FLORIDA DEPARTMENT OF TRANSPORTATION
AVIATION AND SPACEPORTS OFFICE

Operations Counting at Non-Towered Airports Assessment

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FDOT

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INTRODUCTION

The Florida Department of Transportation (FDOT) Aviation and Spaceports Office has initiated this report to better understand best practices that non-towered and part-time towered airports can implement to determine annual operations counts. The Federal Aviation Administration (FAA), FDOT, and airports use operations counts for several reasons including the justification of airport improvement projects, construction of air traffic control towers and navigational aids, to develop airport environmental documents, forecasts, economic impact statements, and performance measures, to update the FAA's Airport Master Record Form 5010, and to inform system plans and master plans.

The Transportation Research Board's (TRB) Airport Cooperative Research Program (ACRP) Report 129 provides national guidance on evaluation methods for counting aircraft operations at non-towered airports. Based on the unique requirements at Florida airports, the magnitude of aviation activity, and the number of general aviation airports, the FDOT Aviation and Spaceports Office commissioned this study to assess the capabilities of technology and equipment options for sampling aircraft operations using a generally accepted methodology as well as to explore two non-sampling methods. Through this project, FDOT compared and analyzed TRB's recommended techniques and technologies in the Florida context. The findings of this report are intended to help FDOT and Florida's airport better prepare annual operations counts.

TRB ACRP guidance is promulgated through two studies: ***ACRP Synthesis 4 - Counting Aircraft Operations at Non-Towered Airports*** (ACRP Synthesis 4) and ***ACRP Report 129 - Evaluating Methods for Counting Aircraft Operations at Non-Towered Airports*** (ACRP Report 129). Completed in 2007, ACRP Synthesis 4 is a nationwide survey and review of the existing estimation methods and counting technologies used to determine aircraft operations at non-towered airports. ACRP Report 129, completed in 2015, is a field test of operations estimation methods and operations counting technologies.

The purpose of this study is to explore the application of different technologies and methods to count aircraft operations at non-towered airports in Florida. Study results provide an understanding of the types of technologies and methods that are most applicable and accurate for Florida's different types of airports and aviation activities.

FDOT used the TRB's best practices presented in ACRP Report 129 to develop a Florida specific approach to assess aircraft operations technologies and estimation methods at non-towered airports. ACRP Report 129 examines the following techniques and technologies:

- Techniques:
  - IFR Flight Plans: evaluates the statistical relationship between Instrument Flight Rules (IFR) / Traffic Flow Management System Count (TFMSC) flight plans and total Terminal Area Forecast (TAF) operations recorded

- Florida Variables: evaluates the following factors for correlation to operations: number of based aircraft, number of runways, maximum runway length, population within a 30-minute drive to the airport
- Technologies:
  - General Audio Recording Device (G.A.R.D.): a software that monitors an airport's Unicom frequency to identify and record airport traffic
  - Acoustic Aircraft Detection System (ADS Phoenix): a technology that analyses acoustic signals for the sound of a takeoff to estimate the number of aircraft operations
  - Infrared Trail Cameras (Trail Camera): are motion activated cameras
  - Vector Airport Systems (Vector)[1]: a video image detection (VID) system

Technologies were implemented over several months at various airports throughout Florida, capturing a range of weather conditions, activities, and airport configurations among other factors. This report details the background research, project approach, and study findings.

STUDY PURPOSE

Aircraft operation counts are important data used in developing airport master plans, aviation system plans, and environmental studies. More importantly, operation counts are vital for determining design and funding criteria. Because of this, an airport's volume and type of operations determine critical aircraft for design purposes, infrastructure needs and demands, and potential for revenue generation and budgeting, and are a factor in State and Federal funding decisions and community concerns and compatibility.

At airports with air traffic control towers (ATCT), air traffic controllers track and record aircraft operations data. However, it is much more difficult to collect these data at airports without ATCTs (also known as non-towered airports), or at airports with towers only open part of the day (part-time towered airports). As such, non-towered and part-time towered airports do not have a complete understanding of the frequency and type of aircraft operations occurring at their airport. *These airports need an understanding of the cost, accuracy, and complexity of various operations counting options in order to select the most appropriate method for their needs.*

BACKGROUND

Numerous operation estimates are currently publicly available but do not necessarily match the activity that is occurring at airports, making it difficult to know which estimates are accurate. Moreover, no single method estimates total annual operations at non-towered airports with 100 percent accuracy, and existing methods can be time consuming and/or expensive. The gap in understanding of annual aircraft operations at non-towered airports makes the planning process difficult, especially for master plan forecasts and FAA approval of forecasts. The TRB ACRP began researching and testing aircraft operations counting methods and technology to better

[1] *Vector was already installed at two airports in Florida (Witham Field and Venice Municipal Airport). This project only verified the accuracy of the previously installed systems.*

understand and evaluate operations counting methodologies and technologies for non-towered airports.

ACRP Synthesis 4 is the foundation for operations counting projects at non-towered airports, and summarizes the different methods and technologies used by states, airports, and metropolitan planning organizations (MPOs) to count and/or estimate aircraft operations at non-towered airports. ACRP Synthesis 4 was developed first as an initial data gathering effort in which several airports were questioned for information regarding the methodologies they use for counting and estimating aircraft operations. This effort consisted of a questionnaire and literature review. ACRP Report 129 builds on ACRP Synthesis 4 by field testing the previously identified operations estimation methods and technologies for counting aircraft operations. The findings of these studies work cooperatively to analyze, explain, and recommend potential operations counting and estimating methodologies at non-towered airports. Figure 1 summarizes the relationship between the two reports, and the remainder of this section highlights the outcomes of those reports.

	Study	
	ACRP Synthesis 4	**ACRP Report 129**
Purpose	Identify aircraft counting and estimation methods used by non-towered airports	Test and evaluate aircraft counting and estimation methods used by non-towered airports
Method	Literature review and questionnaire	Performed 3 methods of estimating annual operations and 4 counting technology assessments
Sample	61 airports, 51 respondents - 84% response rate	Multiple nonhub airports with FAA Visual Flight Rule (VFR) towers and less than 730 carrier operations per year (defined in the study as the small, towered airport dataset - STAD)
Conclusion	Most accurate and cost effective method is to sample traffic for 2 weeks for each of the 4 seasons and extrapolate into an annual estimate	No practical or consistent Operations per Based Aircraft (OPBA) found. Recommends taking a sample count of actual operations and extrapolating with a statistical process or by use of seasonal/monthly adjustment factors Airports should select counting methods based on varying situations/characteristics

Figure 1. TRB ACRP Research Comparison

TRANSPORTATION RESEARCH BOARD ACRP SYNTHESIS 4, 2007

ACRP Synthesis 4 was published in 2007 and provided the foundation for all future research projects regarding counting methodologies at non-towered airports. Synthesis 4 included a significant research and data collection effort that ultimately provided the basis for the operations counting methodologies to be tested. This research and data collection effort included a literature review and questionnaire.

Literature Review

After a comprehensive search for relevant data and publications, a review of over 20 documents was completed to provide a foundation for the research in Synthesis 4. Major findings of the literature review include:

- The preferred method of counting aircraft is acoustical counters
- Collecting data for two-week periods in each of the four seasons is the most statistically acceptable form of sampling
- There are numerous operations counting and estimating methodologies being used throughout the Country, making the accuracy and, therefore, the results unknown
- Weather is not a good predictor of aircraft operations
- It is unclear if fuel sales or estimating operations based on a towered airport are useful predictors of operations

Questionnaire

A comprehensive survey was developed and distributed as part of Synthesis 4 to determine what methods were being used to estimate aircraft operations at non-towered airports. These surveys were sent to all 50 state aviation agencies, seven airports, and four metropolitan/regional planning organizations. Overall, there was an 84 percent response rate to the survey. Ultimately, the findings of this survey provided information critical to understanding how counting methodologies are actually being utilized around the country.

Synthesis 4 Findings

ACRP Synthesis 4 discovered that there is significant variation in how airports collect and estimate operations data, with airports around the country mainly using the following estimation methods:

1. *Year-round operations count*
2. *Sampling operations and extrapolating for an annual estimate*
3. *Multiplying a predetermined number of operations per based aircraft by the total based aircraft at the airport*
4. *Regression analysis*
5. *Asking the airport manager or other personnel for operations data*

Of these five estimation methods, ACRP Synthesis 4 concluded that deploying an aircraft traffic counter year-round would produce the most accurate operations count, as one might expect; however, continuous, year-round operations tracking is not always feasible for smaller airports with limited staff and funding. Considering this, as a next-best alternative to year-round counting, ACRP Synthesis 4 recommends sampling aircraft traffic for two weeks in each of the year's four seasons and extrapolating those samples into an annual estimate. This extrapolation method represents a more practical, cost-effective approach for small, non-towered airports.

ACRP Synthesis 4 reports methods most commonly used to sample aircraft operations include:

- Acoustical
    - Tape recorder acoustical counter
    - Automated acoustical counter
    - Sound-level meter acoustical counter
- Pneumonic
    - Tube counters
    - Inductance loop counter
- Video
    - Video image detection system
- Airport guest logs
- Fuel sales
- Visual

Additional methodologies noted include:

- Magnetometers
- Radar
- Aircraft navigation systems
- Automatic Dependent Surveillance – Broadcast (ADS-B)

Of these methods, ACRP Synthesis 4 concluded that the most accurate, efficient, and cost-effective methods for sampling aircraft traffic are either acoustical counters or video image detection systems. The report finds acoustical counters to be acceptably accurate and relatively low cost, while video image detection systems were slightly costlier, but also provided more aircraft information, such as tail numbers.

TRANSPORTATION RESEARCH BOARD ACRP REPORT 129, 2015

ACRP Report 129 was published in 2015 to build on the results of the research that was done as part of Synthesis 4 by looking at new research and evaluating the most current methodologies in aircraft operations counting and estimation. ACRP Report 129 specifically tested three operations estimation methods and four operations counting technologies. The three operations estimation methods are:

1. *Multiplying based aircraft by an estimated number of operations per based aircraft (OPBA)*
2. *Applying a ratio of FAA instrument flight plans to total operations (IFPTO)*
3. *Expanding a sample count into an annual estimate through extrapolation*

The four operations counting technologies are:

1. *Automated acoustical counters (Acoustic Aircraft Detection System)*
2. *Sound-level meter acoustical counters*
3. *Security/trail cameras (Infrared Trail Cameras and Vector)*
4. *Video image detection with transponder receiver*

Overview of Operation Estimation Methods[2]

ACRP Report 129 provides an analysis of three different methodologies for estimating annual operations at an airport. The methodologies under study are as follows:

- *Multiplying based aircraft by an estimated number of operations per based aircraft*
  - Report 129's analysis on OPBA resulted in unclear findings that could not be statistically verified. As stated in the report, "*While several different approaches were taken, including full model regression, reduced model regression, and transformation of the data, either the statistical assumptions necessary for the regression to be valid could not be met or there were extremely large variations from actual to estimated operations on the test airports. … Consequently, the research team cannot recommend using a standard number(s) of OPBA for estimating annual aircraft operations.*"
- *Applying a ratio of FAA flight plans to total operations*
  - Report 129's analysis of applying a ration of FAA flight plans to total operations resulted in non-significant findings. As stated in the report, *"…the research team concludes … there are no practical and consistent FAA flight plans to total operations found at small, towered airports that can be used to estimate annual operations at non-towered airports nationally or by climate region. Consequently, the research team cannot recommend using standard ratio(s) of instrument flight plans to total operations for estimating annual airport operations.*"
  - Using this methodology, it was noted that counting all instrument flight rule (IFR) operations (tracked by the FAA regardless of the presence of a tower) may allow an airport to compute a total number of operations based on the number of IFR operations that occur at that airport. It was noted that the frequency of the sampling could greatly alter the results, so it is important to ensure that the portion of IFR operations that are used as samples are representative of the operations that occur throughout the year.
- *Expanding a sample count into an annual estimate through extrapolation*
  - Two separate methods to extrapolate an annual estimate based on a sample of aircraft operations data. Both methods were run using the four counting methodologies described in the next section.
    - Method 1 – Statistical extrapolation that follows FAA Technical Report FAA-APO-85-7, Statistical Sampling of Aircraft Operations at Non-Towered Airports.
      - ◊ This analysis concluded that the "preferred statistical extrapolation method is to sample two weeks per season."
    - Method 2 – Use of regional monthly or seasonal adjustment factors based on small, towered airports.
      - ◊ Regional monthly analysis or seasonal adjustment factors: takes annual operations for each month and calculates monthly and seasonal factors for each region in the pre-defined small, towered airport dataset (STAD), extrapolates annual operations using the monthly and

[2] *Estimation and counting methods that are italicized were also studied in ACRP Synthesis 4*

seasonal factors from the STAD airports, and compares actual operations to the estimates.

