0.0%	73.5%
WSP + NEXRAD + LLWAS	**MB**	89.4%	99.1%	NA	98.3%	49.0%	96.4%
	GF	64.1%	94.3%	NA	93.9%	0.0%	73.5%
MOD-XBAND	**MB**	87.3%	98.7%	76.3%	93.1%	89.2%	26.7%
	GF	86.3%	94.6%	57.0%	87.8%	74.1%	36.3%
WSP + NEXRAD + LIDAR	**MB**	97.1%	98.0%	NA	98.0%	78.5%	97.4%
	GF	87.9%	94.6%	NA	94.6%	70.5%	84.2%

This page intentionally left blank.

APPENDIX D
SAFETY AND DELAY EXPOSURE AND BENEFITS BY SITE AND SYSTEM (LIFE CYCLE 2010–32 FY08$M)

RAW, PILOT and PWS are residual safety exposure values, remaining alternatives show safety exposure relative to NAS protected by pilot training and PWS, and delay reduction benefits based on reduced runway closure time due to wind shift prediction.

Site	ABE	ABQ	ADW	AGS	ALB	AMA	ASE	ATL	AUS	AVL	AVP	AZO	BDL	BGM	BHM	BIL
Type	NoWS	WSP	TDWR	LLWAS	WSP	NoWS	NoWS	TDWR-LLWAS	WSP	LLWAS	NoWS	NoWS	WSP	NoWS	WSP	LLWAS
RAW SAFETY	1.253	24.296	0.023	0.446	2.910	1.656	0.778	227.379	14.023	0.349	0.745	0.366	5.733	0.079	6.997	2.311
PILOT SAFETY	1.031	16.754	0.018	0.328	2.422	1.230	0.576	167.445	9.915	0.249	0.605	0.296	4.724	0.064	5.007	1.717
PWS SAFETY	0.530	7.280	0.014	0.193	1.173	0.663	0.333	68.768	4.234	0.197	0.323	0.239	2.122	0.064	2.337	1.057
CURRENT SAFETY	0.000	6.315	0.012	0.080	0.961	0.000	0.000	61.692	2.828	0.077	0.000	0.000	1.803	0.000	1.804	0.596
DELAY	0.000	1.528	0.006	0.001	0.368	0.000	0.000	27.785	0.459	0.001	0.000	0.000	0.611	0.000	0.315	0.011
TOTAL	0.000	7.843	0.018	0.080	1.329	0.000	0.000	89.477	3.288	0.077	0.000	0.000	2.414	0.000	2.119	0.607
UPGRADED SAFETY	0.000	6.596	0.013	0.080	1.023	0.000	0.000	67.317	2.989	0.077	0.000	0.000	1.886	0.000	2.061	0.596
DELAY	0.000	1.693	0.007	0.001	0.387	0.000	0.000	32.166	0.583	0.001	0.000	0.000	0.636	0.000	0.361	0.011
TOTAL	0.000	8.289	0.020	0.080	1.410	0.000	0.000	99.483	3.572	0.077	0.000	0.000	2.522	0.000	2.422	0.607
TDWR SAFETY	0.000	N/A	0.013	N/A	N/A	0.000	0.000	65.961	N/A	N/A	0.000	0.000	N/A	0.000	N/A	N/A
DELAY	0.000	N/A	0.007	N/A	N/A	0.000	0.000	32.166	N/A	N/A	0.000	0.000	N/A	0.000	N/A	N/A
TOTAL	0.000	N/A	0.020	N/A	N/A	0.000	0.000	98.127	N/A	N/A	0.000	0.000	N/A	0.000	N/A	N/A
WSP SAFETY	0.000	6.596	0.011	N/A	1.023	0.000	0.000	60.617	2.989	N/A	0.000	0.000	1.886	0.000	2.061	N/A
DELAY	0.000	1.693	0.005	N/A	0.387	0.000	0.000	23.248	0.583	N/A	0.000	0.000	0.636	0.000	0.361	N/A
TOTAL	0.000	8.289	0.016	N/A	1.410	0.000	0.000	83.866	3.572	N/A	0.000	0.000	2.522	0.000	2.422	N/A
NEXRAD SAFETY	0.000	6.900	0.010	0.000	0.000	0.638	0.000	66.461	0.077	0.000	0.000	0.004	0.000	0.062	2.233	0.965
DELAY	0.000	1.907	0.005	0.000	0.000	0.324	0.000	32.859	0.199	0.000	0.000	0.035	0.000	0.039	0.514	0.512
TOTAL	0.000	8.807	0.015	0.000	0.000	0.962	0.000	99.320	0.276	0.000	0.000	0.039	0.000	0.100	2.747	1.477
XBAND SAFETY	0.499	6.833	0.012	0.171	1.091	0.628	0.149	64.436	4.009	0.162	0.225	0.227	1.943	0.061	1.051	0.708
DELAY	0.322	1.881	0.007	0.033	0.448	0.341	0.012	31.071	0.993	0.026	0.066	0.178	0.617	0.039	0.087	0.457
TOTAL	0.821	8.713	0.018	0.204	1.539	0.970	0.162	95.507	5.002	0.188	0.291	0.405	2.560	0.100	1.138	1.166
LIDAR SAFETY	0.208	1.623	0.006	0.036	0.506	0.168	0.190	13.747	1.120	0.044	0.110	0.122	0.828	0.022	0.402	0.696
DELAY	0.226	1.248	0.005	0.022	0.317	0.211	0.013	18.797	0.622	0.018	0.051	0.135	0.436	0.025	0.065	0.397
TOTAL	0.434	2.872	0.010	0.058	0.823	0.378	0.203	32.543	1.742	0.063	0.161	0.257	1.265	0.047	0.467	1.093
LLWAS SAFETY	0.234	3.208	0.006	0.080	0.517	0.292	0.147	38.684	1.865	0.077	0.142	0.105	0.935	0.028	1.029	0.596
DELAY	0.005	0.035	0.000	0.001	0.007	0.005	0.006	1.908	0.015	0.001	0.003	0.003	0.011	0.001	0.008	0.011
TOTAL	0.239	3.242	0.006	0.080	0.524	0.297	0.153	40.592	1.881	0.077	0.145	0.108	0.946	0.029	1.037	0.607
TDWR + LIDAR SAFETY	0.208	N/A	0.013	N/A	N/A	0.168	0.190	66.553	N/A	N/A	0.110	0.122	N/A	0.022	N/A	N/A
DELAY	0.226	N/A	0.007	N/A	N/A	0.211	0.013	33.078	N/A	N/A	0.051	0.135	N/A	0.025	N/A	N/A
TOTAL	0.434	N/A	0.020	N/A	N/A	0.378	0.203	99.631	N/A	N/A	0.161	0.257	N/A	0.047	N/A	N/A
WSP + LIDAR SAFETY	0.208	6.939	0.013	N/A	1.136	0.168	0.190	64.619	3.598	N/A	0.110	0.122	2.053	0.022	2.181	N/A
DELAY	0.226	1.982	0.007	N/A	0.443	0.211	0.013	29.276	0.838	N/A	0.051	0.135	0.716	0.025	0.392	N/A
TOTAL	0.434	8.921	0.020	N/A	1.579	0.378	0.203	93.895	4.436	N/A	0.161	0.257	2.769	0.047	2.573	N/A

Site	ABE	ABQ	ADW	AGS	ALB	AMA	ASE	ATL	AUS	AVL	AVP	AZO	BDL	BGM	BHM	BIL
Type	NoWS	WSP	TDWR	LLWAS	WSP	NoWS	NoWS	TDWR-LLWAS	WSP	LLWAS	NoWS	NoWS	WSP	NoWS	WSP	LLWAS
NEXRAD + LIDAR SAFETY	0.208	6.988	0.013	0.036	0.506	0.643	0.190	67.011	1.167	0.044	0.110	0.123	0.828	0.062	2.280	1.020
DELAY	0.226	1.949	0.006	0.022	0.317	0.344	0.013	33.205	0.745	0.018	0.051	0.149	0.436	0.039	0.514	0.536
TOTAL	0.434	8.937	0.019	0.058	0.823	0.987	0.203	100.216	1.912	0.063	0.161	0.273	1.265	0.101	2.794	1.556
XBAND + LIDAR SAFETY	0.509	6.946	0.013	0.180	1.127	0.635	0.241	65.950	4.092	0.174	0.255	0.231	2.006	0.061	1.274	0.913
DELAY	0.349	2.027	0.007	0.041	0.463	0.350	0.016	32.965	1.029	0.038	0.095	0.179	0.702	0.039	0.166	0.537
TOTAL	0.858	8.972	0.020	0.221	1.590	0.985	0.256	98.914	5.121	0.213	0.350	0.410	2.708	0.101	1.440	1.451
TDWR + NEXRAD + LIDAR SAFETY	0.208	N/A	0.013	N/A	N/A	0.643	0.190	67.175	N/A	N/A	0.110	0.123	N/A	0.062	N/A	N/A
DELAY	0.226	N/A	0.007	N/A	N/A	0.344	0.013	33.505	N/A	N/A	0.051	0.149	N/A	0.039	N/A	N/A
TOTAL	0.434	N/A	0.020	N/A	N/A	0.987	0.203	100.680	N/A	N/A	0.161	0.273	N/A	0.101	N/A	N/A
WSP + NEXRAD + LIDAR SAFETY	0.208	7.060	0.013	N/A	1.136	0.643	0.190	67.151	3.631	N/A	0.110	0.123	2.053	0.062	2.281	N/A
DELAY	0.226	2.187	0.007	N/A	0.443	0.344	0.013	33.382	0.925	N/A	0.051	0.149	0.716	0.039	0.516	N/A
TOTAL	0.434	9.248	0.020	N/A	1.579	0.987	0.203	100.533	4.556	N/A	0.161	0.273	2.769	0.101	2.798	N/A
TDWR + LLWAS SAFETY	0.234	N/A	0.013	N/A	N/A	0.292	0.147	67.317	N/A	N/A	0.142	0.105	N/A	0.028	N/A	N/A
DELAY	0.000	N/A	0.007	N/A	N/A	0.000	0.000	32.166	N/A	N/A	0.000	0.000	N/A	0.000	N/A	N/A
TOTAL	0.234	N/A	0.020	N/A	N/A	0.292	0.147	99.483	N/A	N/A	0.142	0.105	N/A	0.028	N/A	N/A
WSP + LLWAS SAFETY	0.234	6.817	0.012	N/A	1.084	0.292	0.147	64.213	3.501	N/A	0.142	0.105	1.980	0.028	2.157	N/A
DELAY	0.000	1.693	0.005	N/A	0.387	0.000	0.000	23.248	0.583	N/A	0.000	0.000	0.636	0.000	0.361	N/A
TOTAL	0.234	8.510	0.017	N/A	1.471	0.292	0.147	87.462	4.085	N/A	0.142	0.105	2.616	0.028	2.518	N/A
NEXRAD + LLWAS SAFETY	0.265	7.015	0.012	0.094	0.593	0.650	0.148	67.661	2.154	0.091	0.150	0.124	1.052	0.062	2.277	1.008
DELAY	0.226	1.949	0.006	0.022	0.317	0.344	0.013	33.205	0.745	0.018	0.051	0.149	0.436	0.039	0.514	0.536
TOTAL	0.491	8.964	0.018	0.116	0.909	0.994	0.161	100.866	2.899	0.110	0.200	0.273	1.488	0.102	2.790	1.545
XBAND + LLWAS SAFETY	0.514	7.008	0.013	0.182	1.130	0.644	0.224	66.977	4.114	0.175	0.266	0.232	2.030	0.062	1.619	0.883
DELAY	0.349	2.027	0.007	0.041	0.463	0.350	0.016	32.965	1.029	0.038	0.095	0.179	0.702	0.039	0.166	0.537
TOTAL	0.862	9.034	0.020	0.223	1.593	0.994	0.239	99.942	5.143	0.214	0.361	0.411	2.732	0.101	1.785	1.420
TDWR + NEXRAD SAFETY	0.000	N/A	0.013	N/A	N/A	0.638	0.000	67.064	N/A	N/A	0.000	0.004	N/A	0.062	N/A	N/A
DELAY	0.000	N/A	0.007	N/A	N/A	0.324	0.000	33.445	N/A	N/A	0.000	0.035	N/A	0.039	N/A	N/A
TOTAL	0.000	N/A	0.020	N/A	N/A	0.962	0.000	100.510	N/A	N/A	0.000	0.039	N/A	0.100	N/A	N/A
TDWR + NEXRAD + LLWAS SAFETY	0.234	N/A	0.013	N/A	N/A	0.646	0.147	67.894	N/A	N/A	0.142	0.110	N/A	0.062	N/A	N/A
DELAY	0.000	N/A	0.007	N/A	N/A	0.324	0.000	33.445	N/A	N/A	0.000	0.035	N/A	0.039	N/A	N/A
TOTAL	0.234	N/A	0.020	N/A	N/A	0.970	0.147	101.339	N/A	N/A	0.142	0.144	N/A	0.101	N/A	N/A
WSP + NEXRAD SAFETY	0.000	6.983	0.012	N/A	1.023	0.638	0.000	66.703	3.045	N/A	0.000	0.004	1.886	0.062	2.248	N/A
DELAY	0.000	2.137	0.006	N/A	0.387	0.324	0.000	33.180	0.730	N/A	0.000	0.035	0.636	0.039	0.515	N/A
TOTAL	0.000	9.121	0.018	N/A	1.410	0.962	0.000	99.884	3.775	N/A	0.000	0.039	2.522	0.100	2.763	N/A
WSP + NEXRAD + LLWAS SAFETY	0.234	7.079	0.012	N/A	1.084	0.646	0.147	67.724	3.558	N/A	0.142	0.110	1.980	0.062	2.285	N/A
DELAY	0.000	2.137	0.006	N/A	0.387	0.324	0.000	33.180	0.730	N/A	0.000	0.035	0.636	0.039	0.515	N/A
TOTAL	0.234	9.217	0.019	N/A	1.471	0.970	0.147	100.905	4.288	N/A	0.142	0.144	2.616	0.101	2.799	N/A

Site	BIS	BNA	BOI	BOS	BTR	BTV	BUF	BUR	BWI	CAE	CAK	CHA	CHS	CID	CLE	CLT
Type	NoWS	TDWR	NoWS	TDWR	LLWAS	NoWS	WSP	NoWS	TDWR	LLWAS	NoWS	LLWAS	WSP	WSP	TDWR	TDWR
RAW SAFETY	0.538	23.604	5.438	26.065	2.272	0.765	3.863	1.299	30.573	1.968	2.062	0.720	3.711	0.761	14.111	41.759
PILOT SAFETY	0.403	16.543	3.773	21.845	1.649	0.614	2.905	0.903	23.428	1.402	1.627	0.531	2.769	0.628	11.006	31.648
PWS SAFETY	0.255	7.548	1.974	9.737	1.095	0.381	1.418	0.432	9.938	0.899	0.744	0.358	1.304	0.362	5.720	13.555
CURRENT SAFETY	0.000	6.847	0.000	8.737	0.424	0.000	1.201	0.000	8.854	0.385	0.000	0.170	1.012	0.317	5.155	12.261
DELAY	0.000	0.904	0.000	4.313	0.002	0.000	0.591	0.000	1.621	0.003	0.000	0.001	0.108	0.120	1.144	3.078
TOTAL	0.000	7.752	0.000	13.050	0.426	0.000	1.792	0.000	10.475	0.388	0.000	0.172	1.121	0.437	6.299	15.339
UPGRADED SAFETY	0.000	7.340	0.000	9.358	0.424	0.000	1.268	0.000	9.478	0.385	0.000	0.170	1.161	0.329	5.528	13.131
DELAY	0.000	1.054	0.000	5.003	0.002	0.000	0.627	0.000	1.873	0.003	0.000	0.001	0.220	0.127	1.339	3.574
TOTAL	0.000	8.394	0.000	14.360	0.426	0.000	1.895	0.000	11.351	0.388	0.000	0.172	1.380	0.456	6.867	16.705
TDWR SAFETY	0.000	7.340	0.000	9.358	N/A	0.000	N/A	0.000	9.478	N/A	0.542	N/A	N/A	N/A	5.528	13.131
DELAY	0.000	1.054	0.000	5.003	N/A	0.000	N/A	0.000	1.873	N/A	0.202	N/A	N/A	N/A	1.339	3.574
TOTAL	0.000	8.394	0.000	14.360	N/A	0.000	N/A	0.000	11.351	N/A	0.743	N/A	N/A	N/A	6.867	16.705
WSP SAFETY	0.000	6.545	0.000	8.566	N/A	0.000	1.268	0.316	7.321	N/A	0.000	N/A	1.161	0.329	5.103	11.939
DELAY	0.000	0.757	0.000	4.345	N/A	0.000	0.627	0.305	1.420	N/A	0.000	N/A	0.220	0.127	1.127	2.647
TOTAL	0.000	7.303	0.000	12.911	N/A	0.000	1.895	0.621	8.741	N/A	0.000	N/A	1.380	0.456	6.230	14.586
NEXRAD SAFETY	0.233	7.058	1.886	7.773	0.000	0.350	1.361	0.000	0.005	0.805	0.247	0.000	0.000	0.000	5.452	0.000
DELAY	0.063	0.967	0.655	4.170	0.000	0.174	0.704	0.000	0.010	0.159	0.164	0.000	0.000	0.000	1.268	0.000
TOTAL	0.296	8.024	2.541	11.943	0.000	0.524	2.065	0.000	0.014	0.964	0.411	0.000	0.000	0.000	6.720	0.000
XBAND SAFETY	0.234	7.147	1.678	9.088	1.018	0.344	1.352	0.321	8.318	0.446	0.711	0.271	1.200	0.344	5.468	12.294
DELAY	0.066	1.028	0.486	4.926	0.113	0.183	0.739	0.275	1.776	0.094	0.358	0.033	0.336	0.153	1.333	3.516
TOTAL	0.300	8.175	2.164	14.015	1.131	0.527	2.092	0.596	10.094	0.540	1.069	0.304	1.536	0.497	6.801	15.810
LIDAR SAFETY	0.113	2.073	1.232	3.666	0.198	0.197	0.645	0.158	4.992	0.204	0.207	0.065	0.209	0.123	2.270	3.009
DELAY	0.048	0.656	0.458	3.422	0.070	0.149	0.540	0.243	1.522	0.058	0.220	0.021	0.217	0.101	0.936	2.063
TOTAL	0.161	2.729	1.690	7.088	0.269	0.346	1.185	0.401	6.514	0.263	0.427	0.086	0.426	0.224	3.206	5.072
LLWAS SAFETY	0.112	3.325	0.870	4.290	0.424	0.168	0.625	0.190	4.379	0.385	0.328	0.170	0.575	0.160	2.520	5.973
DELAY	0.001	0.016	0.012	0.076	0.002	0.004	0.011	0.010	0.029	0.003	0.005	0.001	0.006	0.002	0.020	0.055
TOTAL	0.113	3.341	0.882	4.366	0.426	0.171	0.636	0.201	4.408	0.388	0.333	0.172	0.581	0.162	2.540	6.027
TDWR + LIDAR SAFETY	0.113	7.363	1.232	9.488	N/A	0.197	N/A	0.158	9.669	N/A	0.634	N/A	N/A	N/A	5.579	13.197
DELAY	0.048	1.068	0.458	5.076	N/A	0.149	N/A	0.243	1.965	N/A	0.296	N/A	N/A	N/A	1.349	3.650
TOTAL	0.161	8.431	1.690	14.564	N/A	0.346	N/A	0.401	11.634	N/A	0.930	N/A	N/A	N/A	6.928	16.847
WSP + LIDAR SAFETY	0.113	7.128	1.232	9.430	N/A	0.197	1.373	0.393	9.547	N/A	0.207	N/A	1.220	0.350	5.518	12.887
DELAY	0.048	0.965	0.458	4.890	N/A	0.149	0.719	0.408	1.929	N/A	0.220	N/A	0.321	0.145	1.282	3.201
TOTAL	0.161	8.092	1.690	14.320	N/A	0.346	2.091	0.800	11.475	N/A	0.427	N/A	1.541	0.494	6.800	16.088

Site	BIS	BNA	BOI	BOS	BTR	BTV	BUF	BUR	BWI	CAE	CAK	CHA	CHS	CID	CLE	CLT
Type	NoWS	TDWR	NoWS	TDWR	LLWAS	NoWS	WSP	NoWS	TDWR	LLWAS	NoWS	LLWAS	WSP	WSP	TDWR	TDWR
NEXRAD + LIDAR SAFETY	0.245	7.291	1.915	9.418	0.198	0.362	1.377	0.158	4.996	0.837	0.413	0.065	0.209	0.123	5.529	3.009
DELAY	0.069	1.053	0.767	4.633	0.070	0.207	0.738	0.243	1.531	0.176	0.288	0.021	0.217	0.101	1.334	2.063
TOTAL	0.314	8.344	2.681	14.050	0.269	0.569	2.115	0.401	6.527	1.013	0.701	0.086	0.426	0.224	6.863	5.072
XBAND + LIDAR SAFETY	0.246	7.278	1.844	9.289	1.045	0.359	1.373	0.361	9.597	0.570	0.718	0.291	1.240	0.349	5.539	12.969
DELAY	0.070	1.066	0.586	5.073	0.127	0.207	0.747	0.375	1.968	0.123	0.366	0.046	0.392	0.156	1.350	3.675
TOTAL	0.315	8.343	2.429	14.363	1.172	0.566	2.120	0.736	11.565	0.694	1.085	0.337	1.631	0.505	6.890	16.644
TDWR + NEXRAD + LIDAR SAFETY	0.245	7.370	1.915	9.511	N/A	0.362	N/A	0.158	9.669	N/A	0.635	N/A	N/A	N/A	5.585	13.197
DELAY	0.069	1.076	0.767	5.112	N/A	0.207	N/A	0.243	1.966	N/A	0.297	N/A	N/A	N/A	1.352	3.650
TOTAL	0.314	8.445	2.681	14.623	N/A	0.569	N/A	0.401	11.635	N/A	0.931	N/A	N/A	N/A	6.937	16.847
WSP + NEXRAD + LIDAR SAFETY	0.245	7.352	1.915	9.498	N/A	0.362	1.383	0.393	9.547	N/A	0.413	N/A	1.220	0.350	5.567	12.887
DELAY	0.069	1.068	0.767	5.052	N/A	0.207	0.745	0.408	1.929	N/A	0.288	N/A	0.321	0.145	1.346	3.201
TOTAL	0.314	8.420	2.681	14.550	N/A	0.569	2.128	0.800	11.476	N/A	0.701	N/A	1.541	0.494	6.913	16.088
TDWR + LLWAS SAFETY	0.112	7.415	0.871	9.508	N/A	0.168	N/A	0.191	9.653	N/A	0.623	N/A	N/A	N/A	5.605	13.282
DELAY	0.000	1.054	0.000	5.003	N/A	0.000	N/A	0.000	1.873	N/A	0.202	N/A	N/A	N/A	1.339	3.574
TOTAL	0.112	8.469	0.871	14.510	N/A	0.168	N/A	0.191	11.526	N/A	0.825	N/A	N/A	N/A	6.944	16.856
WSP + LLWAS SAFETY	0.112	6.913	0.871	9.047	N/A	0.168	1.327	0.361	8.448	N/A	0.328	N/A	1.198	0.341	5.347	12.517
DELAY	0.000	0.757	0.000	4.345	N/A	0.000	0.627	0.305	1.420	N/A	0.000	N/A	0.220	0.127	1.127	2.647
TOTAL	0.112	7.671	0.871	13.391	N/A	0.168	1.954	0.666	9.868	N/A	0.328	N/A	1.418	0.468	6.474	15.164
NEXRAD + LLWAS SAFETY	0.244	7.300	1.930	8.710	0.537	0.364	1.388	0.205	5.112	0.846	0.493	0.168	0.639	0.182	5.579	6.694
DELAY	0.069	1.053	0.767	4.633	0.070	0.207	0.738	0.243	1.531	0.176	0.288	0.021	0.217	0.101	1.334	2.063
TOTAL	0.313	8.353	2.697	13.343	0.607	0.571	2.126	0.448	6.644	1.022	0.781	0.189	0.856	0.283	6.914	8.757
XBAND + LLWAS SAFETY	0.244	7.334	1.803	9.391	1.056	0.361	1.382	0.368	9.132	0.655	0.725	0.311	1.251	0.352	5.581	12.900
DELAY	0.070	1.066	0.586	5.073	0.127	0.207	0.747	0.375	1.968	0.123	0.366	0.046	0.392	0.156	1.350	3.675
TOTAL	0.314	8.400	2.389	14.464	1.183	0.568	2.129	0.743	11.100	0.778	1.092	0.357	1.643	0.509	6.931	16.575
TDWR + NEXRAD SAFETY	0.233	7.354	1.886	9.399	N/A	0.350	N/A	0.000	9.478	N/A	0.543	N/A	N/A	N/A	5.578	13.131
DELAY	0.063	1.069	0.655	5.103	N/A	0.174	N/A	0.000	1.874	N/A	0.206	N/A	N/A	N/A	1.347	3.574
TOTAL	0.296	8.423	2.541	14.501	N/A	0.524	N/A	0.000	11.352	N/A	0.749	N/A	N/A	N/A	6.924	16.705
TDWR + NEXRAD + LLWAS SAFETY	0.242	7.427	1.905	9.538	N/A	0.359	N/A	0.191	9.654	N/A	0.624	N/A	N/A	N/A	5.632	13.282
DELAY	0.063	1.069	0.655	5.103	N/A	0.174	N/A	0.000	1.874	N/A	0.206	N/A	N/A	N/A	1.347	3.574
TOTAL	0.305	8.496	2.560	14.641	N/A	0.533	N/A	0.191	11.527	N/A	0.830	N/A	N/A	N/A	6.979	16.856
WSP + NEXRAD SAFETY	0.233	7.215	1.886	8.703	N/A	0.350	1.374	0.316	7.323	N/A	0.247	N/A	1.161	0.329	5.528	11.939
DELAY	0.063	1.029	0.655	4.824	N/A	0.174	0.729	0.305	1.424	N/A	0.164	N/A	0.220	0.127	1.320	2.647
TOTAL	0.296	8.244	2.541	13.527	N/A	0.524	2.103	0.621	8.747	N/A	0.411	N/A	1.380	0.456	6.848	14.586
WSP + NEXRAD + LLWAS SAFETY	0.242	7.344	1.905	9.158	N/A	0.359	1.390	0.361	8.450	N/A	0.469	N/A	1.198	0.341	5.602	12.517
DELAY	0.063	1.029	0.655	4.824	N/A	0.174	0.729	0.305	1.424	N/A	0.164	N/A	0.220	0.127	1.320	2.647
TOTAL	0.305	8.372	2.560	13.982	N/A	0.533	2.119	0.666	9.874	N/A	0.634	N/A	1.418	0.468	6.922	15.164

