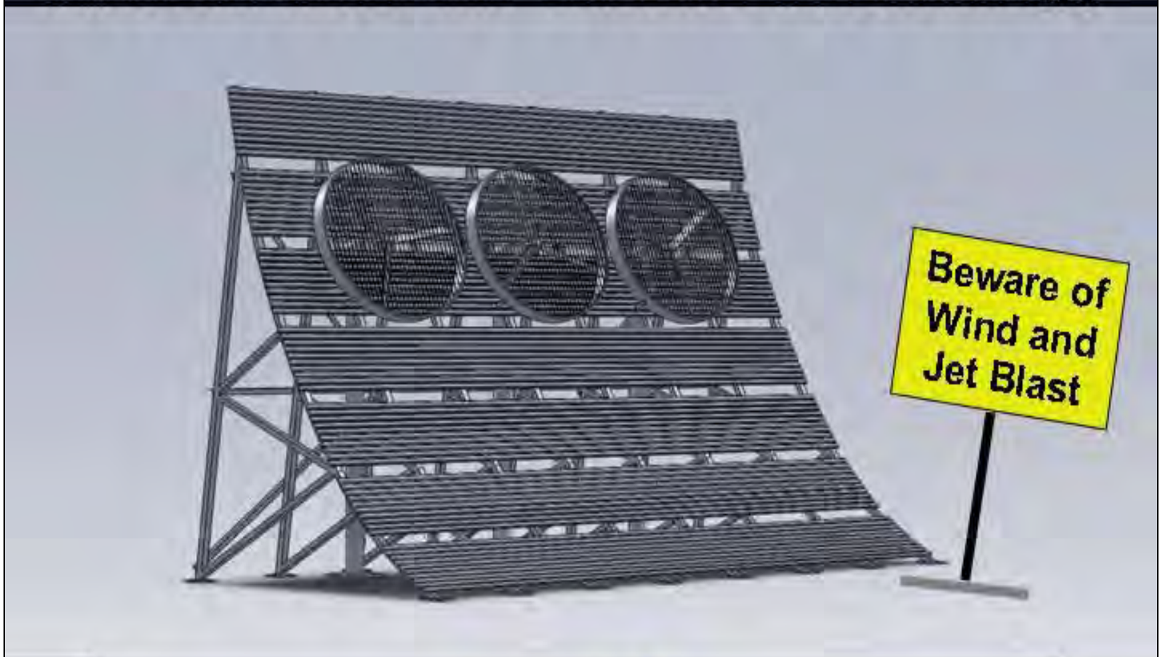
AfWATT

Airfield Wind Air Turbine Technology



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Executive Summary

AfWATT (Airfield Wind Air Turbine Technology) generates electricity from prevailing wind and the jet blast created by aircraft operations. It is designed to be installed in existing blast fences, is constructed using readily available components, and requires little to no maintenance. Recommendations from mechanical designers, airport personnel, and FAA employees were incorporated into the design. A complete set of 3D CAD images is included, one showing AfWATT kit components, the second showing how the design is integrated into the blast fence.

Because it does not alter the structural integrity of the existing blast fence, AfWATT maintains safety standards set by the FAA. NTSB data revealed accidents involving blast fences are extremely rare, accounting for only 0.0009% of all recorded accidents. To reduce risk further, an extensive safety risk assessment was accomplished using the four step process of Safety Risk Management.

Both Federal and State funding is available to lower start-up costs. Although site analysis for San Francisco and San Jose International Airports revealed economic challenges, these challenges are not insurmountable. Further study regarding the effect of jet blast on electrical production is warranted. In addition to generating electrical power and reducing the airport's carbon footprint, AfWATT is a highly effective public relations tool. Millions of passengers will view wind power in operation, increasing public awareness and improving airport-community relations.

AfWATT is clean, safe, and efficient energy production for the 21st century.

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Chapter 1: Problem Statement & Background

Energy efficiency is one of the most important challenges of the 21st Century. As world energy consumption grows, it is projected that non-renewable fuels will be unable to meet demand. Energy costs are projected to increase. It is imperative that we develop sustainable methods of producing energy that ensures an affordable and stable supply. In many locations, wind provides a reliable and efficient way to produce electricity. It is sustainable, produces no pollutants, and is currently being harnessed with existing technology.

Airfields make ideal locations to harness the wind. They are large, open areas where wind can travel uninterrupted. There are relatively few airfield structures, most of which are short in height and have a small footprint. In addition to prevailing wind found on airfields, aircraft operations generate wind. Engine exhaust from a Boeing 737, a small commercial airliner, can create wind speeds of 160 mph as close as 85 feet from the tail. The largest engine in production, used on the Boeing 777, creates sustained wind speeds of up to 160 mph at a distance 310 feet from the tail (USAF 2007). In addition, many maintenance operations require engine run-ups, generating high velocity winds for extended periods. Jet blast has the power to knock a person down, blow vehicles across the ramp and even flip over small planes. Due to such high wind speeds, airports install jet blast fences (JBF's) to divert wind upwards, protecting nearby items such as buildings or roads.

Wind is also of importance to flight operations. Flight crews need to know exact wind speeds and weather conditions above the airfield. As a result, airports have compiled an extensive history of wind conditions at each airfield location. This data can provide valuable insight into harnessing wind power and turn missed opportunities into electricity.

The Airfield Wind Air Turbine Technology (AfWATT), harnesses prevailing wind and jet blast created by aircraft operations. It uses aerogenerators (micro-sized wind turbines) that are integrated into existing blast fences and connected to the airport power grid. The design maintains the same height and footprint of the JBF, and has no adverse affect on the fence's original functionality.

Operation is similar to larger wind turbines. Wind travels across the airfield and approaches the JBF, however before it contacts the blast fence; it is directed towards a blade assembly. The wind rotates the blade assembly, turning the generator to produce electricity. This process slows the wind as the energy is extracted by the blades. The depleted wind then contacts the blast fence, and is directed upwards. Items directly behind the blast fence remain protected just as before. Figure 1-1 below, illustrates wind-flow patterns through AfWATT. For the first time, airports will be able to generate electrical power from the wind while still maintaining airfield safety.

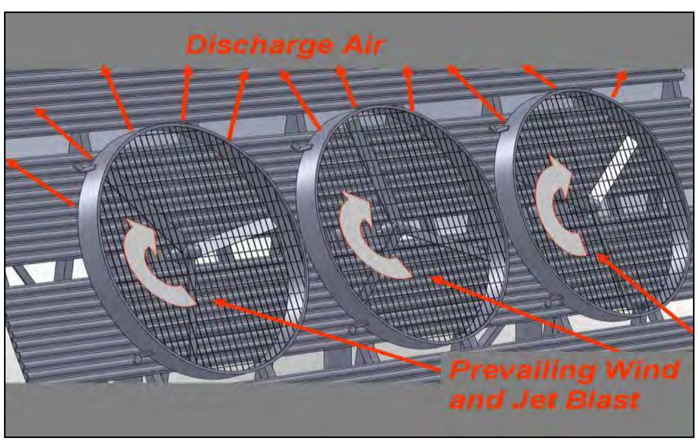

Figure 1-1 Wind-Flow Patterns through AfWATT

Chapter 2: Summary of Literature Review

2.1 The Case for Wind Power.

Wind power has been harnessed for centuries. It is clean, free, and abundant in certain locations. Wind power has the capability to generate environmentally sustainable electricity day and night, reducing dependency on fossil fuels. Technological advances have reduced noise levels to those found in normal conversations, and improvements in generator and blade designs have increased efficiency. Unlike traditional power plants, wind does not require the construction of large factories and supply infrastructure, lowering start-up costs. Financial incentives from both Federal and State governments can also assist with installation. Electrical buyback programs can help reduce yearly operating costs.

Wind power generates electricity without causing harm to the environment. No toxic emissions are created, nor are there any hazardous waste byproducts. Conversely, oil fired and coal burning power plants generate toxic emissions that harm local ecosystems and reduce air quality levels. Oil drilling and its required transportation expose the environment to contamination from spills, as in the Exxon Valdez. Coal must be removed from the ground either by dangerous underground mines or environmentally destructive strip mining methods. Nuclear power creates hazardous byproducts that must be disposed of. In contrast, wind is clean, plentiful and does not require an extensive transportation infrastructure network.

Wind technology has become quieter in recent years. Early wind turbines were considered noisy by many; however technological advances have reduced noise levels substantially. Today, most large scale wind turbines produce about 44 decibels at ground level whereas a normal conversation is rated at approximately 50 decibels (Childs, 2006). Small wind turbines, similar in design to AfWATT, could be expected to produce noise levels between 35 and 50 decibels. In comparison, airfield operations involving jet aircraft routinely have noise levels reaching 120 decibels.

Wind power generation is growing throughout the world, and airports are in a unique position to lead this effort. AfWATT provides a highly visible method of generating electricity on the airfield that would be viewed by millions of passengers yearly. Passenger terminals, parking garages, and hangers all provide roof space to harness wind energy. Wind energy can reduce yearly energy costs and lower the airport's carbon footprint. Modern wind turbines are efficient, highly reliable, and becoming more affordable as energy costs rise. Worldwide, growth in wind power generation has increased 30% each year since 1994 (Legerton 1998).

2.2 Wind Resource Study.

After a proposed location has been selected, a wind resource study will provide an estimate of potential electrical generation. This study measures and records wind speeds and wind direction to establish yearly averages. Wind-flow patterns are also examined. Terrain obstructions such as structures, trees or hills create updrafts or can swirl wind in different directions. This turbulence can reduce wind efficiency. A wind resource study also reveals how seasonal weather patterns and time of day have a large effect on wind speeds. This is demonstrated by Figure 2-1, shown on page 9.

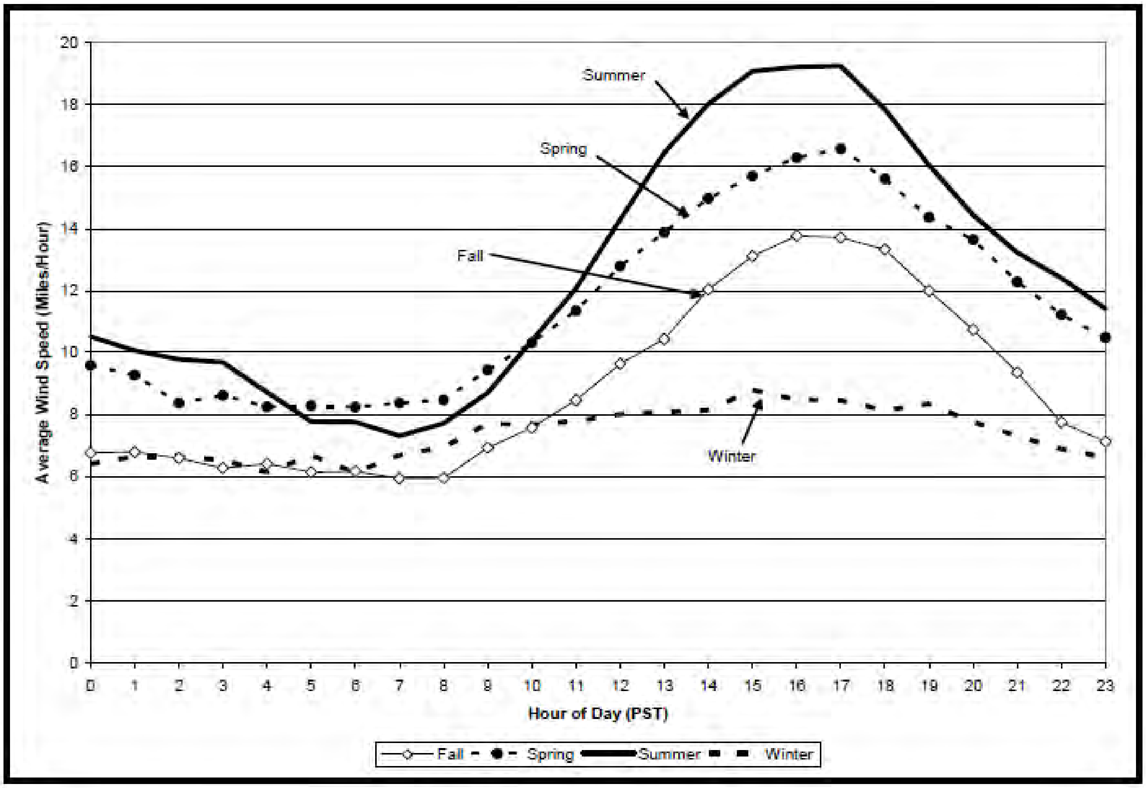

Figure 2-1 San Francisco International Airport Seasonal and Hourly Wind Speeds

Source: Itron, Inc. (2004, September). *City & County of San Francisco wind resource assessment project. Task 5: Data analysis and reporting. Final report.* Retrieved from http://www.energy.ca.gov/reports/2004-10-13_500-04-066.PDF

Common practice when performing wind resource studies is to average daily and seasonal wind variations. This data is then compiled to create a yearly average wind speed. However, wind power does not increase linearly with wind speed. This fact is demonstrated in Figure 2-2, (p. 10), where electrical production is shown for a 1 kilowatt (kW) generator similar to what AfWATT would employ. To obtain truly accurate wind power readings would require the installation of a functioning wind turbine, a step few are willing to make during a feasibility study. Wind power viability was also researched by Pacific Northwest Laboratories. They developed the Wind Power Class chart, Figure

2-3, as a means to quickly assess wind potential at a site (Itron, 2004). Wind power class is based on yearly average wind speed.

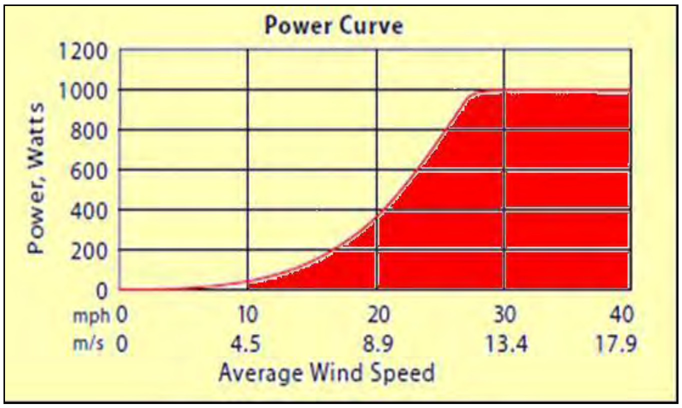

Figure 2-2 Wind Speed Power Curve

Wind Power Class	Wind Speed (Miles/Hour)
1	0.0 to 9.8
2	9.9 to 11.5
3	11.6 to 12.5
4	12.6 to 13.4
5	13.5 to 14.3
6	14.4 to 15.7

Figure 2-3 Wind Power Classes

Source: Itron, Inc. (2004, September). *City & County of San Francisco wind resource assessment project. Task 5: Data analysis and reporting. Final report.* Retrieved from http://www.energy.ca.gov/reports/2004-10-13_500-04-066.PDF

In regards to economic viability, wind speed class 3 is generally considered to be the point at which wind power is capable of turning a profit. Wind speed class 2 has potential under the right circumstances and if kilo-watt-hour (kWh) energy costs are relatively high. Wind speed class 1 does not have enough wind energy to produce economic power generation, however electricity is being produced.

Both San Francisco International Airport (SFO) and San Jose International Airport (SJC) have wind power class ratings below 3; however AfWATT is designed to harness both prevailing wind and wind created by jet blast. Jet blast is significantly higher than wind power class 6, resulting in wind speeds that have the capability to produce large amounts of electricity. With the right location, generator, and blade assembly, AfWATT could generate electrical power at wind speeds up to 120 mph.

A wind resource study can remove much of the uncertainty of whether wind power is suitable for the proposed location; however it provides a rough estimate only. Fortunately, in the case of airfields, there are extensive records of wind conditions over many years. Much of this work was accomplished to support aircraft operations but is useful in determining viability of wind turbine energy.

2.3 Microturbines.

Traditionally, large wind turbines were grouped together to create wind farms. Although highly efficient, these 100 foot tall turbines were not suitable for the airport environment.

In contrast, recent efforts by several manufacturers have been directed at harnessing wind power on a smaller scale. Microturbines are designed to mount on top of buildings, atop city light poles, or in other locations not suitable for larger wind turbines. Rotor blades convert kinetic energy from the wind into rotational energy. The rotational energy is then transmitted through the drive-train into the generator where it is converted to electricity. A connection to the power grid allows the turbine to supply power when wind is plentiful, or to draw power when conditions are calm.

Most microturbines have a power rating from 1.0 kW to about 3.0 kW and are driven by composite blades ranging in diameter from four feet to about 15 feet. They use variable speed generators that are highly efficient and require little to no maintenance. Because of their small size and light weight, they start generating electricity at wind speeds as low as five mph.

Chapter 3: Design and Construction

3.1 Blast Fence Types.

Blast fences began appearing at airports in the late 1950's as a direct result of large piston powered aircraft and the introduction of jet aircraft. High velocity winds generated from propwash or jet exhaust were damaging equipment, other aircraft, and endangering personnel. The blast fence was designed to solve this problem by redirecting hazardous wind upwards. Early designs varied and were made by a variety of manufacturers, however in 1957, the Lynnco blast deflector was approved as the standard for all US Air Force bases. Commercial airports adopted the Air Force findings, and began to install Lynnco deflectors. To meet demand, Lynnco Engineering created a separate blast fence division. This division evolved into Blast Deflectors, Incorporated.

One of the world's largest producers of jet blast fences, Blast Deflectors Incorporated (BDI), is located in Reno, Nevada. They have supplied JBFs to 123 major United States airports, including SFO, LAX, ORD, ATL and JFK, and several US military installations. They have also installed blast fences at over 40 worldwide airports. BDI currently produces two types commonly found at commercial airports: the Taxi-Power series, and the Full-Power series (BDI 2009).

All three major Bay Area airports (SFO, SJC, OAK) employ BDI G14NB-6 through G20NB-6 Taxi-Power series fences. Taxi-Power fences are used in locations where full-power engine runs do not occur, but protection from jet blast is still required. Depending on construction differences, these fences are rated at sustained wind speeds between 140 to 300 mph. Taxi Series range in height from 14 feet tall to 20 feet tall and are made of galvanized steel (BDI 2009). The overall length is dependant upon the location needing protection. In all cases, the JBF is bolted to a concrete support pad. Figure 3-1 shows Taxi Power Series blast fences at SFO and SJC Airports.

Figure 3-1 Taxi-Power Series JBFs at San Francisco and San Jose Airports

AfWATT was designed as an add-on kit to be installed into existing Taxi-Power series blast fences produced by BDI. These fences are in widespread use, have been proven reliable and meet all FAA safety requirements. Don Bergin, Director of Technical Sales, at BDI, and Ross Titlow, BDI Project Manager, reviewed the design of AfWATT and provided our team with technical guidance. Both were supportive of our proposal and expressed interest in possible commercial potential.