In summary, ACRP Report 129 found no practical or consistent OPBAs or IFPTOs estimates based on study data. Like ACRP Synthesis 4, ACRP Report 129 recommends extrapolating a sample count of aircraft operations into an annual estimate. The main advantage of this method is that it allows for each airport, whether towered or not, to base operation estimates on its own sample data, resulting in a specifically tailored annual operations estimate.

Overview of Operation Counting Methods

ACRP Report 129 provides an analysis of four different counting technologies for counting annual operations at an airport. The methodologies under study are as follows:

- *Automated acoustical counter (AAC)*
  - This counting method records audio of aircraft takeoffs and calculates total operations by multiplying that number by two. It was noted in Report 129 that, *"…[these counters] are rugged, dependable, and can be left for months at a time even in below freezing temperatures when a solar panel option is used. On a typical single runway airport, the AAC offers a fairly accurate estimation of annual operations if multiple units are used and positioned properly.*"
  - It was determined that this technology is most accurate on runways that are less than 3,000 feet long. It was noted that longer runways require additional counters, which then requires duplicate recording to be manually removed, thus increasing the potential for human error.
  - Report 129 noted the fact that the AAC has difficulty recording quiet aircraft (ex: Cessna 172 with a Continental O-300 SER engine).
  - Though placing multiple AACs on a runway/airport yielded accuracy rates as high as 90 percent, Report 129 noted that, "*On average across all the airports when just one counter was used in the middle of the runway, the equipment caught less than 50 percent of the airport's traffic.*"
  - **The report also noted AAC** work best at single-runway airports with safety areas of 500 feet or less that do not experience significant traffic from exceptionally quiet aircraft, since AACs often miss these aircraft. AACs provide no detailed aircraft information.
- *Sound level meter acoustical counter (SMAC)*
  - Report 129 found that the results when using SMACs were very similar to the results when using AACs.
  - The report highlighted that SMACs had a shorter battery life than AACs and required frequent calibration.
  - Report 129 also found that, "*The SMAC is more impacted by distance from the runway centerline than the AAC. The farther away from the runway centerline, the more difficulty it had detecting takeoffs. For this same reason, it is a bit more likely to miss a touch-and-go than the AAC. However, at closer distances to the runway (e.g., 50 feet), it seems better at detecting takeoffs by the relatively quieter aircraft than the AAC. At 250 feet from the centerline, the research team was unable to achieve an acceptable level of performance."*

    - **The report found SMACs** work best at airports with single runways and runway safety areas of 150 feet or less. Like AACs, SMACs also often miss exceptionally quiet aircraft, record takeoffs only, and do not provide detailed aircraft information.
- Security/trail cameras (S/TC)
    - This type of operations counting methodology utilizes motion detection cameras to 'visually' track and record aircraft operations. One of the primary benefits of this method is that aircraft N-numbers can be collected, therefore, allowing aircraft makes and models to be analyzed.
    - It was noted that while an accuracy level of near 100 percent is possible for "recording aircraft entering or exiting the runway environment," this methodology is unable to count touch-and-go operations. Therefore, depending on the activity at an airport, this could cause significant variations in actual vs. recorded operations.
    - It was noted in Report 129 that one limitation of this methodology was the fact that once the operations are recorded, they must be manually totaled and summarized. This effort contributes to the pre-existing high level of work effort to achieve accurate operations counts.
    - **Security/trail cameras**: work best at airports with a centralized terminal and hangar area, limited access points, and little to no touch-and-go activity.
- Video image detection with transponder receiver (VID & ADS-B)
    - As noted in Report 129, the VID & ADS-B methodology is the most complete counting package, thus costing significantly more than any other methodology. Additionally, depending on the airfield configuration, additional cameras may be needed to accurately count aircraft operations.
    - It was noted that while an accuracy level of close to 90 percent is possible for "recording aircraft entering or exiting the runway environment," this methodology is unable to count touch-and-go operations. Therefore, depending on the activity at an airport, this could cause significant variations in actual vs. recorded operations.
    - Another limitation of this methodology is the fact that a large majority of the national GA fleet is not equipped with ADS-B transponders. Though there is a federal requirement that all GA aircraft must install this technology by 2020, currently, it is unclear how this will be implemented.
    - **The report notes that VID** works best at airports with centralized terminal and hangar areas, limited access points, and little to no touch-and-go activity.

APPROACH

Given Florida's unique aviation system and climate, FDOT Aviation and Spaceports Office undertook this study to evaluate the methods and technologies for operations counting implemented in ACRP Report 129 to see how they compare when implemented in Florida. To accomplish this, FDOT developed a methodology tailored to Florida that is based on the ACRP studies' findings. Technologies were similar to those from ACRP Report 129 as well as estimation methods using non-counting methodologies, such as instrument flight plans to total operations (IFPTO) and an approach based on the relationship between airport features and operations. A summary of the findings from the non-counting methodology can be found in **Non-Sampling Methods**.

FDOT obtained methodology validation from the ACRP Synthesis 4 and Report 129 project team before and during technology testing. During field preparation, FDOT consulted with the FAA because the agency is tasked with promoting air safety and the efficient use of navigable airspace and technology placement was of paramount concern. Equipment must not interfere with the airport operability, but must also be located for highest accuracy, based on technology capabilities.

The FAA approved equipment locations through the Notice of Proposed Construction or Alteration, FAA Form 7460-1. This is the FAA's formal process to approve any construction or alterations that may affect navigable airspace. Once FAA provided final determinations for Notices of Proposed Construction or Alteration, FDOT tested four types of equipment at a variety of non-towered and part time towered general aviation airports, summarized in Table 1.

Table 1. Airports and Technology Summary

Airport	Location	G.A.R.D.	AAC	Infrared Trail Camera	Vector
Lake Wales Municipal Airport	Lake Wales	X	X	X	
Arcadia Municipal Airport	Arcadia	X	X	X	
Okeechobee County Airport	Okeechobee	X	X	X	
Marion County Airport	Dunnellon	X	X	X	
Quincy Municipal Airport	Quincy	X	X	X	
Carrabelle Airport	Carrabelle		X	X	
Flagler Executive Airport	Bunnell	X	X	X	
Perry-Foley Airport	Perry	X	X	X	
Venice Municipal Airport	Venice				X
Witham Field	Stuart				X

The remaining sections of this report describe the methodology and study results in detail as follows:

- **Airports:** describes the airports selected for equipment testing
- **Technologies:** provides a detailed description of each technology tested
- **Analysis Steps:** describes in detail the approach taken to complete the study
- **Non-Sampling Methods:** summarizes non-counting estimation methods
- **Findings:** summarizes testing outcomes at each airport

AIRPORTS

FDOT selected airports in different geographic locations with varying characteristics for this study. This allowed FDOT to begin to understand the types of technology that work best for varying runway configurations, aircraft, activities, airport characteristics, and weather conditions. Table 2 summarizes the airports where testing occurred and their airport characteristics.

Table 2. Operations Equipment Testing Airports

Airport	City	Runway	Runway Length (feet)	Runway Width (feet)	Surface Type	Activities
Lake Wales Municipal Airport	Lake Wales	6/24	3,999	100	Asphalt	• Recreational flying and/or parachuting, ballooning • Agricultural spraying • Corporate/business activity • Aerial photography/surveying • Aerial inspections (pipeline, electric, etc.) • Promotional activities (open houses, air shows, fly-ins) • Military exercises/training • Career training/education • Flight training • Gateway for VIPs/high profile visitors • Staging area for community events • Police/law enforcement • Location for community facilities/utilities
		17/35	3,860	75	Asphalt	
Arcadia Municipal Airport	Arcadia	6/24	3,700	75	Asphalt	• Recreational flying and/or parachuting • Agricultural spraying • Corporate/business activity • Aerial photography/surveying • Promotional activities (open houses, air shows, fly-ins) • Aerial advertising/banner towing • Military exercises/training • Career training/education • Flight training • Emergency medical aviation • Staging area for community events • Police/law enforcement
		13/31	2,780	140	Turf	
Okeechobee County Airport	Okeechobee	5/23	5,000	100	Asphalt	• Agricultural spraying • Corporate/business activity • Aerial photography/surveying • Aerial inspections (pipeline, electric, etc.) • Military exercises/training • Flight training • Emergency medical aviation • Gateway for VIPs/high profile visitors
		14/32	4,001	75	Asphalt	

Airport	City	Runway	Runway Length (feet)	Runway Width (feet)	Surface Type	Activities
Marion County Airport	Dunnellon	5/23	5,000	100	Asphalt	• Parachute testing • Gateway for VIPs/high profile visitors • Disaster relief staging for electrical grid restoration
		10/28	4,702	60	Asphalt	
Quincy Municipal Airport	Quincy	14/32	2,964	75	Asphalt	• Recreational flying and/or parachuting • Agricultural spraying • Aerial advertising/banner towing • Search and rescue • Flight training • Emergency medical aviation • Preservation of open space/wetlands/woodlands
Carrabelle Airport	Carrabelle	5/23	4,000	75	Asphalt	• Recreational flying and/or parachuting • Corporate/business activity • Environmental patrol • Aerial photography/surveying • Aerial inspections (pipeline, electric, etc.) • Promotional activities (open houses, air shows, fly-ins) • Aerial/wildland firefighting • Military exercises/training • Search and rescue • Flight training • Emergency medical aviation • Staging area for community events • Police/law enforcement • Public charters • Preservation of open space/wetlands/woodlands • Real estate tours
Flagler Executive Airport	Bunnell	6/24	5,000	100	Asphalt	• Recreational flying and/or parachuting • Corporate/business activity • Environmental patrol • Aerial photography/surveying • Aerial inspections (pipeline, electric, etc.) • Aerial advertising/banner towing • Promotional activities (open houses, air shows, fly-ins) • Aerial/wildland firefighting • Military exercises/training • Career training/education • Search and rescue
		11/29	5,500	100	Asphalt	
		18W/36W	3,000	500	Water	

Airport	City	Runway	Runway Length (feet)	Runway Width (feet)	Surface Type	Activities
		H1	36	36	Concrete	• Flight training • Emergency medical aviation • Staging area for community events • Police/law enforcement • Preservation of open space/wetlands/woodlands
Perry-Foley Airport	Perry	12/30	4,754	100	Asphalt	• Agricultural spraying • Corporate/business activity • Aerial photography/surveying • Aerial inspections (pipeline, electric, etc.) • Aerial/wildland firefighting • Military exercises/training • Flight training • Emergency medical aviation • Gateway for VIPs/high profile visitors • Police/law enforcement • Preservation of open space/wetlands/woodlands • Prisoner transport • Real estate tours
		18/36	4,986	100	Asphalt	
Venice Municipal Airport	Venice	5/23	5,000	150	Asphalt	• Recreational flying and/or parachuting • Freight/cargo activity • Corporate/business activity • Environmental patrol • Aerial photography/surveying • Promotional activities (open houses, air shows, fly-ins) • Aerial/wildland firefighting • Military exercises/training • Shipping of perishable goods • Search and rescue • Flight training • Emergency medical aviation • Gateway for VIPs/high profile visitors • Staging area for community events • Police/law enforcement • Location for community facilities/utilities • Public charters • Real estate tours
		13/31	4,999	150	Asphalt	

Airport	City	Runway	Runway Length (feet)	Runway Width (feet)	Surface Type	Activities
Witham Field	Stuart	7/25	4,652	100	Asphalt	• Flight training • Recreational flying • Air taxis/charters • Business/corporate aviation • Law enforcement flights • Air ambulances • Experimental Aircraft Association • Air shows • Military aviation
		12/30	5,828	100	Asphalt	
		16/34	4,998	100	Asphalt	

TECHNOLOGIES

For this study, four different technologies were evaluated at Florida airports. Each of these technologies has different functions and abilities that provide a variety of different data related to aircraft operations. The following sections are a brief introduction and summary of the technologies that were evaluated by FDOT as part of this study.