Site	CMH	CMI	COS	CRP	CRW	CSG	CVG	DAB	DAL	DAY	DCA	DEN	DFW	DSM	DTW
Type	TDWR	NoWS	LLWAS	NoWS	LLWAS	LLWAS	TDWR	LLWAS	TDWR	TDWR	TDWR	TDWR-LLWAS	TDWR-LLWAS	WSP	TDWR
RAW SAFETY	7.264	0.526	5.225	0.536	0.337	0.520	25.901	4.453	18.149	4.386	13.912	210.892	162.500	2.603	60.065
PILOT SAFETY	5.654	0.417	3.811	0.377	0.253	0.369	20.085	3.146	13.068	3.420	10.634	160.460	120.188	1.942	48.479
PWS SAFETY	2.722	0.410	2.002	0.243	0.252	0.228	10.445	2.251	5.736	1.745	4.787	73.450	50.823	1.145	21.406
CURRENT SAFETY	2.472	0.000	0.937	0.000	0.099	0.131	9.451	1.162	5.117	1.575	4.288	65.721	45.798	0.902	19.428
DELAY	0.511	0.000	0.017	0.000	0.001	0.001	1.061	0.008	1.111	0.256	2.000	8.098	3.668	0.230	3.481
TOTAL	2.983	0.000	0.954	0.000	0.100	0.133	10.511	1.170	6.228	1.831	6.288	73.819	49.466	1.131	22.910
UPGRADED SAFETY	2.653	0.000	0.937	0.000	0.099	0.131	10.129	1.162	5.475	1.687	4.595	72.974	49.938	0.998	20.845
DELAY	0.597	0.000	0.017	0.000	0.001	0.001	1.236	0.008	1.289	0.297	2.321	9.500	4.288	0.248	4.069
TOTAL	3.250	0.000	0.954	0.000	0.100	0.133	11.365	1.170	6.763	1.984	6.916	82.474	54.226	1.245	24.914
TDWR SAFETY	2.653	0.000	N/A	0.000	N/A	N/A	10.129	N/A	5.475	1.687	4.595	70.501	49.083	N/A	20.845
DELAY	0.597	0.000	N/A	0.000	N/A	N/A	1.236	N/A	1.289	0.297	2.321	9.500	4.288	N/A	4.069
TOTAL	3.250	0.000	N/A	0.000	N/A	N/A	11.365	N/A	6.763	1.984	6.916	80.001	53.371	N/A	24.914
WSP SAFETY	2.362	0.000	N/A	0.000	N/A	N/A	9.042	N/A	2.287	1.549	3.964	45.040	43.601	0.998	18.793
DELAY	0.440	0.000	N/A	0.000	N/A	N/A	1.000	N/A	0.448	0.222	1.922	7.569	3.073	0.248	3.397
TOTAL	2.801	0.000	N/A	0.000	N/A	N/A	10.042	N/A	2.735	1.771	5.886	52.609	46.674	1.245	22.190
NEXRAD SAFETY	0.000	0.000	1.531	0.234	0.239	0.000	0.000	0.000	3.811	0.129	4.086	68.014	46.228	1.085	0.000
DELAY	0.000	0.000	0.604	0.128	0.045	0.000	0.000	0.000	0.700	0.095	1.921	9.226	4.184	0.293	0.000
TOTAL	0.000	0.000	2.135	0.363	0.284	0.000	0.000	0.000	4.511	0.224	6.007	77.240	50.412	1.378	0.000
XBAND SAFETY	2.548	0.393	1.611	0.233	0.160	0.199	9.801	2.107	5.369	1.663	4.122	68.162	48.556	1.079	20.579
DELAY	0.575	0.331	0.689	0.134	0.029	0.056	1.213	0.379	1.279	0.294	1.776	9.429	4.216	0.309	4.088
TOTAL	3.123	0.725	2.300	0.367	0.189	0.256	11.014	2.486	6.648	1.957	5.898	77.591	52.772	1.388	24.667
LIDAR SAFETY	0.923	0.133	0.480	0.062	0.077	0.065	3.509	0.432	1.776	0.471	1.870	47.338	12.401	0.442	6.914
DELAY	0.383	0.212	0.468	0.076	0.019	0.039	0.821	0.221	0.839	0.183	1.301	8.416	2.665	0.212	2.675
TOTAL	1.306	0.345	0.948	0.137	0.096	0.104	4.329	0.653	2.614	0.654	3.171	55.754	15.065	0.654	9.590
LLWAS SAFETY	1.199	0.181	0.937	0.107	0.099	0.131	4.602	1.162	2.527	0.769	2.109	64.976	28.603	0.504	9.432
DELAY	0.009	0.005	0.017	0.002	0.001	0.001	0.018	0.008	0.020	0.004	0.036	1.168	0.318	0.005	0.060
TOTAL	1.208	0.186	0.954	0.109	0.100	0.133	4.621	1.170	2.547	0.774	2.145	66.143	28.921	0.509	9.492
TDWR + LIDAR SAFETY	2.659	0.133	N/A	0.062	N/A	N/A	10.188	N/A	5.568	1.700	4.653	71.737	49.498	N/A	20.903
DELAY	0.600	0.212	N/A	0.076	N/A	N/A	1.247	N/A	1.330	0.302	2.385	9.535	4.354	N/A	4.086
TOTAL	3.259	0.345	N/A	0.137	N/A	N/A	11.435	N/A	6.898	2.002	7.037	81.272	53.852	N/A	24.989
WSP + LIDAR SAFETY	2.609	0.133	N/A	0.062	N/A	N/A	10.026	N/A	3.937	1.675	4.572	67.548	47.749	1.097	20.494
DELAY	0.547	0.212	N/A	0.076	N/A	N/A	1.168	N/A	1.025	0.271	2.251	9.376	3.816	0.293	3.828
TOTAL	3.156	0.345	N/A	0.137	N/A	N/A	11.194	N/A	4.963	1.947	6.823	76.924	51.565	1.389	24.323
NEXRAD + LIDAR SAFETY	0.923	0.133	1.743	0.236	0.244	0.065	3.509	0.432	4.824	0.575	4.623	71.445	49.400	1.112	6.914
DELAY	0.383	0.212	0.684	0.133	0.047	0.039	0.821	0.221	1.084	0.228	2.185	9.507	4.256	0.309	2.675

Site	CMH	CMI	COS	CRP	CRW	CSG	CVG	DAB	DAL	DAY	DCA	DEN	DFW	DSM	DTW
Type	TDWR	NoWS	LLWAS	NoWS	LLWAS	LLWAS	TDWR	LLWAS	TDWR	TDWR	TDWR	TDWR-LLWAS	TDWR-LLWAS	WSP	TDWR
TOTAL	1.306	0.345	2.426	0.368	0.291	0.104	4.329	0.653	5.907	0.803	6.808	80.952	53.656	1.420	9.590
XBAND + LIDAR SAFETY	2.623	0.397	1.680	0.235	0.184	0.218	10.109	2.161	5.540	1.687	4.502	71.160	49.198	1.107	20.761
DELAY	0.602	0.334	0.759	0.135	0.035	0.064	1.248	0.406	1.330	0.301	2.239	9.533	4.318	0.312	4.099
TOTAL	3.224	0.731	2.440	0.370	0.219	0.281	11.357	2.567	6.871	1.988	6.741	80.693	53.516	1.420	24.860
TDWR + NEXRAD + LIDAR SAFETY	2.659	0.133	N/A	0.236	N/A	N/A	10.188	N/A	5.590	1.700	4.674	71.745	49.644	N/A	20.903
DELAY	0.600	0.212	N/A	0.133	N/A	N/A	1.247	N/A	1.337	0.303	2.441	9.537	4.382	N/A	4.086
TOTAL	3.259	0.345	N/A	0.368	N/A	N/A	11.435	N/A	6.927	2.003	7.116	81.282	54.026	N/A	24.989
WSP + NEXRAD + LIDAR SAFETY	2.609	0.133	N/A	0.236	N/A	N/A	10.026	N/A	5.158	1.683	4.664	71.621	49.578	1.117	20.494
DELAY	0.547	0.212	N/A	0.133	N/A	N/A	1.168	N/A	1.140	0.285	2.399	9.530	4.348	0.311	3.828
TOTAL	3.156	0.345	N/A	0.368	N/A	N/A	11.194	N/A	6.299	1.969	7.063	81.151	53.926	1.428	24.323
TDWR + LLWAS SAFETY	2.679	0.181	N/A	0.107	N/A	N/A	10.252	N/A	5.578	1.709	4.665	72.974	49.938	N/A	21.061
DELAY	0.597	0.000	N/A	0.000	N/A	N/A	1.236	N/A	1.289	0.297	2.321	9.500	4.288	N/A	4.069
TOTAL	3.275	0.181	N/A	0.107	N/A	N/A	11.488	N/A	6.867	2.007	6.987	82.474	54.226	N/A	25.130
WSP + LLWAS SAFETY	2.497	0.181	N/A	0.107	N/A	N/A	9.606	N/A	3.785	1.619	4.308	70.841	47.023	1.056	19.851
DELAY	0.440	0.000	N/A	0.000	N/A	N/A	1.000	N/A	0.448	0.222	1.922	7.569	3.073	0.248	3.397
TOTAL	2.937	0.181	N/A	0.107	N/A	N/A	10.606	N/A	4.233	1.841	6.230	78.410	50.096	1.303	23.248
NEXRAD + LLWAS SAFETY	1.364	0.205	1.734	0.238	0.245	0.113	5.257	1.107	4.768	0.933	4.418	72.913	48.860	1.113	10.767
DELAY	0.383	0.212	0.684	0.133	0.047	0.039	0.821	0.221	1.084	0.228	2.185	9.507	4.256	0.309	2.675
TOTAL	1.747	0.418	2.417	0.371	0.292	0.152	6.078	1.328	5.852	1.161	6.603	82.420	53.116	1.422	13.443
XBAND + LLWAS SAFETY	2.632	0.401	1.781	0.237	0.202	0.214	10.104	2.177	5.543	1.700	4.461	72.932	49.797	1.109	20.935
DELAY	0.602	0.334	0.759	0.135	0.035	0.064	1.248	0.406	1.330	0.301	2.239	9.533	4.318	0.312	4.099
TOTAL	3.233	0.735	2.540	0.372	0.237	0.277	11.353	2.583	6.874	2.002	6.700	82.465	54.115	1.421	25.034
TDWR + NEXRAD SAFETY	2.653	0.000	N/A	0.234	N/A	N/A	10.129	N/A	5.509	1.687	4.645	70.643	49.326	N/A	20.845
DELAY	0.597	0.000	N/A	0.128	N/A	N/A	1.236	N/A	1.315	0.298	2.422	9.513	4.376	N/A	4.069
TOTAL	3.250	0.000	N/A	0.363	N/A	N/A	11.365	N/A	6.824	1.985	7.067	80.156	53.701	N/A	24.914
TDWR + NEXRAD + LLWAS SAFETY	2.679	0.181	N/A	0.237	N/A	N/A	10.252	N/A	5.601	1.710	4.700	72.990	50.090	N/A	21.061
DELAY	0.597	0.000	N/A	0.128	N/A	N/A	1.236	N/A	1.315	0.298	2.422	9.513	4.376	N/A	4.069
TOTAL	3.275	0.181	N/A	0.366	N/A	N/A	11.488	N/A	6.916	2.008	7.122	82.503	54.465	N/A	25.130
WSP + NEXRAD SAFETY	2.362	0.000	N/A	0.234	N/A	N/A	9.042	N/A	4.164	1.564	4.331	68.718	47.376	1.099	18.793
DELAY	0.440	0.000	N/A	0.128	N/A	N/A	1.000	N/A	0.801	0.249	2.352	9.403	4.300	0.305	3.397
TOTAL	2.801	0.000	N/A	0.363	N/A	N/A	10.042	N/A	4.965	1.812	6.683	78.121	51.676	1.405	22.190
WSP + NEXRAD + LLWAS SAFETY	2.497	0.181	N/A	0.237	N/A	N/A	9.606	N/A	4.812	1.633	4.533	72.856	49.297	1.118	19.851
DELAY	0.440	0.000	N/A	0.128	N/A	N/A	1.000	N/A	0.801	0.249	2.352	9.403	4.300	0.305	3.397
TOTAL	2.937	0.181	N/A	0.366	N/A	N/A	10.606	N/A	5.613	1.882	6.885	82.259	53.597	1.423	23.248

Site	ELP	ERI	EVV	EWR	FAR	FAY	FLL	FNT	FSD	FSM	FWA	GCN	GEG	GFK	GPT	GRB
Type	WSP	NoWS	NoWS	TDWR	NoWS	LLWAS	TDWR	NoWS	LLWAS	LLWAS	WSP	NoWS	WSP	NoWS	NoWS	LLWAS
RAW SAFETY	7.400	0.121	0.493	20.013	0.633	0.256	79.466	1.548	1.879	0.307	1.913	1.017	6.799	0.963	2.164	0.497
PILOT SAFETY	5.101	0.098	0.368	15.950	0.522	0.194	55.171	1.243	1.322	0.227	1.510	0.756	4.937	0.754	1.489	0.374
PWS SAFETY	2.150	0.096	0.362	6.875	0.321	0.171	21.326	0.639	0.814	0.215	0.854	0.755	2.305	0.645	0.780	0.244
CURRENT SAFETY	1.883	0.000	0.000	6.080	0.000	0.069	19.172	0.000	0.344	0.095	0.665	0.000	1.851	0.000	0.000	0.104
DELAY	0.585	0.000	0.000	9.748	0.000	0.001	6.660	0.000	0.005	0.001	0.098	0.000	0.500	0.000	0.000	0.003
TOTAL	2.468	0.000	0.000	15.828	0.000	0.070	25.832	0.000	0.348	0.096	0.764	0.000	2.350	0.000	0.000	0.107
UPGRADED SAFETY	1.970	0.000	0.000	6.512	0.000	0.069	20.459	0.000	0.344	0.095	0.742	0.000	1.958	0.000	0.000	0.104
DELAY	0.627	0.000	0.000	11.385	0.000	0.001	7.616	0.000	0.005	0.001	0.114	0.000	0.522	0.000	0.000	0.003
TOTAL	2.598	0.000	0.000	17.897	0.000	0.070	28.075	0.000	0.348	0.096	0.856	0.000	2.480	0.000	0.000	0.107
TDWR SAFETY	N/A	0.000	0.000	6.512	0.000	N/A	20.459	0.000	N/A	N/A	N/A	0.000	N/A	0.000	0.000	N/A
DELAY	N/A	0.000	0.000	11.385	0.000	N/A	7.616	0.000	N/A	N/A	N/A	0.000	N/A	0.000	0.000	N/A
TOTAL	N/A	0.000	0.000	17.897	0.000	N/A	28.075	0.000	N/A	N/A	N/A	0.000	N/A	0.000	0.000	N/A
WSP SAFETY	1.970	0.000	0.000	5.806	0.000	N/A	19.762	0.000	N/A	N/A	0.742	0.000	1.958	0.000	0.000	N/A
DELAY	0.627	0.000	0.000	10.443	0.000	N/A	5.431	0.000	N/A	N/A	0.114	0.000	0.522	0.000	0.000	N/A
TOTAL	2.598	0.000	0.000	16.249	0.000	N/A	25.193	0.000	N/A	N/A	0.856	0.000	2.480	0.000	0.000	N/A
NEXRAD SAFETY	0.129	0.000	0.000	0.000	0.000	0.000	19.326	0.347	0.718	0.207	0.078	0.000	2.134	0.267	0.005	0.224
DELAY	0.287	0.000	0.000	0.000	0.000	0.000	5.027	0.186	0.245	0.054	0.046	0.000	0.582	0.295	0.008	0.168
TOTAL	0.416	0.000	0.000	0.000	0.000	0.000	24.352	0.533	0.963	0.261	0.124	0.000	2.717	0.562	0.012	0.393
XBAND SAFETY	2.023	0.079	0.344	6.454	0.288	0.157	20.257	0.604	0.748	0.196	0.798	0.687	2.137	0.613	0.728	0.220
DELAY	0.712	0.056	0.084	11.698	0.161	0.039	7.425	0.237	0.254	0.042	0.141	0.379	0.587	0.405	0.103	0.190
TOTAL	2.735	0.135	0.428	18.153	0.449	0.196	27.683	0.842	1.002	0.237	0.939	1.066	2.724	1.019	0.832	0.410
LIDAR SAFETY	0.444	0.045	0.139	2.875	0.149	0.041	2.828	0.285	0.442	0.051	0.279	0.468	1.135	0.308	0.154	0.127
DELAY	0.428	0.045	0.057	8.560	0.123	0.026	4.137	0.175	0.206	0.024	0.094	0.332	0.473	0.301	0.065	0.154
TOTAL	0.872	0.090	0.196	11.435	0.271	0.067	6.965	0.460	0.648	0.075	0.374	0.799	1.607	0.609	0.219	0.281
LLWAS SAFETY	0.947	0.042	0.159	3.029	0.142	0.069	9.396	0.281	0.344	0.095	0.376	0.333	1.015	0.284	0.344	0.104
DELAY	0.013	0.001	0.001	0.188	0.002	0.001	0.123	0.004	0.005	0.001	0.002	0.007	0.010	0.006	0.002	0.003
TOTAL	0.960	0.043	0.161	3.218	0.144	0.070	9.519	0.285	0.348	0.096	0.379	0.340	1.025	0.290	0.346	0.107
TDWR + LIDAR SAFETY	N/A	0.045	0.139	6.647	0.149	N/A	20.606	0.285	N/A	N/A	N/A	0.468	N/A	0.308	0.154	N/A
DELAY	N/A	0.045	0.057	12.126	0.123	N/A	8.117	0.175	N/A	N/A	N/A	0.332	N/A	0.301	0.065	N/A
TOTAL	N/A	0.090	0.196	18.773	0.271	N/A	28.723	0.460	N/A	N/A	N/A	0.799	N/A	0.609	0.219	N/A
WSP + LIDAR SAFETY	2.044	0.045	0.139	6.605	0.149	N/A	20.367	0.285	N/A	N/A	0.821	0.468	2.233	0.308	0.154	N/A
DELAY	0.738	0.045	0.057	12.132	0.123	N/A	7.148	0.175	N/A	N/A	0.136	0.332	0.624	0.301	0.065	N/A
TOTAL	2.782	0.090	0.196	18.737	0.271	N/A	27.514	0.460	N/A	N/A	0.957	0.799	2.857	0.609	0.219	N/A
NEXRAD + LIDAR SAFETY	0.546	0.045	0.139	2.875	0.149	0.041	20.135	0.573	0.785	0.209	0.345	0.468	2.238	0.531	0.158	0.236
DELAY	0.635	0.045	0.057	8.560	0.123	0.026	6.456	0.219	0.259	0.056	0.114	0.332	0.633	0.367	0.072	0.195

Site	ELP	ERI	EVV	EWR	FAR	FAY	FLL	FNT	FSD	FSM	FWA	GCN	GEG	GFK	GPT	GRB
Type	WSP	NoWS	NoWS	TDWR	NoWS	LLWAS	TDWR	NoWS	LLWAS	LLWAS	WSP	NoWS	WSP	NoWS	NoWS	LLWAS
TOTAL	1.180	0.090	0.196	11.435	0.271	0.067	26.591	0.792	1.045	0.264	0.459	0.799	2.872	0.898	0.231	0.431
XBAND + LIDAR SAFETY	2.054	0.089	0.349	6.615	0.311	0.164	20.548	0.617	0.789	0.204	0.825	0.718	2.227	0.626	0.748	0.235
DELAY	0.776	0.066	0.084	12.299	0.166	0.044	8.149	0.243	0.259	0.051	0.147	0.397	0.632	0.409	0.116	0.200
TOTAL	2.830	0.155	0.434	18.913	0.477	0.207	28.697	0.860	1.048	0.255	0.972	1.115	2.859	1.035	0.864	0.435
TDWR + NEXRAD + LIDAR SAFETY	N/A	0.045	0.139	6.647	0.149	N/A	20.805	0.573	N/A	N/A	N/A	0.468	N/A	0.531	0.158	N/A
DELAY	N/A	0.045	0.057	12.126	0.123	N/A	8.242	0.219	N/A	N/A	N/A	0.332	N/A	0.367	0.072	N/A
TOTAL	N/A	0.090	0.196	18.773	0.271	N/A	29.047	0.792	N/A	N/A	N/A	0.799	N/A	0.898	0.231	N/A
WSP + NEXRAD + LIDAR SAFETY	2.062	0.045	0.139	6.605	0.149	N/A	20.680	0.573	N/A	N/A	0.823	0.468	2.247	0.531	0.158	N/A
DELAY	0.802	0.045	0.057	12.132	0.123	N/A	7.744	0.219	N/A	N/A	0.139	0.332	0.641	0.367	0.072	N/A
TOTAL	2.864	0.090	0.196	18.737	0.271	N/A	28.424	0.792	N/A	N/A	0.962	0.799	2.888	0.898	0.231	N/A
TDWR + LLWAS SAFETY	N/A	0.042	0.159	6.638	0.142	N/A	20.745	0.282	N/A	N/A	N/A	0.333	N/A	0.285	0.344	N/A
DELAY	N/A	0.000	0.000	11.385	0.000	N/A	7.616	0.000	N/A	N/A	N/A	0.000	N/A	0.000	0.000	N/A
TOTAL	N/A	0.042	0.159	18.023	0.142	N/A	28.361	0.282	N/A	N/A	N/A	0.333	N/A	0.285	0.344	N/A
WSP + LLWAS SAFETY	2.026	0.042	0.159	6.254	0.142	N/A	20.130	0.282	N/A	N/A	0.786	0.333	2.101	0.285	0.344	N/A
DELAY	0.627	0.000	0.000	10.443	0.000	N/A	5.431	0.000	N/A	N/A	0.114	0.000	0.522	0.000	0.000	N/A
TOTAL	2.653	0.042	0.159	16.697	0.142	N/A	25.562	0.282	N/A	N/A	0.900	0.333	2.624	0.285	0.344	N/A
NEXRAD + LLWAS SAFETY	1.130	0.047	0.183	3.469	0.164	0.085	20.206	0.490	0.765	0.210	0.466	0.385	2.219	0.453	0.389	0.235
DELAY	0.635	0.045	0.057	8.560	0.123	0.026	6.456	0.219	0.259	0.056	0.114	0.332	0.633	0.367	0.072	0.195
TOTAL	1.765	0.092	0.240	12.029	0.287	0.111	26.662	0.708	1.024	0.266	0.580	0.716	2.852	0.820	0.461	0.430
XBAND + LLWAS SAFETY	2.078	0.087	0.352	6.647	0.304	0.164	20.796	0.620	0.779	0.205	0.825	0.715	2.219	0.628	0.754	0.232
DELAY	0.776	0.066	0.084	12.299	0.166	0.044	8.149	0.243	0.259	0.051	0.147	0.397	0.632	0.409	0.116	0.200
TOTAL	2.854	0.152	0.436	18.946	0.470	0.207	28.945	0.863	1.038	0.256	0.971	1.111	2.851	1.036	0.870	0.431
TDWR + NEXRAD SAFETY	N/A	0.000	0.000	6.512	0.000	N/A	20.728	0.347	N/A	N/A	N/A	0.000	N/A	0.267	0.005	N/A
DELAY	N/A	0.000	0.000	11.385	0.000	N/A	7.997	0.186	N/A	N/A	N/A	0.000	N/A	0.295	0.008	N/A
TOTAL	N/A	0.000	0.000	17.897	0.000	N/A	28.725	0.533	N/A	N/A	N/A	0.000	N/A	0.562	0.012	N/A
TDWR + NEXRAD + LLWAS SAFETY	N/A	0.042	0.159	6.638	0.142	N/A	20.928	0.481	N/A	N/A	N/A	0.333	N/A	0.442	0.349	N/A
DELAY	N/A	0.000	0.000	11.385	0.000	N/A	7.997	0.186	N/A	N/A	N/A	0.000	N/A	0.295	0.008	N/A
TOTAL	N/A	0.042	0.159	18.023	0.142	N/A	28.925	0.667	N/A	N/A	N/A	0.333	N/A	0.738	0.356	N/A
WSP + NEXRAD SAFETY	1.995	0.000	0.000	5.806	0.000	N/A	20.397	0.347	N/A	N/A	0.745	0.000	2.204	0.267	0.005	N/A
DELAY	0.715	0.000	0.000	10.443	0.000	N/A	7.082	0.186	N/A	N/A	0.121	0.000	0.619	0.295	0.008	N/A
TOTAL	2.710	0.000	0.000	16.249	0.000	N/A	27.479	0.533	N/A	N/A	0.866	0.000	2.824	0.562	0.012	N/A
WSP + NEXRAD + LLWAS SAFETY	2.049	0.042	0.159	6.254	0.142	N/A	20.650	0.481	N/A	N/A	0.789	0.333	2.243	0.442	0.349	N/A
DELAY	0.715	0.000	0.000	10.443	0.000	N/A	7.082	0.186	N/A	N/A	0.121	0.000	0.619	0.295	0.008	N/A
TOTAL	2.764	0.042	0.159	16.697	0.142	N/A	27.732	0.667	N/A	N/A	0.910	0.333	2.862	0.738	0.356	N/A

Site	GRR	GSO	GSP	HNL	HOU	HPN	HSV	IAD	IAH	ICT	ILM	IND	ISP	JAN	JAX	JFK
Type	WSP	WSP	LLWAS	WSP	TDWR	WSP	WSP	TDWR	TDWR	TDWR	NoWS	TDWR	WSP	LLWAS	WSP	TDWR
RAW SAFETY	1.679	3.952	0.590	13.291	42.192	0.990	1.550	35.413	133.451	3.822	0.947	26.160	2.450	2.251	21.929	37.584
PILOT SAFETY	1.304	2.978	0.412	9.121	30.525	0.808	1.119	26.127	97.262	2.942	0.706	19.569	1.967	1.519	14.962	29.877
PWS SAFETY	0.734	1.421	0.291	3.826	12.545	0.577	0.693	12.206	42.794	1.735	0.438	8.927	0.944	0.829	6.551	12.658
CURRENT SAFETY	0.630	1.182	0.124	3.144	11.355	0.498	0.600	10.961	38.643	1.564	0.000	7.987	0.677	0.442	5.394	11.426
DELAY	0.224	0.122	0.001	0.757	1.055	0.549	0.121	1.100	6.586	0.442	0.000	1.042	0.440	0.002	0.568	58.221
TOTAL	0.855	1.304	0.125	3.901	12.410	1.048	0.721	12.061	45.229	2.006	0.000	9.028	1.117	0.444	5.963	69.647
UPGRADED SAFETY	0.655	1.272	0.124	3.510	12.086	0.513	0.636	11.730	41.159	1.678	0.000	8.561	0.743	0.442	5.421	12.220
DELAY	0.232	0.146	0.001	1.210	1.206	0.563	0.139	1.279	7.412	0.516	0.000	1.215	0.481	0.002	0.590	67.112
TOTAL	0.887	1.418	0.125	4.721	13.292	1.076	0.774	13.008	48.572	2.193	0.000	9.777	1.224	0.444	6.011	79.332
TDWR SAFETY	N/A	N/A	N/A	N/A	12.086	N/A	N/A	11.730	41.159	1.678	0.000	8.561	N/A	N/A	N/A	12.220
DELAY	N/A	N/A	N/A	N/A	1.206	N/A	N/A	1.279	7.412	0.516	0.000	1.215	N/A	N/A	N/A	67.112
TOTAL	N/A	N/A	N/A	N/A	13.292	N/A	N/A	13.008	48.572	2.193	0.000	9.777	N/A	N/A	N/A	79.332
WSP SAFETY	0.655	1.272	N/A	3.510	11.227	0.513	0.636	9.753	37.588	1.505	0.000	8.132	0.743	N/A	5.421	10.859
DELAY	0.232	0.146	N/A	1.210	0.713	0.563	0.139	0.966	4.325	0.392	0.000	1.004	0.481	N/A	0.590	58.046
TOTAL	0.887	1.418	N/A	4.721	11.940	1.076	0.774	10.719	41.914	1.897	0.000	9.136	1.224	N/A	6.011	68.905
NEXRAD SAFETY	0.711	0.000	0.279	0.000	11.916	0.009	0.000	10.276	31.576	1.585	0.323	8.492	0.890	0.779	6.337	0.000
DELAY	0.268	0.000	0.088	0.000	1.116	0.106	0.000	1.061	4.348	0.445	0.078	1.139	0.567	0.124	0.794	0.000
TOTAL	0.979	0.000	0.367	0.000	13.032	0.115	0.000	11.337	35.924	2.031	0.401	9.632	1.457	0.904	7.131	0.000
XBAND SAFETY	0.703	1.030	0.272	3.412	11.840	0.530	0.633	10.703	38.755	1.616	0.397	8.542	0.886	0.731	6.296	12.039
DELAY	0.274	0.156	0.096	1.323	1.139	0.593	0.169	1.205	6.026	0.497	0.102	1.216	0.577	0.128	0.831	68.441
TOTAL	0.976	1.186	0.368	4.735	12.979	1.123	0.802	11.908	44.781	2.114	0.499	9.758	1.462	0.859	7.127	80.480
LIDAR SAFETY	0.346	0.384	0.072	0.621	1.987	0.257	0.153	4.641	6.821	0.570	0.088	2.518	0.531	0.269	1.381	5.473
DELAY	0.205	0.116	0.056	0.846	0.659	0.308	0.098	0.943	4.203	0.340	0.073	0.753	0.483	0.087	0.461	50.630
TOTAL	0.551	0.500	0.128	1.467	2.646	0.565	0.251	5.584	11.024	0.910	0.161	3.271	1.014	0.357	1.842	56.103
LLWAS SAFETY	0.324	0.626	0.124	1.686	5.527	0.254	0.305	5.378	18.855	0.765	0.193	3.933	0.416	0.442	2.886	5.577
DELAY	0.004	0.003	0.001	0.030	0.019	0.010	0.003	0.020	0.117	0.008	0.002	0.018	0.009	0.002	0.012	1.017
TOTAL	0.328	0.629	0.125	1.716	5.546	0.264	0.308	5.398	18.972	0.772	0.195	3.951	0.425	0.444	2.899	6.594
TDWR + LIDAR SAFETY	N/A	N/A	N/A	N/A	12.157	N/A	N/A	11.878	41.440	1.691	0.088	8.670	N/A	N/A	N/A	12.314
DELAY	N/A	N/A	N/A	N/A	1.257	N/A	N/A	1.323	7.689	0.526	0.073	1.227	N/A	N/A	N/A	68.564
TOTAL	N/A	N/A	N/A	N/A	13.414	N/A	N/A	13.201	49.129	2.217	0.161	9.898	N/A	N/A	N/A	80.878
WSP + LIDAR SAFETY	0.714	1.363	N/A	3.586	11.710	0.557	0.664	11.541	39.479	1.659	0.088	8.464	0.913	N/A	5.788	12.185
DELAY	0.268	0.177	N/A	1.459	1.023	0.605	0.162	1.266	6.153	0.486	0.073	1.127	0.589	N/A	0.698	66.930
TOTAL	0.982	1.540	N/A	5.045	12.733	1.162	0.826	12.807	45.633	2.145	0.161	9.591	1.501	N/A	6.485	79.115
NEXRAD + LIDAR SAFETY	0.715	0.384	0.282	0.621	12.067	0.274	0.153	11.528	34.219	1.665	0.361	8.570	0.921	0.797	6.360	5.473
DELAY	0.274	0.116	0.097	0.846	1.210	0.518	0.098	1.297	6.125	0.516	0.106	1.196	0.589	0.135	0.820	50.630