The decision to create an add-on kit has many benefits. Engineering and construction efforts are substantially less than would be required for a new blast fence design. Regulatory approval will require less time, since AfWATT retains the original JBF's integrity and external dimensions. Kit installation will be quicker, because there are no structural modifications to the existing blast fence. Less design time, quicker regulatory approval, and fewer airfield disruptions, all result in lower installation costs.

3.2 Design Overview.

Our team set four main design goals for AfWATT. First and foremost, it must be engineered with safety in mind. It must not create unacceptable hazards to aircraft, passengers or airport personnel. Second, AfWATT must have the lowest possible start-up costs. To accomplish this, it would be engineered to use commercially available products. Where parts were not available, our team strove to develop components that would be easily manufactured with available technology. Third, AfWATT must be capable of generating electricity over a wide range of wind conditions. Lastly, AfWATT must have low maintenance costs all the while efficiently producing electricity for the lifetime (minimum 20 years) of the turbine.

3.2.1 3D CAD Images.

To help others visualize AfWATT, our team produced scale drawings, distributing them to airport personnel and industry experts. After incorporating their comments and design suggestions, Mechanical Designers Mike Musal and Rod Jensen were contacted. They agreed to convert the scale two-dimensional drawings into 3D CAD images. These images were then redistributed for further comments and design suggestions.

The CAD process revealed several original design problems, including incorrect generator placement, the omission of a support strut, and adequate clearances for the blade assemblies. Our team worked with Mechanical Designers Musal and Jensen to create a shroud assembly that met safety requirements and was attached securely to the existing JBF. The 3D CAD images provided the ability to make adjustments to components and see how a single change affected the rest of the design. Figure 3-2 below, shows a sampling of the 3rd and final revision. This process ensured that AfWATT could be constructed without unforeseen problems so common with paper two-dimensional drawings.

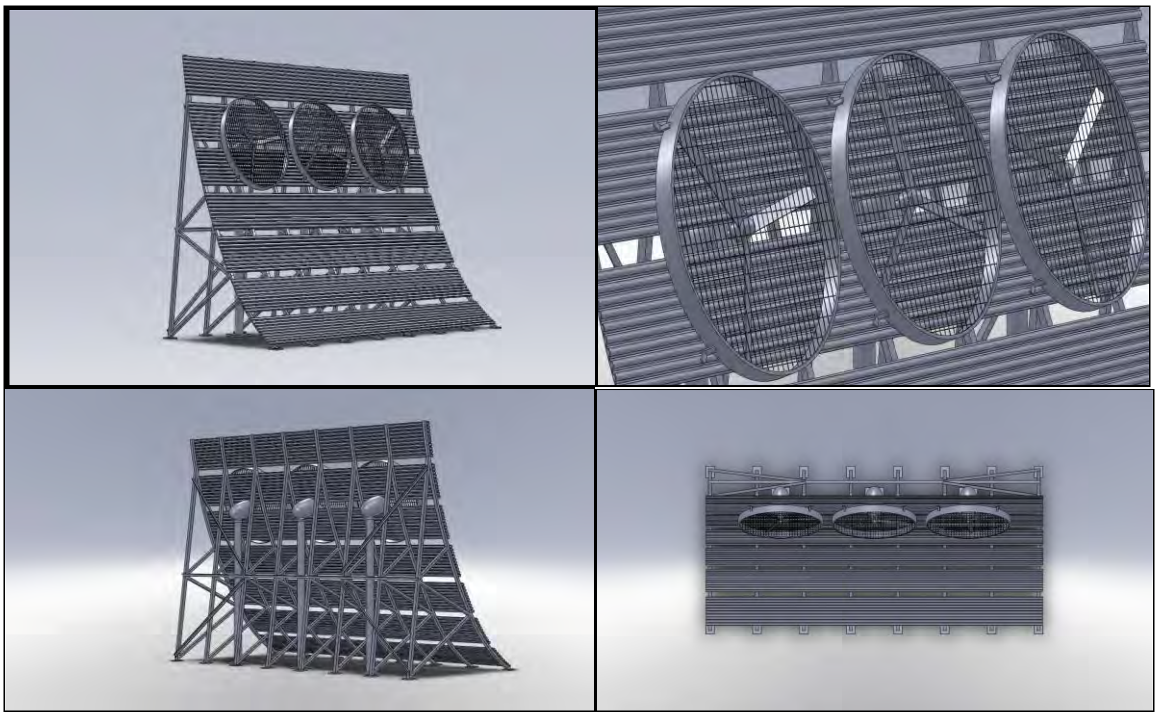

Figure 3-2 3D CAD Images

Appendix H contains a complete set of 16 images organized into three groups; 1) The original JBF as-built by BDI, 2) Kit components of AFWATT, and 3) the installed AFWATT into the JBF. All Appendix H images are screen shots created from SolidWorks, an engineering design program that allows the user to rotate the image to any angle.

3.3 Blades & Generators.

Three main requirements were established to select the type of generator and blade combination. 1) They had to be rated for commercial applications with the ability to connect to existing power grids, 2) be able to operate over a wide range of wind speeds, and 3) be capable of surviving high velocity jet blast. Wind turbines are commonly marketed as a complete unit that includes the generator, invertors, and turbine blade assembly. This ensures components are matched together. "Traditionally, small wind turbines have most commonly used three blades", but "for a given diameter, as the number of blades is increased, the peak power coefficient increases." (Warne, 1983). Both AeroVironment and Cascade Engineering (referenced below in Figure 3-3), manufacture turbine rotors using more than three blades, thereby increasing efficiency.

Composite materials have been used to manufacture wind turbine blades for several years. Composites are made up of two or more materials combined on a macroscopic scale. They have proven to be ideal for structural applications where high strength-to-weight and stiffness-to-weight ratios are required. They are also non-corrosive (International Energy Agency 2001). Composite blades weigh less than steel or aluminum, translating into quicker spool-up times, creating more electricity. AfWATT rotor blades would be constructed from either light weight glass-fiber-reinforced-plastic (GRP) or a combination of composites and carbon filament-reinforced-plastic (CFRP). Both have proven track records when used for turbine blades.

Material fatigue properties are an important consideration in wind turbine design. Blades are subject to both compression stresses from the wind and centrifugal forces from rotation. Regular visual inspections are required to check for blade damage. Nicks can lead to cracks, accelerated by stresses inherent to turbine operation. In addition to regular inspections, one manufacturer requires blade and hardware replacement at 20 years, regardless of visual indications.

Rotor blades convert kinetic energy from the wind into rotational energy, transferring it to the generator. The generator converts the rotational energy into electricity, feeding it to the utility grid. Microturbine generators are able to use small, variable speed generators and solid state invertors to accomplish this, resulting in more efficient power generation. In contrast large wind turbines, such as those in wind farms, must use a gearbox between the blades and generator, resulting in a loss of efficiency.

Cascade Engineering, Southwest Windpower, and AeroVironment all produce a microturbine that includes blades, generator, and necessary components to connect to the power grid. Figure 3-3 compares the features of each microturbine manufacturer.

Domestic Microturbine Options			
Company Name	**Cascade Engineering**	**Southwest Windpower**	**AeroVironment**
Model Designation	Swift	Skystream 3.7	Architectural Wind
Rated Peak Capacity	1.5 kW	2.4 kW	1.75 kW
Estimated Peak (5 ft. rotor)	1.1 kW	1.0 kW	1.6 kW
Rated Wind Speed	29 mph	29 mph	27 mph
Grid Feeding	240 Ph 1	120/240 Ph 1 or 120/208 Ph 3	120/240 Ph 1
Generator Dimensions	N/A	19" x 25"	N/A
Blade Design	5 blade with outer ring	3 blade traditional	5 blade traditional
Blade Construction	Reinforced Polymer	Fiberglass Composite	Carbon-Fiber
Rotor Diameter	7 ft.	12 ft.	5.5 ft.
Cut-in-Wind Speed	8 mph	8 mph	5 mph
Survival Wind Speed	146 mph	140 mph	120 mph
Unit Weight	250 lbs.	170 lbs	130 lbs.
Noise Level	35 dBA	84.9 dBA	50 dBA
Maintenance	Yearly Visual	Yearly visual of blades	Yearly visual
Warranty	5 years	5 years	1 year

Figure 3-3 Microturbine Options

Because AfWATT is an entirely new concept, there is no drop-in fit from any manufacturer. However, initial analysis concluded that Cascade Engineering's Swift and AeroVironment's Architectural Wind present the best choices. Both are proven designs, and are currently available. Although the Swift has a higher survival wind speed for runway applications, in taxiway locations the Architectural Wind would be more than adequate. (BDI's Taxi Series blast fences with 6 ft. support spacing are rated to withstand sustained 140 mph winds.) Both have relatively low noise levels, so the addition of multiple AfWATTs should still be well below noise levels experienced from other airfield sources. In low-wind conditions, the Architectural Wind would be the best choice because it starts generating electricity at only 5 mph.

Southwest Windpower's Skystream 3.7 would be the last choice because this turbine is designed to use a much larger (nearly 12 foot diameter) blade. AfWATT's blades are only 42% of the dimensions of the Skystream blades. As a result, AfWATT blades may not create the force necessary to overcome the magnetic resistance in the Skystream generator. This would lead to inefficiencies in electrical power generation.

For international applications, Cascade Engineering's Swift and Southwest Windpower's Skystream 3.7 are capable of connecting to Europe's power grid. In addition, Ampair, a European wind turbine manufacturer, produces a 600 series turbine that includes a 6 foot blade. Ampair was not included in this study since they do not produce generators capable of connecting to the U.S. power grid, but they are referenced in Appendix G for international customers reviewing this report.

3.4 Shroud Assembly.

The shroud assembly must protect the blades from Foreign Object Debris (FOD) damage and inadvertent human contact. It must be strong enough to withstand high velocity jet blast without separating from the existing blast fence structure, yet allow for the passage of airflow to drive the blades. The shroud must not increase the possibility of nesting locations for rodents or birds.

AfWATT initially used large shrouds that interconnected and faired into the corrugated blast fence panels. This initial design would have been heavy, cumbersome, and difficult to manufacture. After discussions with Mechanical Designers Musal and Jensen, the shroud design was changed to an individual shroud design. Individual shrouds would be easier to manufacture, lowering production costs. Due to their smaller size, they would also reduce the possibility of damage from FOD. If damaged, maintenance crews would be able to replace one shroud, instead of several interconnected shrouds. The individual shroud design also eliminated concerns about nesting locations for wildlife.

To provide maximum airflow and strength, the protective screen directly in front of the turbine blades is constructed of galvanized welded wire mesh. Around the track of the blades, a steel ring contains the blades in the event of blade failure. The ring also channels airflow through the blades. Discharge air from the turbine blades is then allowed to escape through an opening between the steel ring and the corrugated blast fence material. This discharge air is directed upwards by the original design of the blast fence. The entire shroud assembly is attached to existing JBF structural support posts using brackets and standard hardware.

3.5 Support Components.

AfWATT is supported on a galvanized steel pole attached to the concrete JBF support pad. At the top of the flanged pole is an adjustable wedge. The generator is attached to this wedge using bolts. The wedge allows for angle adjustment of the generator to accommodate variations in blast fence designs. All electrical wiring is routed in conduit to protect it from the elements. The conduit is attached to the steel support post, and then runs along the base of the JBF support pad to an underground connection. The underground connection provides access to the airport power grid. Electrical cutoff in the event of a major collision is provided by a mercury motion switch or equivalent.

3.6 Installation & Maintenance.

Installation of AfWATT will be straightforward and could be accomplished by airport engineering and maintenance personnel. To mount the generator support poles, appropriate brackets must be installed into the concrete base. This will require the use of an auger and concrete mix. Once the support pole is in position, the generator can be attached. The generator shaft was designed to extend between the original JBF horizontal corrugated panels. This minimizes or eliminates alteration to the existing blast fence. The last item to be installed is the shroud assembly. The shroud is attached to the existing JBF using the supplied brackets and hardware.

AfWATT was designed for low maintenance. Generators are sealed units, electrical components meet current Federal Codes, and materials are designed to withstand harsh weather conditions. Regular visual inspections are required to check for abnormal wear or damage to the blade assembly. This ensures maximum service life and guarantees structural integrity.

3.7 Regulatory Approval.

AfWATT was carefully designed to meet existing FAA regulations on JBFs, as explained in FAA Advisory Circular 150/5300-13. It is installed into approved existing blast fences only, and does not alter blast fence structural integrity, height, or footprint.

In discussions with BDI, our team learned that blast fences are not designed to be frangible. Blast fence collisions are extremely rare, as demonstrated in the following risk analysis. Both the FAA and the International Civil Aviation Organization (ICAO) have approved installation of BDI fences at facilities around the world. However, because safety was our primary design goal, AfWATT was engineered so that it will provide the least amount of resistance, should a collision take place. Wind resource studies, which include prevailing wind and jet blast data, will determine the ideal location to install AfWATT. Because JBFs are positioned throughout the airfield, it is highly probable that many locations will be near terminals or taxiways that are well away from the hazards of runway diversions.

Chapter 4: Safety Risk Assessment

4.1 General Background.

Safety in aviation is paramount; however a certain amount of risk will always be present. The goal of any safety program is to reduce risk to an acceptable level. Often this can be accomplished through changes in procedures, training, or equipment.

Both the National Transportation Safety Board (NTSB) and the FAA have a long history of improving safety in aviation by providing recommendations and directives. NTSB investigations, FAA Advisory Directives, Advisory Circulars, and certification standards all reduce the levels of risk through education and corrective actions.

One of the most comprehensive safety publications is the FAA Safety Management System Manual (SMS). This manual describes how to implement a safety program, including how to evaluate risk, manage that risk, and ensure a safety culture exists within the organization. In addition to the SMS manual, Advisory Circular 150/5200-37 describes in detail the process of Safety Risk Management (SRM). "SRM is a systematic, explicit, and comprehensive approach for managing safety risk at all levels throughout the airport."(A/C 150/5200-37, 2007, p. 9). The ultimate goal of this assessment is to determine whether AfWATT will be free of unacceptable risk. However, it is important to understand that SMS is an ongoing process, and safety must be continually monitored and assessed until all risks have been identified and found to be at acceptable levels.

4.2 NTSB Incident Review.

The NTSB has compiled one of the most extensive records of incidents and accidents. Any safety assessment would be remiss without consulting this database. It is important to determine the frequency and severity of occurrences where an aircraft has contacted a blast fence.

Our team researched the NTSB Safety Database for all accidents involving blast fences located at airports. Of the over 140,000 aviation-related accidents documented by the NTSB since 1962, we found 711 cases involving blast fences. Of these, 583 were general aviation accidents at smaller airports and consisted of collisions with various types of fences, including perimeter fences. The remaining 128 accidents involved airliners at major airports, colliding with a blast fence similar to that used by AfWATT. The causal factors of accidents involving blast fences can be grouped into three basic categories: human error, mechanical error, or environmental conditions.

NTSB analysis concluded that human error accounted for the majority of cases. The flight crew was at fault 82% of the time, with over half of these accidents occurring during takeoff or landing. Wells and Rodriuges, authors of Commercial Aviation Safety (2004), point out that "The probability of an accident is significantly higher during takeoff and landing than any other phase of flight" (p.102). Southwest Airlines flight 1455 collided with a blast fence at Burbank Airport due to excessive landing speeds. (NTSB ID # DCA00MA030). Occasionally, a taxing aircraft will impact a JBF, such as in NTSB File #BFO92IA046, where a UPS 747-100 wingtip was damaged by the collision with a blast fence. In May 2006, a taxiing Quantas Airlines 747-400 struck a blast fence at JFK airport, damaging the right wingtip (ATSB Report #200603130).

Mechanical error accounted for approximately 6% of accidents involving blast fences. In 1992, a TWA Lockheed L-1011 aborted takeoff at JFK, swerving off the runway to avoid the blast fence (NTSB AAR-93-04). It was found that the stall warning system and deficiencies in TWA's maintenance program contributed to this accident.

Environmental conditions resulted in 12% of collisions involving blast fences. Southwest Airlines flight 1248 crashed through a JBF located at Chicago Midway Airport, resulting in one fatality (NTSB ID # DCA06MA009). Contributing environmental factors, including ice and snow, combined with an insufficient runway overrun length, caused the aircraft to collide with the JBF. In another case, a Midway Airlines DC-9 overran a runway at DFW airport, colliding with the localizer. The NTSB determined the cause to be inadequate snow removal by airport personnel (NTSB File # CHI90IA044).

After evaluating the data, there was no common connection between individual cases that would suggest the design of the blast fence caused the accidents. There have been nearly 140,000 total documented accidents, with only 711 involving fences of any sort. Based on this data, the chance of an aircraft hitting a fence (perimeter fences included), is approximately 0.005%. If only commercial airliners at major airports (128 accidents) are considered, the chance of a JBF collision drops to 0.0009%.

There were eleven cases of fatalities involving airliners at major airports. Based on this, if you were unfortunate enough to be a passenger on one of the 0.0009% of aircraft that collided with a JBF, there would be a 0.09% chance for a fatality. Put otherwise, when looking at all aviation accidents, there is a 0.00008% chance of a fatality involving a blast fence. Clearly, the risk of a fatality involving a JBF is extremely low when compared to other causes of accidents.

The NTSB evidence reveals that accidents involving blast fences seldom occur. Figures 4-1 and 4-2 below, illustrate how low the risk of a collision or fatality is with a JBF. Therefore, we believe the addition of a wind-powered turbine system to existing blast fences would not increase the probability of aircraft accidents.

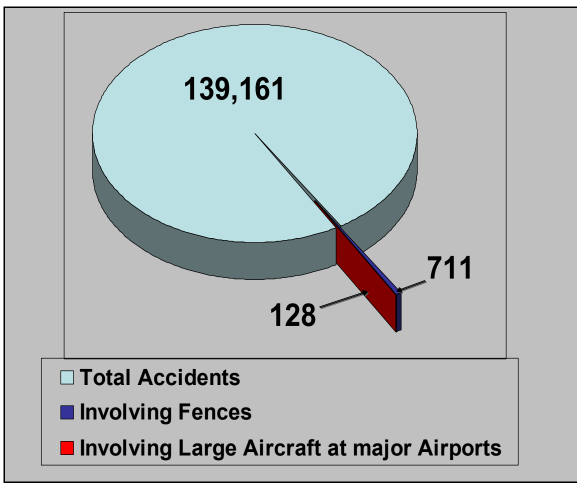

Figure 4-1 JBF Accidents

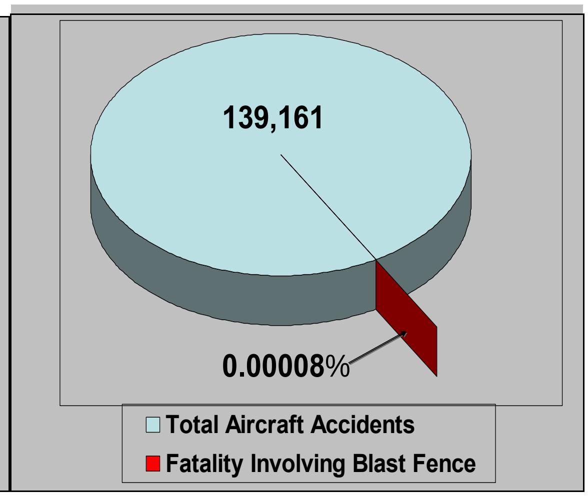

Figure 4-2 JBF Fatalities

4.3 Safety Analysis.

Both SMS 3.3.1 *Items Requiring Evaluation for Safety Risk*, and FAA Order 1100.161, *Air Traffic Safety Oversight*, specifically cite the following categories of changes as requiring a safety analysis:

1. Changes to airport procedures and standards that impact safety, including physical changes to the airport operations area.
2. The introduction of new equipment that may impact safety.