GENERAL AUDIO RECORDING DEVICE (G.A.R.D.)

Developed by Invisible Intelligence, LLC, General Audio Recording Device (G.A.R.D.) software monitors an airport's Unicom frequency and uses automated speech recognition to identify and record airport traffic to a computer hard drive. The software uses an algorithm to analyze communication, and users input the estimated number of transmissions per arriving and departing aircraft. Based on user input and recordings, the software provides an estimated number of operations. The system must be in the same room as the Unicom and near a window. Metal roofs and white noise can affect system operation. The system currently advertises for $3,000 to $4,000.

Note: operations are an estimate based on the user's input of the estimated number of transmissions per aircraft. If the estimated number of transmissions is wrong, then the estimated number of operations is exponentially wrong.

AUTOMATED ACOUSTIC COUNTER (AIRCRAFT DETECTION SYSTEM 4000 PHOENIX)

Developed by Wilderness Technologies, Aircraft Detection System (ADS) 4000 Phoenix is an acoustic aircraft counter that analyses acoustic signals for unique features, identifying a specific type of event, like a takeoff, to estimate the number of aircraft operations on a runway. A microprocessor signals conditioning electronics, analyzes the data, and stores data in internal memory. If the technology detects a signal that meets the criteria for a take-off, the microprocessor stores the date and time of the event. The system records hourly and daily data. However, the technology does not record detailed aircraft information.

ACRP Report 129 found accuracy rates of 90 percent or higher when placed up to 250 feet from the runway centerline and approximately 700 feet from the aircraft lift-off point at an airport with no more than one runway. The report recommends multiple counters for runways measuring 3,000 feet or more, increasing the implementation costs. The technology often misses exceptionally quiet aircraft.

The developer created the technology for "back country", or rural, airports with short, turf runways. Therefore, the sound profile of take-offs in Florida may be different than the sound profile the technology was originally developed to detect. The technology costs $4,950 per unit.

INFRARED TRAIL CAMERAS

Airports with a centralized terminal and hangar areas and limited access points can accurately use motion activated security or trail cameras to estimate operations. Trail cameras monitor taxiways at each runway access point. FDOT used the same brand trail camera used by TRB ACRP because of the equipment's exceptional night vision distance: Reconyx Hyperfire Cellular Professional Cover Camera Trap. ACRP Report 129 reported accuracy levels approaching 100 percent at appropriate airports, but units did not capture touch-and-go activity on runways. The cameras may also miss slow moving aircraft. This technology requires manual review, increasing labor costs. However, airports can record detailed aircraft information, such as aircraft registration numbers and aircraft type. Trail cameras are a low-cost option, with an approximate cost of $1,500 per camera.

VECTOR AIRPORT SYSTEMS

ACRP Report 129 also evaluated Vector Airport System, a video image detection (VID) system. The system was originally intended to automate the billing process for landing fees, but it is also useful for counting aircraft operations. The VID system combines electronic-based tracking and advanced video tracking (i.e. cameras). FAA near real-time traffic data from the National Airspace System (NAS) (also known as the Aircraft Situation Display to Industry (ASDI)) is one of the electronic-based tracking sources and includes information on aircraft operating in radar control. VID can provide aircraft N-number, make, model, and owner information. The ASDI feed provides detailed aircraft data; the camera equipment captures an image of the aircraft registration number and the service provider analyzes the image.

ACRP Report 129 reported accuracy results of 90 percent. However, since the system does not capture touch-and-go activity, accuracy is dependent on the number of touch-and-go operations at the airport. Currently, the Vector system costs $45,000 to $120,000 dollars to purchase and install and $15,000 to $20,000 per year to operate.

ANALYSIS STEPS

The basis of FDOT's approach in evaluating operations counting methods and equipment is thorough research of the technologies and methods presented in ACRP Synthesis 4 and ACRP Report 129. With a comprehensive understanding of the testing completed for ACRP Report 129, FDOT selected study airports and determined the best location for equipment based on airport configuration, among other important factors. During project preparation, FDOT coordinated with the TRB ACRP project team to gain project buy in and the FAA to submit Notices of Proposed Construction or Alteration for official approval of equipment placement (Refer to **Appendix B** for applications and letters). FDOT implemented equipment testing over a period of months and in all weather conditions. After testing, FDOT compiled and analyzed data trends, summarized in the **Findings**. The subsections below summarize FDOT's project approach as follows:

1. Field Preparation
    a. Equipment Placement
    b. FAA Coordination
    c. Scheduling

2. Field Testing
    a. Installation
    b. Data Collection
3. Analysis

FIELD PREPARATION

To ensure the most accurate field data collection possible, steps were taken to balance equipment accuracy considerations with state and federal regulations to determine testing locations at each airport. Following FAA approval of testing locations, FDOT contacted airports to schedule testing dates and ensure airport managers could issue Notice to Airmen (NOTAMs) during testing.

Equipment Placement

Federal regulations protect areas of the airfield for safety considerations, but certain spatial requirements impact equipment accuracy. Table 3 summarizes the spatial and technical requirements that control where technologies can be placed. Understanding these boundaries and federal regulations, FDOT identified appropriate locations at each airport where the technologies would be most effective. For example, the project team had to ensure trail cameras were close enough to the taxiway to capture taxing aircraft, but also far enough away to stay out of the taxiway object free area (TOFA) and taxiway safety area (TSA).

Table 3. Equipment Placement Considerations

Technology	Considerations
G.A.R.D.	• Must be in the same room as the UNICOM • Best placed near windows to ensure a good signal and away from white noise to prevent interference
Trail Cameras	• Place in a central location where most aircraft taxi by to access a runway, terminal, or self-service fuel • It is important to identify commonly used locations that are not duplicative with another camera • Range of approximately 100 feet during the day and 75 feet at night
ADS Phoenix	• Should be 700 feet within take off point • Should be within 250 feet of the runway centerline

Technology	Considerations
Vector	Vector must be professionally installed. No Vector systems were installed as part of this study. FDOT selected previously installed systems for testing. However, systems should: • Monitor central location where most aircraft taxi by to access a runway, terminal, or self-service fuel

Equipment placement at each airport is unique when considering airport layout, the number of runways, and the airport size. Table 4 summarizes the Runway Design Code (RDC) and Taxiway Design Group (TDG) for each airport and runway; both of which determine the size of safety and object free areas.

Per AC 150/5300-13A, Airport Design, the object free area is "*provided to enhance the safety of aircraft operations by remaining clear of objects, except for those that need to be in the object free area for air navigation and aircraft ground maneuvering purposes*."

The purpose of runway safety areas (RSA), runway object free areas (ROFA), taxiway safety areas (TSA), and taxiway object free areas (TOFA) are to improve safety and protect maneuvering aircraft from objects that could be a hazard. The ROFA and TOFA always encompass the RSA and TSA, respectively. *The FAA stated that all equipment must be outside the runway safety area (RSA), runway object free area (ROFA), taxiway safety area (TSA), taxiway object free area (TOFA), and primary surface, unless equipped with obstruction lighting and frangible mounts, discussed further in* ***FAA Coordination****.* Figure 2 through Figure 9 display final equipment locations.

Table 4. Airport Design Considerations

Airport	Runway	RDC	TDG	RSA Width (total)	RSA Beyond	ROFA Width (total)	ROFA Beyond	Primary Surface Width*	TSA Width (total)	TOFA Width (total)
OBE: Okeechobee	05/23	D-II	2	500	1,000	800	1,000	500	79	131
OBE: Okeechobee	14/32	B-II	2	150	300	500	300	500	79	131
X06: Arcadia	06/24	B-I Small	1 or 2	120	240	250	240	250	49/79	89/131
X06: Arcadia	13/31**	B-I Small	1 or 2	120	240	250	240	250**	49/79	89/131
FIN: Flagler	All	C-II	2	500	1000	800	1000	500	79	131
X07: Lake Wales* **	17/35	A-I	1	120	240	400	240	250	49	89
X35: Marion County	05/23	B-II	2	150	300	500	300	500	79	131
X35: Marion County	10/28	B-I	1	120	240	400	240	250	49	89
40J: Perry-Foley	12/30	B-II	2	150	300	500	300	500	79	131
40J: Perry-Foley	18/36	B-II	2	150	300	500	300	500	79	131
2J9: Quincy	14/32	A-I	1	120	240	400	240	250	49	89
X13: Carrabelle	05/23	B-I	1	120	240	400	240	250	49	89
***The primary surface extends 200' beyond the runway end**										
**** For turf runways, the primary surface does not extend beyond the runway end**										
*****Runway 06/24 was closed during testing**										