Site	GRR	GSO	GSP	HNL	HOU	HPN	HSV	IAD	IAH	ICT	ILM	IND	ISP	JAN	JAX	JFK
Type	WSP	WSP	LLWAS	WSP	TDWR	WSP	WSP	TDWR	TDWR	TDWR	NoWS	TDWR	WSP	LLWAS	WSP	TDWR
TOTAL	0.989	0.500	0.378	1.467	13.277	0.792	0.251	12.826	40.344	2.181	0.467	9.766	1.510	0.933	7.180	56.103
XBAND + LIDAR SAFETY	0.711	1.134	0.280	3.446	12.035	0.548	0.648	11.713	40.562	1.670	0.418	8.617	0.917	0.792	6.327	12.275
DELAY	0.275	0.183	0.101	1.429	1.249	0.640	0.178	1.325	7.277	0.526	0.125	1.227	0.594	0.139	0.834	68.986
TOTAL	0.986	1.317	0.381	4.876	13.284	1.188	0.826	13.038	47.838	2.197	0.543	9.844	1.511	0.932	7.161	81.261
TDWR + NEXRAD + LIDAR SAFETY	N/A	N/A	N/A	N/A	12.220	N/A	N/A	11.891	41.709	1.693	0.361	8.716	N/A	N/A	N/A	12.314
DELAY	N/A	N/A	N/A	N/A	1.275	N/A	N/A	1.331	7.769	0.528	0.106	1.231	N/A	N/A	N/A	68.564
TOTAL	N/A	N/A	N/A	N/A	13.495	N/A	N/A	13.222	49.478	2.221	0.467	9.947	N/A	N/A	N/A	80.878
WSP + NEXRAD + LIDAR SAFETY	0.717	1.363	N/A	3.586	12.202	0.559	0.664	11.831	41.139	1.687	0.361	8.633	0.922	N/A	6.376	12.185
DELAY	0.274	0.177	N/A	1.459	1.248	0.625	0.162	1.324	6.975	0.523	0.106	1.213	0.594	N/A	0.827	66.930
TOTAL	0.991	1.540	N/A	5.045	13.450	1.184	0.826	13.155	48.114	2.211	0.467	9.846	1.516	N/A	7.203	79.115
TDWR + LLWAS SAFETY	N/A	N/A	N/A	N/A	12.243	N/A	N/A	11.909	41.729	1.699	0.193	8.712	N/A	N/A	N/A	12.387
DELAY	N/A	N/A	N/A	N/A	1.206	N/A	N/A	1.279	7.412	0.516	0.000	1.215	N/A	N/A	N/A	67.112
TOTAL	N/A	N/A	N/A	N/A	13.449	N/A	N/A	13.187	49.142	2.215	0.193	9.928	N/A	N/A	N/A	79.499
WSP + LLWAS SAFETY	0.687	1.325	N/A	3.582	11.581	0.539	0.654	10.767	39.133	1.593	0.193	8.422	0.830	N/A	5.869	11.615
DELAY	0.232	0.146	N/A	1.210	0.713	0.563	0.139	0.966	4.325	0.392	0.000	1.004	0.481	N/A	0.590	58.046
TOTAL	0.919	1.470	N/A	4.793	12.294	1.102	0.793	11.732	43.458	1.984	0.193	9.427	1.312	N/A	6.459	69.662
NEXRAD + LLWAS SAFETY	0.721	0.706	0.284	1.837	12.202	0.297	0.341	11.280	36.985	1.664	0.378	8.690	0.915	0.803	6.429	6.464
DELAY	0.274	0.116	0.097	0.846	1.210	0.518	0.098	1.297	6.125	0.516	0.106	1.196	0.589	0.135	0.820	50.630
TOTAL	0.995	0.823	0.381	2.683	13.413	0.815	0.439	12.577	43.109	2.179	0.484	9.886	1.504	0.938	7.249	57.094
XBAND + LLWAS SAFETY	0.716	1.223	0.281	3.561	12.189	0.552	0.662	11.458	40.800	1.675	0.418	8.710	0.913	0.780	6.406	12.316
DELAY	0.275	0.183	0.101	1.429	1.249	0.640	0.178	1.325	7.277	0.526	0.125	1.227	0.594	0.139	0.834	68.986
TOTAL	0.991	1.406	0.382	4.990	13.438	1.193	0.840	12.783	48.077	2.201	0.543	9.936	1.507	0.919	7.240	81.302
TDWR + NEXRAD SAFETY	N/A	N/A	N/A	N/A	12.196	N/A	N/A	11.785	41.566	1.686	0.323	8.707	N/A	N/A	N/A	12.220
DELAY	N/A	N/A	N/A	N/A	1.258	N/A	N/A	1.299	7.665	0.523	0.078	1.227	N/A	N/A	N/A	67.112
TOTAL	N/A	N/A	N/A	N/A	13.455	N/A	N/A	13.084	49.231	2.209	0.401	9.933	N/A	N/A	N/A	79.332
TDWR + NEXRAD + LLWAS SAFETY	N/A	N/A	N/A	N/A	12.323	N/A	N/A	11.945	42.001	1.705	0.370	8.790	N/A	N/A	N/A	12.387
DELAY	N/A	N/A	N/A	N/A	1.258	N/A	N/A	1.299	7.665	0.523	0.078	1.227	N/A	N/A	N/A	67.112
TOTAL	N/A	N/A	N/A	N/A	13.581	N/A	N/A	13.244	49.666	2.227	0.448	10.017	N/A	N/A	N/A	79.499
WSP + NEXRAD SAFETY	0.714	1.272	N/A	3.510	12.129	0.515	0.636	10.992	40.073	1.637	0.323	8.586	0.893	N/A	6.362	10.859
DELAY	0.272	0.146	N/A	1.210	1.196	0.586	0.139	1.188	6.289	0.489	0.078	1.183	0.583	N/A	0.815	58.046
TOTAL	0.986	1.418	N/A	4.721	13.325	1.101	0.774	12.181	46.362	2.125	0.401	9.769	1.476	N/A	7.178	68.905
WSP + NEXRAD + LLWAS SAFETY	0.722	1.325	N/A	3.582	12.260	0.541	0.654	11.494	40.893	1.674	0.370	8.715	0.914	N/A	6.431	11.615
DELAY	0.272	0.146	N/A	1.210	1.196	0.586	0.139	1.188	6.289	0.489	0.078	1.183	0.583	N/A	0.815	58.046
TOTAL	0.994	1.470	N/A	4.793	13.456	1.127	0.793	12.683	47.182	2.163	0.448	9.898	1.497	N/A	7.247	69.662

Site	LAN	LAS	LAX	LBB	LEX	LFT	LGA	LGB	LIT	LNK	MAF	MBS	MCI	MCO	MDT
Type	LLWAS	TDWR	WSP	WSP	LLWAS	NoWS	TDWR-LLWAS	NoWS	LLWAS	LLWAS	LLWAS	NoWS	TDWR	TDWR-LLWAS	WSP
RAW SAFETY	0.773	93.831	14.401	3.308	0.461	1.284	11.227	5.046	6.006	0.398	2.180	0.528	40.716	191.072	0.587
PILOT SAFETY	0.616	65.632	10.151	2.393	0.359	0.925	9.016	3.392	4.354	0.314	1.561	0.424	31.816	136.057	0.470
PWS SAFETY	0.333	30.719	4.659	1.237	0.303	0.785	4.064	1.803	2.245	0.246	0.819	0.197	13.026	52.361	0.269
CURRENT SAFETY	0.144	23.168	3.144	1.068	0.130	0.000	3.673	0.000	1.173	0.138	0.394	0.000	11.811	47.382	0.213
DELAY	0.003	7.000	1.127	0.393	0.002	0.000	9.822	0.000	0.007	0.002	0.009	0.000	1.574	3.013	0.177
TOTAL	0.147	30.168	4.271	1.461	0.131	0.000	13.494	0.000	1.180	0.140	0.404	0.000	13.385	50.396	0.390
UPGRADED SAFETY	0.144	25.143	3.832	1.116	0.130	0.000	3.981	0.000	1.173	0.138	0.394	0.000	12.669	51.693	0.215
DELAY	0.003	8.237	1.660	0.420	0.002	0.000	11.494	0.000	0.007	0.002	0.009	0.000	1.844	3.487	0.193
TOTAL	0.147	33.381	5.493	1.536	0.131	0.000	15.475	0.000	1.180	0.140	0.404	0.000	14.513	55.179	0.407
TDWR SAFETY	N/A	25.143	N/A	N/A	N/A	0.000	3.942	0.000	N/A	N/A	N/A	0.000	12.669	50.694	N/A
DELAY	N/A	8.237	N/A	N/A	N/A	0.000	11.494	0.000	N/A	N/A	N/A	0.000	1.844	3.487	N/A
TOTAL	N/A	33.381	N/A	N/A	N/A	0.000	15.436	0.000	N/A	N/A	N/A	0.000	14.513	54.180	N/A
WSP SAFETY	N/A	21.031	3.832	1.116	N/A	0.000	1.148	0.899	N/A	N/A	N/A	0.000	12.183	48.734	0.215
DELAY	N/A	8.569	1.660	0.420	N/A	0.000	4.748	0.224	N/A	N/A	N/A	0.000	1.591	2.687	0.193
TOTAL	N/A	29.600	5.493	1.536	N/A	0.000	5.897	1.122	N/A	N/A	N/A	0.000	13.774	51.421	0.407
NEXRAD SAFETY	0.001	0.000	0.000	1.175	0.000	0.000	0.000	0.000	2.150	0.142	0.775	0.000	1.977	0.935	0.000
DELAY	0.009	0.000	0.000	0.487	0.000	0.000	0.000	0.000	0.300	0.053	0.336	0.000	0.621	0.688	0.000
TOTAL	0.010	0.000	0.000	1.661	0.000	0.000	0.000	0.000	2.449	0.194	1.111	0.000	2.597	1.623	0.000
XBAND SAFETY	0.307	18.818	4.243	1.180	0.288	0.738	3.842	1.546	2.045	0.233	0.771	0.183	12.546	50.264	0.213
DELAY	0.184	8.368	2.149	0.535	0.109	0.090	11.389	0.504	0.297	0.097	0.366	0.156	1.850	3.531	0.090
TOTAL	0.491	27.186	6.393	1.715	0.397	0.828	15.231	2.050	2.341	0.330	1.138	0.339	14.396	53.795	0.303
LIDAR SAFETY	0.156	18.238	1.628	0.358	0.074	0.145	1.814	0.449	0.737	0.083	0.184	0.078	2.997	8.137	0.085
DELAY	0.139	8.644	1.690	0.329	0.063	0.052	8.154	0.347	0.208	0.064	0.216	0.114	1.065	1.929	0.061
TOTAL	0.295	26.881	3.318	0.687	0.137	0.197	9.969	0.796	0.945	0.146	0.401	0.192	4.063	10.066	0.145
LLWAS SAFETY	0.144	13.535	2.053	0.545	0.130	0.346	1.487	0.794	1.173	0.138	0.394	0.087	5.739	40.257	0.119
DELAY	0.003	0.202	0.038	0.008	0.002	0.001	0.215	0.010	0.007	0.002	0.009	0.002	0.027	0.270	0.004
TOTAL	0.147	13.737	2.091	0.553	0.131	0.347	1.703	0.804	1.180	0.140	0.404	0.089	5.766	40.526	0.123
TDWR + LIDAR SAFETY	N/A	28.494	N/A	N/A	N/A	0.145	3.969	0.449	N/A	N/A	N/A	0.078	12.713	50.928	N/A
DELAY	N/A	9.432	N/A	N/A	N/A	0.052	11.577	0.347	N/A	N/A	N/A	0.114	1.851	3.586	N/A
TOTAL	N/A	37.926	N/A	N/A	N/A	0.197	15.546	0.796	N/A	N/A	N/A	0.192	14.564	54.515	N/A
WSP + LIDAR SAFETY	N/A	28.794	4.371	1.185	N/A	0.145	2.840	1.277	N/A	N/A	N/A	0.078	12.539	50.111	0.245
DELAY	N/A	11.353	2.285	0.491	N/A	0.052	9.587	0.347	N/A	N/A	N/A	0.114	1.717	3.149	0.205
TOTAL	N/A	40.147	6.656	1.676	N/A	0.197	12.427	1.624	N/A	N/A	N/A	0.192	14.256	53.260	0.450
NEXRAD + LIDAR SAFETY	0.157	18.238	1.628	1.196	0.074	0.145	1.814	0.449	2.177	0.196	0.788	0.078	4.685	8.804	0.085
DELAY	0.144	8.644	1.690	0.523	0.063	0.052	8.154	0.347	0.316	0.081	0.367	0.114	1.368	2.419	0.061

Site	LAN	LAS	LAX	LBB	LEX	LFT	LGA	LGB	LIT	LNK	MAF	MBS	MCI	MCO	MDT
Type	LLWAS	TDWR	WSP	WSP	LLWAS	NoWS	TDWR-LLWAS	NoWS	LLWAS	LLWAS	LLWAS	NoWS	TDWR	TDWR-LLWAS	WSP
TOTAL	0.301	26.881	3.318	1.720	0.137	0.197	9.969	0.796	2.493	0.277	1.155	0.192	6.053	11.223	0.145
XBAND + LIDAR SAFETY	0.322	25.368	4.492	1.190	0.292	0.753	3.926	1.658	2.155	0.238	0.786	0.190	12.599	50.653	0.225
DELAY	0.188	11.081	2.436	0.538	0.110	0.098	11.564	0.623	0.321	0.097	0.380	0.165	1.853	3.613	0.119
TOTAL	0.510	36.449	6.928	1.729	0.403	0.851	15.490	2.280	2.476	0.335	1.166	0.354	14.452	54.266	0.344
TDWR + NEXRAD + LIDAR SAFETY	N/A	28.494	N/A	N/A	N/A	0.145	3.969	0.449	N/A	N/A	N/A	0.078	12.716	50.938	N/A
DELAY	N/A	9.432	N/A	N/A	N/A	0.052	11.577	0.347	N/A	N/A	N/A	0.114	1.852	3.594	N/A
TOTAL	N/A	37.926	N/A	N/A	N/A	0.197	15.546	0.796	N/A	N/A	N/A	0.192	14.568	54.532	N/A
WSP + NEXRAD + LIDAR SAFETY	N/A	28.794	4.371	1.205	N/A	0.145	2.840	1.277	N/A	N/A	N/A	0.078	12.582	50.189	0.245
DELAY	N/A	11.353	2.285	0.532	N/A	0.052	9.587	0.347	N/A	N/A	N/A	0.114	1.771	3.206	0.205
TOTAL	N/A	40.147	6.656	1.736	N/A	0.197	12.427	1.624	N/A	N/A	N/A	0.192	14.352	53.396	0.450
TDWR + LLWAS SAFETY	N/A	27.231	N/A	N/A	N/A	0.346	3.981	0.795	N/A	N/A	N/A	0.087	12.808	51.693	N/A
DELAY	N/A	8.237	N/A	N/A	N/A	0.000	11.494	0.000	N/A	N/A	N/A	0.000	1.844	3.487	N/A
TOTAL	N/A	35.468	N/A	N/A	N/A	0.346	15.475	0.795	N/A	N/A	N/A	0.087	14.652	55.179	N/A
WSP + LLWAS SAFETY	N/A	25.167	4.147	1.159	N/A	0.346	2.215	1.280	N/A	N/A	N/A	0.087	12.478	50.473	0.236
DELAY	N/A	8.569	1.660	0.420	N/A	0.000	4.748	0.224	N/A	N/A	N/A	0.000	1.591	2.687	0.193
TOTAL	N/A	33.736	5.807	1.579	N/A	0.346	6.963	1.504	N/A	N/A	N/A	0.087	14.070	53.159	0.429
NEXRAD + LLWAS SAFETY	0.171	15.390	2.341	1.204	0.150	0.385	1.734	0.881	2.194	0.194	0.796	0.099	7.455	43.346	0.124
DELAY	0.144	8.644	1.690	0.523	0.063	0.052	8.154	0.347	0.316	0.081	0.367	0.114	1.368	2.419	0.061
TOTAL	0.315	24.034	4.031	1.728	0.213	0.437	9.888	1.228	2.510	0.275	1.163	0.213	8.823	45.766	0.185
XBAND + LLWAS SAFETY	0.319	24.597	4.446	1.205	0.295	0.761	3.925	1.674	2.144	0.239	0.793	0.190	12.749	51.789	0.233
DELAY	0.188	11.081	2.436	0.538	0.110	0.098	11.564	0.623	0.321	0.097	0.380	0.165	1.853	3.613	0.119
TOTAL	0.507	35.678	6.882	1.743	0.405	0.859	15.489	2.296	2.465	0.336	1.173	0.354	14.602	55.402	0.352
TDWR + NEXRAD SAFETY	N/A	25.143	N/A	N/A	N/A	0.000	3.942	0.000	N/A	N/A	N/A	0.000	12.674	50.713	N/A
DELAY	N/A	8.237	N/A	N/A	N/A	0.000	11.494	0.000	N/A	N/A	N/A	0.000	1.846	3.501	N/A
TOTAL	N/A	33.381	N/A	N/A	N/A	0.000	15.436	0.000	N/A	N/A	N/A	0.000	14.521	54.214	N/A
TDWR + NEXRAD + LLWAS SAFETY	N/A	27.231	N/A	N/A	N/A	0.346	3.981	0.795	N/A	N/A	N/A	0.087	12.813	51.712	N/A
DELAY	N/A	8.237	N/A	N/A	N/A	0.000	11.494	0.000	N/A	N/A	N/A	0.000	1.846	3.501	N/A
TOTAL	N/A	35.468	N/A	N/A	N/A	0.346	15.475	0.795	N/A	N/A	N/A	0.087	14.659	55.213	N/A
WSP + NEXRAD SAFETY	N/A	21.031	3.832	1.194	N/A	0.000	1.148	0.899	N/A	N/A	N/A	0.000	12.238	48.854	0.215
DELAY	N/A	8.569	1.660	0.516	N/A	0.000	4.748	0.224	N/A	N/A	N/A	0.000	1.663	2.775	0.193
TOTAL	N/A	29.600	5.493	1.710	N/A	0.000	5.897	1.122	N/A	N/A	N/A	0.000	13.900	51.630	0.407
WSP + NEXRAD + LLWAS SAFETY	N/A	25.167	4.147	1.209	N/A	0.346	2.215	1.280	N/A	N/A	N/A	0.087	12.529	50.593	0.236
DELAY	N/A	8.569	1.660	0.516	N/A	0.000	4.748	0.224	N/A	N/A	N/A	0.000	1.663	2.775	0.193
TOTAL	N/A	33.736	5.807	1.725	N/A	0.346	6.963	1.504	N/A	N/A	N/A	0.087	14.192	53.368	0.429

Site	MDW	MEM	MGM	MHT	MIA	MKE	MLI	MLU	MOB	MSN	MSP	MSY	MYR	OAK	OKC
Type	TDWR	TDWR	LLWAS	NoWS	TDWR	TDWR	LLWAS	LLWAS	LLWAS	WSP	TDWR	TDWR-LLWAS	NoWS	NoWS	TDWR
RAW SAFETY	34.439	53.627	0.691	2.615	136.686	15.128	0.876	0.476	1.239	1.584	35.687	31.483	1.726	1.638	7.393
PILOT SAFETY	26.815	37.588	0.481	2.180	93.630	11.932	0.661	0.347	0.849	1.277	27.871	21.308	1.281	1.267	5.514
PWS SAFETY	11.314	17.327	0.320	0.985	35.527	5.842	0.406	0.342	0.556	0.759	12.061	8.704	0.566	0.581	2.576
CURRENT SAFETY	10.278	15.707	0.119	0.000	31.542	5.264	0.202	0.166	0.246	0.565	10.919	7.813	0.000	0.000	2.326
DELAY	6.186	1.782	0.001	0.000	4.408	0.960	0.003	0.001	0.001	0.176	4.466	0.516	0.000	0.000	0.518
TOTAL	16.464	17.489	0.119	0.000	35.950	6.224	0.205	0.167	0.247	0.741	15.385	8.330	0.000	0.000	2.844
UPGRADED SAFETY	11.020	16.811	0.119	0.000	33.557	5.643	0.202	0.166	0.246	0.644	11.722	8.407	0.000	0.000	2.494
DELAY	7.207	2.063	0.001	0.000	4.990	1.121	0.003	0.001	0.001	0.199	5.239	0.588	0.000	0.000	0.606
TOTAL	18.228	18.874	0.119	0.000	38.547	6.764	0.205	0.167	0.247	0.843	16.962	8.995	0.000	0.000	3.100
TDWR SAFETY	11.020	16.811	N/A	0.000	33.557	5.643	N/A	N/A	N/A	N/A	11.722	8.316	0.000	0.000	2.494
DELAY	7.207	2.063	N/A	0.000	4.990	1.121	N/A	N/A	N/A	N/A	5.239	0.588	0.000	0.000	0.606
TOTAL	18.228	18.874	N/A	0.000	38.547	6.764	N/A	N/A	N/A	N/A	16.962	8.904	0.000	0.000	3.100
WSP SAFETY	2.768	14.174	N/A	0.405	31.358	4.523	N/A	N/A	N/A	0.644	10.882	7.776	0.000	0.469	2.327
DELAY	2.831	1.366	N/A	0.254	3.047	0.781	N/A	N/A	N/A	0.199	4.376	0.381	0.000	1.928	0.498
TOTAL	5.598	15.540	N/A	0.660	34.405	5.304	N/A	N/A	N/A	0.843	15.258	8.157	0.000	2.397	2.825
NEXRAD SAFETY	10.589	16.540	0.003	0.000	33.413	0.966	0.376	0.000	0.521	0.017	11.435	5.169	0.447	0.000	2.452
DELAY	7.285	2.007	0.005	0.000	4.403	0.491	0.119	0.000	0.085	0.063	5.165	0.327	0.040	0.000	0.578
TOTAL	17.873	18.546	0.008	0.000	37.816	1.456	0.495	0.000	0.607	0.080	16.600	5.496	0.487	0.000	3.029
XBAND SAFETY	10.799	15.935	0.297	0.914	33.500	5.334	0.334	0.316	0.519	0.699	11.519	8.078	0.484	0.515	2.455
DELAY	7.226	2.000	0.048	0.395	4.782	1.109	0.097	0.039	0.095	0.258	5.196	0.573	0.053	2.117	0.607
TOTAL	18.025	17.935	0.345	1.310	38.282	6.443	0.431	0.355	0.614	0.957	16.714	8.651	0.537	2.632	3.061
LIDAR SAFETY	4.485	5.238	0.114	0.445	4.356	2.477	0.151	0.066	0.142	0.238	3.710	1.591	0.150	0.238	0.710
DELAY	4.932	1.392	0.033	0.306	2.737	0.808	0.070	0.027	0.059	0.167	3.328	0.338	0.041	1.688	0.386
TOTAL	9.417	6.630	0.147	0.751	7.093	3.284	0.221	0.093	0.201	0.405	7.038	1.930	0.191	1.926	1.096
LLWAS SAFETY	4.985	7.634	0.119	0.434	15.653	2.574	0.202	0.166	0.246	0.334	5.314	2.406	0.250	0.256	1.135
DELAY	0.107	0.031	0.001	0.007	0.082	0.017	0.003	0.001	0.001	0.004	0.078	0.012	0.001	0.046	0.009
TOTAL	5.093	7.666	0.119	0.441	15.735	2.591	0.205	0.167	0.247	0.338	5.391	2.418	0.251	0.302	1.144
TDWR + LIDAR SAFETY	11.046	16.873	N/A	0.445	33.948	5.698	N/A	N/A	N/A	N/A	11.781	8.381	0.150	0.238	2.511
DELAY	7.267	2.118	N/A	0.306	5.354	1.132	N/A	N/A	N/A	N/A	5.254	0.614	0.041	1.688	0.621
TOTAL	18.313	18.991	N/A	0.751	39.303	6.830	N/A	N/A	N/A	N/A	17.035	8.995	0.191	1.926	3.131
WSP + LIDAR SAFETY	6.929	15.960	N/A	0.805	32.660	5.589	N/A	N/A	N/A	0.723	11.620	8.172	0.150	0.542	2.479
DELAY	5.896	1.943	N/A	0.420	4.494	1.050	N/A	N/A	N/A	0.244	4.898	0.522	0.041	2.542	0.578
TOTAL	12.824	17.904	N/A	1.225	37.154	6.638	N/A	N/A	N/A	0.967	16.517	8.695	0.191	3.084	3.057
NEXRAD + LIDAR SAFETY	11.052	16.815	0.115	0.445	33.952	3.249	0.389	0.066	0.535	0.246	11.748	5.884	0.519	0.238	2.502
DELAY	7.286	2.108	0.036	0.306	5.155	0.950	0.120	0.027	0.097	0.199	5.227	0.480	0.056	1.688	0.614