Using the SRM decision process shown in Figure 4-3 below, a preliminary safety analysis was conducted.

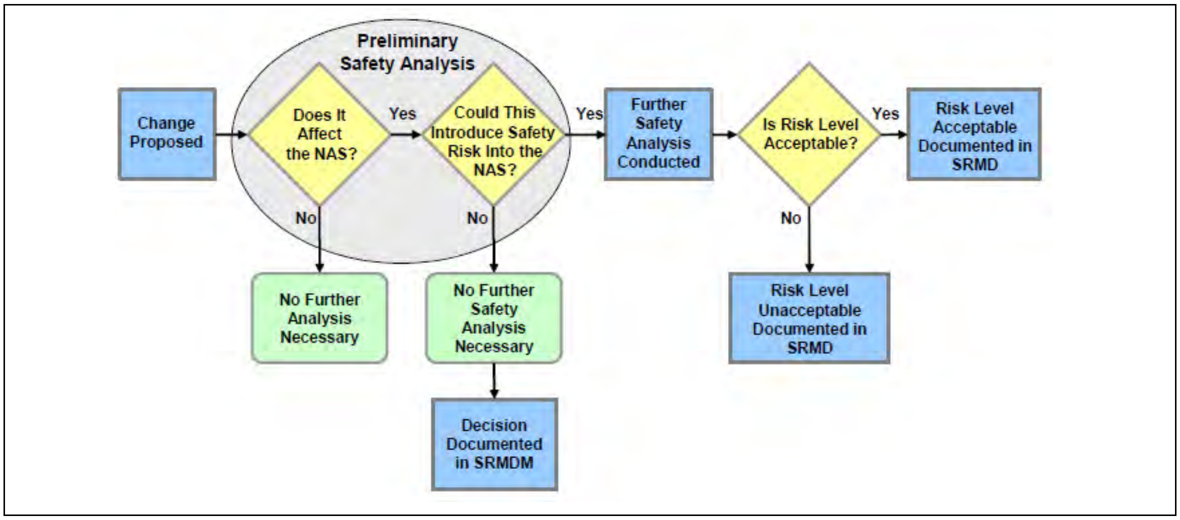

Figure 4-3 SRM Decision Making Process

Source: Federal Aviation Administration, SMS Version 2.1. (2009). *Air traffic organization—Safety management system manual.* Washington, D.C.: U.S. Government Printing Office. Retrieved from:http://platinum.ts.odu.edu/Apps/FAAUDCA.nsf/SMSManual.pdf

Because AfWATT involves changes that could introduce safety risk into the airfield operating environment, further safety analysis would be required. Figure 4-4, as seen on p. 27, titled *Accomplishing a Safety Analysis,* was used as a guideline to conduct this study. FAA Safety Inspector Margaret Freydoz guided our team through the process of conducting the safety analysis and the proper use of the risk matrix. Dave Flint, an FAA Air Traffic Control Supervisor, provided technical expertise in identifying risks associated with Air Traffic Control hardware and procedures.

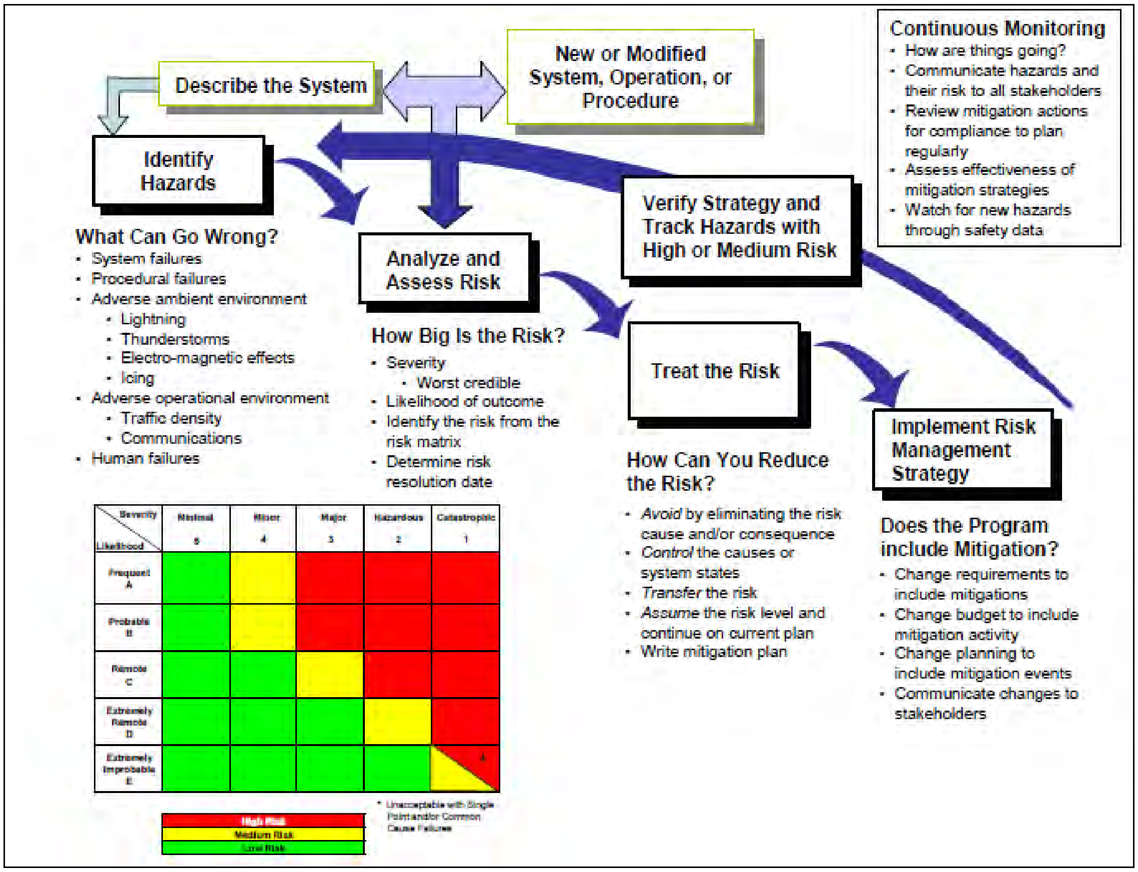

Figure 4-4 Accomplishing a Safety Analysis

Source: Federal Aviation Administration, SMS Version 2.1. (2009). *Air traffic organization—Safety management system manual.* Washington, D.C.: U.S. Government Printing Office. Retrieved from:http://platinum.ts.odu.edu/Apps/FAAUDCA.nsf/SMSManual.pdf

Describe the System.

AfWATT is designed to harness prevailing wind and jet blast from taxiing or departing aircraft. It will operate both day and night, and in all weather conditions. It is designed as an addition to existing blast fences and has been engineered for ease of installation. Electricity will be generated by a moveable blade assembly connected to an electrical generator. AfWATT will be interconnected to the main airport power grid and be used to power airport or airfield devices as needed.

Identify Hazards.

Our team identified four categories of potential safety hazards.

1. The physical installation of the design
    a. Mesh shroud strength
    b. Blade damage resulting in an out of balance condition which could lead to blade failure
    c. Generator hazards, including failure, fire, etc.
    d. Harmonic vibrations created by wind-flow over blades, causing damage to existing blast fence

2. The physical installation in relation to aircraft movement.
    a. NTSB research results (see Figure 4-1 JBF Accidents)
    b. Increases severity of aircraft collisions with blast fence
        1. Impact exposes live electrical circuits
        2. Generator hazards in relation to impact
        3. Blade hazards in relation to impact
    c. Electromotive force (EMF) produced by generator may interfere with aircraft or air traffic control navigation aids (NAVAIDS)
    d. Damage from jet blast

3. The physical installation in relation to human interaction
    a. Possible runway or taxiway closures for installation
    b. Rotating blade hazards during maintenance
    c. Compliance with OSHA regulations
    d. Human Factors issues

4. The physical installation in relation to environmental issues
    a. Possibility of unintended rodent or bird nesting locations
    b. Weather related issues, such as icing, snow, etc
    c. Ground contamination from lubricants

Analyze & Assess Risk.

To properly estimate risk levels, guidelines from Figure 4-4, p. 27, *Accomplishing a Safety Analysis* and its included chart, *The Predictive Risk Matrix* were followed.

The likelihood of the following conditions would be remote and would result in minor safety effects:

- EMF produced by the generator
- Ground contamination from lubricants
- Generator failure

The following conditions are remote but could result in a major safety effect:

- Liberation of the mesh shroud from the fence
- Blade damage resulting in failure
- Harmonic vibration damage caused by wind-flow from turbine
- Damage from jet blast
- Rodent or bird nesting

The following conditions are probable, especially under harsh conditions; however they will likely pose little safety effect:

- Weather related issues

The highest safety risk is classified as extremely remote; however it could result in a catastrophic condition:

- Impact of aircraft with blast fence
- Rotating blade hazards during maintenance

The extreme severity of an aircraft collision or personal injury during maintenance demands closer attention to reduce these risks to acceptable levels.

Treat Risk.

Our team has made focused efforts to design an error-tolerant system that mitigates the above identified risks or reduces them to levels that are acceptable. Numbered sections refer to categories of hazards identified earlier on page 28.

1. In regards to physical installation hazards, we have been able to mitigate these to acceptable levels. The mesh shroud can be strengthened with additional bracing and attachment points to prevent liberation from the fence. An out of balance blade condition will cause a shear pin to internally disconnect the shaft to the generator, essentially eliminating damage from vibration to surrounding areas. This would also activate a friction brake to keep the blades from windmilling. Overtemp sensors on the generator would automatically disconnect the generator in case of overheat or fire. Harmonic vibrations should be monitored throughout the test period to establish acceptable safety levels.

2. In relation to aircraft movement, impact with the blast fence could increase the severity of damage to the aircraft. However, strengthening of the blast fence may reduce the chance of damage to persons and property beyond the fence. In most cases, fences are located to protect areas from jet blast. AfWATT might assist in slowing the progression of any aircraft beyond the blast fence, thereby reducing stopping distance. We also recommend in locations where possible, the inclusion of a runway arresting system, such as EMASMAX. This system uses lightweight, crushable concrete that would slow aircraft down before impacting the blast fence

(Koczkodaj, 2008). However, the existing blast fence presents an impact hazard without the addition of AfWATT.

The generator shall be mounted with frangible hardware, and the electrical circuit shall be protected with a motion activated mercury switch or equivalent. The blade assembly is attached to the shaft with shear bolts or pin that will allow free movement of the composite blades upon impact. We have discussed EMF concerns with both Ms. Freydoz and Mr. Flint. Neither of them were overly concerned with the possibility and mentioned numerous other generator devices located on the airfield. Jet blast damage from rocks and other FOD would need to be monitored during the test period.

3. Human interaction concerns are reduced by employing proven human factors principles, OSHA regulations, and the input of those who will be responsible for AfWATT operation and maintenance. For maintenance issues, workers must be able to secure blades to avoid personal injury. Any airfield construction would require a formal airport plan that would designate closures of surrounding areas and safety procedures. Furthermore, a Notice to Airmen (NOTAM) would be required until airport charts could be updated.

4. To reduce airport environmental hazards, AfWATT would not increase water collection nor create a habitat for rodents or birds. We foresee no increase in bird activity. It is possible that the motion and noise created by the rotating blades will act as a deterrent to birds. Weather related issues may either increase or hamper

the efficiency of AfWATT. It is unlikely that prevailing wind will exceed jet blast speeds, so high wind is not expected to create adverse effects. Ice and snow may form on the mesh screen during storms. This condition would need to be monitored during the test period to establish whether further action would be necessary. All of the aerogenerator components are sealed to prevent ground contamination and are approved for use in commercial applications.

4.4 Risk Analysis Conclusions.

NTSB research concluded that during a period of 47 years, there were only a handful of accidents involving blast fences. Although some of these involved fatalities, the installation or position of the JBF was not the primary cause of the accident.

A thorough safety analysis was conducted using the SMS guidelines and the Risk Management process. Our team considered installation hazards, aircraft interactions, human factors, and environmental consequences. The goal was to identify and mitigate all of the concerns that were discovered at this early stage of development. The safety analysis concluded that risk levels of AfWATT are acceptable. We recommend a prototype be constructed for testing.

An important part of any risk analysis is the inclusion of all involved parties, manufacturers, and industry experts. Before implementation, discussions should be held with Airport Facilities Personnel, including engineering, maintenance, and airfield operations. Any risk analysis conclusions must also be in compliance with ICAO and FAA safety standards before proceeding.

Chapter 5: Financial Analysis

5.1 Federal Government Funding.

Economic incentives and subsidies from the Federal government can reduce the cost of installing AfWATT. The Voluntary Airport Low Emissions program (VALE) was introduced by the FAA to encourage the use of green technology. "Funding of eligible costs is 75% for large and medium hub airports and 95% for smaller commercial service airports" (FAA-VALE, 2009). Both San Francisco and San Jose Airports have taken advantage of this program to reduce their overall carbon footprint.

In addition to VALE, the Federal government offers two different tax incentives that apply to wind turbine installations, including AfWATT. The first is the Business Investment Tax Credit, which offers a Federal tax credit to offset installation costs. "The credit is equal to 10% of expenditures, with no maximum credit limit stated (explicitly)" (Database of State Incentives for Renewables & Efficiency, 2009). The credit for microturbines, such as AfWATT, is capped at $200 per kW of capacity.

"The second Federal incentive is the Renewable Electricity Production Tax Credit (PTC). This incentive provides tax credit based on the kWh output of the alternative energy source. For wind power, it totals "2.1 cents per kWh" (Database of State Incentives for Renewables & Efficiency, 2009).

The U.S. Department of the Treasury offers incentives as well, however these are exclusive to the tax credits offered by the IRS. The Treasury offers grants "equal to 10% of the total cost of the microturbine and is capped at $200 per kW of capacity." (Database of State Incentives for Renewables & Efficiency, 2009).

5.2 State Funding.

Each state has its own individual incentives. In California, energy companies have been required to buy-back electricity from wind and solar producers since 1996. This process is called net metering, in which customer electricity purchases are "netted" against what they produce from wind power. In short, the customer sees a lower electricity bill. California Assembly Bill (AB 920), introduced in February 2009, would expand this program (Lingbloom 2009). Other states have similar funding programs to assist businesses who wish to "go green".

5.3 Site Analysis.

To determine the viability of AfWATT, JBF locations at SFO and SJC airports were examined. To harness maximum wind potential, only blast fences that faced into prevailing winds were considered. Based on wind speeds at both airports, AeroVironment's Architectural Wind was selected. It begins generating electricity at only 5 mph, below yearly average wind speeds at SFO (10.6 mph) and SJC (6.5 mph). Figure 5-1 shows yearly costs for one AfWATT.

AfWATT Projected Yearly Cost—Each

	Year One	Year Two	Year Three	Year Four	Year Five
Architectural Wind	$11,000	$0	$0	$0	$0
Installation Costs (parts, labor)	$2,500	$0	$0	$0	$0
Yearly Maintenance Costs	$0	$200	$200	$200	$200
Yearly Cost per Unit	$13,500	$200	$200	$200	$200

Figure 5-1 AfWATT Yearly Costs

5.3.1 Calculating the Potential of Wind.

The following formulas were provided by the American Wind Energy Association (AWEA) and used to estimate the electrical production of AfWATT.

Rotor Swept Area is the amount of area the turbine blades cover as they rotate. It is an essential element in determining wind turbine power, and is expressed in meters squared. AfWATT has a rotor swept area of 1.8 m^2.

- ✈ *Rotor Swept Area = 3.14(Blade Diameter /2)^2*

Wind turbine power is a realistic estimate of how much power can be extracted from the wind, and is expressed as "Watts Generated" in Figures 5-2, 5-3, and 5-6.

- ✈ *Wind turbine power = .5(air density) (rotor swept area) (coefficient of performance) (wind speed ^3) (generator efficiency) (bearing efficiency)*
    - Air density at sea level = 1.225 kg/m^3
    - Rotor Swept Area =1.8 m^2
    - Coefficient of performance = .35 is industry standard
    - Generator efficiency = 80%
    - Bearing efficiency = 95%

Electricity is measured and sold in kilo-watt-hours (kWh). If the turbine generates one watt, and it runs continuously for one year (8750 hours) then you have 8750 watt-hours, or 8.8 kWh. This amount is then multiplied by the going rate for electricity, currently about 12 cents per kWh. Figures 5-2, 5-3 and 5-6 express this as "Money Generated at 12 cents/kWh".

5.3.2 San Francisco International Airport.

Yearly average wind speed at San Francisco Airport is approximately 10.1 mph or 4.5 m/s and faces towards Runways 28 left and 28 right for the majority of the year.

There are seven blast fences totaling 2900 feet in length, each standing approximately 15 feet tall. This represents a maximum capacity of 410 AfWATTs. Appendix I illustrates the JBF locations, their length, and their capacity for AfWATTs.

However, none of these blast fences are directly behind congested taxiways or runways. The SFO JBFs receive limited and infrequent amounts of jet blast from a wide variety of aircraft. To establish accurate data, anemometers would need to record aircraft operations over a specified period. Consequently, the SFO analysis includes only prevailing wind to determine energy production.

Phase 1 would install 27 AfWATTs to the 192 foot blast fence located at the intersection of Charlie and Uniform Taxiways. This JBF receives undisturbed wind and can be seen from the airport terminal and the adjacent rental car facility. Figure 5-2 provides estimated costs and electricity generation for the first five years of service.

