Title of Design

Green Gates: Locally Powered Gate Electrification System

Design Challenge Addressed

Airport Environmental Interactions

University Name

Stevens Institute of Technology

Undergraduate Team Members: 4

Bradford Antes
James Clague
Steven Koch
Daniel Nuzzetti

Graduate Team Members: 0

Advisor(s): 2

Eirik Hole
Christina Jauregui

Partner(s): 3

The Port Authority of New York and New Jersey
Stevens Institute of Technology Physical Plant
Hobart Ground Power

THE PORT AUTHORITY OF NY & NJ

STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

1.0 Executive Summary

Title: Green Gates: Locally Powered Gate Electrification System

Team: Four undergraduates from the Engineering Management Department, School of Systems and Enterprises

University: Stevens Institute of Technology

Ground handling services, specifically gate electrification, are an aspect of airport operations that can affect the operator in starkly different ways. They have the ability to be an expensive detriment or a sustainable and profitable advantage in solving problems faced by the aviation industry. It is widely understood by the Federal Aviation Administration, and general public, that unmitigated aircraft emissions from airports are damaging to the environment and health of local residents. The FAA recognizes its responsibility to work with airspace users to reduce the environmental impact of the National Airspace System.

The following proposal describes an alternative approach, consisting of natural-gas generators, air-conditioning, and power systems, to gate electrification, whereby environmentally friendliness and cost efficiency compared with a current practice is improved. It considers a scenario where the electrical capacity requirements are insufficient to support a conventional implementation or where grid independence is favored. Rather than relying on archetypal methods, the proposed system calls for airports to utilize out-of-the-box technologies and leverage readily available energy sources to manage environmental impact. The alternative methodology to meeting operational needs offers a more sustainable way for airport operators to meet their respective stakeholder requirements.

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2.0 Project Background & Problem Statement

Energy efficiency in ground handling operations is a complicated technical challenge for airport operators. Failure to employ energy conscious practices for aircraft during turnaround contributes significantly to an airport's carbon footprint and worsens local air quality. In developed and developing countries, there is a need for airports to be less detrimental to the environment. The Natural Resources Defense Council has identified aircraft ground and flight emissions, and their effect on climate change, as two of the top environmental concerns pertaining to airports [1]. They contribute to ten percent of transportation emissions in the United States and their global growth rate currently outpaces the rate of efficiency improvements [2]. At airports, addressing environmental concerns can entail complex and expensive projects that involve retrofitting facilities with new infrastructure. Utilizing locally produced energy for electrical needs, as opposed to grid power, positions managers to mitigate environmental deficiencies in an effective and sustainable manner. As a result of a comprehensive study of operations at Newark Liberty International Airport's Terminal B, a design for a gate electrification system, powered by a dedicated local electricity source, is being proposed that, with implementation, can result in the reduction of harmful pollutants produced. Gate electrification, whereby terminal gates are equipped with preconditioned air (PCA) and ground power units (GPU) is a common practice in the aviation industry. Rather than having to rely on onboard auxiliary power units (APU) for air conditioning and electricity, pilots at appropriately

Figure 1: Ground handling with gate electrification at JFK International Airport

equipped gates are able to take advantage of standard connections to PCAs and GPUs to avoid fuel waste, harmful emissions production, and unnecessary wear on the aircraft.

With global airline passenger capacity expected to grow by an average of 3.6 percent by 2030 [3], there is a need for organizations to be more customer-centric and thoroughly evaluate processes to minimize waste. As evidenced by the development of the NextGen Air Transportation System, strained and antiquated components of the aviation system require overhauling to comply with modern safety, capacity, cost and environmental performance requirements [4]. Terminal B's fifteen international gates at its B2 and B3 satellites are candidates for such action because of the absence of a uniform aircraft emission management program there. The facility is currently nearing the end of a $347 million dollar renovation project [5] to improve passenger capacity, security, and customer service, but there is no project being undertaken to addresses the environmental impacts of aircraft docked at the gates.

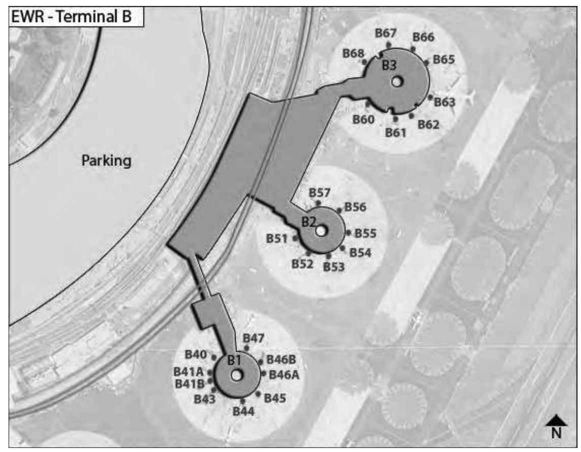

Figure 2: Newark Liberty International Airport Terminal B Map

In addition to decreasing negative environmental impacts, cost savings for airlines and a new profit center for the airport could result from implementing a gate electrification solution. Installing PCAs and GPUs has been hindered mostly by the fact that the current electrical capacity of Newark Airport does not allow for the addition of significant load bearing equipment to the existing infrastructure. The only feasible solution that has been proposed is for the airport to expand capacity by obtaining access to a fourth electrical substation on the local grid. Doing so has been estimated to cost roughly eighteen-million dollars (James Heitmann). These circumstances have been the primary driver behind the team's effort of creating an alternative design that relies on locally sourced electrical power from a dedicated source.