Figure 2. Perry-Foley Airport Equipment Locations

Figure 3. Flagler Executive Airport Equipment Locations

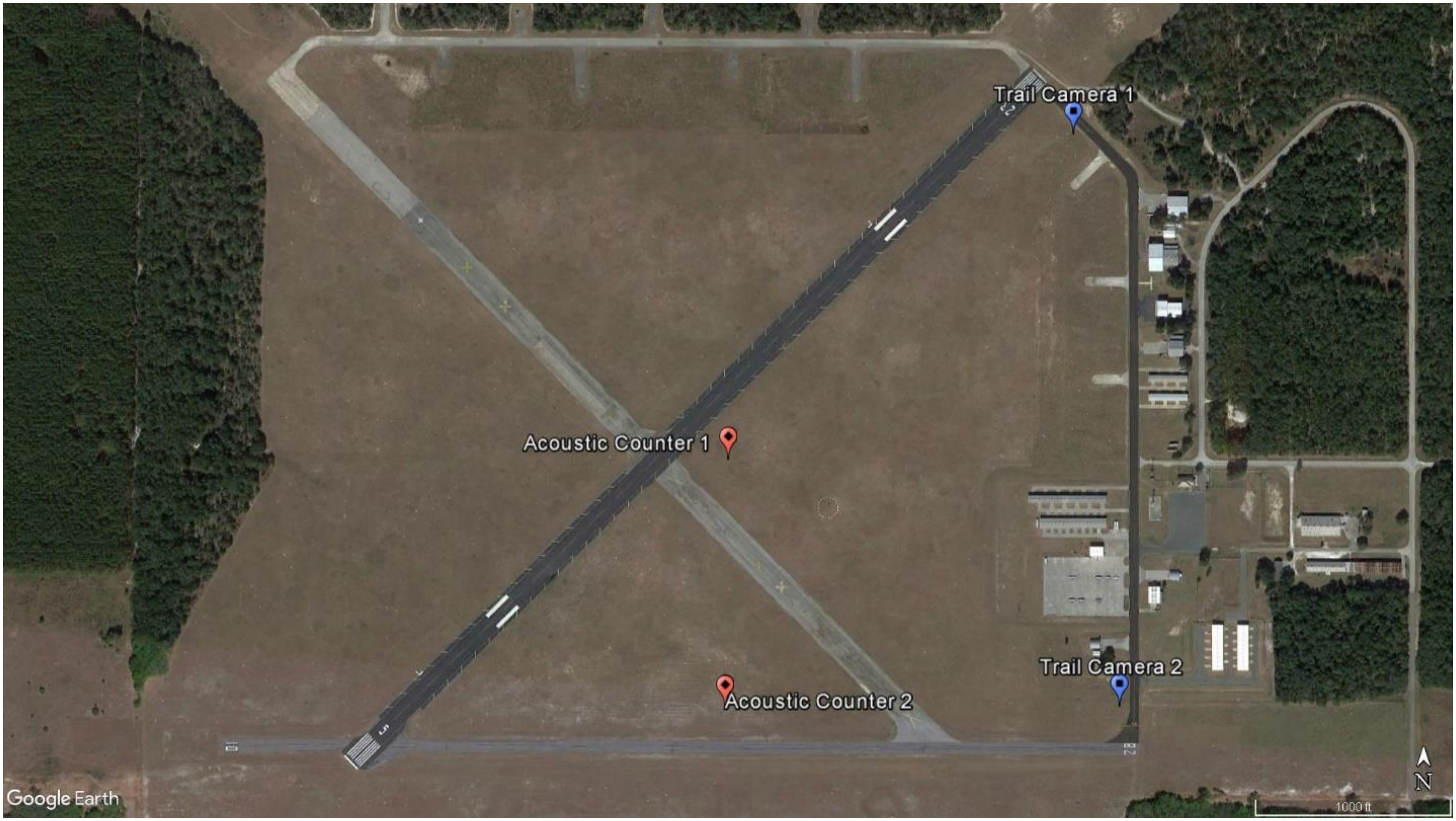

Figure 4. Marion County Airport Equipment Locations

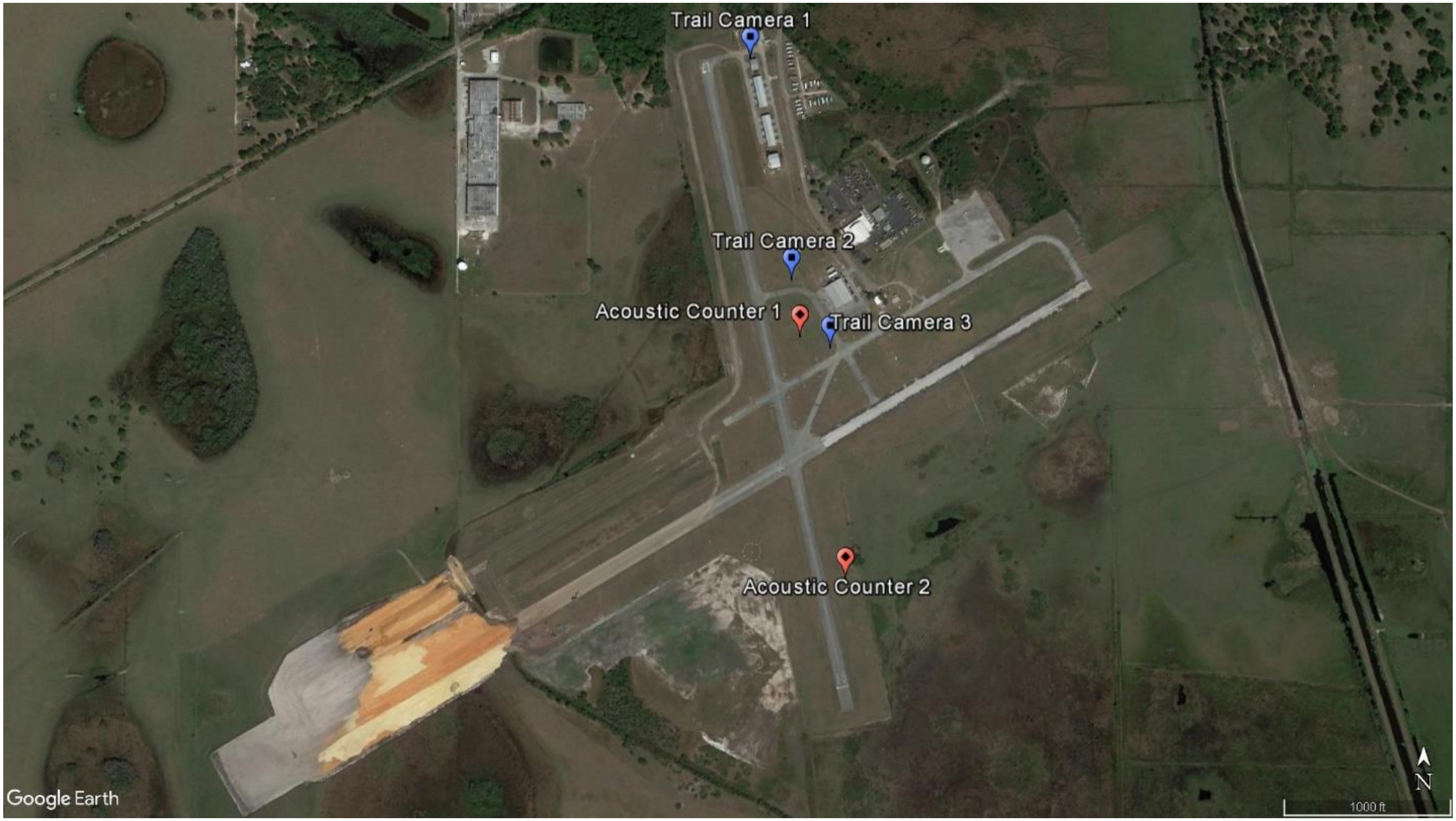

Figure 5. Lake Wales Municipal Airport Equipment Locations.

Note: Runway 06/24 was closed during testing.

Figure 6. Arcadia Municipal Airport Equipment Locations

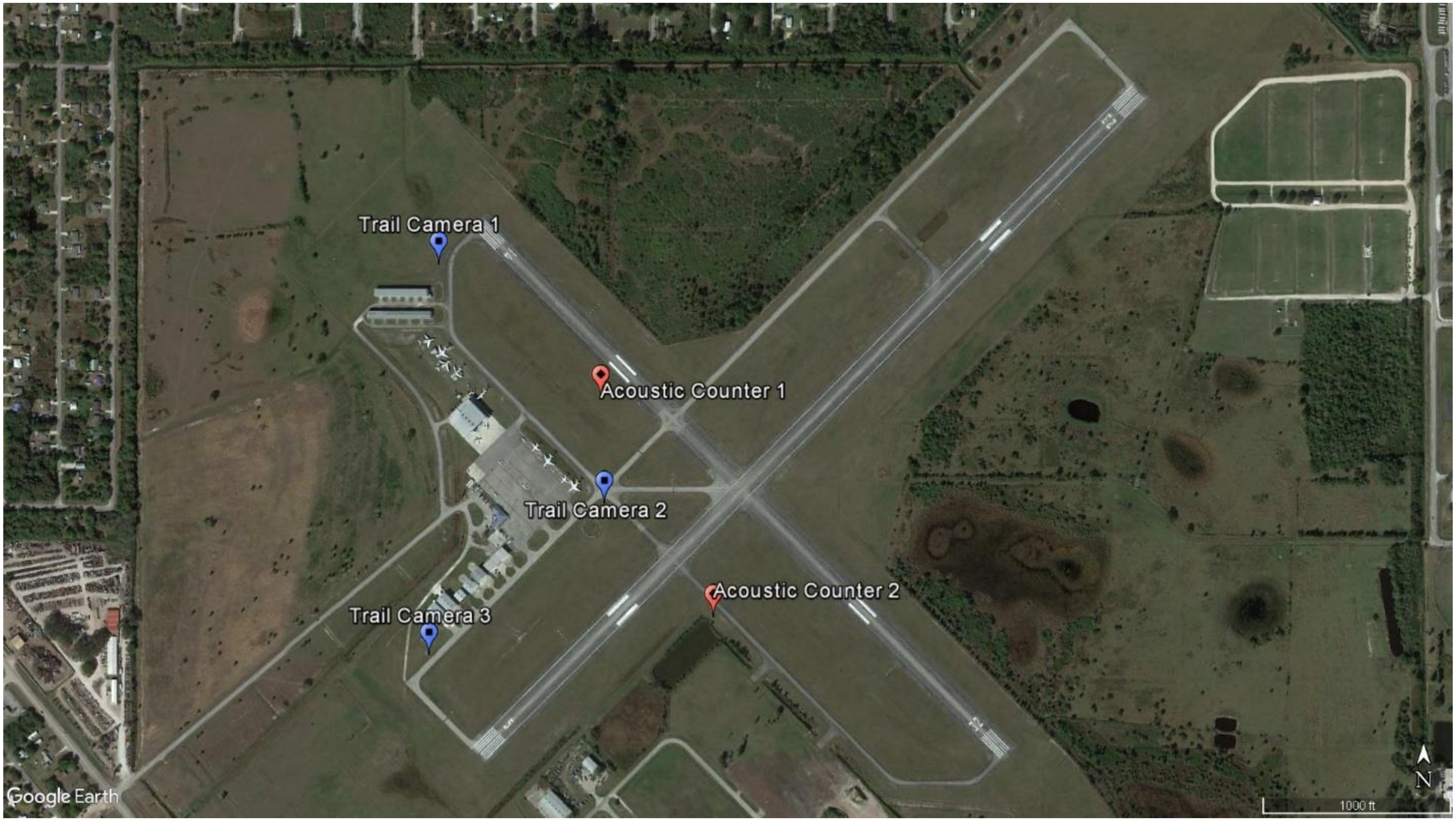

Figure 7. Okeechobee County Airport Equipment Locations

Figure 8. Quincy Municipal Airport Equipment Locations

Figure 9. Carrabelle Airport Equipment Locations

FAA Coordination

After general conversations with the FAA and determining equipment placement, FDOT submitted a FAA Form 7460-1, Notice of Proposed Construction or Alteration for each study airport, using the FAA's Obstruction Evaluation / Airport Airspace Analysis (OE/AAA) website. The completed form and attachments provided detail on the equipment, locations, and testing dates. Refer to **Appendix B** for an example FAA Form 7460-1 submission package. Based on the submitted form, the FAA provided feedback, ensuring equipment placement was outside of the ROFA, TOFA, and primary surface.

Federal Aviation Regulation (FAR) Part 77 allows the *"FAA to identify potential aeronautical hazards in advance thus preventing or minimizing the adverse impacts to the safe and efficient use of navigable airspace".* An object constitutes an obstruction to navigation if it is:

- 200 ft. above ground level or 200 ft. above the airport elevation (whichever is greater) up to 3 miles (for runway lengths > 3200 ft.) from the airport. - Increase 100 ft. every mile up to 500 ft. at 6 miles from the ARP (airport reference point)
- 500 ft. or more above ground level at the object site
- Penetrates an imaginary surface (a function of the precision of the runway)
- Penetrates the terminal obstacle clearance area (includes initial approach segment)
- Penetrates the enroute obstacle clearance area (includes turn and termination areas of federal airways)

Any temporary or permanent structure constituted an obstruction per FAR Part 77 must be lighted in accordance with AC 70/7460-1L. As applicable to this project, all equipment in a primary surface must be lighted with obstruction lighting. Furthermore, per AC 150/5220-23, any objects placed in an object free or safety area must be mounted on frangible mounts. FDOT researched the cost of obstruction lighting and frangible mounts and found it cost prohibitive to implement such measures so to place equipment in a FAR Part 77 surface, safety area, or object free area. Solar powered obstruction lights cost around $1,500 per unit and frangible mounts start at around $100 per unit. These items cost the same or even more than the equipment itself. Thus, the project team verified all equipment was outside of the ROFA, TOFA, and primary surfaces prior to testing.

Scheduling

FDOT reached out to airport managers after obtaining final determinations on the FAA Form 7460-1, Notice of Proposed Construction or Alterations to schedule testing dates. Table 5 summarizes testing dates at each airport. Operations were manually counted during these dates to verify technology counts.