Phase 1: Taxiway Charlie @ Uniform JBF
Wind speed = 10.1 mph or 4.5 m/s

	Year One	Year Two	Year Three	Year Four	Year Five
Start-Up Cost for 27 AfWATTs	$364,500	$0	$0	$0	$0
Yearly Maintenance Cost	$0	$5,400	$5,400	$5,400	$5,400
Carry-Over Cost from Previous Year	$0	**<$363,743>**	**<$368,386>**	**<$373,029>**	**<$377,672>**
Watts Generated	720.9	720.9	720.9	720.9	720.9
Watts Generated Yearly	263.1 kW	263.1 kW	263.1 kW	263.1 kW	236.1 kW
kWh per year	6307.9 kWh	6307.9 kWh	6307.9 kWh	6307.9 kWh	6307.9 kWh
Money Generated @ 12 cents/kWh	$757	$757	$757	$757	$757
Total Money Generated per Year	**<$363,743>**	**<$368,386>**	**<$373,029>**	**<$377,672>**	**<$382,315>**

Figure 5-2 SFO Phase 1 AfWATT Installation

5.3.3 San Jose International Airport.

Yearly average wind speed at San Jose Airport is approximately 6.5 mph or 2.9 m/s and faces the majority of the year towards Runways 30 left and 30 right. (California Climate Data Archive, 2009). Located directly behind these runways and alongside approaching taxiway Alpha One is the South Blast Fence. This fence is approximately 2284 feet long, stands 15 feet tall, and is roughly 300 feet away from taxiway Alpha One. Its main purpose is to protect both an airport service road and a city maintained street. Appendix I illustrates the SJC South Blast Fence.

The South Blast Fence has a total capacity of 326 AfWATTs however; Phase 1 would install only 27 AfWATTs to establish project viability. Figure 5-3, below, provides estimated costs and electricity generation for the first five years of service.

Electricity Generated by Prevailing Wind

Wind Speed = 6.5 mph or 2.9 m/s

	Year One	Year Two	Year Three	Year Four	Year Five
Start-Up Cost for 27 AfWATTs	$364,500	$0	$0	$0	$0
Yearly Maintenance Cost	$0	$5,400	$5,400	$5,400	$5,400
Carry-Over Cost from Previous Year	$0	<$364,297>	<$3699,494>	<$374,691>	<$379,888>
Watts Generated	193.2	193.2	193.2	193.2	193.2
Watts Generated Yearly	70.5 kW	70.5 kW	70.5 kW	70.5 kW	70.5 kW
kWh per year	1690.5 kWh	1690.5 kWh	1690.5 kWh	1690.5 kWh	1690.5 kWh
Money Generated at 12 cents/kWh	$203	$203	$203	$203	$203
Total Money Generated per year	<$364,297>	<$3699,494>	<$374,691>	<$379,888>	<$385,085>

Figure 5-3 SJC Electricity from Prevailing Wind

SJC averages 390 air carriers and air taxi departures per day (G.C.R. & Associates, 2006). All large aircraft must depart on Runway 30 left or 30 right, subjecting the South Blast Fence to jet blast. The majority of SJC commercial departures involve the Boeing 737; however SJC is served daily by larger aircraft. To provide a conservative and realistic analysis, our team chose to use breakaway jet blast speeds obtained from the Boeing 737. By observing aircraft operations, data showed jet blast impacted each AfWATT for approximately 25 seconds at an estimated wind speed of 30 mph. Figure 5-4, shown below, depicts jet blast wind speeds, while Figure 5-5 provides data for estimated daily amounts of jet blast at SJC Airport.

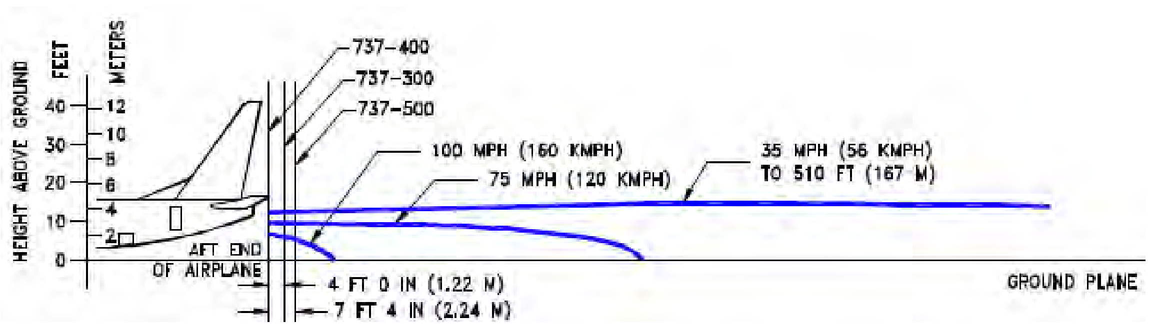

Figure 5-4 Boeing 737 Breakaway Thrust Jet Blast Speeds

Source: Boeing Aircraft Co.—737 Airplane Characteristics for Airport Planning (October, 2005). *Operating Conditions -Jet engine wake and noise data.* Retrieved from: http://www.boeing.com/commercial/airports/acaps/737sec6.pdf

Estimated Jet Blast	
Total Aircraft departing daily	390
B737 Breakaway Thrust at JBF	30 mph or 13.4 m/s
Time of Jet Blast per Aircraft	25 seconds
Daily Total Time of Jet Blast Impact	2.7 hours

Figure 5-5 Estimated SJC Daily Jet Blast Totals

Wind power does not increase in a linear curve. A wind speed of 20 mph creates nearly eight times the energy of a wind speed of 10 mph. Therefore, Figure 5-6, shown on page 39, includes daily jet blast totals added to prevailing winds to estimate actual energy production.

Electricity Created by Prevailing Wind & Jet Blast					
	Year One	Year Two	Year Three	Year Four	Year Five
Start-Up Costs for 27 AfWATTs	$364,500	$0	$0	$0	$0
Yearly Maintenance Cost	$0	$5,400	$5,400	$5,400	$5,400
Carry-over Cost from Previous Year	$0	**<$361,127>**	**<$363,154>**	**<$365,181>**	**<$367,208>**
Watts from Jet Blast & Wind (36.5 mph)	27 kW	27 kW	27 kW	27 kW	27 kW
Watts Yearly from Jet Blast & Wind	266 kW	266 kW	266 kW	266 kW	266 kW
Watts Generated from Wind	193.2 W	193.2 W	193.2 W	193.2 W	193.2 W
Watts Generated Yearly from Wind	70.5 kW	70.5 kW	70.5 kW	70.5 kW	70.5 kW
kWh per year Jet Blast & Wind (985.5 Hrs)	26,608 kWh	26,608 kWh	26,608 kWh	26,608 kWh	26,608 kWh
kWh per year Wind Only (7774.5 Hrs)	1,502 kWh	1,502 kWh	1,502 kWh	1,502 kWh	1,502 kWh
Total Combined kWh per year	28,110 kWh	28,110 kWh	28,110 kWh	28,110 kWh	28,110 kWh
Money Generated at 12 cents/kWh	$3,373	$3,373	$3,373	$3,373	$3,373
Total Money Generated per Year	**<$361,127>**	**<$363,154>**	**<$365,181>**	**<$367,208>**	**<$369,235>**

Figure 5-6 SJC Phase 1 Electricity from Prevailing Wind and Jet Blast

5.3.4 Site Analysis Conclusions.

SFO figure 5-2, *AfWATT Phase 1 Installation*, demonstrates that wind power alone is not sufficient to make AfWATT cost-effective based on financial reasons. SJC Figure 5-6, *Phase 1 Electricity from Prevailing Wind and Jet Blast*, demonstrates that the combination of wind power and jet blast does not make AfWATT cost-effective either. In 2004, The City & County of San Francisco commissioned a study to investigate wind power at several locations, including SFO. They concluded that "the wind energy resources at the monitored sites (SFO) appear to be quite modest relative to levels associated with commercial wind energy development." However, as electrical costs increase, "these wind speeds may justify development on financial grounds" (Itron, 2004, p.45-46). These findings were supported by discussions with AeroVironment, who stated that small wind turbines are still in the experimental stages of development. Future advances in technology and efficiency could make AfWATT financially viable.

From a public relations standpoint, AfWATT has a much larger potential. Wind turbines provide one of the most visible alternative energy sources with little to no adverse side effects. When placed on the airfield, millions of passengers would be exposed to the image of spinning turbines, reinforcing the airport's "green" commitment. At SFO and SJC, AfWATT would be visible from aircraft, the passenger terminal, local buildings, and city streets. This visible commitment could improve public relations, reducing or eliminating obstacles from future airport improvement projects. AfWATT could also lead to new funding opportunities, such as sponsorship or advertising. Lastly, an AfWATT installation would bring national publicity to the airport and label it as a leader in emerging "green" technology.

Chapter 6: Implementation

After receiving regulatory permission, a prototype AfWATT should be constructed at a suitable airport location. This would allow for accurate real-world testing to analyze associated risks and appropriate methods of mitigating those risks. A prototype would also establish true energy production rates, giving a clearer picture of the viability of the AfWATT design.

An operational prototype would require cooperation from several companies. First, any alteration to an existing blast fence would require the approval of the manufacturer, in this case, BDI. Existing components from wind turbine manufacturers would need to be modified to work with AfWATT, involving AeroVironment, Cascade Engineering or Southwest Windpower. New products, such as the shroud, would require development and testing before production. Some items, including the support pole, inverters, and associated hardware could be used without modification. Finally, local energy companies would be called upon to install power grid connections.

At the airport level, Federal and State grants would need to be pursued, an environmental assessment conducted, and modifications to the airport layout plan would require approval. The FAA would also have to be notified in compliance with FAR Part 157 "Notice of Construction, Alteration, Activation and Deactivation of Airports".

An accurate timeline for full-scale implementation would be difficult at this early stage of design, however a prototype could likely be built and be operational approximately one year after receiving approval.

Although not mounted on a JBF, AeroVironment has already partnered with BOS airport and installed twenty Architectural Wind turbines on top of one of the airport's buildings (Ritchie, 2009).

Figure 6-1 BOS Airport

Source: AeroVironment, Inc. (2008). *Architectural Wind-Case Studies.* PDF Document received from Jason Groves, AeroVironment Account Executive.

Chapter 7: Airport & Industry Experts

7.1 Thank You.

A project of this magnitude could not be undertaken without the help of several individuals who gave their time and expertise. In this section we express our gratitude for their help. They provided access to airfields, directed our team to other resources, or pointed out design inefficiencies. Their input and critical analysis resulted in a safe, practical, and efficient AfWATT that is capable of generating electricity for years.

7.2 Airport Advisors.

SFO Airport personnel from four different disciplines assisted with AfWATT. Dan D'Innocenti, SFO Duty Manager, provided access to the airfield to measure a BDI Taxi Series JBF. These measurements were used to create scale drawings, which were then provided to Mechanical Designers Musal and Jensen. Glenn Brotman and Drake Poston, both Airfield Operations Managers, reviewed our design and set-up an airfield tour to examine suitable blast fence locations favorable to prevailing winds. During the airfield tour, Donn Vazquez, Airfield Safety Officer, drove the team to each JBF location where he assisted with measurements. ASO Vazquez also provided us with valuable information about how airline operations, such as the location of parked ground service equipment, might affect AfWATT. Nixon Lam from Environmental Compliance explained Federal and State environmental regulations. Finally, Jimmy Chiu from Engineering reviewed our drawings, answered questions about SFO procedures, and provided average wind speed information for the airport.

7.3 FAA Advisors.

To ensure AfWATT would comply with FAA guidelines, our team consulted with FAA Safety Inspector Margaret Freydoz, and Dave Flint, FAA Air Traffic Control Supervisor. Ms. Freydoz assisted our team with understanding SMS guidelines and how to apply them to the design. She reviewed the Safety Risk Analysis, providing feedback to better mitigate or reduce risk to acceptable levels. Mr. Flint provided design assistance in regards to ATC issues, such as NAVAID interference. His working knowledge of both SJC and SFO Airports gave the team valuable insight into airfield operations.

7.4 Industry Experts.

The team contacted Blast Deflectors International, since AfWATT is integrated into their Taxi Series blast fences. Don Bergin, Director of Technical Sales, and Ross Titlow, BDI Project Engineer, answered questions and provided technical feedback. The team sent copies of the two-dimensional paper drawings and some of the 3D CAD images for review. BDI also supplied statistical information, including data on jet blast speeds taken at different heights relative to the blast fence. Both individuals were enthusiastic about AfWATT and interested in future possibilities.

Mechanical Designer Mike Musal was instrumental in our proposal by taking paper drawings and converting them to 3D CAD images. His images provide the audience the unique opportunity to "visualize" AfWATT before construction. The team worked with Mr. Musal over a four week time span, where he created three revisions based on the original design. Mechanical Designer Rod Jensen also assisted in converting the drawings to 3D CAD images.

Throughout the design of AfWATT, wind turbine manufacturers AeroVironment, Swift Wind Turbines, and Southwest Windpower were contacted. Their sales representatives supplied wind turbine data including specifications, wind performance charts, and associated costs.

Chapter 8: Summary & Conclusions

Wind provides clean, sustainable energy that is readily available at airports. Wide-open spaces offer uninterrupted flow while aircraft operations create high velocity wind from jet blast. Until now, this potential energy source has been largely overlooked.

AfWATT is designed to harness this energy source. It absorbs energy from prevailing winds and jet blast to generate electricity while maintaining airfield safety. Consultation with airport personnel, FAA employees, and mechanical designers created a viable and efficient design. AfWATT mounts to existing jet blast fences without modifying their height or footprint and connects to existing airport power grids. It is engineered to use commercially available components, and can be installed with minimal airport disruption.

A comprehensive safety assessment was conducted, including an NTSB accident database search. Careful analysis revealed that the chance of a fatal JBF accident was 0.00008%. In all cases, the JBF was not the primary cause of the accident. The principles of Safety Risk Management were also applied. Our team followed the four step SRM process and was able to mitigate or reduce identified risks. Conclusion: AfWATT is free of unacceptable risks and maintains airfield safety.

A financial review of AfWATT was completed, including both Federal and state government incentives. The site analysis of SFO reviewed wind power potential, while SJC included estimates of wind power potential and jet blast. Although estimated electricity production at these airports cannot justify installation based solely on economics, technological advances coupled with increasing energy costs may change this. Currently, AfWATT has several non-economic benefits. It affirms the airport's commitment to developing "green" technologies, lowers an airport's carbon footprint, and improves public relations. Improved public relations can often reduce or eliminate obstacles to future airport development projects.

AfWATT harnesses prevailing wind and jet blast that has been overlooked until now. It is well-engineered, easy to install, and requires little to no maintenance. Because AfWATT is integrated into existing blast fences, airfield safety is maintained. Government incentives and rebates lower AfWATT start-up costs, while efficient generators produce electricity day and night. Seen by millions of passengers each year, AfWATT would improve public relations and establish the airport as an environmental leader.

AfWATT is clean, safe, and efficient energy production for the 21st century.

Appendix A—Contact Information

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Appendix B—SJSU Description

Founded in 1857, San Jose State University (SJSU) is the oldest public institution of higher education on the west coast. Located on 154 acres in downtown San Jose, the university offers a comprehensive education, granting bachelors and master's degrees in 134 areas of study. The college is situated in close proximity to San Jose, San Francisco, and Oakland International Airports while the NASA Ames Research Center is only minutes away. Internships with local airports and aerospace companies offer students exceptional learning opportunities.

The Department of Aviation, located in the College of Engineering, is at the forefront of technological change and innovation. Faculty and staff are committed to providing a world-class learning environment, offering small class sizes with personal attention from faculty members. State-of-the-art equipment and technology, combined with facilities at San Jose International Airport prepare students for success after graduation.

SJSU is also the oldest and largest provider of aviation degrees on the west coast. During the past 60 years, more than 3,800 students have graduated from the program and can be found working in locations around the globe. The department offers undergraduate Bachelor of Science degrees with four options, including two in management, one in operations, and one in avionics. In addition, the department also offers a graduate degree in Quality Assurance. Students acquire a strong foundation of business management principles, finance and accounting skills, information systems knowledge and communication skills. Students learn the value of teamwork in an aviation setting, participating in student associations such as, Alpha-Eta-Rho, Women in Aviation, or the American Association of Airport Executives (AAAE). Operations majors are able to earn flight hours through the Flying Twenty Flying Club and the Santa Clara Chapter Ninety-Nines. Operations majors are also eligible to join the SJSU Precision Flight Team, representing SJSU in national competitions.

To clear your career for takeoff, contact SJSU Aviation:

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  Website: www.engr.sjsu.edu/avtech

Appendix C—Non University Partners

There were no official non-university partners used in the development of this proposal, however our team was assisted by the following:

- SFO and SJC airports provided access to the airfield
- Mechanical Designers Musal and Jensen
- Blast Deflectors Inc. contributed assistance and technical support
- Wind turbine manufacturers AeroVironment, Cascade Engineering, Southwest Windpower

Individual contributions are described in Chapter 7, while business contact information is described in Appendices G and H.

Appendix E—Student & Faculty Evaluation

Student Authors

E-1 ***Steve Anderson***

The 2010 FAA Design Competition was highly beneficial. Our team was able to develop and present an entirely new solution to the problem of airfield energy efficiency. We analyzed the benefits and shortfalls of wind power, were involved at all stages of the design process, and learned how to apply Risk Management principles to AfWATT. The team examined the financial feasibility of our design. Most importantly, everyone was involved at all stages of this project. The competition demanded considerable time and effort but the knowledge gained was well worth it. I would highly recommend students participate in future Design Competitions.

The most significant challenge faced by our team was the constant evolution of our design. Throughout the process, our discussions with industry experts often raised new questions about the proposal. Each time this occurred, the team researched the question until we were satisfied with the answers. During the original design process, we received input from mechanical designers, manufacturers, and FAA personnel. Each suggested different changes, resulting in several weeks of design modifications. In the case of the financial analysis, we conducted three different analyses as the team learned more about the effects of jet blast and potential wind power.

Developing our hypothesis was a three-step process. Each team member wrote down several ideas and did preliminary research regarding the viability of their designs. The hypotheses were then presented to the group for consideration. Each idea was critiqued to ensure the proposal was an entirely new concept, could be constructed with available technology, and was financially within reach. Our team rejected several concepts over a time-span of three weeks before selecting the concept of AfWATT.

This project could not have been undertaken without help from industry experts and airport personnel. Their knowledge of specific areas revealed strengths and weaknesses of our design. They offered technical information, provided access to SFO and SJC airfields, and brought real world experience to our design. Our team was able to meet with several of them more than once. Those out of the area were contacted via e-mail and telephone multiple times. All of these aviation experts gave freely of their time and deserve much of the credit for AfWATT. Their individual efforts are described in Chapter 7.

The competition stresses many of the same ideas that project management requires in the real world. Students must work together to reach a common goal, recognizing that each person brings specific skills to the project. Time management is critical to ensure deadlines are met, while leadership must be clear, reasonable and fair. We met regularly and discussed various aspects as the project progressed, establishing consensus before moving on. This is the largest team project I have been involved with at SJSU and it was very satisfying to work with everyone. I was able to renew old friendships and make new ones that will hopefully open doors to new career possibilities.