3.0 Summary of Literature Review

To facilitate the development of a design, literature from many different sources was collected and reviewed. Managers at Newark suggested review of federal guidelines and programs related to the environment and gate electrification. FAA goals and safety documentation was studied to understand the impacts that the design could have on both Newark and the greater aviation system. Independent research resulted in the discovery of studies and documents about industry best practices, the negative impacts of APU usage, benefits of gate electrification, and adverse effects of aviation on the environment.

As a means of addressing air quality concerns, the FAA endorses practices such as gate electrification through the Voluntary Airport Low Emission Program (VALE). The purpose of the program is to assist commercial airport operators to meet regulation criterion set up by the Clean Air Act and National Ambient Air Quality Standards [6]. This is done by providing grants to eligible airports for qualified projects. Of the 494 airports across the United States that are approved for possible VALE funding, Newark was discovered to be among them. Review of the VALE website and technical guidelines played an important role in design development. It provided insight on the types of clean fuels and electrification strategies that could be leveraged in the design of an emissions reduction system or program.

In order to align possible future actions of Newark's management with the priorities of the FAA, the proposed solution reflects both organizations' needs of being safe, environmentally friendly, cost effective, and more efficient than current practices. There are several statements in the 2011 FAA Portfolio of Goals that were considered throughout the design process. They include “Aviation Fuel Efficiency”, “Cost Control”, and “On-Time Arrivals” [9]. The solution was designed to help to solve environmental issues associated with enhanced capacity by minimizing the volume of jet fuel burned. It adheres to stringent cost control measures that both organizations have adopted in lieu of adverse global economic conditions [7], [8]. Additionally, the system promotes more rapid processing of aircraft for better on-time arrival rates through reduced refueling times. Lastly, the impacts of the design solution contribute to a safer environment for airport workers and passengers. This closely parallels the FAA’s safety goals [9]. A detailed safety analysis of the system is outlined in Section 8 – *Safety Risk Assessment*.

Implementation of the proposed design is believed to result in considerable benefits for all stakeholders. An example that sheds light on the positive impacts that a managed gate electrification program can have is one conducted at Zurich Airport in Switzerland. A 2005 analysis at Zurich showed that ground handling activities are typically the second largest contributor to an airport’s emissions [10]. Since implementation, gate electrification systems have reduced carbon dioxide emissions markedly. In 2007, 44,000 tons of CO_2 [11], or today’s equivalent of over 21 million dollars of jet fuel, was saved during normal operations. Figure 3 [10] shows an estimate of what the difference in environmental impact would have been if APU’s had been used. Percentages shown represent the contribution to total airport emissions produced.

	2007	
Total Movements	268,476	
Operation with FES/GPU (actual)		
Total Airport NOx	1,014 t	
APU NOx	21 t	(2.1%)
Total Airport CO_2	305,340 t	
APU CO_2	11,554 t	(3.8%)
Operation with APU only (scenario)		
Total Airport NOx	1,096 t	
APU NOx	103 t	(9.4%)
Total airport CO_2	338,800 t	
APU CO_2	45,000 t	(13.3%)

Figure 3: Zurich benefits of gate electrification

In the case of the proposed system for Newark, the local environment and residents of the densely populated Essex County area would benefit as a result of lower airplane exhaust emissions being emitted from the airport [12]. For airlines, reductions in fuel and engine maintenance costs are a direct result of being able to reduce APU usage. The airport stands to avoid the costly eighteen-million dollar capacity upgrade needed before PCAs and GPUs can be installed and gains the opportunity to build a revenue stream from offering the new services to airlines.

Additional material was reviewed to provide team members with a background education on aviation regulations, the environment, emissions mitigation techniques, and industry best practices. The FAA Air Quality Handbook was utilized for general information about environmental impact assessment and to understand the regulatory context surrounding airport operations [13]. A 1999 evaluation by the US Environmental Protection Agency (EPA) on air pollution from commercial aircraft discussed a landing and takeoff cycle emission measurement methodology and the relevance of aircraft emissions on public health [14]. The impacts of flight delays on the economy and environment were studied through review of studies by the US Senate's Joint Economic Committee [15] and the National Center of Excellence [16] for Aviation Operations Research.

No accounts of gate electrification systems that rely on a dedicated local energy source were discovered in the team's research. It stands to reason that at airports where gate electrification infrastructure exists, the electrical needs are met either from a central power plant or the grid. The information researched by the team, as well as documents obtained from industry experts helped members to build a relevant design. Technical material outlining the specifications and features of PCAs, GPUs, and gas generator technologies was used extensively and influenced what types of equipment was chosen in development of the system and analysis models.