Table 5. Equipment Testing Dates

Equipment Testing Dates	
Quincy Municipal Airport	1/4/2018 to 1/7/2018
Carrabelle Airport	1/25/2018 to 1/28/2018
Okeechobee County Airport	3/29/2018 to 4/1/2018
Lake Wales Municipal Airport	5/10/2018 to 5/13/2018
Marion County Airport	6/7/2018 to 6/10/2018
Flagler Executive Airport	6/14/2018 to 6/17/2018
Perry-Foley Airport	6/21/2018 to 6/24/3018
Arcadia Municipal Airport	7/19/2018 to 7/22/2018

FIELD TESTING

Field testing included technology installation and manual operations counting. Technology installation involved setting up and verifying technology was operational. The project team checked equipment twice a day to ensure it was performing as intended. To validate the counts collected by each technology, someone manually counted aircraft operations by aircraft type and hour during testing dates.

Installation

The project team set up G.A.R.D. in airport terminals and accessed the airfield to set up AACs on runways and trail cameras on taxiways. For safety, an airport operations employee accompanied the team on the airfield. Each technology installed was tested to ensure it was operating properly. The project team confirmed G.A.R.D. was operational by listening for a radio transmission and confirming the software recorded the transmission. A vehicle drove past trail cameras to ensure they were capturing movement, and a whistle into the AAC microphone confirmed it was recording sound. Refer to **Appendix C** for an installation manual.

Data Collection

Persons conducting manual counts situated themselves within view of all runways, taxiways, and aprons to visually count aircraft operations on runways. They recorded data each hour in a spreadsheet by aircraft type and runway each day of testing; an example is shown in Table 6. Weather conditions were also recorded. For this study, an operation is defined as either a take-off or landing, and a touch-and-go counted as two operations. Manual counts are compared to technology counts during analysis to verify the accuracy of each technology.

Table 6. Data Collection Example, Thursday, May 10, 2018

Begin Time	End Time	Single Engine Count	Double Engine Count	Jet Count	Helo Count	Power Paraglide Count	Other Count	Other Desc.	Notable Weather	Total
8:00 AM	**8:59 AM**	2	0	0	2	4	0		Clear	8
9:00 AM	**9:59 AM**	1	0	0	4	0	2	Helo w/ wheels	Clear	7
10:00 AM	**10:59 AM**	10	0	0	0	0	1	Helo w/ wheels	Clear	11
11:00 AM	**11:59 A**	10	0	0	0	0	0		Clear	10
12:00 PM	**12:59 PM**	0	0	0	2	0	0		Clear	2
1:00 PM	**1:59 PM**	2	0	0	0	0	0		Clear	2
2:00 PM	**2:59 PM**	0	0	0	0	0	0		Clear	0
3:00 PM	**3:59 PM**	2	0	0	0	0	0		Clear	2
4:00 PM	**4:59 PM**	3	0	0	0	0	0		Clear	3
5:00 PM	**5:59 PM**	2	0	0	0	0	0		Clear	2
	Total:	**32**	**0**	**0**	**8**	**4**	**3**			**47**

Following data collection, the project team compiled visual and technology counts into a single database. G.A.R.D., ADS Phoenix, and Vector technologies record data in Microsoft Excel. However, trail cameras required additional effort to compile data. The project team reviewed saved photographs to count operations on taxiways and compared images from different trail cameras to remove double counts. When a taxiway served two runways, operations were assigned to the runway with the most activity for that hour.

This study measures technology accuracy as:

$$\frac{Technology\ Count}{Manual\ Count} = Technology\ Performance$$

At times, the technologies counted more operations than occurred; these days are considered outliers. When this happens, days with over counts are removed from the accuracy calculation.

Figure 10 shows a table of aircraft operation data at Flagler Executive Airport from June 14th to 17th, 2018 produced by the G.A.R.D system. Each row in the table represents a full day and the individual squares represent each hour of each day. The squares are colored according to how many operations occurred that hour, with red being the lowest number (one) and blue being the highest number (273). The graphic shows that transmissions peaked between the hours of 7:00 am and 1:00 pm during testing dates.

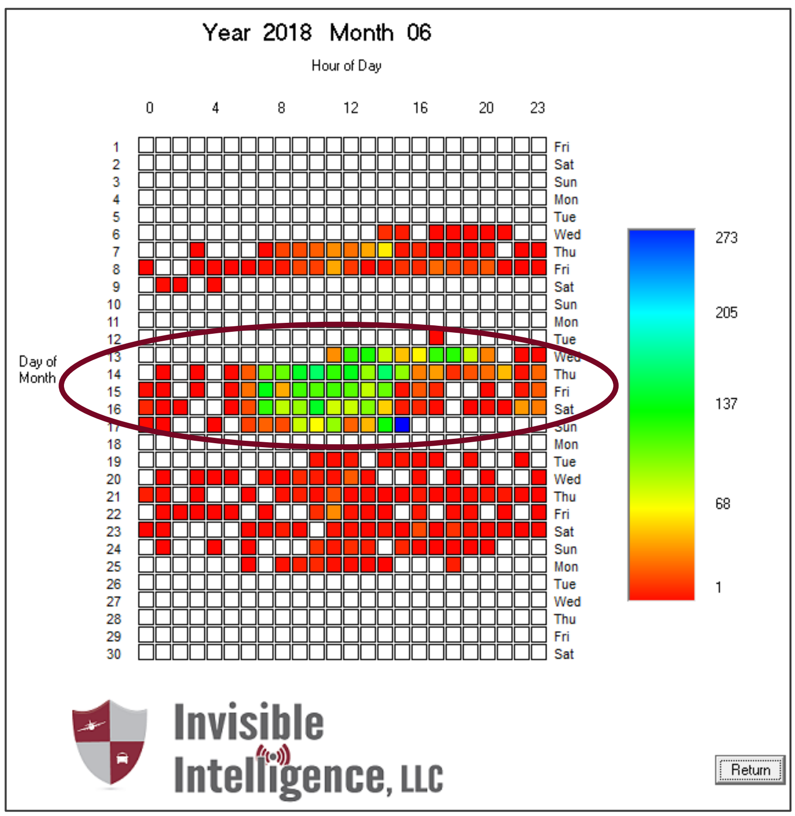

Figure 10. G.A.R.D. Data Results Example

Figure 11 presents a graph of data collected by the ADS 4000 Phoenix automated acoustic counter. In this example, the graph shows the number of operations per hour on runway 06/24 at Flagler Executive Airport. Peak hours recorded by the AAC in Figure 11 are similar to peak hours recorded by G.A.R.D. in Figure 10.

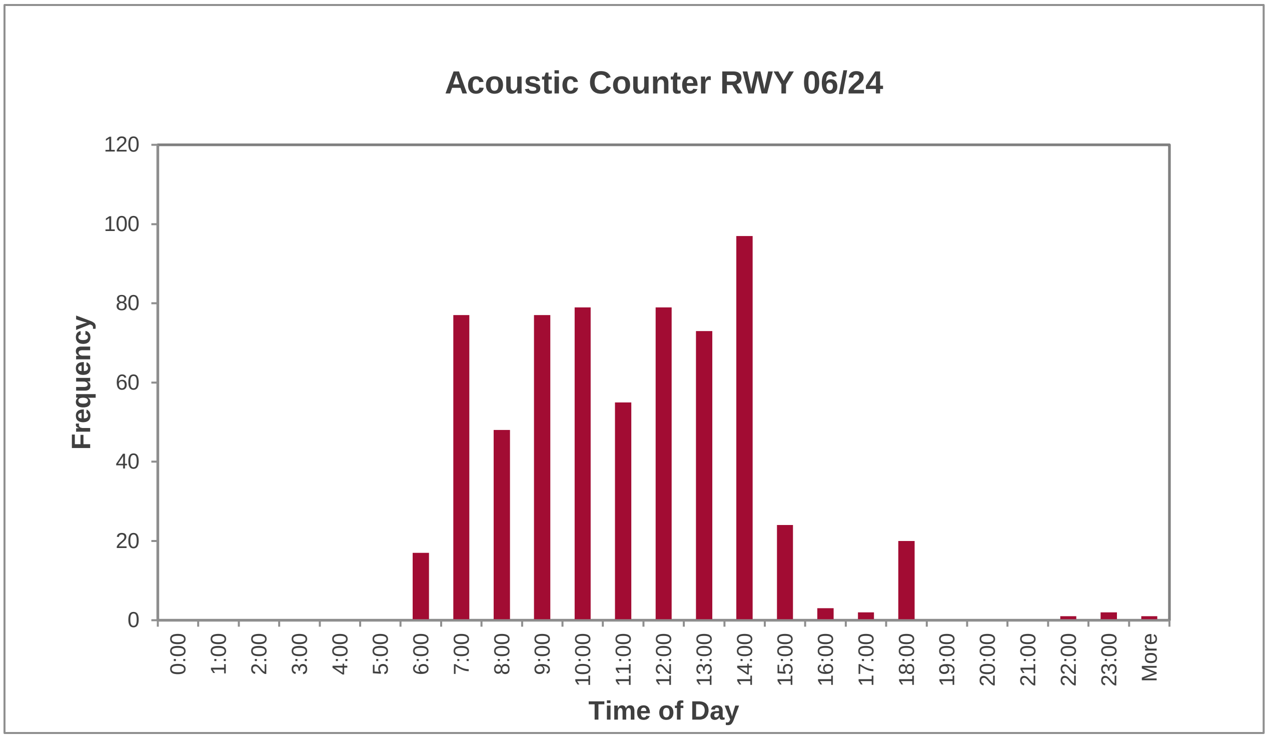

Figure 11. Phoenix ADS Data Results Example

Figure 12 shows data collected by the VECTOR system at Witham Field for the month of April 2018. The graph depicts daily operations broken down by arrival or departure. The red bars represent arrival operations, while green bar represent departure operations. The column on the left shows the date and the total operations for that day.

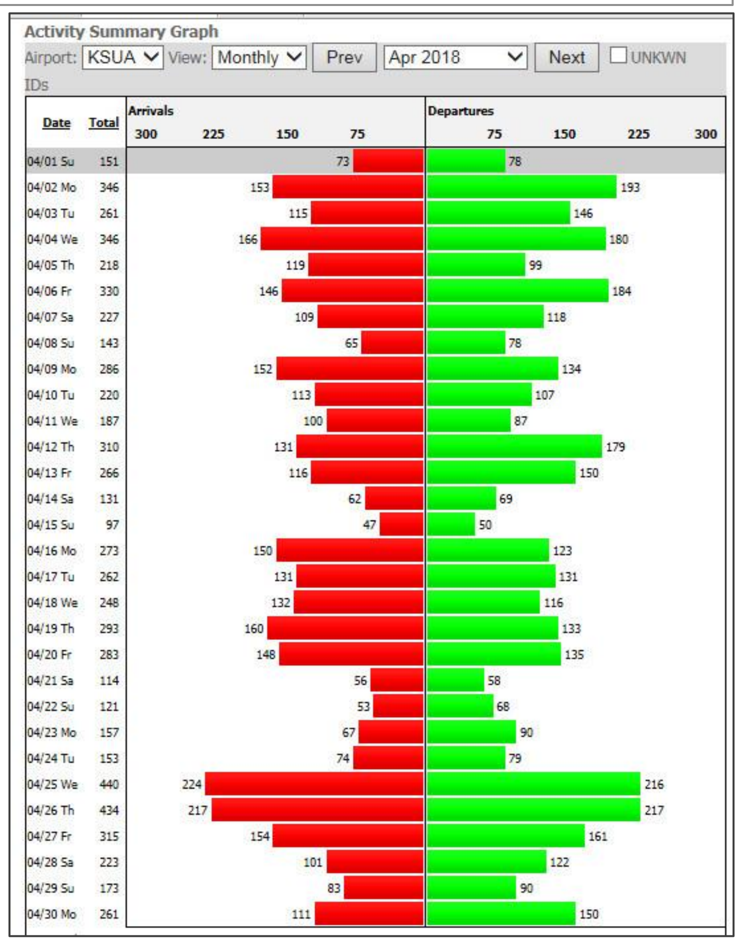

Figure 12. Vector Data Results Example

NON-SAMPLING METHODS

Based on the findings of ACRP Synthesis 4 and Report 129, two non-counting methodologies were evaluated to determine if there was a possible lower-cost way to determine the total number of operations without any technology or in-person counts.