E-2 ***Jason Lewis***

The FAA design competition has been very meaningful for our team. Our project has taught us a lot about different types of wind turbine technologies. We have learned the amount of power the turbines can produce at different velocities using different types of applications. Furthermore, we have learned a great deal about the designing and manufacturing of blast fences used today at airports around the nation. This competition taught our team to have more of a hands-on approach by gathering information from several professional resources that are up-to-date in the aviation industry.

The first challenge our team encountered was coordinating a time when everyone could meet. Our team consists of six people with very different schedules. In-order to over come this problem we had to write out all our schedules, and then choose the best times when everyone could meet. Furthermore, our team made an agreement that the members who live far away from San Jose State will choose a location to meet that is close to where they live. This made it fairer for all the members in our team. Another challenge our team had to overcome was narrowing down the main focus of our project. At first, our team was focusing on how much energy we could create by capturing the aircrafts jet blast with the wind turbines, however, as the project progressed our team learned more about how wind turbine technology. With this new knowledge of wind turbines we discovered that the majority of the power would be generated from the prevailing winds, not the jet blast created from the aircraft engines. The jet blast from the aircraft taking off is more of an added bonus of energy. Overall, our team had very little challenges to overcome.

The process used to select our hypotheses was quit simple. First, everyone wrote down several ideas that they believed would have potential in becoming a well developed project. Once each member submitted their ideas, our team then analyzed each idea by discussed why or why not the idea would work. After hours of discussion on all the ideas submitted, our team narrowed it down to three main topics. Our team then reanalyzed the three topics and narrowed it down to our wind turbine proposal. Our team agreed that the process was very productive and fair.

Our team had several participants in the industry who helped with our project. Our team was able to interview and discuss our proposal with several airport operation mangers at San Francisco International Airport and San Jose International Airport. This allowed our team to gain the knowledge needed about airport environment and safety related issues. By interviewing different participants it allowed our team to gain outside knowledge on our proposal. They brought new ideas to our attention that our team would have never discovered without their insight.

Our team has learned several important skills that will prepare us for feature endeavors. First, our team gained a great deal of knowledge about wind turbines, how they are constructed, and how they generate power. Our team also learned about the design and construction of blast fences used at airports. Not only has our team gained all this knowledge about wind turbine technology, we have gained several skills as well. We have learned how to communicate between ourselves as well as with others outside our team. We learned how to work together as a team. We also leaned how to listen to our fellow team members and how to confront each other professionally when we have a disagreement. Overall, it has taught us how to work together as one team to accomplish one common goal.

E-3 *Monte Miller*

Yes, the design competition provided a meaningful learning experience for me. I learned much about the intricacies of the federal regulations regarding airport design. Additionally, I broadened my horizons and learned about the possible applications of wind technology, a subject I had no knowledge in before.

Our team ran into considerable challenges trying to find others who could understand our concept. Coming up with an idea that has never been done before poses significant challenges when trying to have others envision, and then assist in its development.

Our team first brainstormed potential problem areas at airports, as well as areas that weren't necessarily deficient, but could use improvement. We then refined our ideas down into more specific regions. Finally, we weeded out those that already had solutions being developed, so that we could work on something unique.

Industry participation was helpful, as it brought to light many design obstacles that we would never have considered. Talking to those with knowledge in the field assisted us in overcoming unseen hurdles.

I learned much about working in a team environment, which is always beneficial to future commercial pilots who will have to deal with crew resource management.

E-4 ***Olufela Williams***

The FAA design competition has provided a meaningful learning experience because it gives a motivation to be creative to the extent that the actual idea, if a potential winner, could actually be utilized in the near future.

Challenges:

-Finding relevant content, since we are using an idea that has not been implemented before.

-Time management: Making time available for all group members to meet.

-Meeting personnel (professionals at airports etc) to discuss project practicality

Solutions:

-Researching specific information on each area, and then combining all information.

-Communicating through email or in person to discuss meeting times and venues.

-Scheduling meetings with professionals ahead of time.

Process used for developing hypothesis:

-Accident Reports (NTSB)

-Research of particular runway component (i.e. blast-fence use and dimensions)

-Research of proposed idea and its efficiency.

-Risk Analysis of product.

Participation by industry in project being appropriate?

-Yes, it has been appropriate because it gives realism to generated ideas and Measurements (dimensions), so as to more accurately assess our project.

I'm learning how to be an innovative and critical thinker. This class has helped me with the skills and knowledge needed to be successful for entry into the workforce because I can dedicate time to research when needed.

E-7 Faculty Advisor

Professor Glynn Falcon

1. *Describe the value of the educational experience for your student(s) participating in this Competition submission.*

Entering this competition has proven to be an excellent Capstone experience for our graduating seniors. They have now experienced “real-world” deadlines, planning, schedules, teamwork and personal commitment, personal and group conflicts, interfacing and consulting with aviation experts, and preparing and editing a professional report. As their professor, I was able to observe their growth throughout the process, and see how they overcame problems which, in other college courses, would have left them stymied and looking to their instructor for resolution. Not here, as I was able to act merely as facilitator for access to information and expertise, and left these student competitors to find their own solutions.

2. *Was the learning experience appropriate to the course level or context in which the competition was undertaken?*

Yes. The Department restricted these college-sponsored Design Projects to graduating seniors enrolled in the Capstone class. In this way, it was believed that we could witness their culminating learning experience with a, hopefully, successful outcome.

This belief has, in fact, proven to be true. Without an exception, each of our seniors demonstrated maturity at educational excellent levels. Their competence in the approach to submitting their designs to the FAA also revealed dedication, group commitment, and strong work ethic.

3. *What challenges did the students face and overcome?*

Beyond the parade of deadlines and time management, students faced many other challenges. The most significant challenges seemed to be adapting to working efficiently within the group dynamics, and with developing sufficient personal knowledge and expertise within their proposed design submissions so as to detect and appreciate possible flaws and limitations of their proposals.

I also placed an additional requirement upon their work, and that was to document in a video presentation of their group’s progress and setbacks.

They compiled and edited their video into a 10 to 15 minute presentations which were available to be submitted with their designs. The videos were played for our faculty review, and at the student's Fall graduation for their families and friends.

4. *Would you use this Competition as an educational vehicle in the future? Why or why not?*

Yes. As a "competition," I have previously commented upon some of the earlier inequities that existed under the former rules, which had caused us some concern. Those comments were taken to heart by the Design Committee, and are no longer an issue. As a "learning experience," this program remains an outstanding opportunity to have our senior class demonstrate their readiness for employment within government and the aviation industry.

5. *Are there changes to the Competition that you would suggest for future years?*

Yes. I have previously requested, without success, that the competition be divided into two separate competitions (for semester programs) or even three (for quarter programs) instead of having just the one "annual" competition. In this way, within the same university, we won't be competing one graduating class against another. We also believe that the Spring submitters have an advantage in this competition, as not only do they have several additional months to research and prepare their projects, but (at least within the university) they have the advantage of witnessing the work, designs, and deficiencies of the Fall submitters.

<u>Conclusion.</u>

Again, let me express my thanks for providing this excellent program for our students to compete.

Respectfully submitted: April 12, 2010

Glynn Falcon

Director of Aviation
Aviation &Technology Dept.
College of Engineering
San Jose State University

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Appendix G—Manufacturer Addresses

AeroVironment

AV Corporate Headquarters
181 W. Huntington Drive Suite 202
Monrovia, CA. 91016
(626) 357-9983
(626) 359-9628 fax
http://www.avinc.com/engineering/architecturalwind1
Contact: Jason Groves, Account Executive

Ampair (outside US only)

Park Farm
West End Lane
Warfield
Berkshire
RG42 5RH
UK
+44 (0)1344 303 313
+44 (0)1344 303 312 fax
http://www.ampair.com/

Cascade Engineering (US division) -OR-

Swift Wind Turbines
4855 37th Street SE
Grand Rapids, MI. 49512
(866) 544-5520
(616) 975-4719
(616) 975-4717 fax
http://www.cascadeng.com/markets/renewable_energy/index.htm
Contact: Rich Peek

Renewable Devices (UK division)

SAC Bush Estate
Edinburgh
United Kingdom EH26 0PH
+44 (0)131-535-3301
+44 (0)131-535-3303 fax
http://www.renewabledevices.com/

Blast Deflectors Incorporated

5595 Equity Avenue, suite 650
Reno, NE 89502
(775) 856-1928
(775) 856-1686 fax
http://www.blastdeflectors.com/index.htm
Contact: Don Bergin, Director of Technical Sales
Ross Titlow, Project Engineer

<u>Southwest Windpower</u> (applications available outside US)

1801 W. Route 66
Flagstaff, AZ. 86001
(928) 779-9463
(928) 779-1485 fax
http://www.windenergy.com/index_wind.htm

Appendix H—3D CAD Images

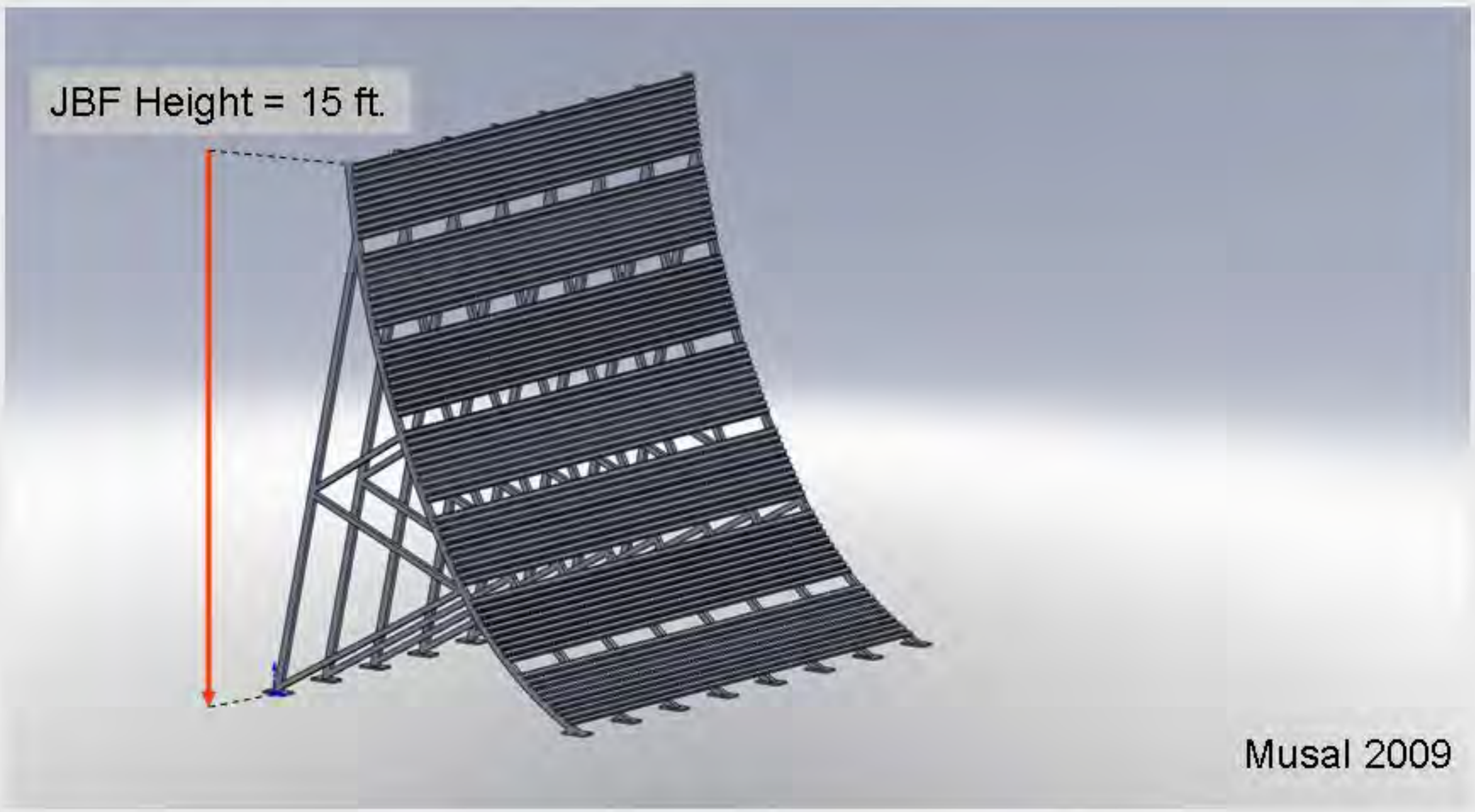
All 3D CAD images were produced by: Mike Musal, Mechanical Designer
190 Pau Hana Drive
Soquel, CA. 95073

With assistance from: Rod Jensen, Mechanical Designer
244 Larita Drive
Ben Lomand, CA. 95005
(831) 336-2653

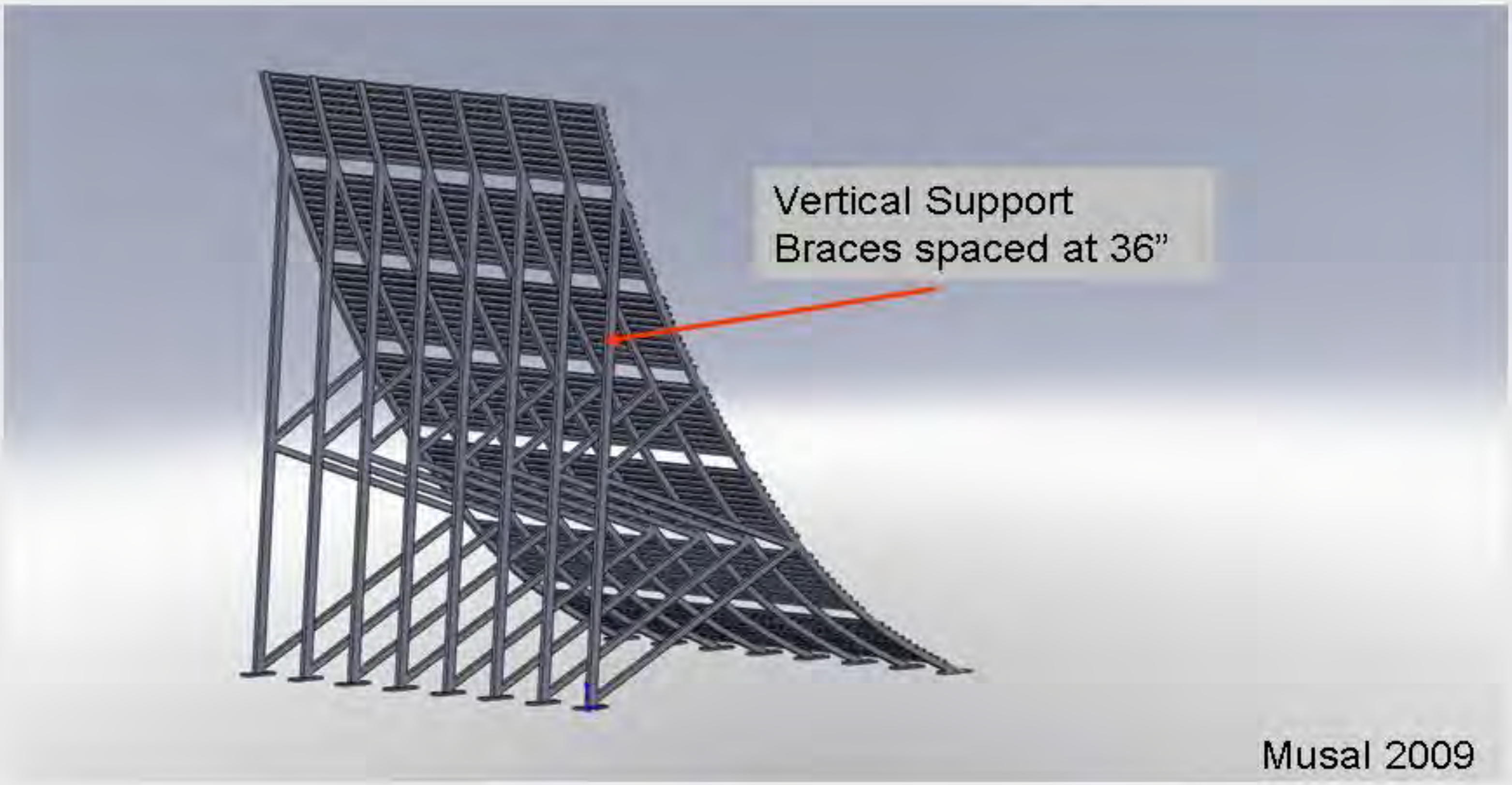
H-1 Original Blast Fence Design (as Built by BDI)

H-2 AfWATT Design Assembly (Kit Parts Only)