4.0 Problem Solving Approach

As a case, Newark represents an airport without adequate access to electricity, but with an abundant alternative source of energy at its disposal. The team used this as the basis for its design, believing that the climatic and geologic diversity in the United States presents a unique opportunity for the nation's airports to cleanly and cost efficiently meet energy requirements for gate electrification applications.

The central goal for the project was to contribute to an effort that would address environmental, facilitates, and/or cost management concerns of a client organization by performing economic and ecologic analyses. Being located within a short distance of major airports, James Heitmann, the Deputy General Manager of New Jersey Airports at the Port Authority of New York and New Jersey (PANYNJ), was approached to gain an understanding of the local aviation industry, the role of the Port Authority, and the agency's current operational needs. After explaining much about its active initiatives, Mr. Heitmann encouraged consideration of gate electrification at Newark Airport's Terminal B as a project topic. He described it as an area of serious interest to Newark's managers, but one that received little attention due to severe financial restrictions, preoccupation with other projects, and limiting factors of the facilities. Review of the competition guidelines revealed that a gate electrification project was applicable to Section III-C: *"Airport Environmental Interactions – Increasing energy efficiency in the management of airfields."*

By utilizing theory and tools learned from the Engineering Management and System Engineering curriculums at Stevens, the team, consisting of four undergraduates, developed a solution that can be implemented at Newark to address its gate electrification needs while avoiding significant capital expenditure for grid capacity upgrades. A project Gantt chart, found in Appendix G, was created to define the scope of the two-semester long effort. Responsibilities were delegated among team members equally and according to proficiencies and preferences. Meetings occurred on a three times weekly or as-needed basis. Regular meetings were scheduled with project partners to answer questions and resolve discrepancies.

The project was divided into multiple phases including "Facilities and Technology Research", "Data Collection", "Design Formation", "Analysis" and "Implementation Planning". The "Facilities and Technology Research" phase consisted of an airside tour of Terminal B and studying different gate electrification products and power generation technologies. "Data Collection" involved a visit to Newark's Operations department where detailed flight schedules and gate activity reports were gathered. Different products and power generation technologies were weighed against one another in the "Design Formation" phase. After concluding what type of system was most appropriate for the problem at hand, safety, economic, and ecological analyses were conducted against the selected design during the "Analysis" phase. A theorized implementation scenario was created last to describe a feasible scenario on how the proposal could be executed on by the Port Authority.

5.0 Interaction with Airport Operators and Industry Experts

Members of the Port Authority, equipment vendors, and facilities experts were consulted to provide information pertaining to the airport, advice on the types of equipment that should be used in the design, validate assumptions, and verify the accuracy of conclusions drawn pertaining to power consumption, cost, and savings. Interactions with professionals added considerable value to the team's ability to develop a relevant and realistic system. A project kick-off meeting took place at Newark with contacts at the Port Authority in early November 2011. E-mail and phone calls were used extensively to send and receive data files, organize further in-person meetings, and answer questions promptly.

Two additional visits to Newark and one to the Port Authority's Union Square office took place between November and January. The first meeting was an airside tour of Terminal B, provided by Frank Radics, Manager of Airport Maintenance at Newark. Technical and logistical details about the airport, facilities management policies, and the turnaround process were explained to team members. The Port Authority's strict regard for safety and security was highly emphasized.

Figure 4: Dan and Steve speaking with Frank Radics and Mario Suarez during airside tour

The second meeting was with Christopher Perez, International Facility Duty Manager, in Newark's Airport Operations Division. Mr. Perez aided in the provision and interpretation of operational data needed for the ecological and economic models. On the trip to Union Square, Jorge Reis-Filho in the Aviation Department helped the team obtain the operational plan map of B2 and B3. Mark Byrd, the HVAC Manager at the Stevens Physical Plant, assisted by answering questions and helping members understand the appropriate generator capacity to run gate electrification equipment on the needed scale. He also provided documents and information about different alternative energy initiatives being undertaken by Stevens that involve power generation on campus. Mark Frink, a sales representative from Hobart Ground Power, was contacted to provide information about PCAs and GPUs. He gave data related to the sizing and costs associated with the equipment that would be used in the design.

6.0 Current Process & Best Practices

With the increased price and variability of jet fuel, reducing fuel costs has become one of the major objectives of airlines worldwide. It is essential for the Port Authority to address its gate electrification deficiencies in order for Terminal B to remain a desirable location for airlines to operate out of, and for the agency to be a better steward of sustainability in the industry. Sound ground handling procedures and equipment can help to ensure that aircraft are more safely and efficiently managed during the turnaround process. As stated, the primary inhibitor to having this capability is the absence of suitable electrical power. The airside tour revealed that there is currently no unified approach to managing preconditioned air and ground power for aircraft at the gates. The most prevalent practice for aircraft is to use auxiliary power from the APU for the duration of the aircraft's stay at the gate. As a current alternative, some airlines operating out of Terminal B have elected to use diesel-powered mobile PCAs and GPUs provided by third party ground services vendors. While it is difficult to get a handle on what every airline is doing at Terminal B, the simple fact of the matter is that, regardless of the operator, airplanes require the same resources and as the owner of the property, the Port Authority has the ability to unify this process and benefit all stakeholders involved.