INSTRUMENT FLIGHT PLANS TO TOTAL OPERATIONS

As previously stated, the first testing method included testing a ratio of instrument flight rule (IFR) flight plans to total operations (IFPTO). To test this method, annual flight plans filed into select towered airports in Florida were compared to the total operations observed by the tower. In total, 26 airports were evaluated:

- Albert Whitted Airport
- Bartow Municipal Airport
- Boca Raton Airport
- Brooksville-Tampa Bay Regional Airport
- Cecil Airport
- Executive Airport
- Fort Lauderdale Executive Airport
- Jacksonville Executive At Craig Airport
- Kissimmee Gateway Airport
- Lake City Gateway Airport
- Lakeland Linder Regional Airport
- Leesburg International Airport
- Miami Executive Airport
- Miami-Opa-Locka Executive Airport
- Naples Municipal Airport
- New Smyrna Beach Municipal Airport
- North Perry Airport
- Northeast Florida Regional Airport
- Ocala International-Jim Taylor Field
- Ormond Beach Municipal Airport
- Page Field
- Pompano Beach Airpark
- Space Coast Regional Airport
- Treasure Coast International Airport
- Vero Beach Municipal Airport
- Witham Field

To determine this, each airport's annual operations will be divided by the number of flight plans filed for the facility for five historic years (2013 – 2017). A summary of the analysis and findings for this evaluation are provided in **Appendix A**. Based on the results, it appears as though there is a weak correlation between the number of operations and the filed flight plans.

FLORIDA VARIABLES

In addition, a methodology analyzing the relationship between airport features and operations generation was conducted at the airports where the technology tests were conducted. Airport features evaluated included the number of based aircraft, runway length, and population. A summary of the analysis and findings for this evaluation are provided in **Appendix A**. Based on the results, it appears as though there is a weak correlation between the number of operations and the airport features.

FINDINGS

This section presents the data collected by the four technologies during testing, as well as the daily operation counts compiled visually at each airport. Some tables in this section present two measures of total accuracy: an overall percentage with outliers and an overall percentage without outliers. Sometimes technologies counted more operations than were visually observed. Because counting operations that did not occur would skew the overall accuracy calculations, days where the technologies registered more operations than were visually observed have been removed from the accuracy calculation as outliers.

G.A.R.D.

G.A.R.D. estimates aircraft operations based on radio transmissions and is generally one of the most accurate technologies tested as part of this study. Since G.A.R.D. is based on the expected number of transmissions at take-off and landing, the project team verified the average number of transmissions at take-off and landing at each airport. All airports averaged three transmissions at take-off and four transmissions at landing. This average produced the most accurate results, expect for Arcadia Municipal Airport and Okeechobee County Airport. Table 7 through Table 13 summarize visual and G.A.R.D. counts at testing airports.

Table 7 shows that G.A.R.D. captured about 50 percent of aircraft operations at Arcadia Municipal Airport, not considering outliers. When using an average of three transmission per take-off and four transmissions per landing, the technology over counted operations on two days. The technology was slightly more accurate when the averages were increased to four and five, respectively. Over counts may be due to the fact that Arcadia Municipal Airport shares a Unicom frequency with nearby airports.

Table 7. Arcadia Municipal Airport G.A.R.D. Results

Date	Visual	G.A.R.D. 3-4	G.A.R.D. 3-4 Percent of Operations Captured	G.A.R.D. 4-5	G.A.R.D. 4-5 Percent of Operations Captured
7/19/2018	20	9	45%	7	35%
7/20/2018	12	13	108%	10	83%
7/21/2018	14	7	50%	5	36%
7/22/2018	6	8	133%	6	100%
Total	**52**	**37**	**71% / 47%***	**28**	**54% / 48%***

**Does not include outliers. Outliers are days in which the technology over counted operations. Visual and technology counts for these days are not included in the percent of operations captured.*

G.A.R.D. was the second most accurate at Flagler Executive Airport and Perry-Foley Airport. Table 8 summarizes daily counts at Flagler Executive Airport. The technology never over counted;

most likely because the airport is towered and almost all aircraft are consistently using the radio to communicate with the tower and each other, not other airports.

Table 8. Flagler Executive Airport G.A.R.D. Results

Date	Visual	G.A.R.D. 3-4	G.A.R.D. 3-4 Percent of Operations Captured	G.A.R.D. 4-5	G.A.R.D. 4-5 Percent of Operations Captured
6/14/2018	332	273	82%	212	64%
6/15/2018	226	178	79%	139	62%
6/16/2018	229	177	77%	138	60%
6/17/2018	145	111	77%	86	59%
Total	**932**	**739**	**79%**	**575**	**62%**

Generally, G.A.R.D. captured about 50 percent of aircraft operations at Lake Wales Municipal Airport during testing. The airport manager noted the radio receives about 24 transmissions a day related to Lake Wales Municipal Airport, aligning with the average of three transmission per take-off and four per landing. Table 9 summarizes daily counts.

Table 9. Lake Wales Municipal Airport G.A.R.D. Results

Date	Visual	G.A.R.D. 3-4	G.A.R.D. 3-4 Percent of Operations Captured	G.A.R.D. 4-5	G.A.R.D. 4-5 Percent of Operations Captured
5/10/2018	47	20	43%	16	34%
5/11/2018	39	22	56%	17	44%
5/12/2018	43	21	49%	16	37%
5/13/2018	12	11	92%	8	67%
Total	**141**	**157**	**52%**	**122**	**40%**

G.A.R.D. did not capture radio transmissions on June 9th and 10th at Marion County Airport, as shown in Table 10. Otherwise, G.A.R.D. captured about 60 percent of aircraft operations. White noise may have interfered G.A.R.D. during testing, causing it to capture no data.

Table 10. Marion County Airport G.A.R.D. Results

Date	Visual	G.A.R.D. 3-4	G.A.R.D. 3-4 Percent of Operations Captured	G.A.R.D. 4-5	G.A.R.D. 4-5 Percent of Operations Captured
6/7/2018	114	64	56%	50	44%
6/8/2018	69	51	74%	39	57%
6/9/2018	116	0	0%	0	0%
6/10/2018	10	0	0%	0	0%
Total	**309**	**115**	**63%**	**89**	**49%**

Table 11 shows that G.A.R.D. was most accurate at Okeechobee County Airport, using an average of four transmissions at take-off and five at landing. Even so, G.A.R.D. overcounted two of the four days in this scenario. Again, over counts are likely due to airports sharing a Unicom frequency.

Table 11. Okeechobee County Airport G.A.R.D. Results

Date	Visual	G.A.R.D. 3-4	G.A.R.D. 3-4 Percent of Operations Captured	G.A.R.D. 4-5	G.A.R.D. 4-5 Percent of Operations Captured
3/29/2018	119	164	138%	128	108%
3/30/2018	159	187	118%	146	92%
3/31/2018	86	118	137%	92	107%
4/1/2018	23	24	104%	19	83%
Total	**387**	**493**	**127%**	**385**	**99% / 91%***

**Does not include outliers. Outliers are days in which the technology over counted operations. Visual and technology counts for these days are not included in the percent of operations captured.*

Table 12 shows that G.A.R.D. captured about 80 percent of operations at Perry-Foley Airport. On June 23rd, the technology overcounted in both scenarios: 1) three transmissions at take-off and four at landing and 2) four transmissions at take-off and five at landing.

Table 12. Perry-Foley Airport G.A.R.D. Results

Date	Visual	G.A.R.D. 3-4	G.A.R.D. 3-4 Percent of Operations Captured	G.A.R.D. 4-5	G.A.R.D. 4-5 Percent of Operations Captured
6/21/2018	18	16	89%	12	67%
6/22/2018	24	17	71%	13	54%
6/23/2018	10	15	150%	12	120%
6/24/2018	16	13	81%	10	63%
Total	**68**	**61**	**90% / 79%***	**47**	**69% / 60%***

**Does not include outliers. Outliers are days in which the technology over counted operations. Visual and technology counts for these days are not included in the percent of operations captured.*

Table 13 shows that G.A.R.D. captured about 40 percent of total operations during testing. The technology was not operational the first day of testing, and it over counted on the last day of testing.

Table 13. Quincy Municipal Airport G.A.R.D. Results

Date	Visual	G.A.R.D. 3-4	G.A.R.D. 3-4 Percent of Operations Captured	G.A.R.D. 4-5	G.A.R.D. 4-5 Percent of Operations Captured
1/4/2018	11	0	0%	0	0%
1/5/2018	33	7	21%	5	15%
1/6/2018	40	24	60%	18	45%
1/7/2018	41	58	141%	44	107%
Total	**125**	**104**	**71% / 37%***	**79**	**54% / 27%***

**Does not include outliers. Outliers are days in which the technology over counted operations. Visual and technology counts for these days are not included in the percent of operations captured.*

An airport's role, main aviation activity, and activity levels impact the number of transmissions during take-off and landing. In general, G.A.R.D. is well suited for airports with medium to high activity levels and for airports that feature a large amount of flight training, charter flights, corporate/business aviation, or other activity that usually results in frequent use of radio transmissions. Flagler Executive Airport and Okeechobee County Airport had the most operations and highest G.A.R.D. accuracy during testing. G.A.R.D. may not be accurate at airports that share a Unicom frequency, such as Arcadia Municipal Airport.

ADS 4000 PHOENIX

The ADS 4000 Phoenix is an automated acoustic counter (AAC) that uses an algorithm designed to note the sound of a take-off to estimate operations. Overall, it's accuracy at testing airports ranged from 2 percent to 76 percent. At Carrabelle Airport, Flagler Executive Airport, and Marion County Airport, ADS 4000 Phoenix registered about 70 percent of observed aircraft operations. However, at Lake Wales Municipal Airport, Perry-Foley Airport, and Okeechobee County Airport, the equipment registered about 20 percent of observed aircraft operations. Several factors affect this technology, from the physical distance to the runway and distance from taxiways, to the sound profile of quieter aircraft.

The ability of ADS 4000 Phoenix to capture a take-off increases the closer the equipment is to the runway centerline and take-off point. Implementing this technology is challenging at airports with large runway object free areas or primary surfaces, such as Okeechobee County Airport. The airport's runway object free area is 800 feet wide. This means the project team placed the technology 400 feet from the runway centerline instead of 250 feet or less, as recommended by the manufacturer. The manufacturer also recommends placing the equipment within 700 feet of the aircraft take-off point. This is difficult to estimate on runways longer than 5,000 feet. Therefore, such runways benefit from placing more than one counter by the runway.

Sometimes the AACs did not pick up quieter aircraft, such as experimental aircraft and small single engine aircraft. AACs may not be the most desirable technology for counting operations at airports that see a lot of activity from these aircraft. Moreover, the sound profile of a take-off varies for different geographies. The manufacturer designed this technology for back country airports nestled between mountain ranges. Thus, the take-off sound profile the technology is designed for is slightly different than a take-off sound profile in Florida, where the topography is flat. The manufacturer is adjusting the technology so that the algorithm can be modified in the field.

As shown in Table 14, ADS 4000 Phoenix captured about half of the observed aircraft operations on runway 06/24 at Arcadia Municipal Airport. AACs count is low most likely due to the distance from the runway edge, 250 feet.

Table 14. Arcadia Municipal Airport Acoustic Counter Results

Date	Visual Total	Acoustic Counter P22	Percent of Operations Captured
7/19/2018	20	9	45%
7/20/2018	12	7	58%
7/21/2018	14	7	50%
7/22/2018	6	8	133%
Total	**52**	**31**	**60% / 50%***

**Does not include outliers. Outliers are days in which the technology over counted operations. Visual and technology counts for these days are not included in the percent of operations captured.*

There were no operations at Carrabelle Airport during two days of testing due to poor weather, shown in Table 15. The project team placed a ADS 4000 Phoenix on either end of runway 05/23 since it is about 5,000 feet long. Each AAC captured about 70 percent of aircraft observations. AAC distance from pavement edge was 125 feet.