Site	MDW	MEM	MGM	MHT	MIA	MKE	MLI	MLU	MOB	MSN	MSP	MSY	MYR	OAK	OKC
Type	TDWR	TDWR	LLWAS	NoWS	TDWR	TDWR	LLWAS	LLWAS	LLWAS	WSP	TDWR	TDWR-LLWAS	NoWS	NoWS	TDWR
TOTAL	18.339	18.923	0.152	0.751	39.108	4.199	0.509	0.093	0.632	0.445	16.975	6.364	0.575	1.926	3.116
XBAND + LIDAR SAFETY	10.930	16.540	0.308	0.943	34.037	5.654	0.368	0.327	0.533	0.725	11.671	8.323	0.537	0.548	2.488
DELAY	7.280	2.122	0.050	0.441	5.337	1.134	0.114	0.047	0.101	0.265	5.255	0.617	0.065	2.361	0.622
TOTAL	18.210	18.661	0.358	1.384	39.374	6.788	0.482	0.373	0.633	0.990	16.926	8.940	0.602	2.909	3.110
TDWR + NEXRAD + LIDAR SAFETY	11.053	16.914	N/A	0.445	34.580	5.702	N/A	N/A	N/A	N/A	11.782	8.461	0.519	0.238	2.512
DELAY	7.287	2.130	N/A	0.306	5.473	1.134	N/A	N/A	N/A	N/A	5.260	0.619	0.056	1.688	0.622
TOTAL	18.340	19.043	N/A	0.751	40.053	6.835	N/A	N/A	N/A	N/A	17.042	9.080	0.575	1.926	3.135
WSP + NEXRAD + LIDAR SAFETY	11.052	16.902	N/A	0.805	34.488	5.607	N/A	N/A	N/A	0.724	11.773	8.377	0.519	0.542	2.513
DELAY	7.287	2.122	N/A	0.420	5.342	1.074	N/A	N/A	N/A	0.250	5.251	0.573	0.056	2.542	0.621
TOTAL	18.339	19.024	N/A	1.225	39.831	6.681	N/A	N/A	N/A	0.975	17.024	8.949	0.575	3.084	3.135
TDWR + LLWAS SAFETY	11.131	16.995	N/A	0.434	34.273	5.722	N/A	N/A	N/A	N/A	11.856	8.407	0.250	0.256	2.525
DELAY	7.207	2.063	N/A	0.000	4.990	1.121	N/A	N/A	N/A	N/A	5.239	0.588	0.000	0.000	0.606
TOTAL	18.339	19.058	N/A	0.434	39.263	6.843	N/A	N/A	N/A	N/A	17.095	8.995	0.250	0.256	3.131
WSP + LLWAS SAFETY	6.606	15.387	N/A	0.665	32.570	5.070	N/A	N/A	N/A	0.689	11.336	7.950	0.250	0.512	2.419
DELAY	2.831	1.366	N/A	0.254	3.047	0.781	N/A	N/A	N/A	0.199	4.376	0.381	0.000	1.928	0.498
TOTAL	9.436	16.753	N/A	0.919	35.617	5.851	N/A	N/A	N/A	0.888	15.712	8.331	0.250	2.440	2.916
NEXRAD + LLWAS SAFETY	10.917	16.914	0.163	0.492	34.483	3.411	0.388	0.168	0.539	0.388	11.715	6.331	0.505	0.286	2.512
DELAY	7.286	2.108	0.036	0.306	5.155	0.950	0.120	0.027	0.097	0.199	5.227	0.480	0.056	1.688	0.614
TOTAL	18.203	19.023	0.199	0.799	39.638	4.361	0.508	0.195	0.636	0.587	16.943	6.812	0.561	1.974	3.126
XBAND + LLWAS SAFETY	11.028	16.619	0.308	0.946	34.520	5.574	0.368	0.329	0.537	0.727	11.760	8.295	0.526	0.541	2.511
DELAY	7.280	2.122	0.050	0.441	5.337	1.134	0.114	0.047	0.101	0.265	5.255	0.617	0.065	2.361	0.622
TOTAL	18.308	18.741	0.359	1.387	39.856	6.708	0.482	0.376	0.638	0.993	17.015	8.913	0.591	2.902	3.132
TDWR + NEXRAD SAFETY	11.038	16.890	N/A	0.000	34.463	5.649	N/A	N/A	N/A	N/A	11.726	8.421	0.447	0.000	2.503
DELAY	7.287	2.115	N/A	0.000	5.302	1.130	N/A	N/A	N/A	N/A	5.258	0.608	0.040	0.000	0.614
TOTAL	18.325	19.005	N/A	0.000	39.765	6.780	N/A	N/A	N/A	N/A	16.985	9.029	0.487	0.000	3.116
TDWR + NEXRAD + LLWAS SAFETY	11.146	17.055	N/A	0.434	34.828	5.728	N/A	N/A	N/A	N/A	11.860	8.488	0.493	0.256	2.530
DELAY	7.287	2.115	N/A	0.000	5.302	1.130	N/A	N/A	N/A	N/A	5.258	0.608	0.040	0.000	0.614
TOTAL	18.433	19.170	N/A	0.434	40.129	6.859	N/A	N/A	N/A	N/A	17.118	9.096	0.533	0.256	3.144
WSP + NEXRAD SAFETY	10.589	16.714	N/A	0.405	34.140	4.595	N/A	N/A	N/A	0.647	11.513	8.145	0.447	0.469	2.485
DELAY	7.286	2.075	N/A	0.254	4.851	0.916	N/A	N/A	N/A	0.211	5.227	0.505	0.040	1.928	0.610
TOTAL	17.874	18.789	N/A	0.660	38.991	5.512	N/A	N/A	N/A	0.858	16.741	8.650	0.487	2.397	3.095
WSP + NEXRAD + LLWAS SAFETY	10.917	16.949	N/A	0.665	34.530	5.139	N/A	N/A	N/A	0.692	11.749	8.255	0.493	0.512	2.521
DELAY	7.286	2.075	N/A	0.254	4.851	0.916	N/A	N/A	N/A	0.211	5.227	0.505	0.040	1.928	0.610
TOTAL	18.202	19.024	N/A	0.919	39.381	6.056	N/A	N/A	N/A	0.904	16.976	8.761	0.533	2.440	3.131

Site	OMA	ONT	ORD	ORF	ORL	PBI	PDK	PDX	PHF	PHL	PHX	PIA	PIE	PIT	PNS	PVD
Type	LLWAS	WSP	TDWR-LLWAS	WSP	NoWS	TDWR	NoWS	WSP	NoWS	TDWR	TDWR	LLWAS	NoWS	TDWR	LLWAS	LLWAS
RAW SAFETY	6.235	5.434	200.647	3.767	1.308	23.502	1.289	6.466	1.179	28.414	49.283	0.703	5.398	8.826	3.791	2.728
PILOT SAFETY	4.891	3.715	157.589	2.864	0.929	16.216	0.947	5.161	0.914	22.501	35.202	0.545	3.693	6.780	2.582	2.207
PWS SAFETY	2.459	1.702	68.858	1.232	0.929	6.814	0.946	2.314	0.526	9.860	13.776	0.334	2.139	3.193	1.413	0.988
CURRENT SAFETY	1.038	1.359	61.708	0.791	0.000	6.022	0.000	1.831	0.000	8.521	11.681	0.146	0.000	2.881	0.584	0.474
DELAY	0.007	0.540	12.229	0.307	0.000	1.065	0.000	0.848	0.000	5.369	2.458	0.001	0.000	0.493	0.005	0.015
TOTAL	1.045	1.899	73.936	1.098	0.000	7.086	0.000	2.679	0.000	13.890	14.139	0.147	0.000	3.374	0.588	0.490
UPGRADED SAFETY	1.038	1.492	67.774	0.983	0.000	6.408	0.000	2.055	0.000	9.123	12.449	0.146	0.000	3.093	0.584	0.474
DELAY	0.007	0.622	14.084	0.605	0.000	1.215	0.000	0.925	0.000	6.207	2.907	0.001	0.000	0.579	0.005	0.015
TOTAL	1.045	2.115	81.857	1.589	0.000	7.623	0.000	2.980	0.000	15.330	15.356	0.147	0.000	3.671	0.588	0.490
TDWR SAFETY	N/A	N/A	66.057	N/A	0.880	6.408	0.921	N/A	0.000	9.123	12.449	N/A	2.049	3.093	N/A	N/A
DELAY	N/A	N/A	14.084	N/A	0.285	1.215	0.394	N/A	0.000	6.207	2.907	N/A	0.452	0.579	N/A	N/A
TOTAL	N/A	N/A	80.141	N/A	1.165	7.623	1.315	N/A	0.000	15.330	15.356	N/A	2.502	3.671	N/A	N/A
WSP SAFETY	N/A	1.492	55.470	0.983	0.420	0.000	0.044	2.055	0.002	7.442	11.800	N/A	1.016	2.705	N/A	N/A
DELAY	N/A	0.622	10.105	0.605	0.115	0.000	0.040	0.925	0.006	4.074	2.858	N/A	0.219	0.476	N/A	N/A
TOTAL	N/A	2.115	65.575	1.589	0.534	0.000	0.084	2.980	0.008	11.516	14.658	N/A	1.235	3.181	N/A	N/A
NEXRAD SAFETY	2.200	0.000	51.765	0.005	0.001	0.000	0.709	0.000	0.444	0.052	12.996	0.082	2.080	3.097	0.000	0.888
DELAY	0.505	0.000	14.383	0.049	0.002	0.000	0.229	0.000	0.424	0.380	4.474	0.030	0.485	0.572	0.000	0.960
TOTAL	2.705	0.000	66.148	0.055	0.003	0.000	0.938	0.000	0.868	0.432	17.470	0.112	2.565	3.669	0.000	1.848
XBAND SAFETY	2.242	1.551	63.084	1.086	0.852	6.463	0.889	1.749	0.452	8.741	12.526	0.304	2.019	0.630	1.319	0.939
DELAY	0.365	0.683	13.578	0.948	0.260	1.159	0.377	0.433	0.449	5.741	3.162	0.071	0.426	0.166	0.307	0.954
TOTAL	2.608	2.234	76.662	2.034	1.112	7.622	1.266	2.181	0.900	14.482	15.688	0.375	2.445	0.796	1.626	1.894
LIDAR SAFETY	0.816	0.601	27.578	0.404	0.168	0.988	0.204	0.573	0.167	3.800	3.016	0.132	0.372	1.144	0.292	0.435
DELAY	0.247	0.492	10.450	0.682	0.154	0.649	0.224	0.348	0.324	4.677	2.138	0.050	0.257	0.128	0.170	0.683
TOTAL	1.063	1.093	38.028	1.086	0.322	1.638	0.428	0.920	0.491	8.477	5.153	0.182	0.629	1.272	0.462	1.118
LLWAS SAFETY	1.038	0.750	47.693	0.543	0.409	3.002	0.417	1.020	0.232	4.344	6.070	0.146	0.943	1.407	0.584	0.474
DELAY	0.007	0.015	1.303	0.016	0.004	0.019	0.006	0.019	0.008	0.101	0.070	0.001	0.007	0.009	0.005	0.015
TOTAL	1.045	0.765	48.996	0.559	0.414	3.021	0.423	1.038	0.240	4.445	6.140	0.147	0.950	1.415	0.588	0.490
TDWR + LIDAR SAFETY	N/A	N/A	66.991	N/A	0.892	6.517	0.923	N/A	0.167	9.514	12.879	N/A	2.070	3.116	N/A	N/A
DELAY	N/A	N/A	14.423	N/A	0.294	1.270	0.400	N/A	0.324	6.713	3.648	N/A	0.475	0.579	N/A	N/A
TOTAL	N/A	N/A	81.414	N/A	1.186	7.787	1.322	N/A	0.491	16.227	16.527	N/A	2.545	3.695	N/A	N/A
WSP + LIDAR SAFETY	N/A	1.617	64.974	1.157	0.568	0.988	0.245	2.171	0.168	9.258	12.650	N/A	1.333	3.013	N/A	N/A
DELAY	N/A	0.802	13.468	0.923	0.212	0.649	0.256	1.011	0.331	6.170	3.813	N/A	0.357	0.492	N/A	N/A
TOTAL	N/A	2.420	78.442	2.080	0.779	1.638	0.501	3.182	0.499	15.428	16.463	N/A	1.690	3.505	N/A	N/A
NEXRAD + LIDAR SAFETY	2.383	0.601	62.781	0.409	0.169	0.988	0.808	0.573	0.506	3.840	13.380	0.202	2.089	3.107	0.292	0.961
DELAY	0.505	0.492	14.514	0.732	0.156	0.649	0.319	0.348	0.463	4.972	4.680	0.062	0.486	0.574	0.170	0.963

Site	OMA	ONT	ORD	ORF	ORL	PBI	PDK	PDX	PHF	PHL	PHX	PIA	PIE	PIT	PNS	PVD
Type	LLWAS	WSP	TDWR-LLWAS	WSP	NoWS	TDWR	NoWS	WSP	NoWS	TDWR	TDWR	LLWAS	NoWS	TDWR	LLWAS	LLWAS
TOTAL	2.888	1.093	77.295	1.141	0.325	1.638	1.127	0.920	0.969	8.812	18.060	0.264	2.575	3.681	0.462	1.925
XBAND + LIDAR SAFETY	2.291	1.609	66.293	1.179	0.886	6.562	0.911	1.873	0.504	9.481	12.923	0.322	2.058	1.526	1.334	0.956
DELAY	0.377	0.806	14.400	1.075	0.289	1.263	0.401	0.621	0.513	6.642	3.855	0.075	0.469	0.254	0.309	0.963
TOTAL	2.668	2.416	80.693	2.254	1.175	7.825	1.312	2.494	1.017	16.123	16.778	0.397	2.527	1.780	1.643	1.919
TDWR + NEXRAD + LIDAR SAFETY	N/A	N/A	67.231	N/A	0.892	6.517	0.924	N/A	0.506	9.517	13.437	N/A	2.089	3.118	N/A	N/A
DELAY	N/A	N/A	14.514	N/A	0.294	1.270	0.404	N/A	0.463	6.738	4.716	N/A	0.488	0.580	N/A	N/A
TOTAL	N/A	N/A	81.745	N/A	1.186	7.787	1.328	N/A	0.969	16.256	18.153	N/A	2.577	3.698	N/A	N/A
WSP + NEXRAD + LIDAR SAFETY	N/A	1.617	66.109	1.159	0.568	0.988	0.808	2.171	0.507	9.283	13.436	N/A	2.089	3.115	N/A	N/A
DELAY	N/A	0.802	14.514	0.943	0.212	0.649	0.320	1.011	0.468	6.354	4.725	N/A	0.487	0.577	N/A	N/A
TOTAL	N/A	2.420	80.623	2.102	0.779	1.638	1.128	3.182	0.975	15.637	18.161	N/A	2.577	3.692	N/A	N/A
TDWR + LLWAS SAFETY	N/A	N/A	67.774	N/A	0.900	6.572	0.929	N/A	0.232	9.417	12.814	N/A	2.081	3.134	N/A	N/A
DELAY	N/A	N/A	14.084	N/A	0.285	1.215	0.394	N/A	0.000	6.207	2.907	N/A	0.452	0.579	N/A	N/A
TOTAL	N/A	N/A	81.857	N/A	1.185	7.787	1.324	N/A	0.232	15.624	15.721	N/A	2.533	3.712	N/A	N/A
WSP + LLWAS SAFETY	N/A	1.562	63.874	1.077	0.640	3.005	0.444	2.147	0.234	8.417	12.477	N/A	1.506	2.909	N/A	N/A
DELAY	N/A	0.622	10.105	0.605	0.115	0.000	0.040	0.925	0.006	4.074	2.858	N/A	0.219	0.476	N/A	N/A
TOTAL	N/A	2.184	73.979	1.682	0.755	3.005	0.484	3.072	0.240	12.491	15.335	N/A	1.725	3.386	N/A	N/A
NEXRAD + LLWAS SAFETY	2.312	0.831	64.510	0.621	0.456	3.331	0.824	1.081	0.482	5.029	13.360	0.209	2.103	3.135	0.687	0.935
DELAY	0.505	0.492	14.514	0.732	0.156	0.649	0.319	0.348	0.463	4.972	4.680	0.062	0.486	0.574	0.170	0.963
TOTAL	2.817	1.323	79.024	1.353	0.612	3.980	1.143	1.428	0.945	10.001	18.040	0.271	2.590	3.709	0.857	1.898
XBAND + LLWAS SAFETY	2.309	1.617	67.260	1.160	0.891	6.638	0.917	1.982	0.489	9.315	13.077	0.318	2.078	1.818	1.353	0.961
DELAY	0.377	0.806	14.400	1.075	0.289	1.263	0.401	0.621	0.513	6.642	3.855	0.075	0.469	0.254	0.309	0.963
TOTAL	2.686	2.423	81.659	2.235	1.180	7.901	1.318	2.602	1.002	15.957	16.932	0.393	2.547	2.072	1.662	1.924
TDWR + NEXRAD SAFETY	N/A	N/A	66.501	N/A	0.880	6.408	0.923	N/A	0.444	9.126	13.294	N/A	2.088	3.116	N/A	N/A
DELAY	N/A	N/A	14.504	N/A	0.285	1.215	0.403	N/A	0.424	6.234	4.610	N/A	0.487	0.580	N/A	N/A
TOTAL	N/A	N/A	81.004	N/A	1.165	7.623	1.326	N/A	0.868	15.360	17.904	N/A	2.575	3.696	N/A	N/A
TDWR + NEXRAD + LLWAS SAFETY	N/A	N/A	68.025	N/A	0.900	6.572	0.931	N/A	0.479	9.421	13.474	N/A	2.107	3.146	N/A	N/A
DELAY	N/A	N/A	14.504	N/A	0.285	1.215	0.403	N/A	0.424	6.234	4.610	N/A	0.487	0.580	N/A	N/A
TOTAL	N/A	N/A	82.529	N/A	1.185	7.787	1.334	N/A	0.903	15.655	18.084	N/A	2.595	3.725	N/A	N/A
WSP + NEXRAD SAFETY	N/A	1.492	59.123	0.986	0.420	0.000	0.709	2.055	0.444	7.475	13.137	N/A	2.080	3.109	N/A	N/A
DELAY	N/A	0.622	14.386	0.631	0.115	0.000	0.229	0.925	0.425	4.317	4.640	N/A	0.486	0.577	N/A	N/A
TOTAL	N/A	2.115	73.509	1.618	0.534	0.000	0.938	2.980	0.870	11.792	17.777	N/A	2.566	3.685	N/A	N/A
WSP + NEXRAD + LLWAS SAFETY	N/A	1.562	66.218	1.079	0.640	3.005	0.804	2.147	0.479	8.450	13.398	N/A	2.103	3.141	N/A	N/A
DELAY	N/A	0.622	14.386	0.631	0.115	0.000	0.229	0.925	0.425	4.317	4.640	N/A	0.486	0.577	N/A	N/A
TOTAL	N/A	2.184	80.604	1.711	0.755	3.005	1.033	3.072	0.904	12.767	18.037	N/A	2.589	3.718	N/A	N/A

Site	PWM	RDU	RIC	RNO	ROA	ROC	RST	RSW	SAN	SAT	SAV	SBN	SDF	SEA	SFB	SFO
Type	NoWS	TDWR	WSP	NoWS	LLWAS	WSP	LLWAS	LLWAS	NoWS	WSP	LLWAS	NoWS	TDWR	WSP	NoWS	LLWAS
RAW SAFETY	0.887	11.988	3.462	12.557	0.643	2.799	0.314	15.701	4.581	12.835	3.965	0.927	14.640	5.868	6.983	1.889
PILOT SAFETY	0.733	8.883	2.650	8.561	0.477	2.253	0.250	11.889	3.005	9.258	2.875	0.748	11.379	4.711	4.949	1.441
PWS SAFETY	0.402	4.243	1.413	4.142	0.356	1.136	0.169	4.412	1.308	3.918	1.434	0.508	5.016	2.095	2.999	0.672
CURRENT SAFETY	0.000	3.829	0.927	0.000	0.170	1.024	0.066	1.922	0.000	3.448	0.662	0.000	4.539	1.585	0.000	0.332
DELAY	0.000	0.726	0.164	0.000	0.003	0.365	0.002	0.012	0.000	0.978	0.004	0.000	1.078	2.669	0.000	0.066
TOTAL	0.000	4.555	1.091	0.000	0.173	1.389	0.068	1.933	0.000	4.425	0.666	0.000	5.616	4.253	0.000	0.398
UPGRADED SAFETY	0.000	4.107	1.129	0.000	0.170	1.040	0.066	1.922	0.000	3.534	0.662	0.000	4.858	1.791	0.000	0.332
DELAY	0.000	0.843	0.229	0.000	0.003	0.370	0.002	0.012	0.000	1.019	0.004	0.000	1.254	2.971	0.000	0.066
TOTAL	0.000	4.950	1.358	0.000	0.173	1.410	0.068	1.933	0.000	4.552	0.666	0.000	6.112	4.762	0.000	0.398
TDWR SAFETY	0.000	4.107	N/A	0.000	N/A	N/A	N/A	N/A	0.000	N/A	N/A	0.000	4.858	N/A	2.882	N/A
DELAY	0.000	0.843	N/A	0.000	N/A	N/A	N/A	N/A	0.000	N/A	N/A	0.000	1.254	N/A	0.678	N/A
TOTAL	0.000	4.950	N/A	0.000	N/A	N/A	N/A	N/A	0.000	N/A	N/A	0.000	6.112	N/A	3.560	N/A
WSP SAFETY	0.012	3.588	1.129	0.000	N/A	1.040	N/A	N/A	0.160	3.534	N/A	0.000	3.981	1.791	0.001	N/A
DELAY	0.063	0.598	0.229	0.000	N/A	0.370	N/A	N/A	0.580	1.019	N/A	0.000	0.811	2.971	0.002	N/A
TOTAL	0.075	4.186	1.358	0.000	N/A	1.410	N/A	N/A	0.741	4.552	N/A	0.000	4.792	4.762	0.003	N/A
NEXRAD SAFETY	0.272	3.834	0.598	0.000	0.000	0.000	0.000	0.000	0.000	3.516	0.257	0.007	4.749	0.000	0.000	0.000
DELAY	0.223	0.780	0.176	0.000	0.000	0.000	0.000	0.000	0.000	1.235	0.099	0.017	1.208	0.000	0.000	0.000
TOTAL	0.495	4.614	0.774	0.000	0.000	0.000	0.000	0.000	0.000	4.751	0.356	0.024	5.957	0.000	0.000	0.000
XBAND SAFETY	0.383	3.680	1.221	2.496	0.270	1.085	0.161	4.194	1.122	3.750	1.272	0.470	4.401	1.944	2.821	0.508
DELAY	0.222	0.807	0.319	0.380	0.063	0.431	0.158	1.705	1.154	1.236	0.193	0.105	1.050	3.456	0.626	1.995
TOTAL	0.605	4.487	1.540	2.877	0.333	1.517	0.319	5.899	2.276	4.986	1.465	0.575	5.452	5.400	3.447	2.503
LIDAR SAFETY	0.198	1.196	0.465	2.531	0.093	0.385	0.055	0.695	0.373	1.239	0.273	0.200	1.646	0.854	0.470	0.270
DELAY	0.166	0.523	0.248	0.464	0.054	0.280	0.101	0.870	0.771	0.774	0.138	0.077	0.790	2.455	0.401	1.614
TOTAL	0.364	1.719	0.713	2.995	0.147	0.665	0.156	1.565	1.144	2.013	0.411	0.277	2.436	3.309	0.870	1.885
LLWAS SAFETY	0.177	1.869	0.623	1.825	0.170	0.500	0.066	1.922	0.576	1.726	0.662	0.224	2.210	0.923	1.321	0.332
DELAY	0.003	0.013	0.006	0.033	0.003	0.006	0.002	0.012	0.031	0.018	0.004	0.002	0.019	0.058	0.012	0.066
TOTAL	0.180	1.882	0.628	1.858	0.173	0.507	0.068	1.933	0.607	1.745	0.666	0.225	2.229	0.981	1.333	0.398
TDWR + LIDAR SAFETY	0.198	4.133	N/A	2.531	N/A	N/A	N/A	N/A	0.373	N/A	N/A	0.200	4.887	N/A	2.897	N/A
DELAY	0.166	0.863	N/A	0.464	N/A	N/A	N/A	N/A	0.771	N/A	N/A	0.077	1.279	N/A	0.692	N/A
TOTAL	0.364	4.996	N/A	2.995	N/A	N/A	N/A	N/A	1.144	N/A	N/A	0.277	6.167	N/A	3.589	N/A
WSP + LIDAR SAFETY	0.201	4.040	1.331	2.531	N/A	1.098	N/A	N/A	0.537	3.776	N/A	0.200	4.705	1.995	0.470	N/A
DELAY	0.186	0.776	0.332	0.464	N/A	0.405	N/A	N/A	1.505	1.152	N/A	0.077	1.138	3.535	0.402	N/A
TOTAL	0.387	4.816	1.662	2.995	N/A	1.503	N/A	N/A	2.042	4.928	N/A	0.277	5.843	5.530	0.871	N/A
NEXRAD + LIDAR SAFETY	0.386	4.023	0.962	2.531	0.093	0.385	0.055	0.695	0.373	3.824	0.501	0.204	4.889	0.854	0.470	0.270
DELAY	0.223	0.840	0.313	0.464	0.054	0.280	0.101	0.870	0.771	1.250	0.187	0.086	1.265	2.455	0.401	1.614