To get a better understanding of the procedures for turning an aircraft around, a process chart was made based on terminal servicing requirements published by the Boeing Aircraft Company. It can be found in Appendix H. With these requirements in mind, any change in the current process would have to account for the time, resources required, and cost associated with performing said tasks in order to properly assess the change's benefit. With respect to gate electrification, there are very few changes to the existing process and airlines are fully aware of the benefits of reducing APU use.

Flight operations best practices call for pilots to minimize APU use whenever possible, and tailor their use with operational requirements. Based on a conversation with a Delta 767-300 pilot (John Clague) and his ability to reference Delta Air Lines internal recommendations, the following is a breakdown of general best practices and techniques.

1. **Crew arrival at aircraft** - Ensure PCAs and GPUs are connected when available. Ensure Flight Attendants ask passengers during boarding to open all gasper vents if installed, turn off reading lights and close shades on the sunny side of aircraft. Note that janitorial services could also be asked to also confirm these steps inside the aircraft cabin are adhered to.
2. **Pushback -** Start APU approximately 5 minutes prior to actual pushback when ground power is available and air is adequate to control cabin temperature. Note: Allow approximately 60 seconds to start the APU.
3. **Engine start -** Do not delay turning off the APU after it is no longer required for engine start.
4. **Taxi-out -** Utilize single engine taxi when operational conditions allow. Utilize cross-bleed engine start procedures for the second/multiple engine start. Note: Leave APU running if cross-bleed start will not be utilized unless an extended delay (greater than 10 minutes) is anticipated.

5. **Taxi-in -** Start cool down timing as soon as engines are at reverse idle. Accomplish single engine taxi when operational conditions allow. If planning to start the APU on arrival, time the start to match block in. Note: During cold/moderate weather ops leave packs and bleed air switch off so APU shuts down without a 90 to 60 second cool down cycle.
6. **Shutdown** - Shut down the APU as soon as practical after block in. Note: If required (warm weather ops / no ground air), operate APU bleed air and packs for passenger comfort until the majority of passengers have deplaned then, turn off packs and APU.
7. **Crew Departing aircraft -** Ensure GPU and PCA are connected when available. Ensure Flight Attendants ask passengers during deplaning to open all gasper vents if installed, turn off reading lights and close shades on the sunny side of aircraft. Ensure flight deck air vents are open, lights and window heat switches are off and available shades installed on the sunny side of the aircraft. Turn off the APU before leaving the aircraft. If power is not available leave the aircraft "dark" after all passengers have deplaned.

Since Newark Airport does not have PCA and GPU systems available at satellites B2 and B3, the only option for the majority of the flights is that they operate the APU for air circulation. If ground power and air conditioning systems were available, the only time an APU would need to be operated would be about 5 minutes before departure, as it is needed to start the first main engine. Assuming an average turnaround time of 120 minutes for a Boeing 777-200 aircraft, the airline would save 84.19 gallons, or $277 dollars, of jet fuel and 2.32, 0.24, and 5.36 pounds of CO, HC, and NO_x respectively by not using its APU.

7.0 Technical Aspects Addressed

The proposed system consists of five 1.5 Megawatt natural gas powered generators to serve one dedicated mobile GPU and one mobile PCA unit at each of fifteen gates at satellites B2 and B3. This combination adequately meets Terminal B's gate electrification requirements in a cost effective manner. This configuration was the basis for all analysis performed. Explanations of the components, the reasons for their selection, and the chosen configuration are described in subsections 7.1 to 7.4. Technical documentation pertaining to equipment evaluated is provided in Appendix J.

7.1 Natural Gas Powered Generator

The use of a natural gas powered generator to provide electricity for use in PCAs and GPUs is the element that distinguishes this solution from normal gate electrification systems. Instead of using electricity from the grid, power obtained from a generator that runs on natural gas provides three primary benefits: cost, environmental friendliness, and wide availability. Compared with jet fuel used by APUs, natural gas is less expensive and less harmful to the environment. Expressing both fuels in terms of million British thermal units (MMBtu), natural gas costs about $6.20 per MMBtu compared with roughly $27.70 per MMBtu of jet fuel. According to the US Department of Energy, natural gas produces 53.06 kilograms per MMbtu of CO_2 versus 70.88 kilograms per MMbtu for jet fuel [17]. Additionally, between the satellites and beneath the tarmac, there is a high-flow natural gas line present. Executing on the proposed design would not require any additional infrastructure to deliver fuel to the site.

The total power requirement for the entire system is 5.89 Megawatts, derived in the calculation below. Five 1.5 Megawatt generators and power distribution equipment were selected to exceed the power needed. Under normal operation, four units are capable of meeting both satellites' demand. The fifth generator is included for use as a backup when another unit is down for maintenance or repair. Because multiple small units were selected instead of a single larger unit, the generators may be used according to the scheduled demand at the gates. This provides a greater level of control over the amount of energy consumed at the terminal, and thus provides for greater emission control.