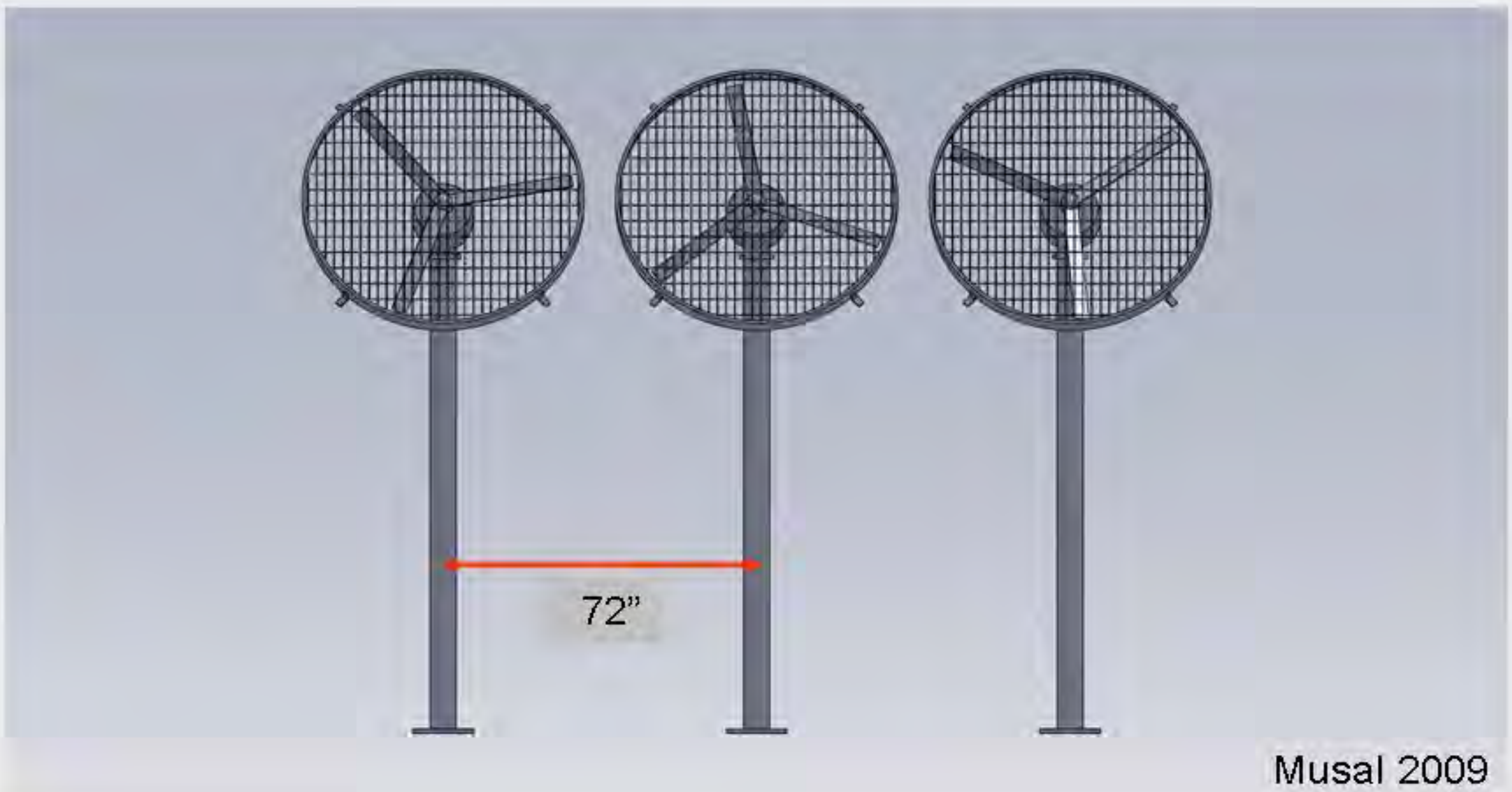
H-3 AfWATT Design Attached to JBF



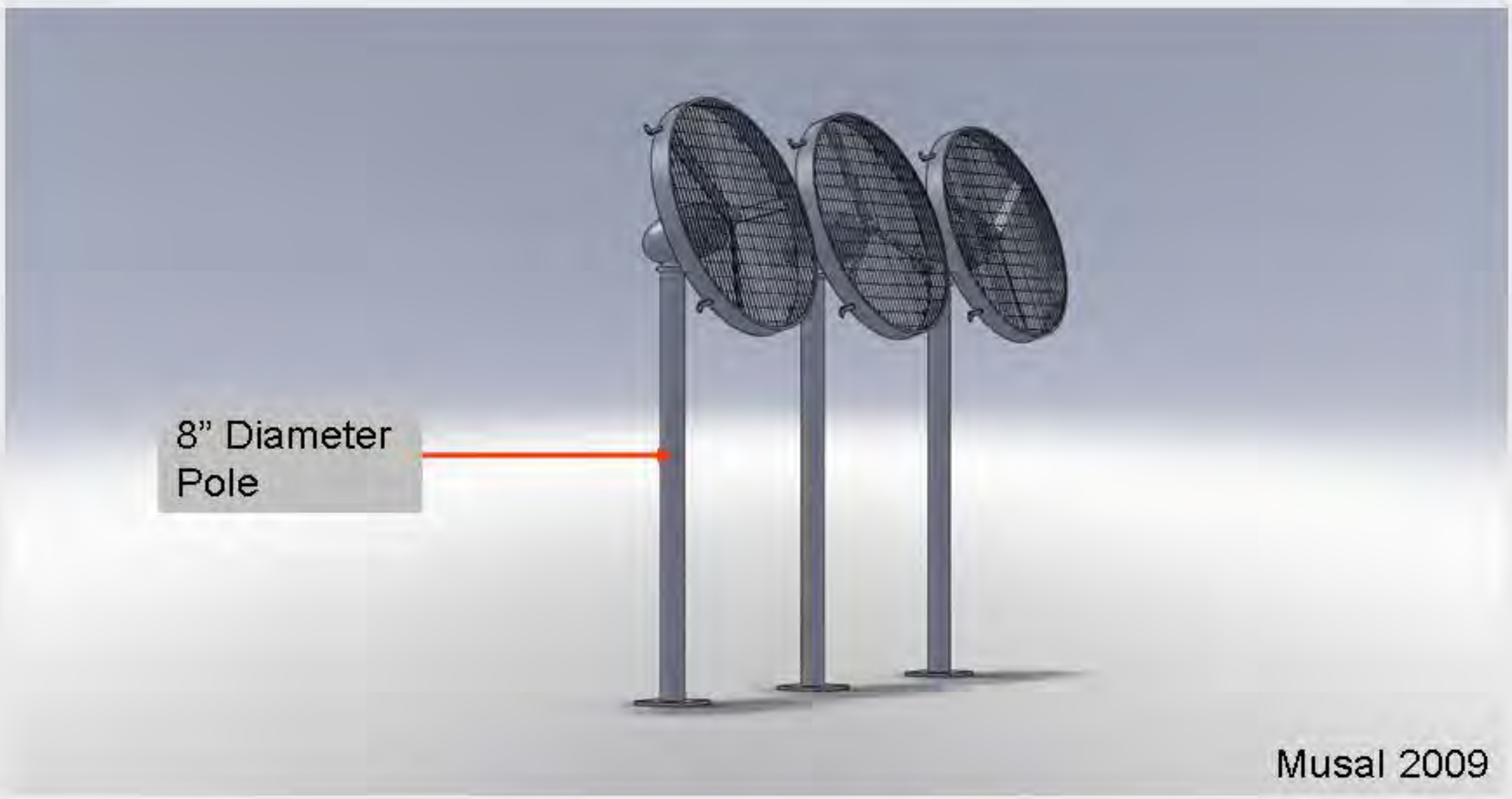
H-1-1 Original JBF Front Three-Quarter View



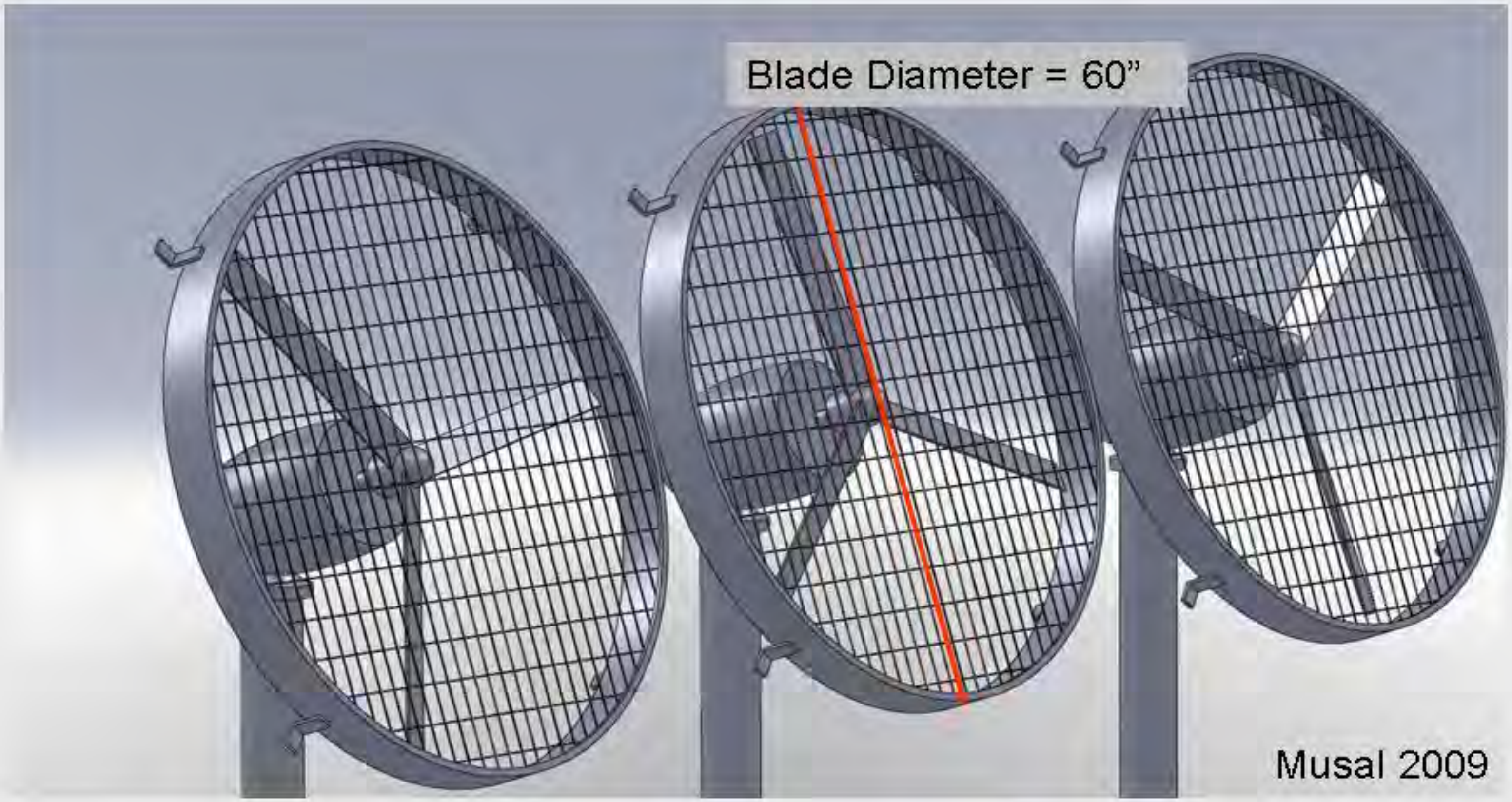
H-1-2 Original JBF Rear Three-Quarter View



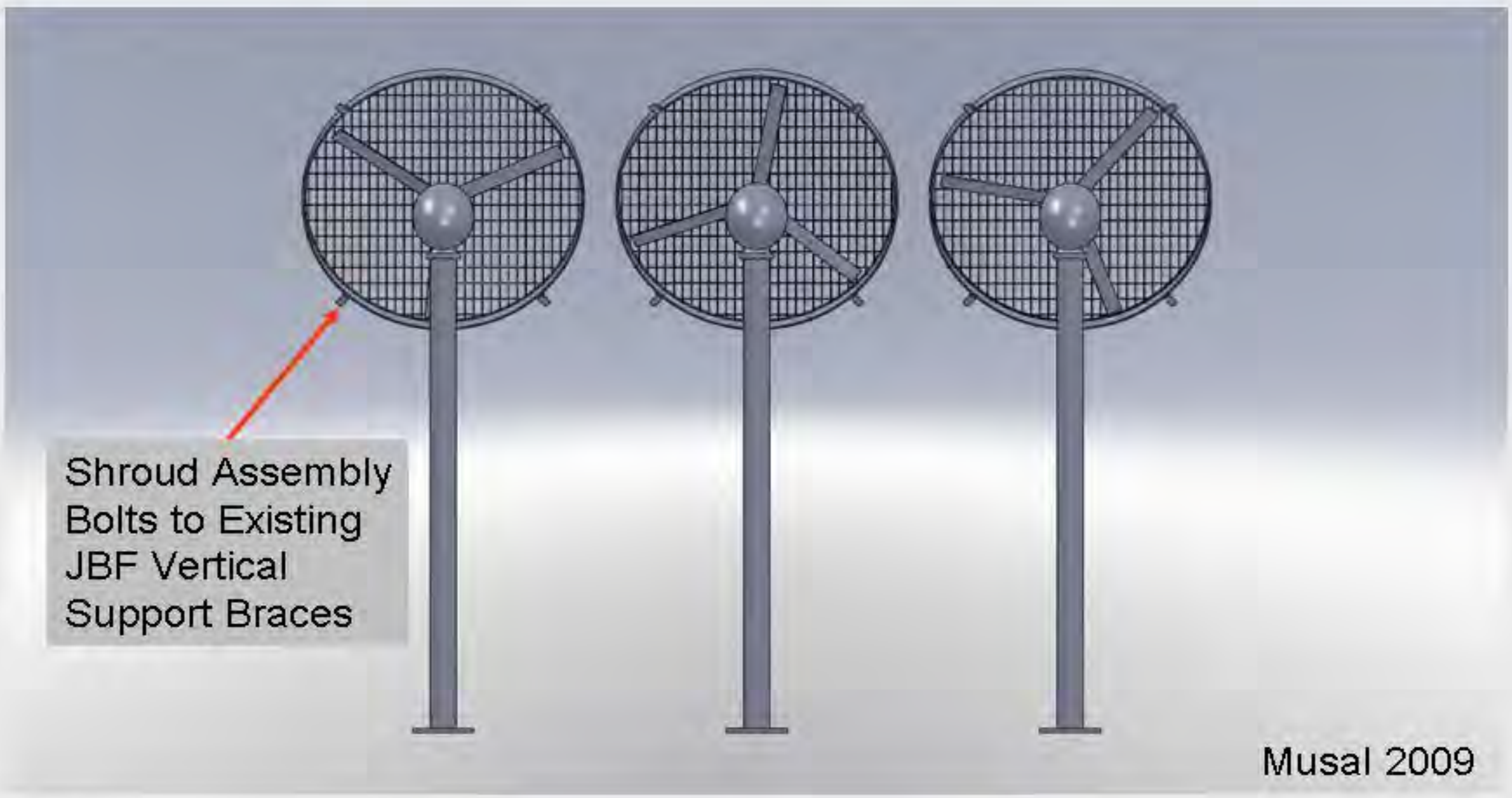
H-2-1 AFWATT Kit Front View



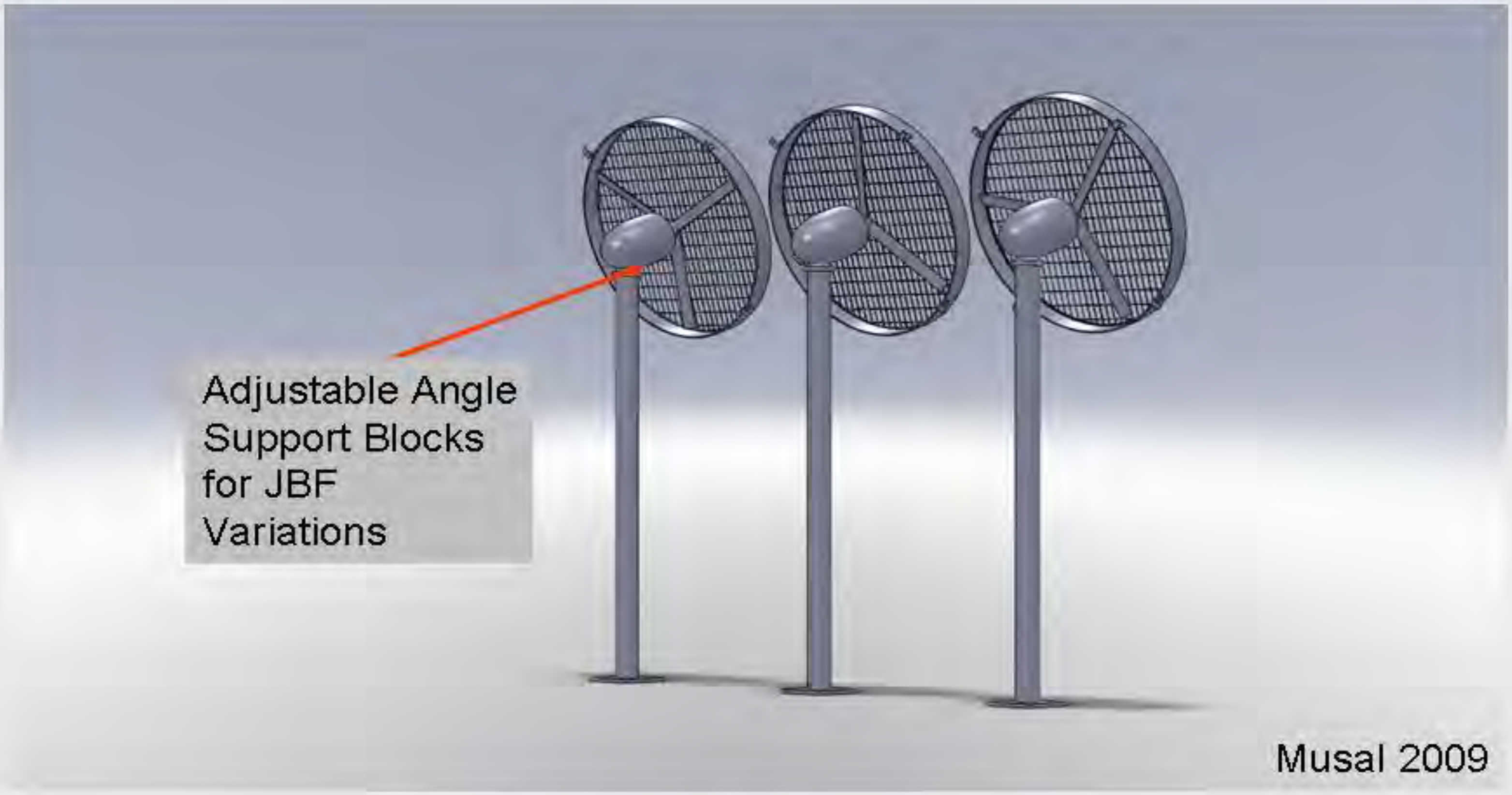
H-2-2 AFWATT Kit Front Three-Quarter View