Site	PWM	RDU	RIC	RNO	ROA	ROC	RST	RSW	SAN	SAT	SAV	SBN	SDF	SEA	SFB	SFO
Type	NoWS	TDWR	WSP	NoWS	LLWAS	WSP	LLWAS	LLWAS	NoWS	WSP	LLWAS	NoWS	TDWR	WSP	NoWS	LLWAS
TOTAL	0.609	4.863	1.275	2.995	0.147	0.665	0.156	1.565	1.144	5.075	0.688	0.290	6.154	3.309	0.870	1.885
XBAND + LIDAR SAFETY	0.389	4.002	1.352	3.463	0.291	1.099	0.163	4.224	1.187	3.792	1.361	0.491	4.782	2.011	2.879	0.573
DELAY	0.223	0.866	0.372	0.592	0.097	0.433	0.160	1.727	1.324	1.248	0.237	0.112	1.220	3.722	0.728	2.634
TOTAL	0.613	4.868	1.724	4.055	0.388	1.532	0.323	5.951	2.510	5.041	1.599	0.603	6.002	5.733	3.607	3.207
TDWR + NEXRAD + LIDAR SAFETY	0.386	4.141	N/A	2.531	N/A	N/A	N/A	N/A	0.373	N/A	N/A	0.204	4.900	N/A	2.897	N/A
DELAY	0.223	0.872	N/A	0.464	N/A	N/A	N/A	N/A	0.771	N/A	N/A	0.086	1.288	N/A	0.692	N/A
TOTAL	0.609	5.013	N/A	2.995	N/A	N/A	N/A	N/A	1.144	N/A	N/A	0.290	6.188	N/A	3.589	N/A
WSP + NEXRAD + LIDAR SAFETY	0.386	4.131	1.357	2.531	N/A	1.098	N/A	N/A	0.537	3.827	N/A	0.204	4.893	1.995	0.470	N/A
DELAY	0.223	0.862	0.358	0.464	N/A	0.405	N/A	N/A	1.505	1.251	N/A	0.086	1.275	3.535	0.402	N/A
TOTAL	0.609	4.993	1.715	2.995	N/A	1.503	N/A	N/A	2.042	5.078	N/A	0.290	6.168	5.530	0.871	N/A
TDWR + LLWAS SAFETY	0.177	4.156	N/A	1.827	N/A	N/A	N/A	N/A	0.577	N/A	N/A	0.224	4.917	N/A	2.913	N/A
DELAY	0.000	0.843	N/A	0.000	N/A	N/A	N/A	N/A	0.000	N/A	N/A	0.000	1.254	N/A	0.678	N/A
TOTAL	0.177	4.999	N/A	1.827	N/A	N/A	N/A	N/A	0.577	N/A	N/A	0.224	6.171	N/A	3.591	N/A
WSP + LLWAS SAFETY	0.189	3.836	1.238	1.827	N/A	1.076	N/A	N/A	0.676	3.678	N/A	0.224	4.389	1.911	1.324	N/A
DELAY	0.063	0.598	0.229	0.000	N/A	0.370	N/A	N/A	0.580	1.019	N/A	0.000	0.811	2.971	0.002	N/A
TOTAL	0.251	4.434	1.467	1.827	N/A	1.447	N/A	N/A	1.256	4.697	N/A	0.224	5.200	4.882	1.325	N/A
NEXRAD + LLWAS SAFETY	0.335	4.030	1.005	1.909	0.168	0.570	0.085	2.157	0.623	3.706	0.835	0.260	4.874	1.048	1.468	0.323
DELAY	0.223	0.840	0.313	0.464	0.054	0.280	0.101	0.870	0.771	1.250	0.187	0.086	1.265	2.455	0.401	1.614
TOTAL	0.558	4.870	1.318	2.372	0.222	0.850	0.186	3.027	1.394	4.956	1.022	0.346	6.139	3.504	1.869	1.937
XBAND + LLWAS SAFETY	0.391	3.957	1.318	3.170	0.308	1.107	0.165	4.292	1.193	3.824	1.354	0.488	4.710	2.015	2.910	0.582
DELAY	0.223	0.866	0.372	0.592	0.097	0.433	0.160	1.727	1.324	1.248	0.237	0.112	1.220	3.722	0.728	2.634
TOTAL	0.615	4.823	1.690	3.762	0.405	1.541	0.325	6.020	2.516	5.073	1.592	0.600	5.930	5.737	3.638	3.215
TDWR + NEXRAD SAFETY	0.272	4.125	N/A	0.000	N/A	N/A	N/A	N/A	0.000	N/A	N/A	0.007	4.882	N/A	2.882	N/A
DELAY	0.223	0.866	N/A	0.000	N/A	N/A	N/A	N/A	0.000	N/A	N/A	0.017	1.281	N/A	0.678	N/A
TOTAL	0.495	4.991	N/A	0.000	N/A	N/A	N/A	N/A	0.000	N/A	N/A	0.024	6.163	N/A	3.560	N/A
TDWR + NEXRAD + LLWAS SAFETY	0.335	4.171	N/A	1.827	N/A	N/A	N/A	N/A	0.577	N/A	N/A	0.231	4.934	N/A	2.913	N/A
DELAY	0.223	0.866	N/A	0.000	N/A	N/A	N/A	N/A	0.000	N/A	N/A	0.017	1.281	N/A	0.678	N/A
TOTAL	0.557	5.037	N/A	1.827	N/A	N/A	N/A	N/A	0.577	N/A	N/A	0.248	6.215	N/A	3.591	N/A
WSP + NEXRAD SAFETY	0.272	3.995	1.179	0.000	N/A	1.040	N/A	N/A	0.160	3.644	N/A	0.007	4.768	1.791	0.001	N/A
DELAY	0.223	0.835	0.297	0.000	N/A	0.370	N/A	N/A	0.580	1.236	N/A	0.017	1.246	2.971	0.002	N/A
TOTAL	0.495	4.830	1.476	0.000	N/A	1.410	N/A	N/A	0.741	4.879	N/A	0.024	6.013	4.762	0.003	N/A
WSP + NEXRAD + LLWAS SAFETY	0.335	4.097	1.275	1.827	N/A	1.076	N/A	N/A	0.676	3.766	N/A	0.231	4.869	1.911	1.324	N/A
DELAY	0.223	0.835	0.297	0.000	N/A	0.370	N/A	N/A	0.580	1.236	N/A	0.017	1.246	2.971	0.002	N/A
TOTAL	0.558	4.933	1.572	1.827	N/A	1.447	N/A	N/A	1.256	5.002	N/A	0.248	6.114	4.882	1.325	N/A

Site	SGF	SHV	SJC	SJU	SLC	SMF	SNA	SPI	SRQ	STL	SUX	SYR	TLH	TOL	TPA	TRI
Type	LLWAS	LLWAS	NoWS	TDWR	TDWR	NoWS	NoWS	LLWAS	WSP	TDWR-LLWAS	LLWAS	WSP	LLWAS	WSP	TDWR-LLWAS	LLWAS
RAW SAFETY	1.344	1.324	0.698	7.293	49.861	2.072	1.329	0.250	5.195	26.554	0.081	1.525	1.695	1.280	92.695	0.643
PILOT SAFETY	1.017	0.941	0.493	4.947	35.591	1.548	0.943	0.193	3.572	19.659	0.064	1.254	1.174	1.016	63.308	0.488
PWS SAFETY	0.673	0.647	0.231	2.148	17.397	0.719	0.453	0.188	1.795	8.767	0.062	0.651	0.817	0.538	24.927	0.325
CURRENT SAFETY	0.258	0.292	0.000	1.924	14.706	0.000	0.000	0.075	1.688	7.920	0.033	0.494	0.367	0.343	22.175	0.143
DELAY	0.002	0.002	0.000	0.478	3.269	0.000	0.000	0.001	0.631	1.230	0.001	0.252	0.001	0.068	0.834	0.001
TOTAL	0.260	0.294	0.000	2.402	17.975	0.000	0.000	0.076	2.318	9.150	0.033	0.746	0.368	0.412	23.009	0.144
UPGRADED SAFETY	0.258	0.292	0.000	2.052	15.711	0.000	0.000	0.075	1.712	8.592	0.033	0.540	0.367	0.417	24.164	0.143
DELAY	0.002	0.002	0.000	0.549	3.788	0.000	0.000	0.001	0.656	1.440	0.001	0.273	0.001	0.096	0.945	0.001
TOTAL	0.260	0.294	0.000	2.602	19.499	0.000	0.000	0.076	2.368	10.032	0.033	0.812	0.368	0.513	25.109	0.144
TDWR SAFETY	N/A	N/A	0.000	2.052	15.711	0.000	0.000	N/A	N/A	8.493	N/A	N/A	N/A	N/A	23.577	N/A
DELAY	N/A	N/A	0.000	0.549	3.788	0.000	0.000	N/A	N/A	1.440	N/A	N/A	N/A	N/A	0.945	N/A
TOTAL	N/A	N/A	0.000	2.602	19.499	0.000	0.000	N/A	N/A	9.933	N/A	N/A	N/A	N/A	24.522	N/A
WSP SAFETY	N/A	N/A	0.122	0.000	12.590	0.153	0.080	N/A	1.712	7.796	N/A	0.540	N/A	0.417	23.597	N/A
DELAY	N/A	N/A	0.657	0.000	3.219	0.400	0.717	N/A	0.656	1.231	N/A	0.273	N/A	0.096	0.885	N/A
TOTAL	N/A	N/A	0.779	0.000	15.809	0.553	0.796	N/A	2.368	9.026	N/A	0.812	N/A	0.513	24.482	N/A
NEXRAD SAFETY	0.643	0.611	0.000	0.000	0.000	0.682	0.000	0.118	1.742	8.386	0.000	0.000	0.732	0.000	24.243	0.000
DELAY	0.119	0.111	0.000	0.000	0.000	1.044	0.000	0.055	0.769	1.441	0.000	0.000	0.065	0.000	1.036	0.000
TOTAL	0.762	0.722	0.000	0.000	0.000	1.725	0.000	0.174	2.511	9.828	0.000	0.000	0.798	0.000	25.278	0.000
XBAND SAFETY	0.638	0.602	0.197	1.975	15.210	0.683	0.385	0.180	1.724	8.363	0.056	0.594	0.730	0.469	24.049	0.242
DELAY	0.132	0.130	0.996	0.480	4.048	1.093	1.729	0.057	0.762	1.445	0.031	0.336	0.083	0.129	1.036	0.036
TOTAL	0.770	0.732	1.193	2.455	19.258	1.776	2.114	0.237	2.486	9.808	0.088	0.930	0.813	0.598	25.085	0.278
LIDAR SAFETY	0.197	0.170	0.106	0.474	8.641	0.282	0.222	0.081	0.386	2.674	0.024	0.274	0.179	0.244	3.966	0.075
DELAY	0.081	0.077	1.038	0.322	3.723	0.778	1.537	0.041	0.421	0.906	0.022	0.249	0.056	0.102	0.547	0.022
TOTAL	0.278	0.247	1.144	0.796	12.364	1.060	1.759	0.122	0.806	3.580	0.047	0.524	0.235	0.346	4.513	0.097
LLWAS SAFETY	0.258	0.292	0.102	0.947	7.665	0.317	0.200	0.075	0.791	3.523	0.033	0.287	0.367	0.237	13.636	0.143
DELAY	0.002	0.002	0.025	0.009	0.082	0.017	0.037	0.001	0.011	0.047	0.001	0.005	0.001	0.002	0.049	0.001
TOTAL	0.260	0.294	0.127	0.956	7.747	0.334	0.237	0.076	0.802	3.570	0.033	0.292	0.368	0.239	13.685	0.144
TDWR + LIDAR SAFETY	N/A	N/A	0.106	2.067	16.632	0.282	0.222	N/A	N/A	8.532	N/A	N/A	N/A	N/A	23.947	N/A
DELAY	N/A	N/A	1.038	0.574	4.999	0.778	1.537	N/A	N/A	1.449	N/A	N/A	N/A	N/A	1.014	N/A
TOTAL	N/A	N/A	1.144	2.640	21.631	1.060	1.759	N/A	N/A	9.981	N/A	N/A	N/A	N/A	24.961	N/A
WSP + LIDAR SAFETY	N/A	N/A	0.186	0.474	16.300	0.416	0.287	N/A	1.730	8.314	N/A	0.627	N/A	0.517	23.869	N/A
DELAY	N/A	N/A	1.038	0.322	4.558	0.913	1.537	N/A	0.702	1.355	N/A	0.334	N/A	0.131	0.952	N/A
TOTAL	N/A	N/A	1.224	0.796	20.858	1.329	1.823	N/A	2.432	9.669	N/A	0.961	N/A	0.648	24.821	N/A
NEXRAD + LIDAR SAFETY	0.652	0.621	0.106	0.474	8.641	0.696	0.222	0.170	1.754	8.545	0.024	0.274	0.769	0.244	24.318	0.075
DELAY	0.130	0.125	1.038	0.322	3.723	1.124	1.537	0.056	0.770	1.448	0.022	0.249	0.088	0.102	1.043	0.022

Site	SGF	SHV	SJC	SJU	SLC	SMF	SNA	SPI	SRQ	STL	SUX	SYR	TLH	TOL	TPA	TRI
Type	LLWAS	LLWAS	NoWS	TDWR	TDWR	NoWS	NoWS	LLWAS	WSP	TDWR-LLWAS	LLWAS	WSP	LLWAS	WSP	TDWR-LLWAS	LLWAS
TOTAL	0.782	0.746	1.144	0.796	12.364	1.820	1.759	0.226	2.524	9.994	0.047	0.524	0.857	0.346	25.361	0.097
XBAND + LIDAR SAFETY	0.650	0.621	0.217	2.031	16.564	0.697	0.432	0.182	1.733	8.463	0.060	0.627	0.781	0.516	24.151	0.263
DELAY	0.134	0.134	1.285	0.558	4.618	1.149	2.200	0.058	0.769	1.452	0.033	0.352	0.097	0.141	1.050	0.048
TOTAL	0.784	0.755	1.502	2.589	21.182	1.846	2.632	0.240	2.502	9.914	0.092	0.979	0.878	0.657	25.200	0.310
TDWR + NEXRAD + LIDAR SAFETY	N/A	N/A	0.106	2.067	16.632	0.696	0.222	N/A	N/A	8.564	N/A	N/A	N/A	N/A	24.337	N/A
DELAY	N/A	N/A	1.038	0.574	4.999	1.124	1.537	N/A	N/A	1.451	N/A	N/A	N/A	N/A	1.050	N/A
TOTAL	N/A	N/A	1.144	2.640	21.631	1.820	1.759	N/A	N/A	10.016	N/A	N/A	N/A	N/A	25.387	N/A
WSP + NEXRAD + LIDAR SAFETY	N/A	N/A	0.186	0.474	16.300	0.697	0.287	N/A	1.754	8.563	N/A	0.627	N/A	0.517	24.338	N/A
DELAY	N/A	N/A	1.038	0.322	4.558	1.137	1.537	N/A	0.770	1.451	N/A	0.334	N/A	0.131	1.049	N/A
TOTAL	N/A	N/A	1.224	0.796	20.858	1.834	1.823	N/A	2.524	10.014	N/A	0.961	N/A	0.648	25.387	N/A
TDWR + LLWAS SAFETY	N/A	N/A	0.102	2.083	16.238	0.317	0.200	N/A	N/A	8.592	N/A	N/A	N/A	N/A	24.164	N/A
DELAY	N/A	N/A	0.000	0.549	3.788	0.000	0.000	N/A	N/A	1.440	N/A	N/A	N/A	N/A	0.945	N/A
TOTAL	N/A	N/A	0.102	2.632	20.026	0.317	0.200	N/A	N/A	10.032	N/A	N/A	N/A	N/A	25.109	N/A
WSP + LLWAS SAFETY	N/A	N/A	0.168	0.947	14.563	0.407	0.246	N/A	1.736	8.148	N/A	0.585	N/A	0.467	24.093	N/A
DELAY	N/A	N/A	0.657	0.000	3.219	0.400	0.717	N/A	0.656	1.231	N/A	0.273	N/A	0.096	0.885	N/A
TOTAL	N/A	N/A	0.825	0.947	17.781	0.807	0.963	N/A	2.392	9.379	N/A	0.858	N/A	0.563	24.978	N/A
NEXRAD + LLWAS SAFETY	0.657	0.628	0.116	1.054	8.782	0.699	0.226	0.152	1.764	8.536	0.031	0.330	0.776	0.274	24.571	0.155
DELAY	0.130	0.125	1.038	0.322	3.723	1.124	1.537	0.056	0.770	1.448	0.022	0.249	0.088	0.102	1.043	0.022
TOTAL	0.787	0.753	1.154	1.376	12.505	1.823	1.763	0.208	2.534	9.984	0.054	0.580	0.865	0.376	25.615	0.177
XBAND + LLWAS SAFETY	0.654	0.623	0.213	2.058	16.190	0.700	0.418	0.184	1.755	8.523	0.059	0.621	0.775	0.503	24.507	0.282
DELAY	0.134	0.134	1.285	0.558	4.618	1.149	2.200	0.058	0.769	1.452	0.033	0.352	0.097	0.141	1.050	0.048
TOTAL	0.787	0.758	1.497	2.617	20.808	1.849	2.619	0.242	2.524	9.975	0.092	0.973	0.873	0.644	25.557	0.330
TDWR + NEXRAD SAFETY	N/A	N/A	0.000	2.052	15.711	0.682	0.000	N/A	N/A	8.553	N/A	N/A	N/A	N/A	24.309	N/A
DELAY	N/A	N/A	0.000	0.549	3.788	1.044	0.000	N/A	N/A	1.450	N/A	N/A	N/A	N/A	1.047	N/A
TOTAL	N/A	N/A	0.000	2.602	19.499	1.725	0.000	N/A	N/A	10.003	N/A	N/A	N/A	N/A	25.356	N/A
TDWR + NEXRAD + LLWAS SAFETY	N/A	N/A	0.102	2.083	16.238	0.695	0.200	N/A	N/A	8.628	N/A	N/A	N/A	N/A	24.594	N/A
DELAY	N/A	N/A	0.000	0.549	3.788	1.044	0.000	N/A	N/A	1.450	N/A	N/A	N/A	N/A	1.047	N/A
TOTAL	N/A	N/A	0.102	2.632	20.026	1.738	0.200	N/A	N/A	10.078	N/A	N/A	N/A	N/A	25.641	N/A
WSP + NEXRAD SAFETY	N/A	N/A	0.122	0.000	12.590	0.684	0.080	N/A	1.749	8.442	N/A	0.540	N/A	0.417	24.304	N/A
DELAY	N/A	N/A	0.657	0.000	3.219	1.081	0.717	N/A	0.769	1.449	N/A	0.273	N/A	0.096	1.046	N/A
TOTAL	N/A	N/A	0.779	0.000	15.809	1.765	0.796	N/A	2.518	9.891	N/A	0.812	N/A	0.513	25.350	N/A
WSP + NEXRAD + LLWAS SAFETY	N/A	N/A	0.168	0.947	14.563	0.697	0.246	N/A	1.767	8.565	N/A	0.585	N/A	0.467	24.591	N/A
DELAY	N/A	N/A	0.657	0.000	3.219	1.081	0.717	N/A	0.769	1.449	N/A	0.273	N/A	0.096	1.046	N/A
TOTAL	N/A	N/A	0.825	0.947	17.781	1.778	0.963	N/A	2.536	10.014	N/A	0.858	N/A	0.563	25.638	N/A

Site	TUL	TUS	TWF	TYS	TOTALS	ANNUAL
Type	TDWR	WSP	NoWS	WSP	2010 to 2032	
RAW SAFETY	6.159	7.918	0.272	1.044	2775.2	263.4
PILOT SAFETY	4.676	5.726	0.212	0.771	2046.4	194.3
PWS SAFETY	2.253	2.771	0.201	0.524	897.3	85.2
CURRENT SAFETY	2.037	2.158	0.000	0.451	751.7	71.4
DELAY	0.389	0.740	0.000	0.112	231.8	22.0
TOTAL	2.426	2.898	0.000	0.563	983.5	93.4
UPGRADED SAFETY	2.182	2.343	0.000	0.477	812.1	77.1
DELAY	0.454	0.886	0.000	0.120	268.5	25.5
TOTAL	2.636	3.230	0.000	0.597	1080.5	102.6
TDWR SAFETY	2.182	N/A	0.000	N/A	737.6	70.0
DELAY	0.454	N/A	0.000	N/A	249.5	23.7
TOTAL	2.636	N/A	0.000	N/A	987.1	93.7
WSP SAFETY	1.964	2.343	0.000	0.477	682.4	64.8
DELAY	0.340	0.886	0.000	0.120	214.7	20.4
TOTAL	2.305	3.230	0.000	0.597	897.0	85.1
NEXRAD SAFETY	2.169	0.000	0.000	0.000	540.4	51.3
DELAY	0.456	0.000	0.000	0.000	133.3	12.7
TOTAL	2.625	0.000	0.000	0.000	673.8	64.0
XBAND SAFETY	2.086	2.608	0.176	0.145	818.4	77.7
DELAY	0.432	1.303	0.169	0.059	293.9	27.9
TOTAL	2.518	3.910	0.345	0.204	1112.2	105.6
LIDAR SAFETY	0.640	0.598	0.156	0.138	282.4	26.8
DELAY	0.285	0.798	0.160	0.075	209.3	19.9
TOTAL	0.925	1.396	0.316	0.213	491.7	46.7
LLWAS SAFETY	0.993	1.221	0.088	0.231	478.3	45.4
DELAY	0.007	0.022	0.003	0.002	9.0	0.9
TOTAL	1.000	1.243	0.092	0.233	487.3	46.3
TDWR + LIDAR SAFETY	2.196	N/A	0.156	N/A	759.4	72.1
DELAY	0.464	N/A	0.160	N/A	270.0	25.6
TOTAL	2.659	N/A	0.316	N/A	1029.4	97.7
WSP + LIDAR SAFETY	2.157	2.497	0.156	0.503	787.5	74.7
DELAY	0.425	1.201	0.160	0.138	278.9	26.5
TOTAL	2.582	3.699	0.316	0.641	1066.4	101.2
NEXRAD + LIDAR SAFETY	2.199	0.598	0.156	0.138	670.0	63.6
DELAY	0.463	0.798	0.160	0.075	260.8	24.8

Site	TUL	TUS	TWF	TYS	TOTALS	ANNUAL
Type	TDWR	WSP	NoWS	WSP	2010 to 2032	
TOTAL	2.662	1.396	0.316	0.213	930.8	88.4
XBAND + LIDAR SAFETY	2.167	2.650	0.194	0.253	853.2	81.0
DELAY	0.464	1.414	0.202	0.111	313.4	29.8
TOTAL	2.630	4.065	0.395	0.364	1166.7	110.7
TDWR + NEXRAD + LIDAR SAFETY	2.201	N/A	0.156	N/A	766.7	72.8
DELAY	0.467	N/A	0.160	N/A	273.5	26.0
TOTAL	2.668	N/A	0.316	N/A	1040.2	98.7
WSP + NEXRAD + LIDAR SAFETY	2.200	2.497	0.156	0.503	817.2	77.6
DELAY	0.465	1.201	0.160	0.138	294.3	27.9
TOTAL	2.665	3.699	0.316	0.641	1111.5	105.5
TDWR + LLWAS SAFETY	2.208	N/A	0.089	N/A	764.1	72.5
DELAY	0.454	N/A	0.000	N/A	249.5	23.7
TOTAL	2.662	N/A	0.089	N/A	1013.6	96.2
WSP + LLWAS SAFETY	2.072	2.494	0.089	0.493	774.4	73.5
DELAY	0.340	0.886	0.000	0.120	214.7	20.4
TOTAL	2.412	3.381	0.089	0.613	989.1	93.9
NEXRAD + LLWAS SAFETY	2.205	1.364	0.103	0.255	740.3	70.3
DELAY	0.463	0.798	0.160	0.075	260.8	24.8
TOTAL	2.668	2.161	0.263	0.330	1001.2	95.0
XBAND + LLWAS SAFETY	2.169	2.685	0.189	0.331	860.6	81.7
DELAY	0.464	1.414	0.202	0.111	313.4	29.8
TOTAL	2.633	4.099	0.390	0.442	1174.0	111.4
TDWR + NEXRAD SAFETY	2.197	N/A	0.000	N/A	749.8	71.2
DELAY	0.466	N/A	0.000	N/A	258.5	24.5
TOTAL	2.664	N/A	0.000	N/A	1008.3	95.7
TDWR + NEXRAD + LLWAS SAFETY	2.219	N/A	0.089	N/A	771.3	73.2
DELAY	0.466	N/A	0.000	N/A	258.5	24.5
TOTAL	2.685	N/A	0.089	N/A	1029.8	97.8
WSP + NEXRAD SAFETY	2.172	2.343	0.000	0.477	758.5	72.0
DELAY	0.462	0.886	0.000	0.120	255.9	24.3
TOTAL	2.634	3.230	0.000	0.597	1014.4	96.3
WSP + NEXRAD + LLWAS SAFETY	2.205	2.494	0.089	0.493	808.7	76.8
DELAY	0.462	0.886	0.000	0.120	255.9	24.3
TOTAL	2.667	3.381	0.089	0.613	1064.6	101.1

This page intentionally left blank.

APPENDIX E

NET PRESENT VALUE BASED ON SAFETY AND DELAY BY SITE AND SYSTEM

(LIFE CYCLE 2010–32 FY08$M)

Wind Shear System	ABE	ABQ	ADW	AGS	ALB	AMA	ASE	ATL	AUS	AVL	AVP	AZO	BDL	BGM	BHM	BIL
	NoWS	WSP	TDWR	LLWAS	WSP	NoWS	NoWS	TDWR&LLWAS	WSP	LLWAS	NoWS	NoWS	WSP	NoWS	WSP	LLWAS
TDWR	N/A	N/A	(2.49)	N/A	N/A	N/A	N/A	95.48	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WSP	N/A	7.34	(4.04)	N/A	0.46	N/A	N/A	83.09	2.62	N/A	N/A	N/A	1.57	N/A	1.47	N/A
NEXRAD	(0.24)	8.29	(0.71)	(0.36)	(0.11)	0.51	(0.24)	98.46	0.55	(0.36)	(0.24)	(0.21)	0.11	(0.16)	2.28	0.90
LIDAR	(2.32)	1.17	(3.14)	(2.74)	(1.88)	(2.37)	(2.50)	43.16	(0.71)	(2.73)	(2.53)	(2.46)	(1.31)	(2.62)	(1.95)	(1.82)
LLWAS	(1.18)	2.79	(1.85)	(0.53)	(0.82)	(1.14)	(1.25)	52.79	0.71	(0.53)	(1.25)	(1.29)	(0.26)	(1.35)	(0.21)	(0.00)
X-Band	(5.72)	2.11	(6.82)	(6.31)	(5.00)	(5.60)	(6.22)	89.36	(1.81)	(6.33)	(6.12)	(6.04)	(3.96)	(6.27)	(5.11)	(5.45)
TDWR & NEXRAD	N/A	N/A	(2.73)	N/A	N/A	N/A	N/A	97.10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDWR, NEXRAD, LLWAS	N/A	N/A	(4.09)	N/A	N/A	N/A	N/A	97.58	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDWR & LIDAR	N/A	N/A	(5.39)	N/A	N/A	N/A	N/A	94.57	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDWR & LLWAS	N/A	N/A	(5.14)	N/A	N/A	N/A	N/A	94.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WSP & NEXRAD	N/A	N/A	(3.85)	N/A	N/A	N/A	N/A	96.37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WSP & LIDAR	N/A	7.75	(4.29)	N/A	0.22	N/A	N/A	95.32	2.54	N/A	N/A	N/A	1.33	N/A	1.50	N/A
WSP & LLWAS	N/A	5.18	(6.70)	N/A	(2.06)	N/A	N/A	88.25	0.65	N/A	N/A	N/A	(0.88)	N/A	(1.06)	N/A
WSP, NEXRAD, LIDAR	N/A	6.16	(5.41)	N/A	(0.85)	N/A	N/A	84.73	1.67	N/A	N/A	N/A	0.29	N/A	0.19	N/A
WSP, NEXRAD, LLWAS	N/A	5.20	(6.94)	N/A	(2.30)	N/A	N/A	93.18	0.51	N/A	N/A	N/A	(1.12)	N/A	(1.12)	N/A
NEXRAD & LIDAR	N/A	6.46	(5.65)	N/A	(1.09)	N/A	N/A	94.92	1.59	N/A	N/A	N/A	0.05	N/A	0.17	N/A
NEXRAD & LLWAS	(2.56)	5.74	(3.37)	(2.98)	(2.12)	(2.13)	(2.74)	96.51	(0.82)	(2.97)	(2.77)	(2.69)	(1.55)	(2.82)	(0.35)	(1.70)
X-Band & LIDAR	(1.23)	7.05	(2.08)	(0.74)	(0.76)	(0.84)	(1.49)	99.22	1.26	(0.75)	(1.45)	(1.40)	(0.08)	(1.53)	0.94	0.48
X-Band & LLLWAS	(8.35)	(0.35)	(9.48)	(8.96)	(7.62)	(8.25)	(8.81)	89.36	(4.37)	(8.97)	(8.74)	(8.69)	(6.50)	(8.93)	(7.53)	(7.89)
TDWR,NEXRAD,LIDAR	(7.05)	0.99	(8.19)	(6.91)	(6.33)	(6.95)	(7.53)	91.47	(3.07)	(6.92)	(7.44)	(7.40)	(5.19)	(7.64)	(5.96)	(5.86)
Legacy Case (Upgraded)	0.00	7.34	(2.49)	(0.53)	0.46	0.00	0.00	96.37	2.62	(0.53)	0.00	0.00	1.57	0.00	1.47	(0.00)