((284pcaamps x 15 units) + (189gpu amps x 15units)) x 480volts x 1.73 phase multiplier = 5.89 Megawatts

Figure 5: Power Requirement Calculation

Figure 6: Kawasaki GPB15X CHP Performance Natural Gas Turbine Generator

7.2 Ground Power Units

Ground power units are used to provide electrical power to the aircraft while on the ground. The GPU converts 480 volt, 60 Hertz, 3-phase electrical power from the generator to the required 189 KVA, 400 Hertz and supplies it to the aircraft. GPUs are available in both gate-mounted and mobile versions. The reason mobile GPUs were selected for this application is because of the gang ways used at Terminal B. Because the terminal serves aircraft of various sizes, the gangways used are collapsible and are often adjusted to different distances from the terminal building. Furthermore, for space reasons, if a particular gate is not used for an extended period, the gangway is collapsed back to the building. Each gate requires one unit to serve a single plane that may be located there.

Figure 7: HOBART PoWerMaster®EV 180kVA Mobile Ground Power Unit

7.3 Pre-Conditioned Air Unit

The PCA unit provides cold or warm air to the aircraft, depending on what is needed. The larger planes occupying Terminal B require that the PCA units be in the 90-120 ton range and be capable of approximately 180 pounds per minute of airflow. The PCA units studied have a minimum output temperature of 36° F for cooling. Like the GPUs, each gate will require an individual PCA to serve a single plane. Mobile units were selected again for the same logistical reasons expressed above.

Figure 8: HOBART All Electric Mobile PCA MAE320 Series

7.4 Proposed Layout

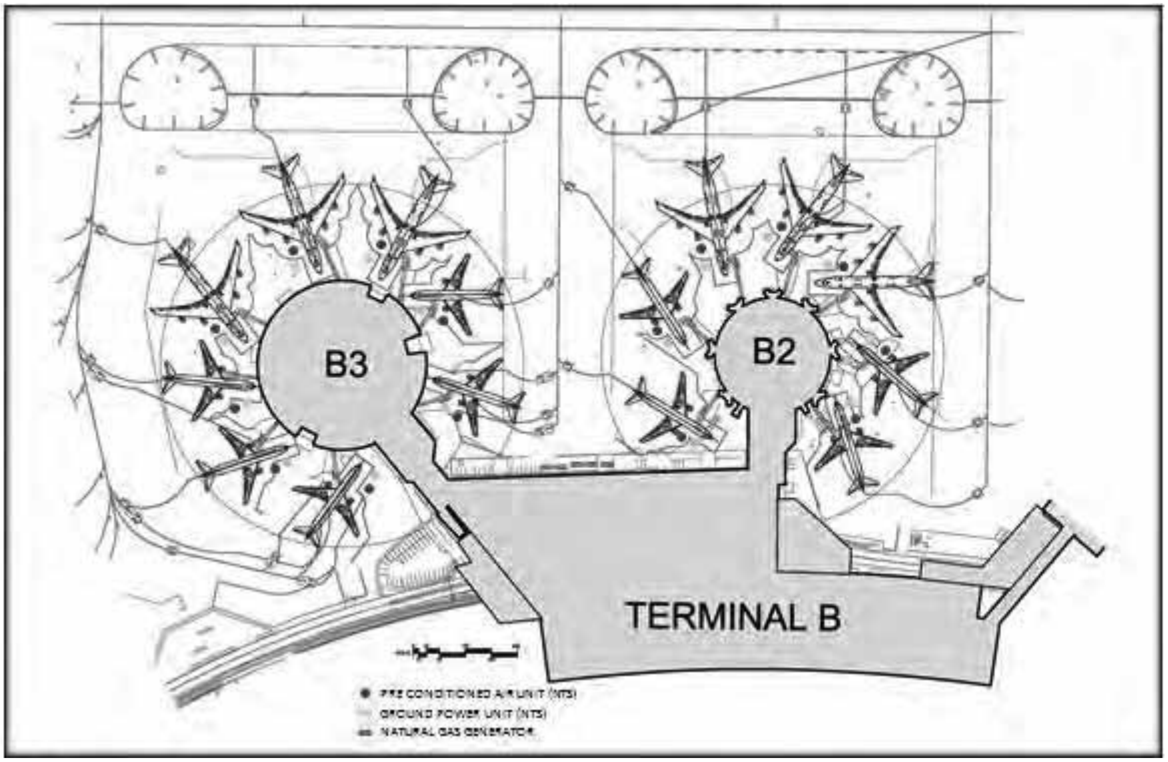

Figure 9: Proposed Green Gates Layout

This is a proposed layout for the Green Gates solution. In between the two satellites are the five 1.5 Megawatt natural gas generators. Each gate, eight for B3 and seven for B2, have their own PCA and GPU for when a plane is docked. Each gate will have an electrical receptacle coming from the generators that the mobile units can plug into whenever they are required for use. This allows for the units to be out of the way when no plane is at the gate and makes for less crowding airside around the satellites.