Table 15. Carrabelle Airport Acoustic Counter Results

Date	Visual	Acoustic Counter P22	Acoustic Counter P22 Percent of Operations Captured	Acoustic Counter P15	Acoustic Counter P15 Percent of Operations Captured
1/25/2018	5	4	80%	5	100%
1/26/2018	12	8	67%	8	67%
1/27/2018	0	0	0%	0	0%
1/28/2018	0	0	0%	0	0%
Total	**17**	**12**	**71%**	**13**	**76%**

Table 16 shows that the ADS 4000 Phoenix captured about 70 percent of operations on runway 06/24 and runway 11/29. The project team placed a single counter about 400 feet from the runway centerline by each runway. The AAC on runway 11/29 over counted one day, likely due to its proximity to a nearby taxiway. The ADS 4000 Phoenix may capture a taxing aircraft as a take-off if the aircraft is moving slowly or performing a runup.

Table 16. Flagler Executive Airport Acoustic Counter Results

Date	Visual 06/24	Acoustic Counter P15 (06/24)	Acoustic Counter P15 Percent of Operations Captured	Visual 11/29	Acoustic Counter P22 (11/29)	Acoustic Counter P22 Percent of Operations Captured
6/14/2018	284	208	73%	48	25	52%
6/15/2018	218	170	78%	8	17	213%
6/16/2018	133	112	84%	96	76	79%
6/17/2018	142	77	54%	3	9	300%
Total	**777**	**567**	**73%**	**155**	**127**	**82% / 70%***

**Does not include outliers. Outliers are days in which the technology over counted operations. Visual and technology counts for these days are not included in the percent of operations captured.*

The project team placed two counters on runway 17/35 about 200 feet from the runway centerline. Table 17 shows the AACs captured about 20 percent of operations at Lake Wales Municipal Airport. Further analysis revealed that the AAC did not capture twenty operations between 10:00 am and 12:00 pm on May 5th. This could be due to a quiet aircraft conducting touch-and-goes.

Table 17. Lake Wales Municipal Airport Acoustic Counter Results

Date	Visual	Acoustic Counter P15	Acoustic Counter P22 Percent of Operations Captured	Acoustic Counter P22	Acoustic Counter P15 Percent of Operations Captured
5/10/2018	47	5	19%	9	11%
5/11/2018	39	11	21%	8	28%
5/12/2018	43	10	14%	6	23%
5/13/2018	12	4	50%	6	33%
Total	**141**	**30**	**21%**	**29**	**21%**

Table 18 shows that ADS 4000 Phoenix registered about 70 percent of aircraft operations at Marion County Airport. The AAC double counted on June 8th, which coincided with mowing. The project team placed the AAC about 200 feet from the runway centerline.

Table 18. Marion County Airport Acoustic Counter Results

Date	Visual 10/28	Acoustic Counter P15 (10/28)	Acoustic Counter Percent of Operations Captured
6/7/2018	73	42	58%
6/8/2018	10	38	380%
6/9/2018	57	49	86%
6/10/2018	7	6	86%
Total	**145**	**135**	**92% / 71%***

**Does not include outliers. Outliers are days in which the technology over counted operations. Visual and technology counts for these days are not included in the percent of operations captured.*

Table 19 summarizes counts at Okeechobee County Airport. Equipment placement at this airport was challenging because of the 800-foot-wide ROFA and airport configuration. The AACs had to be placed close to taxiways, which degraded the sound input to the ADS 4000 Phoenix algorithm. Because of placement, the AAC over counted and under counted on both runways. Overall, the AAC captured 32 percent of operations on runway 14/32 and 2 percent of operation on runway 05/23, not considering outliers.

Table 19. Okeechobee County Airport Acoustic Counter Results

Date	Visual 14/32	Acoustic Counter P22 (14/32)	Acoustic Counter P22 Percent of Operations Captured	Visual 05/23	Acoustic Counter P15 (05/23)	Acoustic Counter P15 Percent of Operations Captured
3/29/2018	81	44	54%	38	45	118%
3/30/2018	153	29	19%	6	26	433%
3/31/2018	1	12	1200%	85	2	2%
4/1/2018	7	3	43%	16	0	0%
Total	**242**	**88**	**36% / 32%***	**145**	**73**	**50% / 2%***

**Does not include outliers. Outliers are days in which the technology over counted operations. Visual and technology counts for these days are not included in the percent of operations captured.*

Table 20 shows that the AACs captured less than 20 percent of aircraft operations on each runway at Perry-Foley Airport. This is most likely because AACs had to be placed 250 feet from the runway centerline.

Table 20. Perry-Foley Airport Acoustic Counter Results

Date	Visual 12/30	Acoustic Counter P15 (12/30)	Acoustic Counter P15 Percent of Operations Captured	Visual 18/36	Acoustic Counter P22 (18/36)	Acoustic Counter P22 Percent of Operations Captured
6/21/2018	17	6	35%	1	0	0%
6/22/2018	23	2	9%	1	1	100%
6/23/2018	8	4	50%	2	0	0%
6/24/2018	14	0	0%	2	0	0%
Total	**62**	**12**	**19%**	**6**	**1**	**17%**

As shown in Table 21, the two AACs placed near each runway end at Quincy Municipal Airport captured between 42 and 55 percent of aircraft operations. The project team placed the AAC about 200 feet from the runway centerline. Analysis after testing revealed that AAC P22 captured more operations on January 7th due to a shift in wind direction.

Table 21. Quincy Municipal Airport Acoustic Counter Results

Date	Visual Total	Acoustic Counter P22	Acoustic Counter P22 Percent of Operations Captured	Acoustic Counter P15	Acoustic Counter P15 Percent of Operations Captured
1/4/2018	11	3	27%	3	27%
1/5/2018	33	25	76%	22	67%
1/6/2018	40	22	55%	19	48%
1/7/2018	41	19	46%	8	20%
Total	**125**	**69**	**55%**	**52**	**42%**

Study results are mixed, but do indicate several factors impact the effectiveness of ADS 4000 Phoenix. An AAC is typically more accurate when placed as close to the runway as possible and further away from taxiways. This technology does not work best at airports with long runways or for airports frequently used by quieter aircraft. ADS 4000 Phoenix may also not capture all touch-and-go activity.

TRAIL CAMERAS

Airports with a centralized terminal and hangar area and limited access points can use trail cameras to estimate aircraft operations by placing them near each runway access points. Trail cameras were the least accurate operations counting technology tested during this study, with accuracy ranging from 14 percent to 66 percent. Quincy Municipal Airport and Perry-Foley Airport had the best results, and Okeechobee County Airport had the lowest accuracy.

Even though there is only one access point to the apron and one to the hangars at Arcadia Municipal Airport, Table 22 shows that trail cameras only captured 35 percent of the activity. Arcadia Municipal Airport is known for agricultural spraying training, so trail cameras did not capture training related touch-and-goes.

Table 22. Arcadia Municipal Airport Trail Camera Results

Date	Visual Total	Trail Camera 1	TC1 Percent of Operations Captured	Trail Camera 2	TC 2 Percent of Operations Captured	Trail Camera Total	Total Trail Camera Percent of Operations Captured
7/19/2018	20	4	20%	0	0%	4	20%
7/20/2018	12	2	17%	3	25%	5	42%
7/21/2018	14	2	14%	5	36%	7	50%
7/22/2018	6	2	33%	0	0%	2	33%
Total	**52**	**10**	**19%**	**8**	**15%**	**18**	**35%**

Like Arcadia Municipal airport, Carrabelle Airport has one access point to the runway from the apron and hangars. Nonetheless, the trail cameras captured operations only on the first day of testing, as shown in Table 23. Poor weather conditions may have impacted the cameras effectiveness.

Table 23. Carrabelle Airport Trail Camera Results

Date	Visual	Trail Camera 1	TC 1 Percent of Operations Captured	Trail Camera 2	TC 2 Percent of Operations Captured	Trail Camera Total	Total Trail Camera Percent of Operations Captured
1/25/2018	5	5	100%	5	100%	10	100%
1/26/2018	12	0	0%	0	0%	0	0%
1/27/2018	0	0	0%	0	0%	0	0%
1/28/2018	0	0	0%	0	0%	0	0%
Total	**17**	**5**	**29%**	**5**	**29%**	**10**	**29%**

Flagler Executive Airport has several runways, taxiways, and runway access points, making it difficult to identify a few primary access points. The project team placed four cameras near the access point of each runway end for testing. Trail cameras 2 and 3 provided access to multiple runways, therefore data was allocated to the runway with the highest activity in that hour. Table

24 summarizes visual and trail camera counts, and Table 25 shows the percent of operations captured by each camera and overall. Overall, the cameras captured about 30 percent of activity.

Table 24. Flagler Executive Airport Trail Camera Totals

Date	Visual 11/29	Trail Camera 1 11/29	Visual 06/24	Trail Camera 4 06/24	Visual Total	Trail Camera Total	Trail Camera 2*	Trail Camera 3*
6/14/2018	48	11	284	64	332	159	33	51
6/15/2018	8	7	218	31	226	93	31	24
6/16/2018	96	2	133	0	229	41	31	8
6/17/2018	3	0	142	0	145	24	23	1
Total	**155**	**20**	**777**	**95**	**932**	**317**	**118**	**84**

**Percent of operations captured is based on hourly runway utilization*

Table 25. Flagler Executive Airport Trail Camera Percentages

Date	TC 1 Percent of Operations Captured	TC 4 Percent of Operations Captured	Total TC Percent of Operations Captured	TC 2 Percent of Operations Captured*	TC 3 Percent of Operations Captured*
6/14/2018	23%	23%	48%	12%	18%
6/15/2018	88%	14%	41%	12%	11%
6/16/2018	2%	0%	18%	23%	6%
6/17/2018	0%	0%	17%	16%	1%
Total	**13%**	**12%**	**34%**	**15%**	**11%**

**Percent of operations captured is based on hourly runway utilization*

Trail cameras captured aircraft taxing to the runway from three different locations at Lake Wales Municipal Airport; one leading to hangars and two leading to the apron. Table 26 and Table 27 Table 27show that despite camera placement in central locations trail cameras only captured about 40 percent of activity at Lake Wales Municipal Airport.

Table 26. Lake Wales Municipal Airport Trail Camera Totals

Date	Visual 17/35	Trail Camera 1	Trail Camera 2	Trail Camera 3	Trail Camera Total
5/10/2018	47	2	2	10	14
5/11/2018	39	5	3	8	16
5/12/2018	43	13	3	5	21
5/13/2018	12	5	1	1	7
Total	**141**	**25**	**9**	**24**	**58**

Table 27. Lake Wales Municipal Airport Trail Camera Percentages

Date	TC 1 Percent of Operations Captured	TC 2 Percent of Operations Captured	TC 3 Percent of Operations Captured	Trail Camera Percent of Operations Captured
5/10/2018	4%	4%	21%	30%
5/11/2018	13%	8%	21%	41%
5/12/2018	30%	7%	12%	49%
5/13/2018	42%	8%	8%	58%
Total	**18%**	**6%**	**17%**	**41%**

At Marion County Airport, trail cameras captured more taxing operations than runway operation on June 8th and June 10th, as shown in Table 28. The project team placed trail cameras on the taxiway near the threshold marking. It is unlikely that the cameras captured taxing operations going that were not going directly to and from the runway. Over counts may be caused by aircraft deciding not to take off. Otherwise, trail cameras captured about 30 percent of operations.