Wind Shear System	BIS	BNA	BOI	BOS	BTR	BTV	BUF	BUR	BWI	CAE	CAK	CHA	CHS	CID	CLE	CLT
	NoWS	TDWR	NoWS	TDWR	LLWAS	NoWS	WSP	NoWS	TDWR	LLWAS	NoWS	LLWAS	WSP	WSP	TDWR	TDWR
TDWR	N/A	5.88	N/A	11.85	N/A	N/A	N/A	N/A	8.84	N/A	N/A	N/A	N/A	N/A	4.36	14.19
WSP	N/A	3.47	N/A	9.17	N/A	N/A	0.94	N/A	5.19	N/A	N/A	N/A	0.43	(0.49)	2.30	10.98
NEXRAD	(0.01)	7.37	1.78	11.73	(0.29)	0.17	1.63	(0.24)	1.48	0.46	0.08	(0.34)	(0.10)	(0.30)	6.02	2.70
LIDAR	(2.53)	0.73	(1.32)	5.47	(2.50)	(2.39)	(1.49)	(2.35)	4.28	(2.51)	(2.33)	(2.70)	(2.19)	(2.54)	0.78	4.28
LLWAS	(1.28)	2.53	(0.66)	4.69	(0.18)	(1.24)	(0.62)	(1.21)	3.93	(0.22)	(1.11)	(0.44)	(0.78)	(1.30)	1.56	6.40
X-Band	(6.12)	1.38	(4.63)	7.25	(5.51)	(5.94)	(4.46)	(5.88)	3.49	(5.98)	(5.52)	(6.22)	(5.01)	(6.02)	(0.03)	9.15
TDWR & NEXRAD	N/A	5.67	N/A	11.72	N/A	N/A	N/A	N/A	8.60	N/A	N/A	N/A	N/A	N/A	4.16	13.95
TDWR, NEXRAD, LLWAS	N/A	4.36	N/A	10.47	N/A	N/A	N/A	N/A	7.38	N/A	N/A	N/A	N/A	N/A	2.85	12.72
TDWR & LIDAR	N/A	3.02	N/A	9.16	N/A	N/A	N/A	N/A	6.17	N/A	N/A	N/A	N/A	N/A	1.51	11.41
TDWR & LLWAS	N/A	3.26	N/A	9.36	N/A	N/A	N/A	N/A	6.42	N/A	N/A	N/A	N/A	N/A	1.76	11.66
WSP & NEXRAD	N/A	4.58	N/A	10.61	N/A	N/A	N/A	N/A	7.62	N/A	N/A	N/A	N/A	N/A	3.06	12.96
WSP & LIDAR	N/A	3.96	N/A	9.39	N/A	N/A	0.87	N/A	4.94	N/A	N/A	N/A	0.19	(0.73)	2.54	10.73
WSP & LLWAS	N/A	1.44	N/A	7.61	N/A	N/A	(1.55)	N/A	4.73	N/A	N/A	N/A	(2.09)	(3.11)	0.10	9.50
WSP, NEXRAD, LIDAR	N/A	2.40	N/A	8.18	N/A	N/A	(0.37)	N/A	4.73	N/A	N/A	N/A	(0.90)	(1.84)	1.13	10.07
WSP, NEXRAD, LLWAS	N/A	1.45	N/A	7.55	N/A	N/A	(1.76)	N/A	4.49	N/A	N/A	N/A	(2.33)	(3.35)	(0.06)	9.26
NEXRAD & LIDAR	N/A	2.71	N/A	8.39	N/A	N/A	(0.48)	N/A	4.50	N/A	N/A	N/A	(1.14)	(2.08)	1.24	9.83
NEXRAD & LLWAS	(2.65)	4.96	(0.77)	10.73	(2.74)	(2.46)	(0.99)	(2.59)	4.05	(2.16)	(2.36)	(2.94)	(2.43)	(2.78)	3.47	4.04
X-Band & LIDAR	(1.37)	6.26	0.53	11.46	(0.28)	(1.17)	0.31	(1.26)	5.44	0.03	(1.00)	(0.67)	(0.80)	(1.45)	4.81	8.28
X-Band & LLLWAS	(8.76)	(1.15)	(7.08)	4.86	(8.14)	(8.57)	(7.10)	(8.44)	2.02	(8.52)	(8.17)	(8.85)	(7.60)	(8.68)	(2.62)	7.15
TDWR,NEXRAD,LIDAR	(7.47)	0.19	(5.82)	6.23	(6.08)	(7.28)	(5.80)	(7.14)	2.93	(6.41)	(6.87)	(6.78)	(6.30)	(7.38)	(1.29)	8.39
Legacy Case (Upgraded)	0.00	5.88	0.00	11.85	(0.18)	0.00	0.94	0.00	8.84	(0.22)	0.00	(0.44)	0.43	(0.49)	4.36	14.19

Wind Shear System	CMH	CMI	COS	CRP	CRW	CSG	CVG	DAB	DAL	DAY	DCA	DEN	DFW	DSM	DTW
	TDWR	NoWS	LLWAS	NoWS	LLWAS	LLWAS	TDWR	LLWAS	TDWR	TDWR	TDWR	TDWR&LLWAS	TDWR&LLWAS	WSP	TDWR
TDWR	0.74	N/A	N/A	N/A	N/A	N/A	8.86	N/A	4.25	(0.53)	4.41	77.35	50.72	N/A	22.40
WSP	(1.17)	N/A	N/A	N/A	N/A	N/A	6.25	N/A	(0.57)	(2.24)	2.06	54.45	43.99	0.30	18.71
NEXRAD	(0.07)	(0.24)	1.49	0.04	(0.14)	(0.35)	1.51	(0.13)	4.21	(0.13)	5.49	77.43	50.29	0.95	4.47
LIDAR	(1.46)	(2.39)	(1.86)	(2.55)	(2.70)	(2.69)	2.55	(2.04)	0.21	(2.21)	0.87	57.85	19.43	(2.04)	9.61
LLWAS	(0.23)	(1.23)	0.34	(1.28)	(0.51)	(0.48)	4.11	0.56	1.50	(0.82)	1.38	69.07	33.37	(0.86)	10.89
X-Band	(3.69)	(5.79)	(4.49)	(6.06)	(6.32)	(6.26)	4.24	(4.29)	(0.17)	(4.88)	(0.71)	71.59	46.08	(5.15)	17.88
TDWR & NEXRAD	0.50	N/A	N/A	N/A	N/A	N/A	8.62	N/A	4.06	(0.77)	4.28	77.23	50.74	N/A	22.16
TDWR, NEXRAD, LLWAS	(0.84)	N/A	N/A	N/A	N/A	N/A	7.35	N/A	2.78	(2.11)	2.96	79.15	51.07	N/A	20.98
TDWR & LIDAR	(2.15)	N/A	N/A	N/A	N/A	N/A	6.01	N/A	1.49	(3.41)	1.66	75.47	48.35	N/A	19.56
TDWR & LLWAS	(1.90)	N/A	N/A	N/A	N/A	N/A	6.26	N/A	1.71	(3.16)	1.85	75.72	48.46	N/A	19.81
WSP & NEXRAD	(0.60)	N/A	N/A	N/A	N/A	N/A	7.59	N/A	2.98	(1.87)	3.10	79.36	51.12	N/A	21.22
WSP & LIDAR	(1.42)	N/A	N/A	N/A	N/A	N/A	6.00	N/A	1.00	(2.46)	2.43	74.55	47.72	0.18	18.46
WSP & LLWAS	(3.54)	N/A	N/A	N/A	N/A	N/A	4.51	N/A	(1.43)	(4.76)	0.12	71.18	45.24	(2.24)	17.73
WSP, NEXRAD, LIDAR	(2.43)	N/A	N/A	N/A	N/A	N/A	5.33	N/A	(0.71)	(3.56)	0.96	73.86	45.51	(1.02)	18.18
WSP, NEXRAD, LLWAS	(3.78)	N/A	N/A	N/A	N/A	N/A	4.27	N/A	(0.57)	(4.99)	0.07	74.31	46.88	(2.45)	17.49
NEXRAD & LIDAR	(2.67)	N/A	N/A	N/A	N/A	N/A	5.09	N/A	0.17	(3.77)	1.22	76.64	48.05	(1.17)	17.94
NEXRAD & LLWAS	(1.70)	(2.63)	(0.95)	(2.61)	(2.79)	(2.93)	2.31	(2.28)	2.68	(2.34)	3.44	77.73	50.24	(1.68)	9.37
X-Band & LIDAR	(0.05)	(1.29)	1.24	(1.32)	(0.60)	(0.70)	5.01	0.44	3.92	(0.76)	4.57	81.09	51.99	(0.39)	13.72
X-Band & LLLWAS	(6.27)	(8.44)	(7.05)	(8.72)	(8.96)	(8.90)	1.86	(6.89)	(2.65)	(7.51)	(2.72)	71.41	44.01	(7.79)	15.37
TDWR,NEXRAD,LIDAR	(4.97)	(7.15)	(4.92)	(7.43)	(6.89)	(6.85)	3.14	(4.82)	(1.36)	(6.21)	(1.46)	74.12	45.79	(6.50)	16.80
Legacy Case (Upgraded)	0.74	0.00	0.34	0.00	(0.51)	(0.48)	8.86	0.56	4.25	(0.53)	4.41	79.36	51.12	0.30	22.40

Wind Shear System	ELP	ERI	EVV	EWR	FAR	FAY	FLL	FNT	FSD	FSM	FWA	GCN	GEG	GFK	GPT	GRB
	WSP	NoWS	NoWS	TDWR	NoWS	LLWAS	TDWR	NoWS	LLWAS	LLWAS	WSP	NoWS	WSP	NoWS	NoWS	LLWAS
TDWR	N/A	N/A	N/A	15.39	N/A	N/A	25.56	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WSP	1.65	N/A	N/A	12.54	N/A	N/A	21.78	N/A	N/A	N/A	(0.09)	N/A	1.53	N/A	N/A	N/A
NEXRAD	0.50	(0.24)	(0.24)	3.16	(0.24)	(0.37)	24.44	0.18	0.45	(0.16)	(0.11)	(0.24)	2.27	0.20	(0.23)	(0.05)
LIDAR	(1.57)	(2.59)	(2.51)	9.64	(2.45)	(2.73)	8.05	(2.30)	(2.22)	(2.72)	(2.34)	(2.03)	(1.04)	(2.19)	(2.49)	(2.56)
LLWAS	(0.20)	(1.34)	(1.24)	4.63	(1.26)	(0.54)	11.55	(1.14)	(0.26)	(0.51)	(1.04)	(1.10)	(0.20)	(1.14)	(1.09)	(0.50)
X-Band	(3.81)	(6.24)	(6.01)	11.25	(6.00)	(6.32)	20.93	(5.68)	(5.63)	(6.28)	(5.59)	(5.51)	(3.84)	(5.55)	(5.68)	(6.15)
TDWR & NEXRAD	N/A	N/A	N/A	15.15	N/A	N/A	25.83	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDWR, NEXRAD, LLWAS	N/A	N/A	N/A	13.89	N/A	N/A	24.64	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDWR & LIDAR	N/A	N/A	N/A	13.16	N/A	N/A	23.42	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDWR & LLWAS	N/A	N/A	N/A	13.41	N/A	N/A	23.42	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WSP & NEXRAD	N/A	N/A	N/A	14.13	N/A	N/A	24.44	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WSP & LIDAR	1.49	N/A	N/A	12.29	N/A	N/A	23.30	N/A	N/A	N/A	(0.33)	N/A	1.56	N/A	N/A	N/A
WSP & LLWAS	(0.86)	N/A	N/A	11.83	N/A	N/A	20.92	N/A	N/A	N/A	(2.67)	N/A	(0.82)	N/A	N/A	N/A
WSP, NEXRAD, LIDAR	0.33	N/A	N/A	11.54	N/A	N/A	20.70	N/A	N/A	N/A	(1.42)	N/A	0.29	N/A	N/A	N/A
WSP, NEXRAD, LLWAS	(1.04)	N/A	N/A	11.59	N/A	N/A	21.39	N/A	N/A	N/A	(2.90)	N/A	(1.04)	N/A	N/A	N/A
NEXRAD & LIDAR	0.18	N/A	N/A	11.30	N/A	N/A	22.15	N/A	N/A	N/A	(1.65)	N/A	0.23	N/A	N/A	N/A
NEXRAD & LLWAS	(1.57)	(2.83)	(2.75)	9.40	(2.69)	(2.97)	23.53	(2.27)	(2.15)	(2.81)	(2.51)	(2.27)	(0.27)	(2.20)	(2.72)	(2.68)
X-Band & LIDAR	0.18	(1.54)	(1.42)	11.17	(1.39)	(0.75)	24.88	(1.05)	0.02	(0.62)	(1.13)	(1.05)	1.00	(0.97)	(1.24)	(0.49)
X-Band & LLLWAS	(6.39)	(8.89)	(8.67)	9.18	(8.64)	(8.97)	19.06	(8.33)	(8.26)	(8.93)	(8.22)	(8.13)	(6.39)	(8.20)	(8.32)	(8.79)
TDWR,NEXRAD,LIDAR	(5.08)	(7.60)	(7.38)	10.50	(7.35)	(6.92)	20.55	(7.04)	(6.22)	(6.88)	(6.93)	(6.85)	(5.11)	(6.91)	(7.02)	(6.74)
Legacy Case (Upgraded)	1.65	0.00	0.00	15.39	0.00	(0.54)	25.56	0.00	(0.26)	(0.51)	(0.09)	0.00	1.53	0.00	0.00	(0.50)

Wind Shear System	GRR	GSO	GSP	HNL	HOU	HPN	HSV	IAD	IAH	ICT	ILM	IND	ISP	JAN	JAX	JFK	LAN
	WSP	WSP	LLWAS	WSP	TDWR	WSP	WSP	TDWR	TDWR	TDWR	NoWS	TDWR	WSP	LLWAS	WSP	TDWR	LLWAS
TDWR	N/A	N/A	N/A	N/A	10.78	N/A	N/A	10.50	46.06	(0.32)	N/A	7.27	N/A	N/A	N/A	76.82	N/A
WSP	(0.06)	0.47	N/A	3.77	8.17	0.13	(0.18)	7.06	39.26	(2.10)	N/A	5.21	0.27	N/A	5.06	67.21	N/A
NEXRAD	0.56	(0.16)	(0.07)	0.57	12.36	(0.07)	(0.24)	10.90	37.76	1.34	0.08	8.93	1.01	0.42	6.51	17.16	(0.34)
LIDAR	(2.20)	(2.17)	(2.67)	(0.70)	1.72	(2.14)	(2.46)	3.70	15.27	(1.95)	(2.53)	1.47	(1.77)	(2.43)	(0.17)	58.04	(2.54)
LLWAS	(1.08)	(0.76)	(0.49)	0.82	5.33	(1.08)	(1.12)	4.90	23.13	(0.77)	(1.22)	3.32	(0.93)	(0.17)	1.99	21.35	(0.46)
X-Band	(5.55)	(5.29)	(6.17)	(1.78)	6.21	(5.40)	(5.71)	5.26	38.73	(4.71)	(5.96)	2.92	(5.10)	(5.72)	0.39	73.36	(6.08)
TDWR & NEXRAD	N/A	N/A	N/A	N/A	10.67	N/A	N/A	10.32	46.34	(0.54)	N/A	7.15	N/A	N/A	N/A	76.58	N/A
TDWR, NEXRAD, LLWAS	N/A	N/A	N/A	N/A	9.41	N/A	N/A	9.09	45.33	(1.89)	N/A	5.86	N/A	N/A	N/A	75.36	N/A
TDWR & LIDAR	N/A	N/A	N/A	N/A	8.04	N/A	N/A	7.77	43.88	(3.20)	N/A	4.50	N/A	N/A	N/A	75.11	N/A
TDWR & LLWAS	N/A	N/A	N/A	N/A	8.23	N/A	N/A	8.01	43.85	(2.95)	N/A	4.71	N/A	N/A	N/A	75.36	N/A
WSP & NEXRAD	N/A	N/A	N/A	N/A	9.55	N/A	N/A	9.29	45.16	(1.66)	N/A	6.03	N/A	N/A	N/A	75.60	N/A
WSP & LIDAR	(0.22)	0.23	N/A	3.53	9.01	(0.10)	(0.42)	8.02	42.52	(2.17)	N/A	5.46	0.23	N/A	5.75	66.96	N/A
WSP & LLWAS	(2.64)	(2.08)	N/A	1.37	6.13	(2.46)	(2.79)	6.12	39.53	(4.56)	N/A	2.91	(2.16)	N/A	2.79	72.44	N/A
WSP, NEXRAD, LIDAR	(1.40)	(0.85)	N/A	2.47	7.08	(1.21)	(1.52)	6.54	39.14	(3.40)	N/A	4.07	(1.02)	N/A	4.06	66.45	N/A
WSP, NEXRAD, LLWAS	(2.87)	(2.32)	N/A	1.13	6.46	(2.68)	(3.03)	6.17	41.26	(4.75)	N/A	2.87	(2.38)	N/A	3.12	72.20	N/A
NEXRAD & LIDAR	(1.58)	(1.09)	N/A	2.23	7.75	(1.43)	(1.76)	7.07	41.83	(3.50)	N/A	4.20	(1.11)	N/A	4.45	66.21	N/A
NEXRAD & LLWAS	(2.09)	(2.41)	(2.72)	(0.94)	9.89	(2.21)	(2.70)	9.47	38.60	(1.21)	(2.53)	6.38	(1.61)	(2.21)	3.89	57.80	(2.77)
X-Band & LIDAR	(0.80)	(0.85)	(0.52)	1.33	11.29	(0.90)	(1.26)	10.55	42.12	0.08	(1.23)	7.76	(0.32)	(0.02)	5.23	59.90	(0.57)
X-Band & LLLWAS	(8.21)	(7.84)	(8.82)	(4.33)	3.78	(8.01)	(8.36)	3.53	38.49	(7.30)	(8.58)	0.33	(7.72)	(8.33)	(2.24)	71.31	(8.72)
TDWR,NEXRAD,LIDAR	(6.91)	(6.48)	(6.77)	(2.95)	5.20	(6.71)	(7.05)	4.61	39.97	(6.01)	(7.29)	1.69	(6.43)	(6.29)	(0.89)	72.64	(6.67)
Legacy Case (Upgraded)	(0.06)	0.47	(0.49)	3.77	10.78	0.13	(0.18)	10.50	46.06	(0.32)	0.00	7.27	0.27	(0.17)	5.06	76.82	(0.46)

Wind Shear System	LAS	LAX	LBB	LEX	LFT	LGA	LGB	LIT	LNK	MAF	MBS	MCI	MCO	MDT	MDW	MEM
	TDWR	WSP	WSP	LLWAS	NoWS	TDWR&LLWAS	NoWS	LLWAS	LLWAS	LLWAS	NoWS	TDWR	TDWR&LLWAS	WSP	TDWR	TDWR
TDWR	30.87	N/A	N/A	N/A	N/A	12.79	N/A	N/A	N/A	N/A	N/A	12.00	51.53	N/A	15.72	16.36
WSP	26.20	4.54	0.59	N/A	N/A	3.90	N/A	N/A	N/A	N/A	N/A	9.87	47.98	(0.54)	4.08	12.16
NEXRAD	5.69	0.70	1.23	(0.35)	(0.24)	2.70	(0.24)	1.78	(0.20)	0.57	(0.24)	4.26	11.21	(0.31)	17.21	17.88
LIDAR	26.37	0.90	(1.95)	(2.67)	(2.51)	7.94	(2.03)	(1.80)	(2.66)	(2.40)	(2.51)	3.00	15.55	(2.61)	8.01	5.92
LLWAS	15.83	1.27	(0.76)	(0.48)	(1.09)	4.28	(0.72)	0.57	(0.47)	(0.21)	(1.30)	5.70	42.87	(1.34)	6.00	8.09
X-Band	21.45	(0.31)	(4.84)	(6.15)	(5.70)	8.31	(4.72)	(4.41)	(6.20)	(5.52)	(6.09)	7.58	47.08	(6.18)	11.22	11.28
TDWR & NEXRAD	30.63	N/A	N/A	N/A	N/A	12.55	N/A	N/A	N/A	N/A	N/A	11.77	51.32	N/A	15.55	16.23
TDWR, NEXRAD, LLWAS	30.98	N/A	N/A	N/A	N/A	12.13	N/A	N/A	N/A	N/A	N/A	10.52	51.86	N/A	14.28	15.00
TDWR & LIDAR	31.64	N/A	N/A	N/A	N/A	9.97	N/A	N/A	N/A	N/A	N/A	9.15	48.91	N/A	12.91	13.60
TDWR & LLWAS	33.38	N/A	N/A	N/A	N/A	10.22	N/A	N/A	N/A	N/A	N/A	9.39	49.15	N/A	13.13	13.81
WSP & NEXRAD	31.22	N/A	N/A	N/A	N/A	12.37	N/A	N/A	N/A	N/A	N/A	10.75	52.07	N/A	14.45	15.15
WSP & LIDAR	25.95	4.30	0.48	N/A	N/A	3.65	N/A	N/A	N/A	N/A	N/A	9.72	47.89	(0.78)	13.63	14.50
WSP & LLWAS	33.54	2.81	(1.96)	N/A	N/A	6.27	N/A	N/A	N/A	N/A	N/A	7.59	46.78	(3.16)	7.17	11.38
WSP, NEXRAD, LIDAR	28.22	3.44	(0.74)	N/A	N/A	3.50	N/A	N/A	N/A	N/A	N/A	8.74	48.15	(1.89)	5.84	11.77
WSP, NEXRAD, LLWAS	33.30	2.57	(2.15)	N/A	N/A	6.03	N/A	N/A	N/A	N/A	N/A	7.43	46.65	(3.40)	11.35	12.03
NEXRAD & LIDAR	27.98	3.20	(0.87)	N/A	N/A	3.26	N/A	N/A	N/A	N/A	N/A	8.59	48.08	(2.13)	12.53	13.32
NEXRAD & LLWAS	26.12	0.66	(1.38)	(2.91)	(2.75)	7.70	(2.27)	(0.84)	(2.79)	(2.05)	(2.75)	4.35	16.23	(2.85)	14.92	15.52
X-Band & LIDAR	23.59	2.53	(0.09)	(0.66)	(1.26)	9.83	(0.63)	1.36	(0.61)	0.14	(1.45)	7.86	46.29	(1.53)	16.10	16.89
X-Band & LLLWAS	27.75	(2.55)	(7.48)	(8.81)	(8.34)	5.85	(7.20)	(6.97)	(8.86)	(8.16)	(8.74)	4.96	44.80	(8.81)	8.71	9.20
TDWR,NEXRAD,LIDAR	26.90	(1.29)	(6.18)	(6.75)	(7.04)	7.14	(5.90)	(4.92)	(6.81)	(6.10)	(7.45)	6.37	47.00	(7.51)	10.08	10.56
Legacy Case (Upgraded)	30.87	4.54	0.59	(0.48)	0.00	12.37	0.00	0.57	(0.47)	(0.21)	0.00	12.00	52.07	(0.54)	15.72	16.36

Wind Shear System	MGM	MHT	MIA	MKE	MLI	MLU	MOB	MSN	MSP	MSY	MYR	OAK	OKC	OMA	ONT
	LLWAS	NoWS	TDWR	TDWR	LLWAS	LLWAS	LLWAS	WSP	TDWR	TDWR&LLWAS	NoWS	NoWS	TDWR	LLWAS	WSP
TDWR	N/A	N/A	36.04	4.25	N/A	N/A	N/A	N/A	14.45	6.25	N/A	N/A	0.59	N/A	N/A
WSP	N/A	N/A	31.24	1.54	N/A	N/A	N/A	(0.11)	11.57	4.13	N/A	N/A	(1.17)	N/A	1.16
NEXRAD	(0.35)	(0.24)	37.25	1.78	0.05	(0.35)	0.15	(0.16)	15.95	5.31	0.15	(0.24)	2.32	1.97	0.07
LIDAR	(2.66)	(2.07)	10.31	0.82	(2.58)	(2.69)	(2.59)	(2.33)	5.95	(0.00)	(2.51)	(1.17)	(1.62)	(1.75)	(1.50)
LLWAS	(0.49)	(1.02)	18.60	1.58	(0.41)	(0.44)	(0.36)	(1.08)	6.02	3.09	(1.17)	(1.13)	(0.28)	0.43	(0.46)
X-Band	(6.20)	(5.32)	31.50	(0.33)	(6.11)	(6.18)	(5.96)	(5.58)	9.93	1.74	(5.92)	(4.31)	(3.77)	(4.21)	(4.30)
TDWR & NEXRAD	N/A	N/A	36.76	4.03	N/A	N/A	N/A	N/A	14.23	6.11	N/A	N/A	0.36	N/A	N/A
TDWR, NEXRAD, LLWAS	N/A	N/A	35.69	2.73	N/A	N/A	N/A	N/A	12.98	5.73	N/A	N/A	(0.98)	N/A	N/A
TDWR & LIDAR	N/A	N/A	34.33	1.41	N/A	N/A	N/A	N/A	11.62	3.50	N/A	N/A	(2.28)	N/A	N/A
TDWR & LLWAS	N/A	N/A	33.98	1.66	N/A	N/A	N/A	N/A	11.86	3.68	N/A	N/A	(2.04)	N/A	N/A
WSP & NEXRAD	N/A	N/A	35.25	2.96	N/A	N/A	N/A	N/A	13.20	5.89	N/A	N/A	(0.75)	N/A	N/A
WSP & LIDAR	N/A	N/A	34.60	1.45	N/A	N/A	N/A	(0.34)	12.48	4.27	N/A	N/A	(1.21)	N/A	0.92
WSP & LLWAS	N/A	N/A	30.73	(0.05)	N/A	N/A	N/A	(2.66)	9.90	1.90	N/A	N/A	(3.65)	N/A	(1.25)
WSP, NEXRAD, LIDAR	N/A	N/A	30.84	0.61	N/A	N/A	N/A	(1.43)	10.56	3.04	N/A	N/A	(2.47)	N/A	(0.14)
WSP, NEXRAD, LLWAS	N/A	N/A	32.60	(0.26)	N/A	N/A	N/A	(2.89)	10.05	1.86	N/A	N/A	(3.83)	N/A	(1.49)
NEXRAD & LIDAR	N/A	N/A	33.55	0.53	N/A	N/A	N/A	(1.66)	11.30	3.14	N/A	N/A	(2.55)	N/A	(0.38)
NEXRAD & LLWAS	(2.90)	(2.31)	35.60	1.31	(2.60)	(2.93)	(2.49)	(2.53)	13.58	3.34	(2.44)	(1.41)	(0.28)	(0.54)	(1.74)
X-Band & LIDAR	(0.67)	(0.98)	37.31	2.73	(0.41)	(0.66)	(0.30)	(1.13)	14.85	5.89	(1.16)	(0.08)	1.02	1.59	(0.27)
X-Band & LLLWAS	(8.84)	(7.92)	29.70	(2.72)	(8.73)	(8.82)	(8.60)	(8.21)	7.43	(0.69)	(8.52)	(6.75)	(6.39)	(6.82)	(6.82)
TDWR,NEXRAD,LIDAR	(6.79)	(6.63)	31.37	(1.49)	(6.68)	(6.77)	(6.55)	(6.92)	8.79	0.58	(7.24)	(5.47)	(5.09)	(4.76)	(5.53)
Legacy Case (Upgraded)	(0.49)	0.00	36.04	4.25	(0.41)	(0.44)	(0.36)	(0.11)	14.45	5.89	0.00	0.00	0.59	0.43	1.16