8.0 Safety Risk Assessment

Within the airport apron, there are inherent risks to the safety of workers and passengers. Concurrent tasks such as airplane maintenance, baggage handling, refueling, passenger boarding, waste removal, and supplies replenishment and the corresponding systems associated with each introduce possible safety risks that must be thoroughly understood, through continuous monitoring, to avoid the likelihood of a catastrophic circumstance. It is crucial for all parties involved with operations or who travel through the area to exercise caution and contribute to the culture of safe practices. When considering changes to an aviation environment, such as the introduction of new systems or processes, it is important that analysis be conducted that considers all scenarios that could compromise human health and safety. In an effort to evaluate risks to safety within the airport apron, the team recalled its experience on the tarmac, discussions with partners, and consulted the FAA Air Traffic Organization Safety Management System Manual. The SRM Decision Process, as shown in Figure 3.3 of the Safety Manual [18], aided in the determination of risks as being either acceptable or not. Members have concluded that the system introduces acceptable risks associated with use of generators within the apron zone and in regards to apron crowding through deployment of additional ground service equipment.

8.1 Generator Use

The installation of five natural gas turbine generators poses the following risks to:

1. **Collision Risk** – Given that many different types of ground support vehicles operate within the apron, the installation of generators in a previously unoccupied area creates a possible collision hazard by other vehicles.
2. **Human Error/Maintenance Risk** – Required repairs and maintenance to the system could result in events that are hazardous to human life. Performing work in the apron environment introduces the risk a serious accident caused by a worker new or unaccustomed to the environment at Terminal B.

3. **Natural Gas Fuel Leak & Fire Risk** – A fuel leak at any point in the system could result in a fire or explosion. Inhalation by bystanders of natural gas or smoke from a fire is a life threatening risk.
4. **Hardware Malfunction Risk** – In order to operate, gas powered generators pressurize fuel to an extremely high level before combustion. Flaws in system design or implementation could result in an explosive event that could do damage to human life and surrounding infrastructure.

8.2 Airport Apron Crowdedness

1. **Collision Risk** – Adding PCAs and GPUs to the area right near planes makes ground support vehicle maneuverability more difficult. Introduction of these system elements at all fifteen gates could result in an accidental collision.
2. **Emergency Evacuation Risk** – In the event of an emergency where an aircraft or the area surrounding it needs to be evacuated, the PCAs and GPUs may become obstacles preventing efficient movement of people and emergency workers.
3. **Electrical Discharge** – The use of electrical equipment near the planes introduces the risk to ground workers of being electrocuted because of damaged connectors or wires. There may be a risk of a fuel fire in the event of an unlikely spill and electrical discharge.

8.3 Risk Mitigation

In order to manage aforementioned risks, a mitigation strategy is required. To prevent the adverse effects of accidents in airfield operations, systems introduced must be "error tolerant", or designed and implemented in such a way as to prevent failures from causing downstream incidents [18]. This entails that all appropriate "fail safes" should be built into the system design.

Any system implemented requires existing safety protocols and documentation pertaining to Terminal B to be revised to accommodate for changes. Coupled with proper training, this will ensure that accidents may be prevented to the maximum extent possible. The following describes possible mitigation strategies to the identified safety risks.

1. **Collision Mitigation –** To prevent collision with the generators, it is advisable for installation to also accommodate for placement of concrete pylons surrounding the units and all electrical distribution equipment. Movement of mobile PCAs and GPUs should be restricted to a range where they may adequately serve aircraft and be removed for maintenance.
2. **System Malfunction Mitigation –** Proper design and implementation of system components is of the utmost importance. Safety measures such as automatic fuel and emergency electrical shutoff mechanisms should be incorporated into the design. This would provide a layer of security against possible incidents associated with fuel leaks and electrical malfunctions. The use of software monitoring tools with remote controllability features is another method that could be used for possible emergency detection.
3. **Human Error Mitigation** – Human error can be prevented through advocating a culture of safety. In addition to properly training employees to conduct themselves in a safe manner, providing a means of reporting possible hazards to management is advisable. For contractors who may be performing maintenance in the area, management should have strong oversight over the workers. Review of the area should take place as to prevent against material left behind becoming a runway incursion.

9.0 Project Analysis & Impacts

In addition to safety, evaluation of the design consisted of ecological and economic analyses were performed to show the environmental impact and commercial viability respectively. Models were developed through reviewing of the Stevens Institute Developers After Tax Analysis Model (DATAM) guidelines, found in Appendix I. Using data provided by the Port Authority and industry standard metrics from the EPA's Procedures for Emission Inventory Preparation [19], strong insight into the operating conditions at Terminal B was gained. In its raw form, the data received from the Port Authority consisted of an Airline Code, Flight Number, Aircraft Type, Origin, Gate, Date, Arrival at Gate Time, and Departure from Gate Time. With over 34,000 international arrivals and departures annually, having records into a comprehensible format was a necessity. Therefore, the data was manually inputted into Microsoft Excel from native PDF files.