Table 28. Marion County Airport Trail Camera Totals

Date	Visual 05/23	Trail Camera 1 05/23	Visual 10/28	Trail Camera 2 10/28	Visual Total	Trail Camera Total
6/7/2018	41	7	73	23	114	30
6/8/2018	59	10	10	11	69	22
6/9/2018	59	13	57	22	116	35
6/10/2018	3	3	7	9	10	12
Total	**162**	**33**	**147**	**66**	**309**	**99**

Table 29. Marion County Airport Trail Camera Percentages

Date	TC 1 Percent of Operations Captured	TC 2 Percent of Operations Captured	Trail Camera Percent of Operations Captured
6/7/2018	17%	32%	26%
6/8/2018	17%	110%	32%
6/9/2018	22%	39%	30%
6/10/2018	100%	129%	120%
Total	**20%**	**45% / 35%***	**32% / 29%***

**Does not include outliers. Outliers are days in which the technology over counted operations. Visual and technology counts for these days are not included in the percent of operations captured.*

Three trail cameras captured operations at Okeechobee County Airport; one by the nearest end of each runway (trail camera one and three) and one at the intersection of several taxiways (trail camera two). Photographs were reviewed to remove potential double counts, and operations at trail camera two were allocated to a runway based on hourly activity. Table 30 and Table 31 show that trail cameras captured very few operations at this airport, with the only 14 percent of the overall operations captured. Flight training touch-and-goes and weather may have impacted the accuracy of trail cameras at Okeechobee County Airport.

Table 30. Okeechobee County Airport Trail Camera Totals

Date	Visual 14/32	Trail Camera 1 14/32	Visual 05/23	Trail Camera 3 05/23	Visual Total	Trail Camera 2*	Trail Camera Total
3/29/2018	81	1	38	6	119	13	20
3/30/2018	153	1	6	0	159	11	12
3/31/2018	1	0	85	9	86	0	9
4/1/2018	7	1	16	8	23	5	14
Total	242	**3**	145	**23**	**387**	**29**	**55**

**Percent of operations captured is based on hourly runway utilization*

Table 31. Okeechobee County Airport Trail Camera Percentages

Date	TC 1 Percent of Operations Captured	TC 3 Percent of Operations Captured	TC 2 Percent of Operations Captured*	Trail Camera Percent of Operations Captured
3/29/2018	1%	16%	15%	17%
3/30/2018	1%	0%	7%	8%
3/31/2018	1%	11%	0%	10%
4/1/2018	0%	50%	31%	61%
Total	**14%**	**16%**	**12%**	**14%**

**Percent of operations captured is based on hourly runway utilization*

Trail camera performance varied at Perry-Foley Airport. Table 32 shows trail camera one, placed near runway end 18, performed almost perfectly, while the other trial cameras only captured about 20 percent of overall operations. Trail camera one over counted on June 23rd.

Table 32. Perry-Foley Airport Trail Camera Totals

Date	Visual 12/30	Trail Camera 3 12/30	Visual 18/36	Trail Camera 1 18/36	Visual Total	Trail Camera 2*	Trail Camera Total
6/21/2018	17	4	1	1	18	4	9
6/22/2018	23	3	1	1	24	4	8
6/23/2018	8	2	2	3	10	4	9
6/24/2018	14	5	2	2	16	3	10
Total	**62**	**14**	**6**	**7**	**68**	**15**	**36**

**Percent of operations captured is based on hourly runway utilization*

Table 33. Perry-Foley Airport Trail Camera Percentages

Date	TC 3 Percent of Operations Captured	TC 1 Percent of Operations Captured	TC 2 Percent of Operations Captured*	Total TC Percent of Operations Captured
6/21/2018	22%	100%	24%	50%
6/22/2018	13%	100%	17%	33%
6/23/2018	20%	150%	38%	90%
6/24/2018	31%	100%	21%	63%
Total	**21%**	**117% / 100%**	**23%**	**53%**

**Percent of operations captured is based on hourly runway utilization*

Trail cameras performed the best at Quincy Municipal Airport, capturing about 66 percent of aircraft operations. The project team placed one trail camera next to a taxiway leading to a set of hangars and another on the apron. This airport does not have a paved taxiway, so aircraft may have not taxied within camera range when accessing the apron.

Table 34. Quincy Municipal Airport Trail Cameras

Date	Visual Total	Trail Camera 1	TC 1 Percent of Operations Captured	Trail Camera 2	TC 2 Percent of Operations Captured	Trail Camera Total	Trail Camera Percent of Operations Captured
1/4/2018	11	2	18%	4	36%	6	55%
1/5/2018	33	7	21%	10	30%	17	52%
1/6/2018	40	9	23%	14	35%	23	58%
1/7/2018	41	15	37%	22	54%	37	90%
Total	**125**	**33**	**26%**	**50**	**40%**	**83**	**66%**

Overall, trail cameras were the least accurate technology. Many factors can impact the performance of trail cameras. Most importantly, trail cameras do not capture touch-and-go activity, which can be a significant portion of operations at some of Florida's general aviation airports. The manufacturer also stated that while a trail camera is sending a picture, it cannot take another picture. Thus, the trail camera may miss an aircraft if it taxis past the camera soon after another aircraft. Very fast moving or slow moving aircraft may not trigger the camera as well.

VECTOR

The Vector system uses automated aircraft tracking (cameras) and VNOMS to monitor airport activity. The project team conducted visual counts a Venice Municipal Airport and Witham Field to verify technology accuracy. Table 35 shows that Vector captured 60 percent of operations at Venice Municipal Airport and Table 36 shows that Vector captured 126 percent of operations at Witham Field. Under counts at Venice Municipal Airport are likely due to touch-and-goes. Over counts at Witham Field are likely due to double counts based on camera placement.

Table 35. Venice Municipal Airport Vector Results

Date	Visual	VECTOR	Percent of Operations Captured
2/22/2018	252	163	65%
2/23/2018	246	142	58%
2/24/2018	411	216	53%
2/25/2018	247	177	72%
Total	**1,156**	**698**	**60%**

Table 36. Witham Field Vector Results

Date	Visual	VECTOR	Percent of Operations Captured
4/26/2018	316	434	137%
4/27/2018	233	315	135%
4/28/2018	206	223	108%
4/29/2018	153	173	113%
Total	**908**	**1,145**	**126%**

RESULTS SUMMARY

Table 37 summarizes the effectiveness of each technology at each test airport. Study results are mixed with no one technology standing out as the most effective. G.A.R.D. was the most effective technology at four of the ten testing airports. AAC was most effective at three airports, and trail cameras were the most effective at one airport. Trail cameras were the least accurate technology at four of the ten airports, and AAC was the least accurate at three testing airports.

Table 37. Results Summary

Airport	G.A.R.D.	ADS Phoenix	Trail Cameras	Vector
Arcadia Municipal Airport	48%	**50%**	35%	N/A
Carrabelle Airport	N/A	**71%-76%**	29%	N/A
Flagler Executive Airport	**79%**	70%-73%	34%	N/A
Lake Wales Municipal Airport	**52%**	21%	41%	N/A
Marion County Airport	63%	**71%**	32%	N/A
Okeechobee County Airport	**91%**	2%-32%	14%	N/A
Perry-Foley Airport	**79%**	17%-19%	53%	N/A
Quincy Municipal Airport	37%	42%-55%	**66%**	N/A
Venice Municipal Airport	N/A	N/A	N/A	60%
Witham Field	N/A	N/A	N/A	126%
Total Overall Accuracy	**85%**	**61%**	**33%**	**89%**

Red, bold text are the technologies most accurate at the airport.

Table 38 displays total visual counts, considering each technology. 2,031 is used when calculating the total accuracy for AACs and trail cameras, while 2,014 is used when calculating G.A.R.D. accuracy, and 2,064 is used when calculating Vector accuracy. Table 39 displays the overall percent of operations captured at all airports by each technology. Vector is the most effective followed by G.A.R.D., using an average of three radio transmission at take-off and four radio transmission at landing. The next most accurate technology is AAC, then trail cameras.

Table 38. Overall Counts

Visual All Airports (No Vector Airports)	Visual without Carrabelle (G.A.R.D. Airports)	Visual Venice and Witham (Vector Airports)
2,031	2,014	2,064

Table 39. Overall Accuracy

Technology	Total Count	Percent of Operations Captured
AAC (ADS 4000 Phoenix)	1,239	1,239 / 2,031 = **61%**
Trail Camera	676	676/ 2,031 = **33%**
G.A.R.D. 3-4	1,706	1,706 / 2,014 = **85%**
G.A.R.D. 4-5	1,325	1,325 / 2,014 = **66%**
Vector	1,843	1,842 / 2,064 = **89%**

CONCLUSION

The FAA, FDOT, and airports use operations counts to develop master plans and system plans, create forecasts, and justify funding for airport improvements. Several operation estimates are publicly available but none match, making it difficult to know which are most accurate. Currently, none of these methods estimate total annual operations with 100 percent accuracy, and existing methods are time consuming and/or expensive. The gap in understanding of annual aircraft operations at non-towered and part-time towered airports makes the planning process difficult.

The TRB ACRP conducted two studies to explore technologies and non-sampling methods that non-towered airports can implement to better determine annual operation counts. ACRP Synthesis 4 is the foundation of research for operation counting projects and is a nationwide survey and review of the existing estimation methods and counting technologies used to determine aircraft operations at non-towered airports. ACRP Report 129, completed in 2015, is a field test of operations estimation methods and operations counting technologies. FDOT implemented a methodology based on ACRP Synthesis 4 and ACRP Report 129 to evaluate technologies and methods in the Florida context that non-towered airports can implement to better determine annual operations counts.

Table 40 summarizes the results of the Florida specific study. While Vector was the most accurate technology during testing, it is also the most expensive and requires significant effort to implement and maintain. Alternatively, G.A.R.D. is similarly accurate but more cost effective and easy to install and monitor. AAC and trail cameras are fairly simple to implement and are some of the most cost-effective options, but they were the least accurate technologies during testing. In summary, airports should consider the following when selecting a technology to count operations:

- Automated acoustic counters:
  - Work best for single runway airports with a small ROFA
  - Are best for airports with simple configurations, where taxiways are far enough from runways that aircraft on taxiways don’t degrade the sound profile and impact AAC performance
  - Are best for runways less than 5,000 feet. Otherwise, two AACs may be needed to capture all take-offs.
  - Work best for airports without a lot of touch-and-go activity, flight training, and quiet aircraft
  - Mowing can interfere with the technology microphone
  - Are best for airports with ample time and resources to purchase, install, and monitor equipment near active runways
- Trail cameras:
  - Work best for airports with central terminal and hangar areas and limited runway access points
  - Are best for airports without a lot of touch-and-go activity and flight training
  - Cannot take a picture when sending a picture via cell service
  - Sometimes do not capture slow or fast moving aircraft
  - Require significant processing effort after data collection but do capture additional details such as end numbers

    - Are cost effective, but often under estimate operations
- G.A.R.D.:
    - Is best for airports that have a lot of activity that requires radio communication
    - Relies on user input to determine the average number of transmissions per take-off and landing
    - Is not best for airports that share Unicom frequencies
    - Must be installed in the same room as the Unicom, away from equipment that generate white noise, and near a window if the terminal has a metal roof
    - Is a low cost and easy to implement
- Vector:
    - Does not capture touch-and-go activity
    - May over count if cameras are placed in a manner that double count aircraft
    - Is the most expensive option including installation and maintenance costs

Each technology has its strength and weaknesses, and study results are mixed. Ultimately, airports should decide which technology is best for them based on available resources, airport configuration, and common aviation activities. No correlation was found for either non-sampling method. Therefore, no method is recommended for use at this time.

Table 40. Technology Summary Matrix

Technology	Percent of Operations Captured	Average Cost	Level of Effort to Implement	Activities Captured
Acoustic Counter (ADS 4000 Phoenix)	61%	$4,950/counter	Medium	Departures
Trail Camera	33%	$1,500/camera	Medium	Taxing aircraft
G.A.R.D. 3-4	85%	$3,000-$4,000	Low	Radio transmissions
G.A.R.D. 4-5	66%	$3,000-$4,000	Low	Radio transmissions
Vector	89%	$45,000-$120,000 + $15,000-20,000/year	High	Taxing aircraft