Wind Shear System	ORD	ORF	ORL	PBI	PDK	PDX	PHF	PHL	PHX	PIA	PIE	PIT	PNS	PVD	PWM	RDU
	TDWR&LLWAS	WSP	NoWS	TDWR	NoWS	WSP	NoWS	TDWR	TDWR	LLWAS	NoWS	TDWR	LLWAS	LLWAS	NoWS	TDWR
TDWR	77.49	N/A	N/A	5.11	N/A	N/A	N/A	12.82	12.85	N/A	N/A	1.16	N/A	N/A	N/A	2.44
WSP	64.72	0.64	N/A	(2.51)	N/A	2.03	N/A	8.26	10.73	N/A	N/A	(0.77)	N/A	N/A	N/A	0.29
NEXRAD	68.36	0.00	(0.24)	0.82	0.50	0.23	0.44	2.74	16.27	(0.26)	1.79	2.94	(0.26)	1.16	0.15	3.95
LIDAR	43.50	(1.62)	(2.41)	(0.31)	(2.33)	(1.47)	(2.28)	6.67	3.92	(2.63)	(2.17)	(1.36)	(2.32)	(1.83)	(2.38)	(0.78)
LLWAS	55.31	(0.74)	(1.04)	2.11	(1.04)	(0.07)	(1.18)	4.89	6.11	(0.46)	(0.61)	0.04	(0.02)	(0.12)	(1.23)	0.66
X-Band	70.72	(4.58)	(5.48)	0.78	(5.36)	(4.15)	(5.64)	7.82	8.77	(6.17)	(4.42)	(5.43)	(5.09)	(4.91)	(5.88)	(2.26)
TDWR & NEXRAD	77.93	N/A	N/A	4.87	N/A	N/A	N/A	12.60	14.60	N/A	N/A	0.94	N/A	N/A	N/A	2.23
TDWR, NEXRAD, LLWAS	79.03	N/A	N/A	3.64	N/A	N/A	N/A	11.48	13.39	N/A	N/A	(0.40)	N/A	N/A	N/A	0.91
TDWR & LIDAR	75.86	N/A	N/A	2.34	N/A	N/A	N/A	10.65	12.14	N/A	N/A	(1.72)	N/A	N/A	N/A	(0.41)
TDWR & LLWAS	75.85	N/A	N/A	2.59	N/A	N/A	N/A	10.88	11.12	N/A	N/A	(1.47)	N/A	N/A	N/A	(0.17)
WSP & NEXRAD	78.75	N/A	N/A	3.88	N/A	N/A	N/A	11.70	11.78	N/A	N/A	(0.17)	N/A	N/A	N/A	1.12
WSP & LIDAR	70.69	0.42	N/A	(2.76)	N/A	1.79	N/A	8.23	12.94	N/A	N/A	(0.63)	N/A	N/A	N/A	0.54
WSP & LLWAS	72.28	(1.63)	N/A	(3.88)	N/A	(0.46)	N/A	8.69	9.50	N/A	N/A	(3.18)	N/A	N/A	N/A	(1.88)
WSP, NEXRAD, LIDAR	70.24	(0.65)	N/A	(1.47)	N/A	0.74	N/A	7.69	9.91	N/A	N/A	(1.98)	N/A	N/A	N/A	(0.88)
WSP, NEXRAD, LLWAS	73.75	(1.86)	N/A	(4.12)	N/A	(0.70)	N/A	8.61	10.60	N/A	N/A	(3.27)	N/A	N/A	N/A	(1.98)
NEXRAD & LIDAR	75.17	(0.87)	N/A	(1.71)	N/A	0.50	N/A	7.66	11.79	N/A	N/A	(1.96)	N/A	N/A	N/A	(0.73)
NEXRAD & LLWAS	74.65	(1.82)	(2.65)	(0.55)	(2.02)	(1.71)	(2.14)	6.69	14.09	(2.80)	(0.86)	0.29	(2.56)	(1.44)	(2.42)	1.49
X-Band & LIDAR	78.23	(0.37)	(1.13)	2.62	(0.71)	(0.01)	(0.87)	8.95	15.36	(0.61)	0.44	1.60	(0.05)	0.73	(1.17)	2.79
X-Band & LLLWAS	71.27	(7.07)	(8.09)	(1.72)	(7.98)	(6.57)	(8.21)	6.46	6.97	(8.81)	(7.01)	(7.31)	(7.74)	(7.55)	(8.53)	(4.62)
TDWR,NEXRAD,LIDAR	73.34	(5.79)	(6.79)	(0.37)	(6.69)	(5.19)	(6.93)	7.61	8.39	(6.76)	(5.71)	(5.79)	(5.67)	(5.50)	(7.24)	(3.36)
Legacy Case (Upgraded)	78.75	0.64	0.00	5.11	0.00	2.03	0.00	12.82	12.85	(0.46)	0.00	1.16	(0.02)	(0.12)	0.00	2.44

Wind Shear System	RIC	RNO	ROA	ROC	RST	RSW	SAN	SAT	SAV	SBN	SDF	SEA	SFB	SFO	SGF	SHV
	WSP	NoWS	LLWAS	WSP	LLWAS	LLWAS	NoWS	WSP	LLWAS	NoWS	TDWR	WSP	NoWS	LLWAS	LLWAS	LLWAS
TDWR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.60	N/A	N/A	N/A	N/A	N/A
WSP	0.41	N/A	N/A	0.46	N/A	N/A	N/A	3.60	N/A	N/A	1.01	3.81	N/A	N/A	N/A	N/A
NEXRAD	0.49	(0.24)	(0.34)	(0.10)	(0.37)	(0.01)	(0.24)	4.30	0.04	(0.22)	5.26	0.64	(0.24)	(0.30)	0.27	0.25
LIDAR	(1.98)	(0.27)	(2.65)	(2.00)	(2.66)	(1.20)	(1.77)	(0.30)	(2.34)	(2.44)	0.03	0.79	(1.98)	(1.26)	(2.53)	(2.54)
LLWAS	(0.75)	0.12	(0.44)	(0.83)	(0.54)	1.32	(0.88)	0.80	0.06	(1.19)	1.18	0.30	(0.31)	(0.21)	(0.35)	(0.32)
X-Band	(5.01)	(4.05)	(6.19)	(5.02)	(6.23)	(1.42)	(4.55)	(1.62)	(5.20)	(5.90)	(1.25)	(1.25)	(3.63)	(4.47)	(5.83)	(5.85)
TDWR & NEXRAD	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.40	N/A	N/A	N/A	N/A	N/A
TDWR, NEXRAD, LLWAS	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.08	N/A	N/A	N/A	N/A	N/A
TDWR & LIDAR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.76	N/A	N/A	N/A	N/A	N/A
TDWR & LLWAS	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.00	N/A	N/A	N/A	N/A	N/A
WSP & NEXRAD	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.29	N/A	N/A	N/A	N/A	N/A
WSP & LIDAR	0.26	N/A	N/A	0.22	N/A	N/A	N/A	3.62	N/A	N/A	1.72	3.57	N/A	N/A	N/A	N/A
WSP & LLWAS	(2.00)	N/A	N/A	(2.12)	N/A	N/A	N/A	1.25	N/A	N/A	(0.82)	1.76	N/A	N/A	N/A	N/A
WSP, NEXRAD, LIDAR	(0.87)	N/A	N/A	(0.87)	N/A	N/A	N/A	2.36	N/A	N/A	(0.03)	2.55	N/A	N/A	N/A	N/A
WSP, NEXRAD, LLWAS	(2.20)	N/A	N/A	(2.36)	N/A	N/A	N/A	1.13	N/A	N/A	(0.80)	1.52	N/A	N/A	N/A	N/A
NEXRAD & LIDAR	(1.02)	N/A	N/A	(1.11)	N/A	N/A	N/A	2.36	N/A	N/A	0.44	2.31	N/A	N/A	N/A	N/A
NEXRAD & LLWAS	(1.77)	(0.51)	(2.89)	(2.24)	(2.90)	(1.44)	(2.01)	1.90	(2.36)	(2.67)	2.75	0.55	(2.22)	(1.50)	(2.37)	(2.39)
X-Band & LIDAR	(0.45)	0.28	(0.64)	(0.80)	(0.69)	1.93	(0.51)	3.10	0.09	(1.34)	4.03	2.00	(0.14)	0.73	(0.18)	(0.20)
X-Band & LLLWAS	(7.53)	(5.77)	(8.81)	(7.67)	(8.88)	(4.03)	(7.03)	(4.23)	(7.75)	(8.54)	(3.47)	(3.66)	(6.17)	(6.59)	(8.48)	(8.50)
TDWR,NEXRAD,LIDAR	(6.26)	(4.71)	(6.75)	(6.37)	(6.83)	(1.93)	(5.74)	(2.92)	(5.71)	(7.25)	(2.24)	(2.36)	(4.85)	(4.53)	(6.43)	(6.44)
Legacy Case (Upgraded)	0.41	0.00	(0.44)	0.46	(0.54)	1.32	0.00	3.60	0.06	0.00	3.60	3.81	0.00	(0.21)	(0.35)	(0.32)

Wind Shear System	SJC	SJU	SLC	SMF	SNA	SPI	SRQ	STL	SUX	SYR	TLH	TOL	TPA	TRI	TUL	TUS
	NoWS	TDWR	TDWR	NoWS	NoWS	LLWAS	WSP	TDWR&LLWAS	LLWAS	WSP	LLWAS	WSP	TDWR&LLWAS	LLWAS	TDWR	WSP
TDWR	N/A	0.09	16.99	N/A	N/A	N/A	N/A	7.28	N/A	N/A	N/A	N/A	21.87	N/A	0.13	N/A
WSP	N/A	(3.51)	12.51	N/A	N/A	N/A	1.42	5.04	N/A	(0.14)	N/A	(0.44)	20.41	N/A	(1.68)	2.28
NEXRAD	(0.24)	(0.18)	3.33	1.11	(0.24)	(0.23)	2.08	9.00	(0.37)	(0.22)	0.32	(0.28)	24.37	(0.35)	1.90	0.29
LIDAR	(1.78)	(1.97)	10.66	(1.84)	(1.30)	(2.69)	(1.67)	1.62	(2.76)	(2.23)	(2.54)	(2.44)	5.31	(2.69)	(1.83)	(1.04)
LLWAS	(1.27)	(0.55)	8.38	(1.10)	(1.18)	(0.53)	(0.38)	4.31	(0.58)	(1.12)	(0.24)	(1.23)	15.37	(0.47)	(0.49)	0.15
X-Band	(5.42)	(4.35)	12.46	(4.96)	(4.71)	(6.29)	(4.05)	2.87	(6.41)	(5.61)	(5.78)	(5.93)	18.11	(6.24)	(4.30)	(2.75)
TDWR & NEXRAD	N/A	(0.15)	16.75	N/A	N/A	N/A	N/A	7.10	N/A	N/A	N/A	N/A	22.30	N/A	(0.09)	N/A
TDWR, NEXRAD, LLWAS	N/A	(1.48)	15.81	N/A	N/A	N/A	N/A	6.72	N/A	N/A	N/A	N/A	22.18	N/A	(1.44)	N/A
TDWR & LIDAR	N/A	(2.78)	15.75	N/A	N/A	N/A	N/A	4.45	N/A	N/A	N/A	N/A	19.66	N/A	(2.75)	N/A
TDWR & LLWAS	N/A	(2.53)	16.00	N/A	N/A	N/A	N/A	4.67	N/A	N/A	N/A	N/A	19.57	N/A	(2.51)	N/A
WSP & NEXRAD	N/A	(1.24)	16.05	N/A	N/A	N/A	N/A	6.92	N/A	N/A	N/A	N/A	22.00	N/A	(1.21)	N/A
WSP & LIDAR	N/A	(3.76)	12.26	N/A	N/A	N/A	1.29	5.47	N/A	(0.38)	N/A	(0.68)	20.85	N/A	(1.68)	2.04
WSP & LLWAS	N/A	(5.54)	13.84	N/A	N/A	N/A	(1.18)	2.89	N/A	(2.67)	N/A	(2.98)	18.02	N/A	(4.13)	(0.01)
WSP, NEXRAD, LIDAR	N/A	(4.12)	12.72	N/A	N/A	N/A	0.08	4.09	N/A	(1.46)	N/A	(1.76)	19.58	N/A	(2.97)	1.04
WSP, NEXRAD, LLWAS	N/A	(5.78)	13.60	N/A	N/A	N/A	(1.35)	2.92	N/A	(2.91)	N/A	(3.22)	18.23	N/A	(4.30)	(0.25)
NEXRAD & LIDAR	N/A	(4.36)	12.48	N/A	N/A	N/A	(0.05)	4.35	N/A	(1.70)	N/A	(2.00)	19.86	N/A	(3.01)	0.80
NEXRAD & LLWAS	(2.02)	(2.21)	10.42	(1.47)	(1.54)	(2.85)	(0.57)	6.47	(3.00)	(2.47)	(2.29)	(2.68)	21.78	(2.93)	(0.73)	(1.28)
X-Band & LIDAR	(0.72)	(0.46)	11.82	(0.18)	(0.25)	(0.67)	0.73	8.65	(0.80)	(1.14)	(0.10)	(1.36)	24.17	(0.68)	0.56	0.62
X-Band & LLLWAS	(7.85)	(6.91)	11.32	(7.56)	(6.98)	(8.95)	(6.70)	0.30	(9.07)	(8.23)	(8.38)	(8.55)	15.54	(8.88)	(6.87)	(5.29)
TDWR,NEXRAD,LIDAR	(6.56)	(5.60)	12.31	(6.27)	(5.70)	(6.90)	(5.39)	1.64	(7.02)	(6.94)	(6.34)	(7.27)	17.11	(6.81)	(5.58)	(3.97)
Legacy Case (Upgraded)	0.00	0.09	16.99	0.00	0.00	(0.53)	1.42	6.92	(0.58)	(0.14)	(0.24)	(0.44)	22.00	(0.47)	0.13	2.28

Wind Shear System	TWF	TYS	
	NoWS	WSP	Total
TDWR	N/A	N/A	861.07
WSP	N/A	(0.35)	703.31
NEXRAD	(0.24)	(0.27)	684.33
LIDAR	(2.42)	(2.52)	148.10
LLWAS	(1.30)	(1.22)	406.15
X-Band	(6.08)	(6.22)	47.30
TDWR & NEXRAD	N/A	N/A	858.84
TDWR, NEXRAD, LLWAS	N/A	N/A	817.14
TDWR & LIDAR	N/A	N/A	748.83
TDWR & LLWAS	N/A	N/A	757.31
WSP & NEXRAD	N/A	N/A	821.21
WSP & LIDAR	N/A	(0.59)	766.79
WSP & LLWAS	N/A	(2.97)	607.92
WSP, NEXRAD, LIDAR	N/A	(1.70)	658.41
WSP, NEXRAD, LLWAS	N/A	(3.21)	618.95
NEXRAD & LIDAR	N/A	(1.94)	691.55
NEXRAD & LLWAS	(2.66)	(2.76)	459.69
X-Band & LIDAR	(1.41)	(1.38)	766.49
X-Band & LLLWAS	(8.70)	(8.76)	(336.34)
TDWR,NEXRAD,LIDAR	(7.42)	(7.40)	(93.92)
Legacy Case (Upgraded)	0.00	(0.35)	902.02

This page intentionally left blank.

APPENDIX F
NET PRESENT VALUE BASED ON SAFETY ANALYSIS ONLY BY SITE AND SYSTEM
(LIFECYCLE 2010–32 FY08$M)

Wind Shear System	ABE	ABQ	ADW	AGS	ALB	AMA	ASE	ATL	AUS	AVL	AVP	AZO	BDL	BGM	BHM	BIL
	NoWS	WSP	TDWR	LLWAS	WSP	NoWS	NoWS	TDWR&LLWAS	WSP	LLWAS	NoWS	NoWS	WSP	NoWS	WSP	LLWAS
TDWR	N/A	N/A	(2.50)	N/A	N/A	N/A	N/A	63.31	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WSP	N/A	5.65	(4.05)	N/A	0.07	N/A	N/A	57.77	2.04	N/A	N/A	N/A	0.94	N/A	1.11	N/A
NEXRAD	(0.24)	6.44	(0.72)	(0.36)	(0.20)	0.26	(0.24)	65.76	0.26	(0.36)	(0.24)	(0.24)	(0.04)	(0.19)	1.80	0.51
LIDAR	(2.50)	(0.18)	(3.14)	(2.75)	(2.21)	(2.53)	(2.51)	21.25	(1.33)	(2.75)	(2.57)	(2.57)	(1.79)	(2.64)	(2.09)	(2.13)
LLWAS	(1.19)	2.37	(1.85)	(0.53)	(0.92)	(1.14)	(1.26)	43.84	0.56	(0.53)	(1.26)	(1.29)	(0.41)	(1.35)	(0.30)	(0.01)
X-Band	(5.96)	0.27	(6.83)	(6.34)	(5.43)	(5.86)	(6.23)	58.04	(2.70)	(6.35)	(6.17)	(6.17)	(4.58)	(6.30)	(5.26)	(5.81)
TDWR & NEXRAD	N/A	N/A	(2.74)	N/A	N/A	N/A	N/A	63.95	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDWR, NEXRAD, LLWAS	N/A	N/A	(4.10)	N/A	N/A	N/A	N/A	64.43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDWR & LIDAR	N/A	N/A	(5.15)	N/A	N/A	N/A	N/A	61.13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDWR & LLWAS	N/A	N/A	(3.86)	N/A	N/A	N/A	N/A	64.21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WSP & NEXRAD	N/A	5.71	(4.30)	N/A	(0.17)	N/A	N/A	62.38	1.84	N/A	N/A	N/A	0.70	N/A	1.02	N/A
WSP & LIDAR	N/A	3.27	(6.71)	N/A	(2.49)	N/A	N/A	58.30	(0.12)	N/A	N/A	N/A	(1.58)	N/A	(1.44)	N/A
WSP & LLWAS	N/A	4.46	(5.42)	N/A	(1.24)	N/A	N/A	59.41	1.09	N/A	N/A	N/A	(0.35)	N/A	(0.17)	N/A
WSP, NEXRAD, LIDAR	N/A	3.13	(6.95)	N/A	(2.73)	N/A	N/A	60.08	(0.34)	N/A	N/A	N/A	(1.82)	N/A	(1.60)	N/A
WSP, NEXRAD, LLWAS	N/A	4.43	(5.66)	N/A	(1.48)	N/A	N/A	61.97	0.89	N/A	N/A	N/A	(0.59)	N/A	(0.31)	N/A
NEXRAD & LIDAR	(2.74)	3.85	(3.38)	(2.99)	(2.45)	(2.40)	(2.75)	63.54	(1.53)	(2.99)	(2.81)	(2.80)	(2.03)	(2.85)	(0.82)	(2.11)
NEXRAD & LLWAS	(1.40)	5.16	(2.09)	(0.76)	(1.09)	(1.10)	(1.50)	66.25	0.55	(0.76)	(1.49)	(1.51)	(0.56)	(1.56)	0.46	0.07
X-Band & LIDAR	(8.61)	(2.30)	(9.49)	(8.99)	(8.06)	(8.51)	(8.82)	56.59	(5.30)	(9.00)	(8.81)	(8.83)	(7.19)	(8.96)	(7.74)	(8.31)
X-Band & LLLWAS	(7.32)	(0.96)	(8.20)	(6.94)	(6.77)	(7.22)	(7.55)	58.70	(3.99)	(6.95)	(7.51)	(7.54)	(5.88)	(7.67)	(6.17)	(6.28)
TDWR,NEXRAD,LIDAR	N/A	N/A	(5.40)	N/A	N/A	N/A	N/A	61.38	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Legacy Case (Upgraded)	0.00	5.65	(2.50)	(0.53)	0.07	0.00	0.00	64.21	2.04	(0.53)	0.00	0.00	0.94	0.00	1.11	(0.01)

Wind Shear System	BIS	BNA	BOI	BOS	BTR	BTV	BUF	BUR	BWI	CAE	CAK	CHA	CHS	CID	CLE	CLT
	NoWS	TDWR	NoWS	TDWR	LLWAS	NoWS	WSP	NoWS	TDWR	LLWAS	NoWS	LLWAS	WSP	WSP	TDWR	TDWR
TDWR	N/A	4.83	N/A	6.85	N/A	N/A	N/A	N/A	6.97	N/A	0.44	N/A	N/A	N/A	3.02	10.62
WSP	N/A	2.65	N/A	4.67	N/A	N/A	0.32	(3.25)	3.66	N/A	N/A	N/A	0.21	(0.62)	1.12	8.11
NEXRAD	(0.06)	6.38	1.28	7.37	(0.29)	0.03	0.94	(0.24)	1.04	0.33	(0.05)	(0.34)	(0.15)	(0.33)	4.74	1.87
LIDAR	(2.57)	(0.01)	(1.67)	1.69	(2.55)	(2.51)	(2.05)	(2.54)	2.68	(2.56)	(2.50)	(2.71)	(2.41)	(2.65)	(0.25)	1.86
LLWAS	(1.28)	2.28	(0.67)	3.47	(0.19)	(1.24)	(0.78)	(1.22)	3.47	(0.22)	(1.11)	(0.44)	(0.83)	(1.33)	1.24	5.53
X-Band	(6.17)	0.35	(5.00)	2.30	(5.60)	(6.08)	(5.17)	(6.10)	1.69	(6.06)	(5.79)	(6.24)	(5.32)	(6.17)	(1.36)	5.62
TDWR & NEXRAD	N/A	4.60	N/A	6.64	N/A	N/A	N/A	N/A	6.73	N/A	0.20	N/A	N/A	N/A	2.82	10.38
TDWR, NEXRAD, LLWAS	N/A	3.30	N/A	5.39	N/A	N/A	N/A	N/A	5.51	N/A	(1.09)	N/A	N/A	N/A	1.50	9.14
TDWR & LIDAR	N/A	2.20	N/A	4.30	N/A	N/A	N/A	N/A	4.47	N/A	(2.13)	N/A	N/A	N/A	0.41	8.02
TDWR & LLWAS	N/A	3.53	N/A	5.61	N/A	N/A	N/A	N/A	5.75	N/A	(0.85)	N/A	N/A	N/A	1.72	9.38
WSP & NEXRAD	N/A	2.93	N/A	4.53	N/A	N/A	0.16	(3.49)	3.41	N/A	N/A	N/A	(0.03)	(0.86)	1.22	7.86
WSP & LIDAR	N/A	0.45	N/A	2.69	N/A	N/A	(2.25)	(5.84)	2.81	N/A	N/A	N/A	(2.39)	(3.25)	(1.20)	6.22
WSP & LLWAS	N/A	1.57	N/A	3.68	N/A	N/A	(0.99)	(4.58)	3.21	N/A	N/A	N/A	(1.12)	(1.97)	(0.05)	7.21
WSP, NEXRAD, LIDAR	N/A	0.39	N/A	2.51	N/A	N/A	(2.48)	(6.08)	2.57	N/A	N/A	N/A	(2.63)	(3.49)	(1.40)	5.98
WSP, NEXRAD, LLWAS	N/A	1.67	N/A	3.53	N/A	N/A	(1.18)	(4.82)	2.97	N/A	N/A	N/A	(1.36)	(2.21)	(0.08)	6.97
NEXRAD & LIDAR	(2.71)	3.91	(1.36)	6.02	(2.79)	(2.62)	(1.70)	(2.78)	2.44	(2.30)	(2.58)	(2.95)	(2.65)	(2.89)	2.14	1.62
NEXRAD & LLWAS	(1.42)	5.21	(0.06)	6.74	(0.34)	(1.33)	(0.41)	(1.45)	3.83	(0.10)	(1.22)	(0.68)	(1.02)	(1.56)	3.47	5.87
X-Band & LIDAR	(8.82)	(2.21)	(7.53)	(0.20)	(8.23)	(8.73)	(7.82)	(8.72)	0.07	(8.62)	(8.45)	(8.89)	(7.95)	(8.83)	(3.96)	3.50
X-Band & LLLWAS	(7.53)	(0.87)	(6.27)	1.17	(6.18)	(7.44)	(6.52)	(7.43)	0.99	(6.50)	(7.15)	(6.82)	(6.65)	(7.53)	(2.64)	4.74
TDWR,NEXRAD,LIDAR	N/A	1.95	N/A	4.07	N/A	N/A	N/A	N/A	4.22	N/A	(2.37)	N/A	N/A	N/A	0.16	7.77
Legacy Case (Upgraded)	0.00	4.83	0.00	6.85	(0.19)	0.00	0.32	0.00	6.97	(0.22)	0.00	(0.44)	0.21	(0.62)	3.02	10.62

Wind Shear System	CMH	CMI	COS	CRP	CRW	CSG	CVG	DAB	DAL	DAY	DCA	DEN	DFW	DSM	DTW	ELP
	TDWR	NoWS	LLWAS	NoWS	LLWAS	LLWAS	TDWR	LLWAS	TDWR	TDWR	TDWR	TDWR&LLWAS	TDWR&LLWAS	WSP	TDWR	WSP
TDWR	0.14	N/A	N/A	N/A	N/A	N/A	7.62	N/A	2.96	(0.82)	2.09	67.85	46.43	N/A	18.33	N/A
WSP	(1.64)	N/A	N/A	N/A	N/A	N/A	5.19	N/A	(1.22)	(2.48)	0.05	46.43	40.63	0.05	15.15	1.02
NEXRAD	(0.21)	(0.24)	1.02	(0.06)	(0.17)	(0.35)	1.22	(0.13)	3.37	(0.27)	3.47	68.14	46.08	0.67	3.52	0.13
LIDAR	(1.89)	(2.56)	(2.22)	(2.61)	(2.72)	(2.72)	1.63	(2.21)	(0.73)	(2.42)	(0.66)	49.18	16.39	(2.26)	6.61	(2.04)
LLWAS	(0.38)	(1.23)	0.33	(1.29)	(0.51)	(0.48)	3.81	0.55	1.18	(0.90)	0.81	65.97	32.13	(0.92)	9.90	(0.36)
X-Band	(4.27)	(6.04)	(5.03)	(6.17)	(6.34)	(6.31)	3.02	(4.58)	(1.45)	(5.17)	(2.61)	62.14	41.84	(5.45)	13.79	(4.50)
TDWR & NEXRAD	(0.10)	N/A	N/A	N/A	N/A	N/A	7.38	N/A	2.75	(1.06)	1.88	67.72	46.39	N/A	18.09	N/A
TDWR, NEXRAD, LLWAS	(1.44)	N/A	N/A	N/A	N/A	N/A	6.12	N/A	1.47	(2.41)	0.57	69.64	46.71	N/A	16.91	N/A
TDWR & LIDAR	(2.50)	N/A	N/A	N/A	N/A	N/A	5.02	N/A	0.39	(3.46)	(0.52)	66.19	44.12	N/A	15.73	N/A
TDWR & LLWAS	(1.20)	N/A	N/A	N/A	N/A	N/A	6.36	N/A	1.69	(2.17)	0.78	69.86	46.83	N/A	17.15	N/A
WSP & NEXRAD	(1.89)	N/A	N/A	N/A	N/A	N/A	4.94	N/A	0.08	(2.72)	0.08	65.12	43.42	(0.11)	14.90	0.80
WSP & LIDAR	(4.10)	N/A	N/A	N/A	N/A	N/A	3.33	N/A	(2.51)	(5.04)	(2.14)	61.77	41.31	(2.53)	13.85	(1.57)
WSP & LLWAS	(2.90)	N/A	N/A	N/A	N/A	N/A	4.28	N/A	(1.35)	(3.80)	(1.06)	65.84	42.16	(1.27)	14.62	(0.30)
WSP, NEXRAD, LIDAR	(4.34)	N/A	N/A	N/A	N/A	N/A	3.09	N/A	(1.75)	(5.28)	(2.31)	64.79	42.55	(2.75)	13.61	(1.80)
WSP, NEXRAD, LLWAS	(3.14)	N/A	N/A	N/A	N/A	N/A	4.04	N/A	(0.74)	(4.03)	(1.12)	67.21	43.75	(1.46)	14.38	(0.52)
NEXRAD & LIDAR	(2.13)	(2.80)	(1.47)	(2.71)	(2.83)	(2.96)	1.39	(2.45)	1.55	(2.58)	1.23	68.22	45.97	(1.97)	6.37	(2.20)
NEXRAD & LLWAS	(0.48)	(1.45)	0.71	(1.42)	(0.64)	(0.73)	4.10	0.27	2.79	(1.01)	2.36	71.58	47.73	(0.68)	10.72	(0.46)
X-Band & LIDAR	(6.87)	(8.70)	(7.63)	(8.82)	(8.98)	(8.95)	0.61	(7.20)	(3.97)	(7.81)	(4.98)	61.88	39.70	(8.09)	11.28	(7.13)
X-Band & LLLWAS	(5.57)	(7.41)	(5.50)	(7.53)	(6.92)	(6.90)	1.90	(5.14)	(2.68)	(6.51)	(3.72)	64.59	41.47	(6.80)	12.71	(5.83)
TDWR,NEXRAD,LIDAR	(2.75)	N/A	N/A	N/A	N/A	N/A	4.77	N/A	0.16	(3.71)	(0.75)	65.95	43.99	N/A	15.48	N/A
Legacy Case (Upgraded)	0.14	0.00	0.33	0.00	(0.51)	(0.48)	7.62	0.55	2.96	(0.82)	2.09	69.86	46.83	0.05	18.33	1.02