Once entered, the time that aircraft spent docked at the gate using APUs was determined. There were two ways this figure could have been calculated; with observed timestamp data or using the times Newark has allocated to aircraft according to an internal policy. The policy at Newark states that, arriving narrow-body and wide-body planes are scheduled to have 45 and 60 minutes for passenger deplaning respectively. Departing narrow-body aircraft have 60 minutes and wide-body aircraft have 90 minutes allocated. Despite the fact that many aircraft spend a longer amount of time at the gate than the policy dictates, these 'policy' times were used for their implied consistency and the fact that APUs are not required during extended stays of inactivity. This adheres to the best practices described in section 6. Analysis based on these 'policy' turnaround times thus offers more accurate estimates for emissions and cost savings. APU type, jet fuel flow rate, and emissions columns were added to the spreadsheet and populated for every flight entry. With these, fuel consumption and emissions statistics were calculated using equations from the EPA's Procedures for Emission Inventory Preparation [19], shown below:

$$E_{ij} = T \times (FF_j/1000) \times (EI_{ij})$$

Where:

- E_{ij} - emissions of pollutant i, in pounds, produced by the APU model installed on aircraft type j for one LTO cycle
- T - operating time per LTO cycle, in minutes
- FF_j - fuel flow, in pounds per minute, for each APU used on aircraft type j
- EI_{ij} - emission index for pollutant i, in pounds of pollutant per one thousand pounds of fuel, for each APU used on aircraft type j
- i - pollutant type (HC, NO_x)
- j - aircraft type (e.g., B-737, MD-11)

Figure 10: EPA Procedures for Emissions Inventory Equation 1

This equation gave us the carbon, hydrocarbon, and nitrous oxide emissions statistics of each flight cycle and a benchmark with which to analyze alternative equipment.

Based on the equation shown below, each flight cycle at Terminal B incurs, on average, \$152 of APU related fuel cost. While maintenance cost could also be included in APU operating costs, airlines claim that because APUs still need to be used for main engine start, reductions in the total APU run time would not affect normal maintenance schedules. The analysis therefor omits maintenance cost from the following equation [20]:

Or $$C_j = TIM \times [MC_j + (FF_j / D \times FC)]$$

Where:

- C_j - total operating and maintenance cost of APU model installed on aircraft type j for one LTO cycle
- TIM - APU operating time per LTO cycle (time in mode), in hours
- MC_j - cost, in dollars per hour, of maintaining the APU model installed on aircraft type j
- OC_j - cost, in dollars per hour, of operating the APU model installed on aircraft type j
- FF_j - APU fuel flow (or fuel consumption), in pounds per hour, of APU model installed on aircraft type j
- D - jet fuel density of 6.6751 pounds per gallon to convert fuel flow units from pounds per hour to gallons per hour
- FC - fuel cost, in dollars per gallon
- j - aircraft type

Figure 11: EPA Procedures for Emissions Inventory Equation 2

This equation gave us the amount of fuel used by an APU during each flight cycle based on aircraft type and the costs associated with running the APU (assuming a unit price of \$3.29 per gallon). Using pivot tables in Excel, consumption, emissions, and cost were easily sorted by gate, airline, and aircraft type. This allowed for the calculation of a diversity factor, defined as the anticipated percentage of time that gates are occupied by aircraft and a figure required for correctly sizing power generation components. The diversity factor was calculated as part of section 7.1 to be 13 units, note however 2 units were added as a safety margin for a total of 15 units.

Using the flight and aircraft type data, and manufacturer recommendations about PCAs and GPUs, the size of the units for Terminal B was determined. Planes at Terminal B range in size from a de Havilland Canada Dash 8 to a Boeing 747-400, which seat 70 and 660 people respectively, depending on the specific airline class configuration. Each gate however is designed to accommodate a set range of aircraft types, based on the sizing constraints of the Terminal. With the pivot table described above, we were able to see which aircraft commonly utilize specific gates. Given that this data is subject to change over the lifecycle of the project however, units were sized to accommodate the largest possible aircraft type at each gate. This, in turn, dictated the amount of electrical power required from the generators. The result of these calculations showed that 5.89 MW of electrical capacity was the peak load during normal operations. Another important statistic provided by the data was the time that all gates are fully occupied, which determined to be 16 hours per day. This figure was used to determine the amount of time that the generators would need to be running at full capacity for this duration.

Based on the criteria of relative fuel efficiency, emissions, and cost, natural gas generators, PCAs and GPUs were selected. These figures were used, in tandem with natural gas and electricity prices, to create an economic model to show the solution's viability. The calculations performed made it possible for an accurate cost comparison of both the Green Gates and a conventional grid powered solution to take place. For both solutions, the same PCA and GPU hardware was selected. The major differences, in terms of cost between the two alternatives are: overhead costs, installation costs, and the utilities /gas cost variability over the lifetime of the project.

For the economic analysis, assumptions were made with respect to financing both the Green Gates (GG) solution and the conventional grid powered solution. Rather than providing the capital for the projects up front, it was assumed that the Port Authority would take out a loan for the total project cost for over 20 year term with an interest rate of 6%. While such financing increases the total amount the solution costs over a twenty year period by almost 13 million dollars, it makes the solution affordable given current budgetary constraints. Appreciation rates for maintenance, jet fuel, utilities, and natural gas were selected based on historical data. Table 1 shows assumptions and statistics that were used for the economic analysis. Table 2 shows current utility prices for the area of Newark Airport.