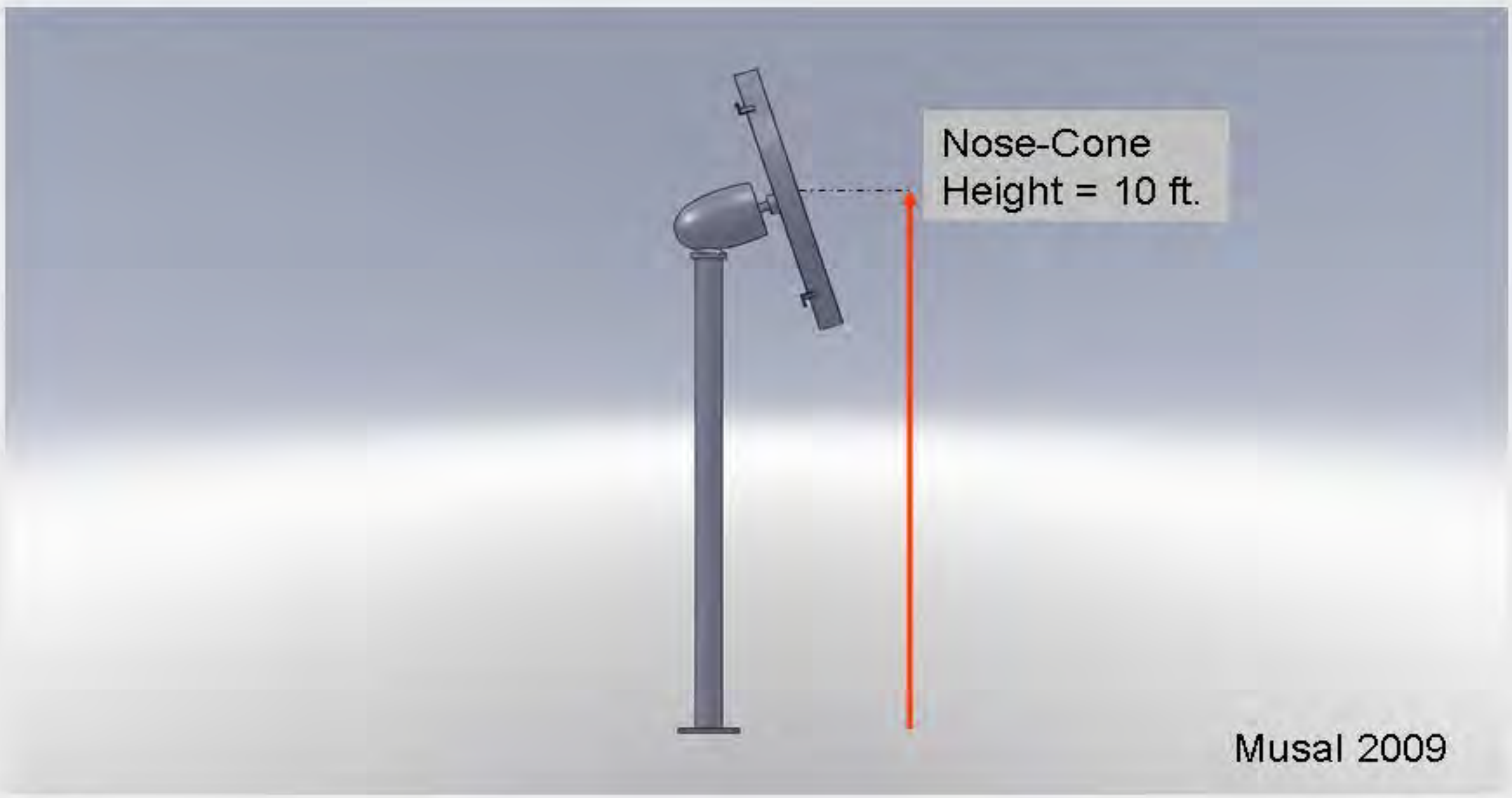
H-2-3 AFWATT Kit Front Three-Quarter View Close-Up



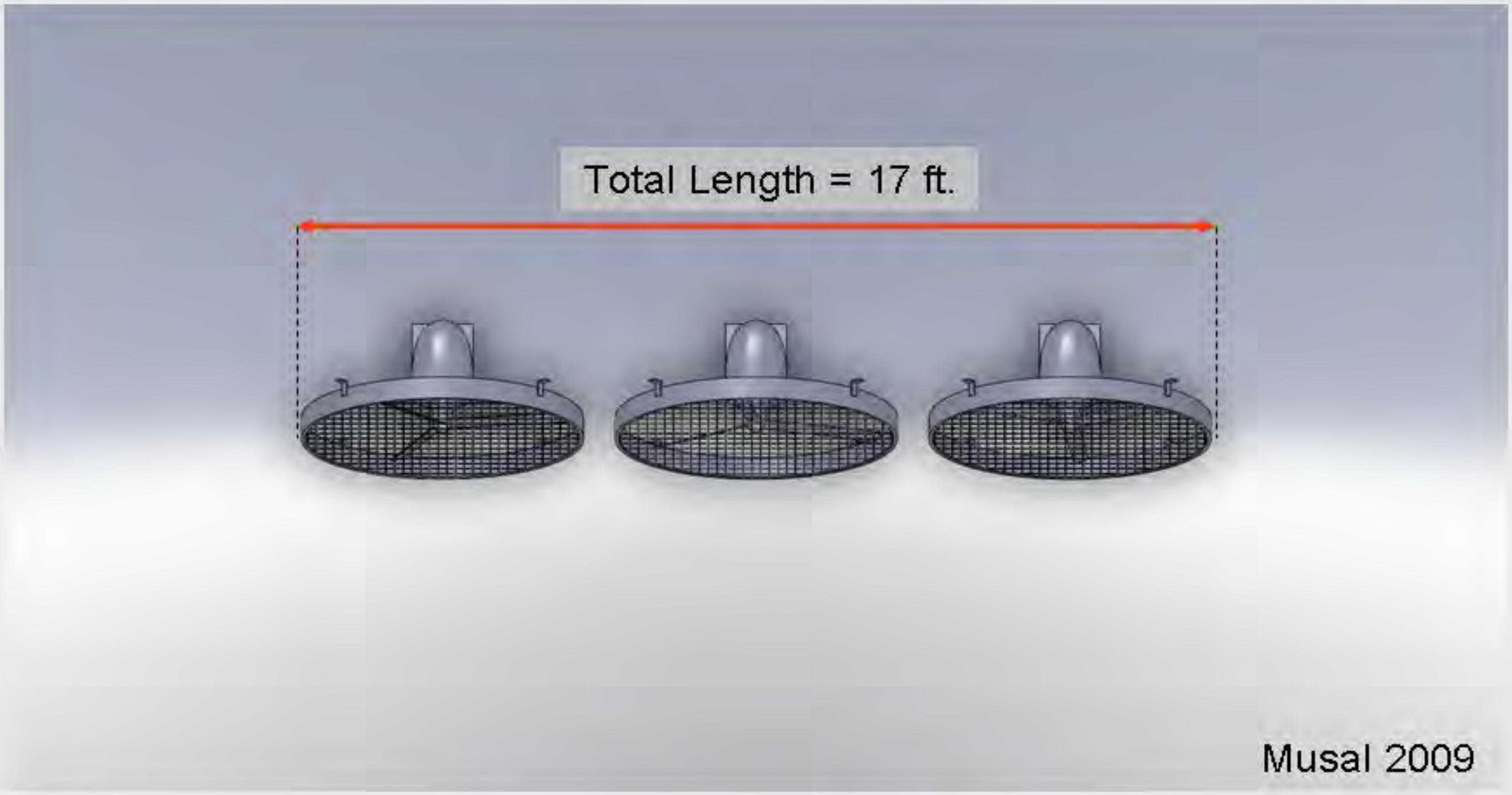
H-2-4 AFWATT Kit Rear View



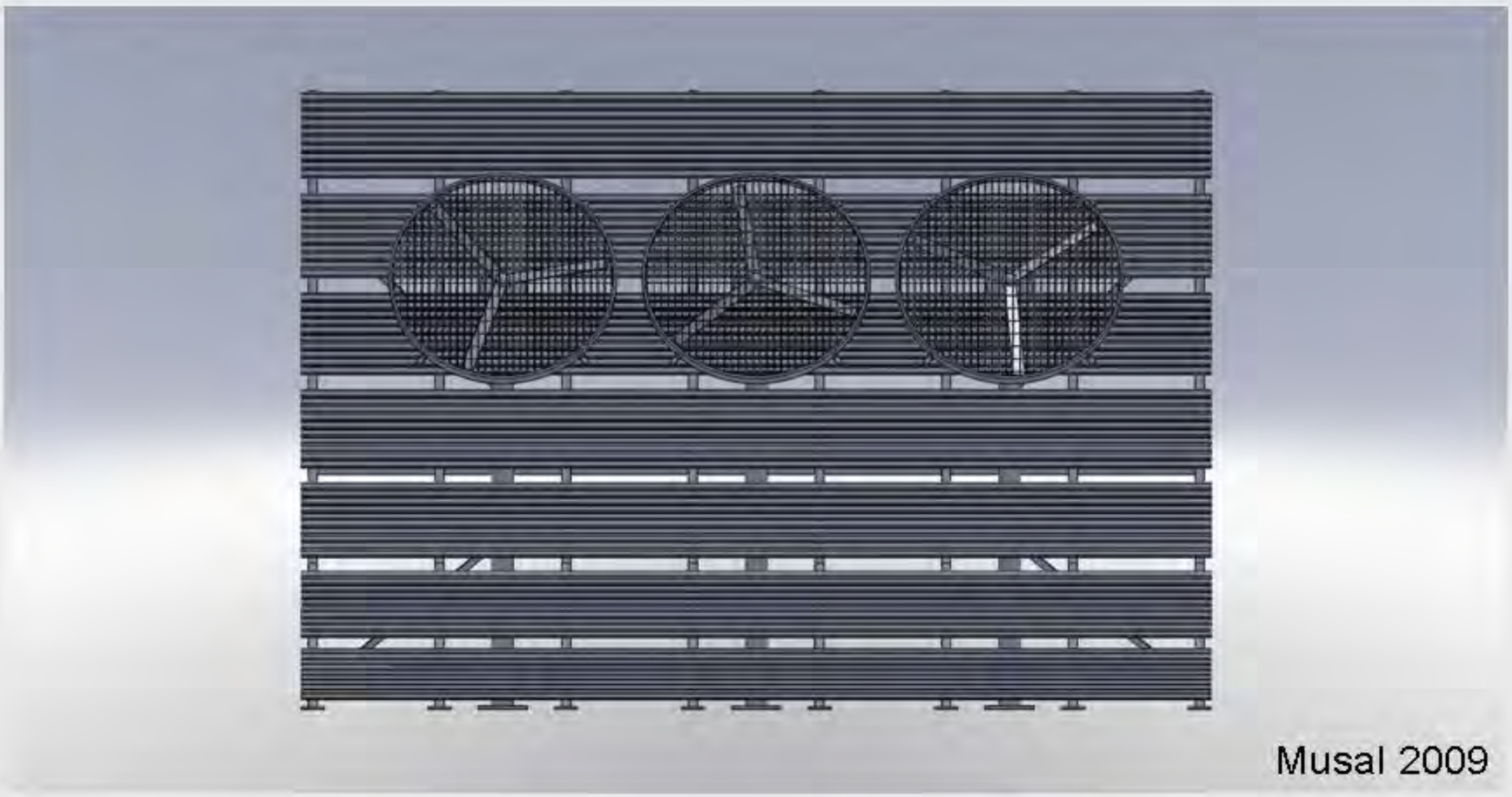
H-2-5 AFWATT Kit Rear Three-Quarter View