Wind Shear System	ERI	EVV	EWR	FAR	FAY	FLL	FNT	FSD	FSM	FWA	GCN	GEG	GFK	GPT	GRB	GRR
	NoWS	NoWS	TDWR	NoWS	LLWAS	TDWR	NoWS	LLWAS	LLWAS	WSP	NoWS	WSP	NoWS	NoWS	LLWAS	WSP
TDWR	N/A	N/A	4.00	N/A	N/A	17.95	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WSP	N/A	N/A	1.88	N/A	N/A	15.84	N/A	N/A	N/A	(0.21)	N/A	1.01	N/A	N/A	N/A	(0.29)
NEXRAD	(0.24)	(0.24)	0.52	(0.24)	(0.37)	18.82	0.04	0.26	(0.20)	(0.18)	(0.24)	1.70	(0.03)	(0.24)	(0.18)	0.30
LIDAR	(2.62)	(2.55)	0.42	(2.54)	(2.75)	3.10	(2.43)	(2.38)	(2.74)	(2.44)	(2.29)	(1.52)	(2.42)	(2.54)	(2.68)	(2.41)
LLWAS	(1.34)	(1.24)	1.84	(1.26)	(0.54)	9.68	(1.14)	(0.27)	(0.51)	(1.07)	(1.11)	(0.33)	(1.15)	(1.09)	(0.51)	(1.14)
X-Band	(6.29)	(6.08)	(0.37)	(6.12)	(6.35)	13.46	(5.87)	(5.83)	(6.32)	(5.72)	(5.80)	(4.41)	(5.86)	(5.76)	(6.29)	(5.82)
TDWR & NEXRAD	N/A	N/A	3.76	N/A	N/A	17.93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDWR, NEXRAD, LLWAS	N/A	N/A	2.50	N/A	N/A	16.73	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDWR & LIDAR	N/A	N/A	1.46	N/A	N/A	15.42	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDWR & LLWAS	N/A	N/A	2.74	N/A	N/A	16.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WSP & NEXRAD	N/A	N/A	1.63	N/A	N/A	16.10	N/A	N/A	N/A	(0.45)	N/A	0.97	N/A	N/A	N/A	(0.49)
WSP & LIDAR	N/A	N/A	(0.13)	N/A	N/A	13.66	N/A	N/A	N/A	(2.80)	N/A	(1.42)	N/A	N/A	N/A	(2.90)
WSP & LLWAS	N/A	N/A	0.87	N/A	N/A	14.76	N/A	N/A	N/A	(1.53)	N/A	(0.24)	N/A	N/A	N/A	(1.63)
WSP, NEXRAD, LIDAR	N/A	N/A	(0.37)	N/A	N/A	13.68	N/A	N/A	N/A	(3.04)	N/A	(1.65)	N/A	N/A	N/A	(3.14)
WSP, NEXRAD, LLWAS	N/A	N/A	0.63	N/A	N/A	14.94	N/A	N/A	N/A	(1.77)	N/A	(0.36)	N/A	N/A	N/A	(1.84)
NEXRAD & LIDAR	(2.86)	(2.79)	0.18	(2.78)	(2.99)	16.81	(2.44)	(2.35)	(2.86)	(2.63)	(2.53)	(0.88)	(2.48)	(2.77)	(2.83)	(2.36)
NEXRAD & LLWAS	(1.57)	(1.47)	1.95	(1.48)	(0.77)	18.16	(1.22)	(0.18)	(0.66)	(1.24)	(1.30)	0.40	(1.25)	(1.30)	(0.64)	(1.06)
X-Band & LIDAR	(8.94)	(8.73)	(2.91)	(8.77)	(9.01)	11.03	(8.52)	(8.46)	(8.97)	(8.36)	(8.44)	(7.00)	(8.51)	(8.40)	(8.94)	(8.47)
X-Band & LLLWAS	(7.65)	(7.44)	(1.59)	(7.48)	(6.96)	12.52	(7.22)	(6.42)	(6.92)	(7.07)	(7.15)	(5.71)	(7.22)	(7.11)	(6.90)	(7.18)
TDWR,NEXRAD,LIDAR	N/A	N/A	1.21	N/A	N/A	15.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Legacy Case (Upgraded)	0.00	0.00	4.00	0.00	(0.54)	17.95	0.00	(0.27)	(0.51)	(0.21)	0.00	1.01	0.00	0.00	(0.51)	(0.29)

Wind Shear System	GSO	GSP	HNL	HOU	HPN	HSV	IAD	IAH	ICT	ILM	IND	ISP	JAN	JAX	JFK	LAN
	WSP	LLWAS	WSP	TDWR	WSP	WSP	TDWR	TDWR	TDWR	NoWS	TDWR	WSP	LLWAS	WSP	TDWR	LLWAS
TDWR	N/A	N/A	N/A	9.58	N/A	N/A	9.22	38.65	(0.83)	N/A	6.05	N/A	N/A	N/A	9.71	N/A
WSP	0.32	N/A	2.56	7.35	(0.44)	(0.31)	6.03	34.22	(2.52)	N/A	4.16	(0.21)	N/A	4.47	7.05	N/A
NEXRAD	(0.20)	(0.13)	0.29	11.22	(0.29)	(0.27)	9.79	32.70	0.88	0.02	7.78	0.46	0.33	5.76	1.54	(0.35)
LIDAR	(2.29)	(2.72)	(1.63)	0.94	(2.51)	(2.57)	2.68	10.32	(2.33)	(2.59)	0.60	(2.25)	(2.49)	(0.66)	3.58	(2.65)
LLWAS	(0.80)	(0.49)	0.51	5.03	(1.22)	(1.16)	4.59	21.32	(0.89)	(1.22)	3.02	(1.05)	(0.17)	1.85	4.95	(0.47)
X-Band	(5.44)	(6.25)	(3.08)	5.05	(5.98)	(5.88)	4.04	32.38	(5.21)	(6.04)	1.71	(5.65)	(5.82)	(0.38)	5.23	(6.22)
TDWR & NEXRAD	N/A	N/A	N/A	9.42	N/A	N/A	9.03	38.74	(1.07)	N/A	5.93	N/A	N/A	N/A	9.47	N/A
TDWR, NEXRAD, LLWAS	N/A	N/A	N/A	8.16	N/A	N/A	7.80	37.73	(2.41)	N/A	4.63	N/A	N/A	N/A	8.25	N/A
TDWR & LIDAR	N/A	N/A	N/A	6.98	N/A	N/A	6.69	36.23	(3.47)	N/A	3.49	N/A	N/A	N/A	7.14	N/A
TDWR & LLWAS	N/A	N/A	N/A	8.34	N/A	N/A	8.01	37.75	(2.18)	N/A	4.81	N/A	N/A	N/A	8.49	N/A
WSP & NEXRAD	0.08	N/A	2.32	7.81	(0.68)	(0.55)	6.81	35.97	(2.66)	N/A	4.27	(0.33)	N/A	4.99	6.80	N/A
WSP & LIDAR	(2.25)	N/A	(0.03)	5.07	(3.05)	(2.94)	4.85	33.08	(5.06)	N/A	1.76	(2.72)	N/A	2.12	5.47	N/A
WSP & LLWAS	(0.99)	N/A	1.26	6.26	(1.78)	(1.66)	5.50	34.10	(3.82)	N/A	3.02	(1.50)	N/A	3.47	6.30	N/A
WSP, NEXRAD, LIDAR	(2.49)	N/A	(0.27)	5.22	(3.29)	(3.18)	4.85	34.18	(5.27)	N/A	1.66	(2.95)	N/A	2.35	5.23	N/A
WSP, NEXRAD, LLWAS	(1.23)	N/A	1.02	6.55	(2.02)	(1.90)	5.86	35.27	(3.99)	N/A	3.01	(1.67)	N/A	3.69	6.06	N/A
NEXRAD & LIDAR	(2.53)	(2.79)	(1.87)	8.68	(2.74)	(2.81)	8.17	32.17	(1.72)	(2.61)	5.18	(2.17)	(2.32)	3.12	3.34	(2.89)
NEXRAD & LLWAS	(0.97)	(0.60)	0.40	10.08	(1.43)	(1.37)	9.26	35.69	(0.43)	(1.31)	6.56	(0.89)	(0.12)	4.46	5.43	(0.69)
X-Band & LIDAR	(8.01)	(8.90)	(5.71)	2.55	(8.63)	(8.52)	2.22	31.18	(7.83)	(8.68)	(0.89)	(8.29)	(8.43)	(3.02)	2.77	(8.87)
X-Band & LLLWAS	(6.65)	(6.85)	(4.33)	3.96	(7.34)	(7.22)	3.29	32.66	(6.53)	(7.39)	0.47	(7.00)	(6.39)	(1.66)	4.09	(6.82)
TDWR,NEXRAD,LIDAR	N/A	N/A	N/A	6.78	N/A	N/A	6.45	36.19	(3.72)	N/A	3.27	N/A	N/A	N/A	6.89	N/A
Legacy Case (Upgraded)	0.32	(0.49)	2.56	9.58	(0.44)	(0.31)	9.22	38.65	(0.83)	0.00	6.05	(0.21)	(0.17)	4.47	9.71	(0.47)

Wind Shear System	LAS	LAX	LBB	LEX	LFT	LGA	LGB	LIT	LNK	MAF	MBS	MCI	MCO	MDT	MDW	MEM
	TDWR	WSP	WSP	LLWAS	NoWS	TDWR&LLWAS	NoWS	LLWAS	LLWAS	LLWAS	NoWS	TDWR	TDWR&LLWAS	WSP	TDWR	TDWR
TDWR	22.63	N/A	N/A	N/A	N/A	1.29	N/A	N/A	N/A	N/A	N/A	10.16	48.04	N/A	8.51	14.30
WSP	17.71	2.88	0.17	N/A	N/A	(2.42)	(2.67)	N/A	N/A	N/A	N/A	8.22	45.11	(0.74)	0.23	10.63
NEXRAD	3.77	0.31	0.76	(0.35)	(0.24)	0.02	(0.24)	1.55	(0.24)	0.31	(0.24)	3.36	9.87	(0.35)	9.94	15.86
LIDAR	17.83	(0.78)	(2.30)	(2.71)	(2.54)	(0.99)	(2.30)	(1.97)	(2.70)	(2.57)	(2.60)	1.75	13.26	(2.71)	2.54	4.37
LLWAS	13.75	0.85	(0.86)	(0.48)	(1.10)	1.44	(0.73)	0.56	(0.47)	(0.22)	(1.30)	5.25	41.86	(1.39)	4.24	7.59
X-Band	13.11	(2.34)	(5.34)	(6.24)	(5.77)	(3.11)	(5.11)	(4.64)	(6.28)	(5.80)	(6.21)	5.73	43.56	(6.30)	4.00	9.27
TDWR & NEXRAD	22.39	N/A	N/A	N/A	N/A	1.05	N/A	N/A	N/A	N/A	N/A	9.92	47.82	N/A	8.28	14.12
TDWR, NEXRAD, LLWAS	22.75	N/A	N/A	N/A	N/A	0.63	N/A	N/A	N/A	N/A	N/A	8.67	48.36	N/A	7.01	12.90
TDWR & LIDAR	24.22	N/A	N/A	N/A	N/A	(1.34)	N/A	N/A	N/A	N/A	N/A	7.54	45.58	N/A	5.88	11.70
TDWR & LLWAS	22.99	N/A	N/A	N/A	N/A	0.87	N/A	N/A	N/A	N/A	N/A	8.91	48.58	N/A	7.24	13.09
WSP & NEXRAD	17.46	2.64	(0.01)	N/A	N/A	(2.67)	(2.91)	N/A	N/A	N/A	N/A	8.01	44.95	(0.98)	6.36	12.42
WSP & LIDAR	22.91	0.67	(2.43)	N/A	N/A	(3.76)	(4.95)	N/A	N/A	N/A	N/A	5.84	43.56	(3.36)	0.97	9.41
WSP & LLWAS	19.73	1.78	(1.16)	N/A	N/A	(2.82)	(3.66)	N/A	N/A	N/A	N/A	7.09	45.28	(2.08)	1.99	10.24
WSP, NEXRAD, LIDAR	22.67	0.43	(2.65)	N/A	N/A	(4.00)	(5.19)	N/A	N/A	N/A	N/A	5.64	43.38	(3.60)	4.09	9.92
WSP, NEXRAD, LLWAS	19.49	1.54	(1.36)	N/A	N/A	(3.06)	(3.90)	N/A	N/A	N/A	N/A	6.89	45.14	(2.32)	5.27	11.25
NEXRAD & LIDAR	17.58	(1.02)	(1.88)	(2.95)	(2.78)	(1.23)	(2.54)	(1.09)	(2.86)	(2.34)	(2.84)	2.87	13.56	(2.95)	7.66	13.42
NEXRAD & LLWAS	15.04	0.85	(0.58)	(0.70)	(1.30)	0.90	(0.90)	1.12	(0.67)	(0.14)	(1.53)	6.38	43.62	(1.63)	8.84	14.79
X-Band & LIDAR	17.33	(4.80)	(8.00)	(8.89)	(8.41)	(5.70)	(7.68)	(7.21)	(8.93)	(8.45)	(8.86)	3.11	41.21	(8.95)	1.45	7.09
X-Band & LLLWAS	16.48	(3.55)	(6.69)	(6.84)	(7.12)	(4.41)	(6.37)	(5.17)	(6.88)	(6.39)	(7.57)	4.52	43.42	(7.65)	2.82	8.45
TDWR,NEXRAD,LIDAR	22.48	N/A	N/A	N/A	N/A	(1.59)	N/A	N/A	N/A	N/A	N/A	7.30	45.34	N/A	5.64	11.48
Legacy Case (Upgraded)	22.63	2.88	0.17	(0.48)	0.00	0.87	0.00	0.56	(0.47)	(0.22)	0.00	10.16	48.58	(0.74)	8.51	14.30

Wind Shear System	MGM	MHT	MIA	MKE	MLI	MLU	MOB	MSN	MSP	MSY	MYR	OAK	OKC	OMA	ONT
	LLWAS	NoWS	TDWR	TDWR	LLWAS	LLWAS	LLWAS	WSP	TDWR	TDWR&LLWAS	NoWS	NoWS	TDWR	LLWAS	WSP
TDWR	N/A	N/A	31.05	3.13	N/A	N/A	N/A	N/A	9.21	5.67	N/A	N/A	(0.02)	N/A	N/A
WSP	N/A	(3.16)	27.74	0.68	N/A	N/A	N/A	(0.31)	6.99	3.70	N/A	(3.10)	(1.70)	N/A	0.54
NEXRAD	(0.35)	(0.24)	32.71	1.14	(0.04)	(0.35)	0.08	(0.26)	10.76	4.92	0.12	(0.24)	1.73	1.58	(0.07)
LIDAR	(2.69)	(2.31)	7.05	(0.06)	(2.64)	(2.71)	(2.64)	(2.50)	2.18	(0.40)	(2.54)	(2.47)	(2.05)	(1.94)	(2.02)
LLWAS	(0.49)	(1.03)	17.37	1.31	(0.41)	(0.44)	(0.36)	(1.13)	4.75	2.94	(1.17)	(1.16)	(0.43)	0.43	(0.62)
X-Band	(6.23)	(5.63)	26.67	(1.45)	(6.18)	(6.21)	(6.03)	(5.82)	4.72	1.16	(5.96)	(5.93)	(4.38)	(4.49)	(4.97)
TDWR & NEXRAD	N/A	N/A	31.53	2.90	N/A	N/A	N/A	N/A	8.98	5.51	N/A	N/A	(0.25)	N/A	N/A
TDWR, NEXRAD, LLWAS	N/A	N/A	30.46	1.60	N/A	N/A	N/A	N/A	7.72	5.12	N/A	N/A	(1.59)	N/A	N/A
TDWR & LIDAR	N/A	N/A	28.71	0.53	N/A	N/A	N/A	N/A	6.61	3.07	N/A	N/A	(2.65)	N/A	N/A
TDWR & LLWAS	N/A	N/A	30.26	1.84	N/A	N/A	N/A	N/A	7.96	5.30	N/A	N/A	(1.35)	N/A	N/A
WSP & NEXRAD	N/A	(3.40)	29.71	0.49	N/A	N/A	N/A	(0.54)	7.25	3.75	N/A	(3.34)	(1.82)	N/A	0.30
WSP & LIDAR	N/A	(5.42)	26.12	(1.12)	N/A	N/A	N/A	(2.89)	4.92	1.36	N/A	(5.69)	(4.24)	N/A	(2.01)
WSP & LLWAS	N/A	(4.28)	27.34	(0.25)	N/A	N/A	N/A	(1.63)	5.98	2.61	N/A	(4.43)	(3.00)	N/A	(0.76)
WSP, NEXRAD, LIDAR	N/A	(5.66)	27.34	(1.35)	N/A	N/A	N/A	(3.13)	4.80	1.28	N/A	(5.93)	(4.45)	N/A	(2.25)
WSP, NEXRAD, LLWAS	N/A	(4.52)	28.67	(0.43)	N/A	N/A	N/A	(1.87)	6.07	2.61	N/A	(4.67)	(3.16)	N/A	(1.00)
NEXRAD & LIDAR	(2.92)	(2.55)	30.48	0.32	(2.69)	(2.95)	(2.57)	(2.73)	8.35	2.84	(2.48)	(2.71)	(0.89)	(0.93)	(2.26)
NEXRAD & LLWAS	(0.70)	(1.22)	32.20	1.74	(0.50)	(0.68)	(0.37)	(1.33)	9.62	5.39	(1.20)	(1.38)	0.41	1.20	(0.79)
X-Band & LIDAR	(8.88)	(8.26)	24.44	(3.85)	(8.82)	(8.86)	(8.68)	(8.46)	2.18	(1.30)	(8.57)	(8.56)	(7.01)	(7.11)	(7.59)
X-Band & LLLWAS	(6.83)	(6.97)	26.12	(2.62)	(6.77)	(6.80)	(6.63)	(7.17)	3.54	(0.03)	(7.29)	(7.28)	(5.70)	(5.05)	(6.29)
TDWR,NEXRAD,LIDAR	N/A	N/A	28.97	0.28	N/A	N/A	N/A	N/A	6.36	2.88	N/A	N/A	(2.90)	N/A	N/A
Legacy Case (Upgraded)	(0.49)	0.00	31.05	3.13	(0.41)	(0.44)	(0.36)	(0.31)	9.21	5.30	0.00	0.00	(0.02)	0.43	0.54

Wind Shear System	ORD	ORF	ORL	PBI	PDK	PDX	PHF	PHL	PHX	PIA	PIE	PIT	PNS	PVD	PWM	RDU
	TDWR&LLWAS	WSP	NoWS	TDWR	NoWS	WSP	NoWS	TDWR	TDWR	LLWAS	NoWS	TDWR	LLWAS	LLWAS	NoWS	TDWR
TDWR	63.41	N/A	0.78	3.90	0.82	N/A	N/A	6.61	9.94	N/A	1.95	0.58	N/A	N/A	N/A	1.60
WSP	53.69	0.03	(3.15)	(2.79)	(3.53)	1.11	N/A	3.69	7.86	N/A	(2.55)	(1.27)	N/A	N/A	(3.56)	(0.37)
NEXRAD	54.05	(0.18)	(0.24)	0.54	0.32	0.01	0.12	1.00	12.17	(0.28)	1.42	2.37	(0.26)	0.42	(0.02)	3.16
LIDAR	32.20	(2.29)	(2.53)	(1.09)	(2.50)	(1.95)	(2.53)	1.64	1.60	(2.67)	(2.36)	(1.59)	(2.45)	(2.36)	(2.50)	(1.38)
LLWAS	51.04	(0.89)	(1.05)	1.82	(1.04)	(0.30)	(1.18)	3.37	5.38	(0.46)	(0.62)	(0.10)	(0.03)	(0.14)	(1.23)	0.45
X-Band	57.03	(5.45)	(5.68)	(0.39)	(5.65)	(4.70)	(5.99)	1.97	5.67	(6.22)	(4.74)	(5.69)	(5.33)	(5.65)	(6.05)	(3.08)
TDWR & NEXRAD	63.52	N/A	0.54	3.66	0.58	N/A	N/A	6.38	10.39	N/A	1.75	0.36	N/A	N/A	N/A	1.37
TDWR, NEXRAD, LLWAS	64.63	N/A	(0.81)	2.43	(0.78)	N/A	N/A	5.26	9.18	N/A	0.40	(0.98)	N/A	N/A	N/A	0.05
TDWR & LIDAR	61.51	N/A	(1.87)	1.34	(1.84)	N/A	N/A	4.28	7.64	N/A	(0.69)	(2.05)	N/A	N/A	N/A	(1.03)
TDWR & LLWAS	64.66	N/A	(0.57)	2.67	(0.54)	N/A	N/A	5.49	8.88	N/A	0.61	(0.75)	N/A	N/A	N/A	0.28
WSP & NEXRAD	56.38	(0.20)	(3.39)	(3.04)	(3.10)	0.87	N/A	3.47	8.70	N/A	(1.73)	(1.20)	N/A	N/A	(3.54)	(0.29)
WSP & LIDAR	58.67	(2.48)	(5.66)	(4.66)	(5.99)	(1.45)	N/A	2.51	5.89	N/A	(4.90)	(3.69)	N/A	N/A	(6.03)	(2.67)
WSP & LLWAS	59.21	(1.25)	(4.30)	(1.75)	(4.50)	(0.18)	N/A	3.12	7.04	N/A	(3.43)	(2.48)	N/A	N/A	(4.75)	(1.54)
WSP, NEXRAD, LIDAR	59.34	(2.72)	(5.90)	(4.90)	(5.66)	(1.69)	N/A	2.29	6.29	N/A	(4.38)	(3.85)	N/A	N/A	(6.08)	(2.83)
WSP, NEXRAD, LLWAS	60.85	(1.49)	(4.54)	(1.99)	(4.38)	(0.42)	N/A	2.90	7.55	N/A	(3.08)	(2.54)	N/A	N/A	(4.85)	(1.57)
NEXRAD & LIDAR	60.23	(2.52)	(2.77)	(1.33)	(2.26)	(2.19)	(2.49)	1.43	9.82	(2.85)	(1.24)	(0.29)	(2.69)	(2.18)	(2.59)	0.65
NEXRAD & LLWAS	63.81	(1.07)	(1.25)	1.84	(0.96)	(0.49)	(1.22)	3.69	11.09	(0.66)	0.06	1.03	(0.18)	(0.01)	(1.35)	1.95
X-Band & LIDAR	56.94	(8.03)	(8.31)	(2.97)	(8.29)	(7.26)	(8.61)	(0.09)	3.34	(8.87)	(7.37)	(7.64)	(7.97)	(8.29)	(8.70)	(5.48)
X-Band & LLLWAS	59.01	(6.76)	(7.02)	(1.62)	(7.00)	(5.88)	(7.33)	1.07	4.75	(6.82)	(6.07)	(6.12)	(5.91)	(6.24)	(7.41)	(4.22)
TDWR,NEXRAD,LIDAR	61.45	N/A	(2.11)	1.09	(2.08)	N/A	N/A	4.03	7.85	N/A	(0.91)	(2.30)	N/A	N/A	N/A	(1.28)
Legacy Case (Upgraded)	64.66	0.03	0.00	3.90	0.00	1.11	0.00	6.61	9.94	(0.46)	0.00	0.58	(0.03)	(0.14)	0.00	1.60

Wind Shear System	RIC	RNO	ROA	ROC	RST	RSW	SAN	SAT	SAV	SBN	SDF	SEA	SFB	SFO	SGF	SHV
	WSP	NoWS	LLWAS	WSP	LLWAS	LLWAS	NoWS	WSP	LLWAS	NoWS	TDWR	WSP	NoWS	LLWAS	LLWAS	LLWAS
TDWR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.35	N/A	2.78	N/A	N/A	N/A
WSP	0.18	N/A	N/A	0.09	N/A	N/A	(3.41)	2.58	N/A	N/A	0.10	0.84	N/A	N/A	N/A	N/A
NEXRAD	0.31	(0.24)	(0.34)	(0.18)	(0.37)	(0.02)	(0.24)	3.12	(0.04)	(0.23)	4.04	(0.05)	(0.24)	(0.31)	0.18	0.16
LIDAR	(2.22)	(0.62)	(2.69)	(2.30)	(2.74)	(1.87)	(2.36)	(1.13)	(2.45)	(2.50)	(0.87)	(1.78)	(2.29)	(2.52)	(2.59)	(2.60)
LLWAS	(0.80)	0.10	(0.44)	(0.92)	(0.54)	1.31	(0.90)	0.55	0.05	(1.19)	0.88	(0.44)	(0.32)	(0.28)	(0.35)	(0.32)
X-Band	(5.31)	(4.34)	(6.24)	(5.43)	(6.35)	(2.73)	(5.44)	(2.80)	(5.34)	(5.98)	(2.35)	(4.60)	(4.11)	(6.02)	(5.93)	(5.95)
TDWR & NEXRAD	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.13	N/A	2.54	N/A	N/A	N/A
TDWR, NEXRAD, LLWAS	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.81	N/A	1.20	N/A	N/A	N/A
TDWR & LIDAR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(0.28)	N/A	0.14	N/A	N/A	N/A
TDWR & LLWAS	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.03	N/A	1.44	N/A	N/A	N/A
WSP & NEXRAD	(0.02)	N/A	N/A	(0.15)	N/A	N/A	(3.65)	2.43	N/A	N/A	0.48	0.60	N/A	N/A	N/A	N/A
WSP & LIDAR	(2.31)	N/A	N/A	(2.51)	N/A	N/A	(5.69)	0.13	N/A	N/A	(1.98)	(1.64)	N/A	N/A	N/A	N/A
WSP & LLWAS	(1.09)	N/A	N/A	(1.24)	N/A	N/A	(4.26)	1.34	N/A	N/A	(0.95)	(0.42)	N/A	N/A	N/A	N/A
WSP, NEXRAD, LIDAR	(2.53)	N/A	N/A	(2.75)	N/A	N/A	(5.93)	(0.07)	N/A	N/A	(2.07)	(1.88)	N/A	N/A	N/A	N/A
WSP, NEXRAD, LLWAS	(1.31)	N/A	N/A	(1.48)	N/A	N/A	(4.50)	1.17	N/A	N/A	(0.80)	(0.66)	N/A	N/A	N/A	N/A
NEXRAD & LIDAR	(2.06)	(0.86)	(2.93)	(2.54)	(2.98)	(2.11)	(2.60)	0.71	(2.51)	(2.74)	1.49	(2.02)	(2.53)	(2.76)	(2.47)	(2.49)
NEXRAD & LLWAS	(0.74)	(0.07)	(0.68)	(1.10)	(0.77)	1.26	(1.10)	1.90	(0.05)	(1.41)	2.77	(0.58)	(0.45)	(0.53)	(0.28)	(0.29)
X-Band & LIDAR	(7.86)	(6.22)	(8.89)	(8.08)	(9.01)	(5.36)	(8.05)	(5.43)	(7.93)	(8.62)	(4.70)	(7.20)	(6.73)	(8.62)	(8.58)	(8.60)
X-Band & LLLWAS	(6.60)	(5.17)	(6.82)	(6.79)	(6.96)	(3.26)	(6.75)	(4.11)	(5.89)	(7.34)	(3.47)	(5.91)	(5.41)	(6.57)	(6.53)	(6.55)
TDWR,NEXRAD,LIDAR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	(0.52)	N/A	(0.10)	N/A	N/A	N/A
Legacy Case (Upgraded)	0.18	0.00	(0.44)	0.09	(0.54)	1.31	0.00	2.58	0.05	0.00	2.35	0.84	0.00	(0.28)	(0.35)	(0.32)