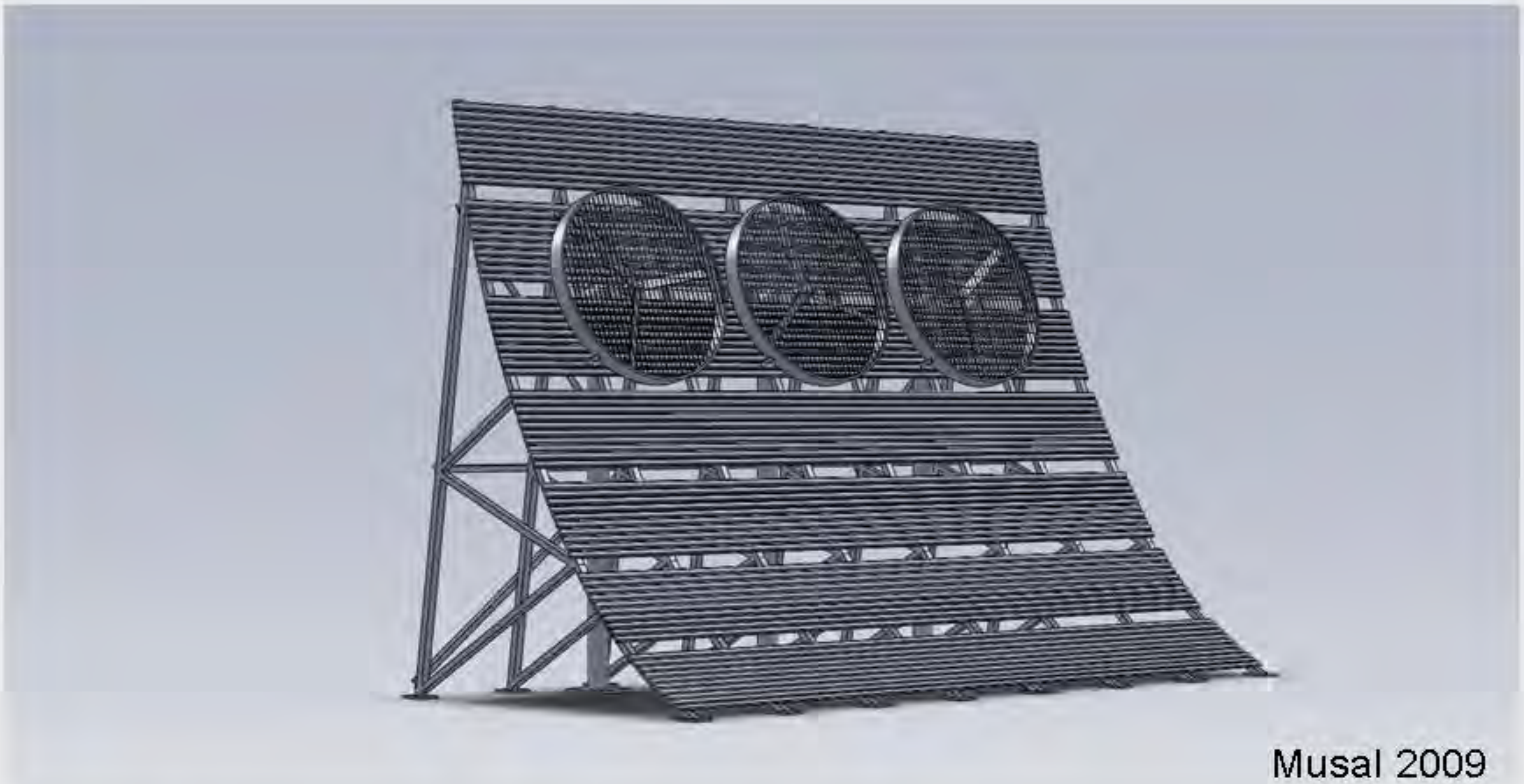
H-2-6 AFWATT Kit Side View



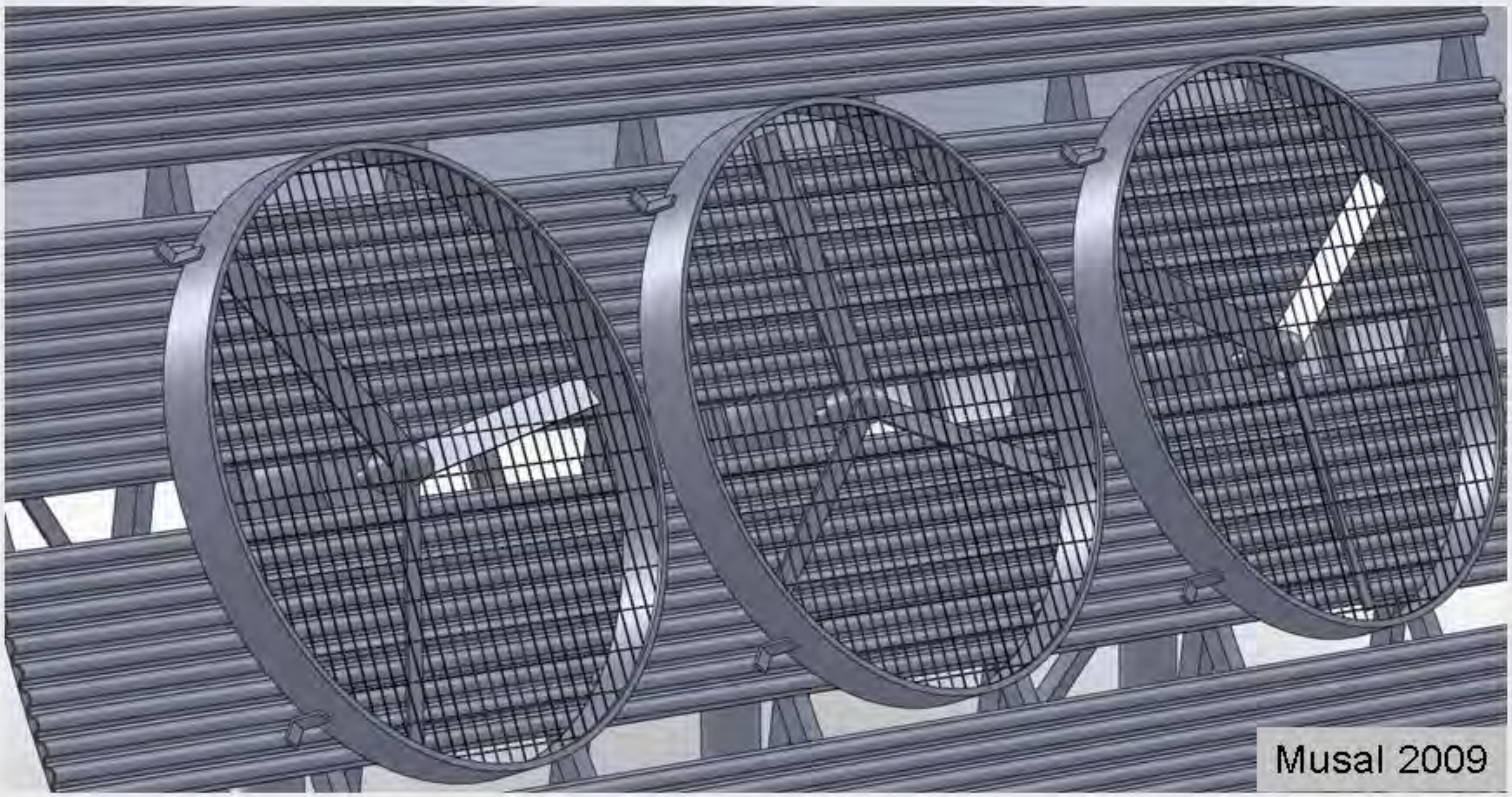
H-2-7 AFWATT Top View



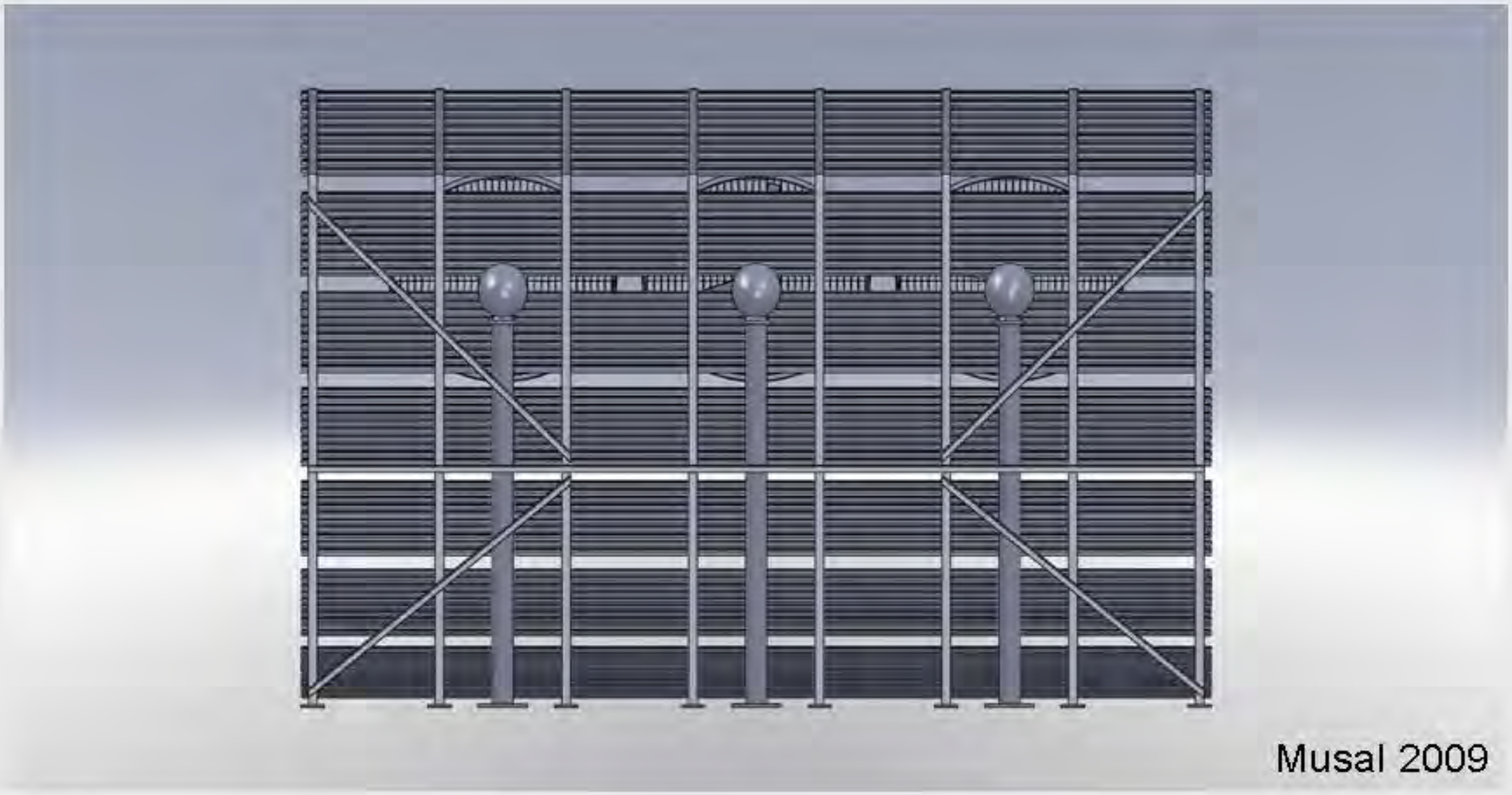
H-3-1 AFWATT Installation Front View



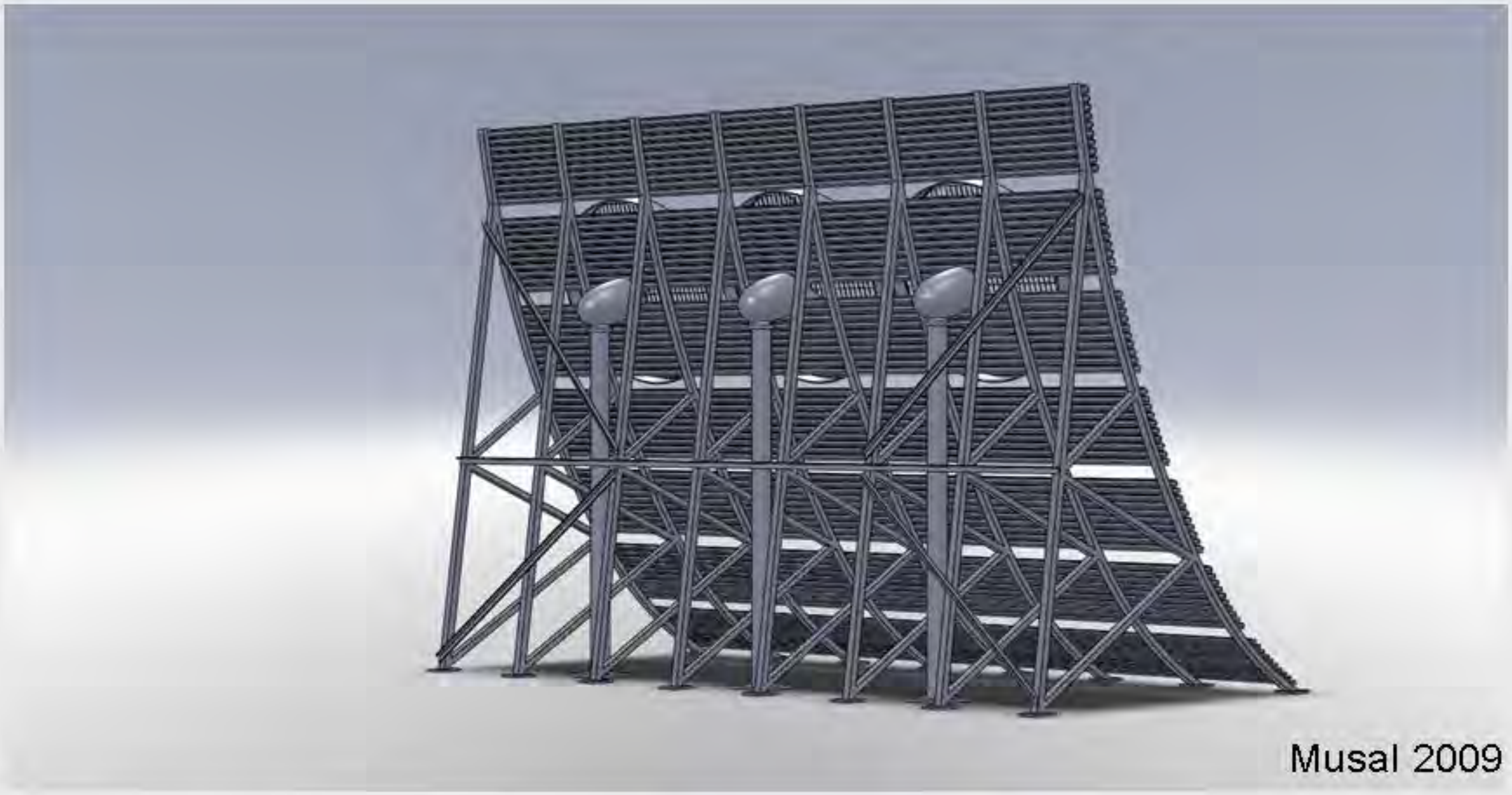
H-3-2 AFWATT Installation Front Three-Quarter View



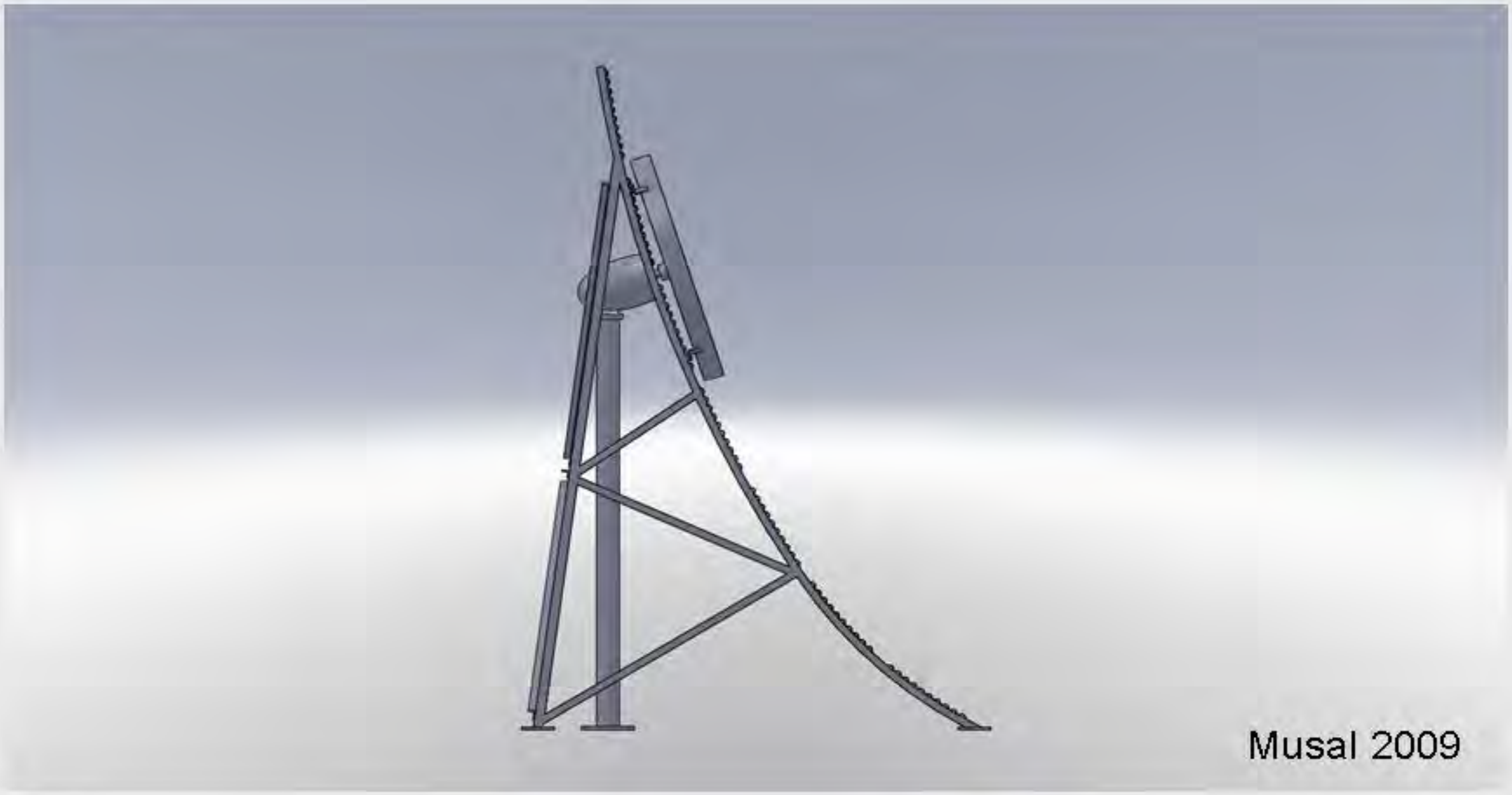
H-3-3 AFWATT Installation Front Three-Quarter View Close-Up



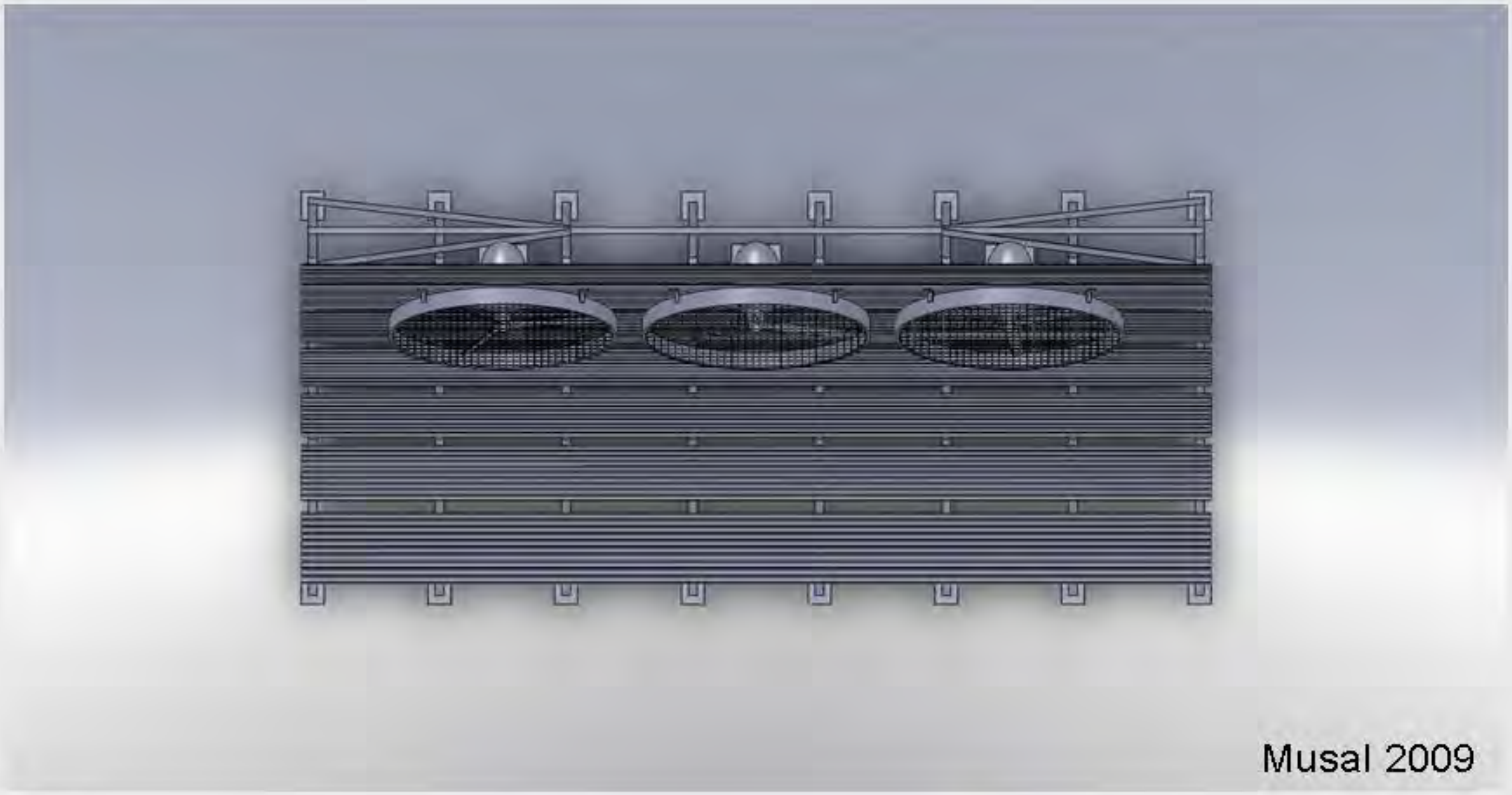
H-3-4 AFWATT Installation Rear View



H-3-5 AFWATT Installation Rear Three-Quarter View



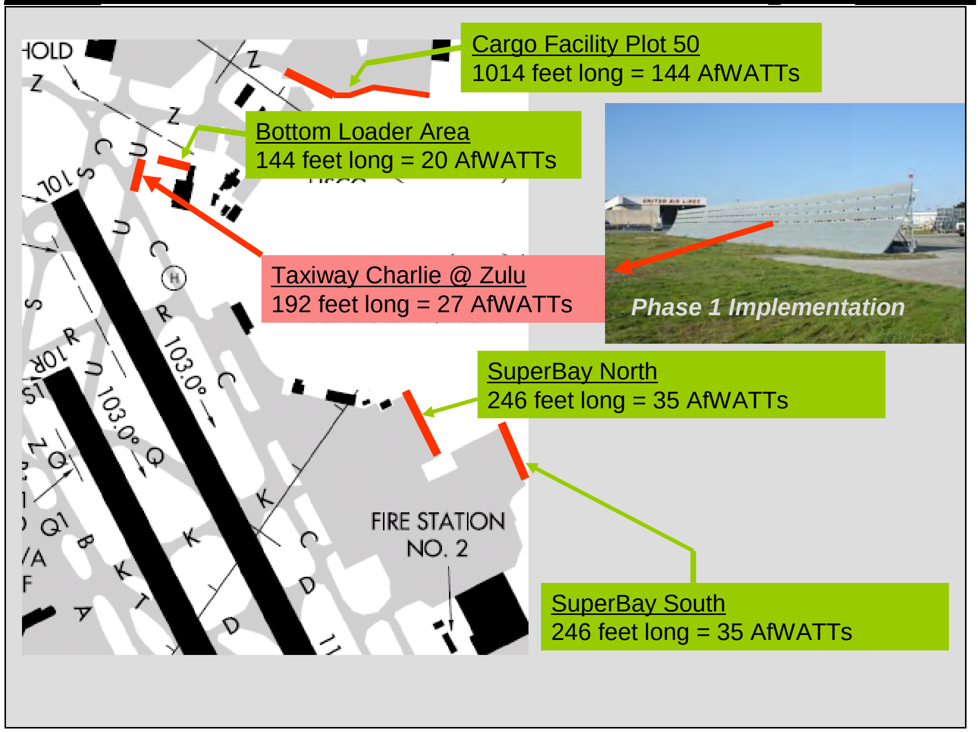
H-3-6 AFWATT Installation Side View



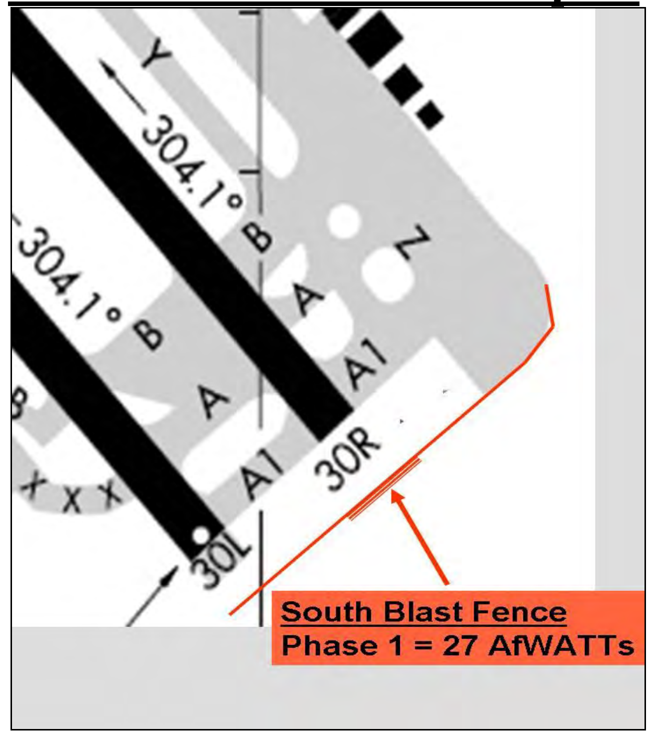
H-3-7 AFWATT Installation Top View

Appendix I—SFO & SJC JBF Locations

San Francisco International Airport



San Jose International Airport



SFO Not Shown: Boarding Area A JBF, Length 456 feet, capacity for 65 AfWATTs
Boarding Area G JBF, Length 594 feet, capacity for 84 AfWATTs

AfWATT

Airfield Wind Air Turbine Technology