Interest Rate	6.0%
Term	20
Maintenance Cost Appreciation Rate	5.0%
Jet Fuel Cost Appreciation Rate	5.0%
Grid Electricity Cost Appreciation Rate	3.0%
Natural Gas Cost Appreciation Rate	2.0%
GG Equipment Value at Project Commission	$ 12,072,500
GG Equipment Install Costs	$ 5,500,000
Grid Power Equipment Value at Project Commission	$ 18,810,000
Grid Power Install Cost	$ 1,000,000
GG Annual Maintenance Cost	$ 25,000
GG Equipment Depreciation Rate	5.0%
Equipment Life (Years)	20
GG Equiptmen Salvage Value at End of Life	$ 4,327,821.00

Table 1: Assumptions and statistics for economic analysis

		Unit
Fuel Cost	$3.29	$/Gal
Grid Cost	$ 0.11	$/kw-hr
Natural Gas Cost	$ 0.62	$/Therm

Table 2: Utility prices used for calculations

9.1 Economic Impact

The positive economic benefits of the Green Gates (GG) local natural gas powered solution are significant compared to a conventional gate electrification solution and the current APU use practices. If paid for outright, the solution would reach a positive return on investment in less than five years as seen in the graph below.

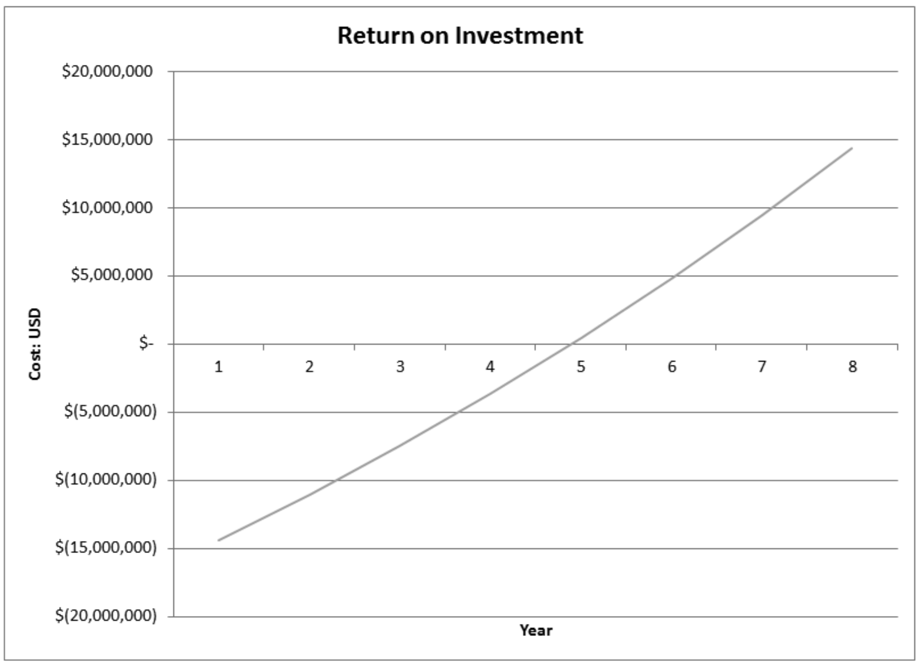

Figure 12: Return on investment graph

Since the project would likely be financed, however, our analysis has chosen to observe the economic impacts in terms of reduced costs for all stakeholders. These reduced costs are observed in a comprehensive cash flow spreadsheet shown in Table 3.

	Year 1	Year 2
Annual energy costs without improvements (APU)	$ (5,327,402.08)	$ (5,593,772.19)
Annual energy costs with grid power	$ (3,854,400.00)	$ (3,970,032.00)
Annual energy cost with GG	$ (2,174,971.00)	$ (2,218,470.42)
GG Annual energy cost savings vs APU	**$ 3,152,431.08**	**$ 3,375,301.77**
GG Annual energy cost savings vs grid power	**$ 1,679,429.00**	**$ 1,751,561.58**
GG Equipment value w/ depreciation	$ 11,468,875.00	$ 10,895,431.25
GG Annual maintenance cost	$ (25,000.00)	$ (26,250.00)
Payment for financing GG Project	$ (1,510,680.00)	$ (1,510,680.00)
Payment for financing grid power	$ (1,703,040.00)	$ (1,703,040.00)
Cumulative Cash Flow Grid Power	$ (5,557,440.00)	$ (5,673,072.00)
Net Benefit Grid Power vs APU	$ (230,037.92)	$ (79,299.81)
Cumulative Cash Flow GG	$ (3,710,651.00)	$ (3,755,400.42)
Net Benefit GG vs APU	**$ 1,616,751.08**	**$ 1,838,371.77**
Net Benefit GG vs Grid Power	**$ 1,846,789.00**	**$ 1,917,671.58**

Table 3: Comprehensive cash flow spreadsheet

It is important to note that while costs are being reduced for the airlines, they are being transitioned to the Port Authority. The reduction in costs therefore represents an important figure that the Port Authority can use to determine a pricing model for charging airlines for the new services. If, for example, the Port Authority decided to charge its tenants at cost, airlines would collectively save 92 million dollars over a 20 year period. Presumably however, the Port Authority would charge its airline tenants some percentage above cost, generating a profit while providing them with a lower cost alternative to APU use. The total reduction in costs can be seen in Figure 13.

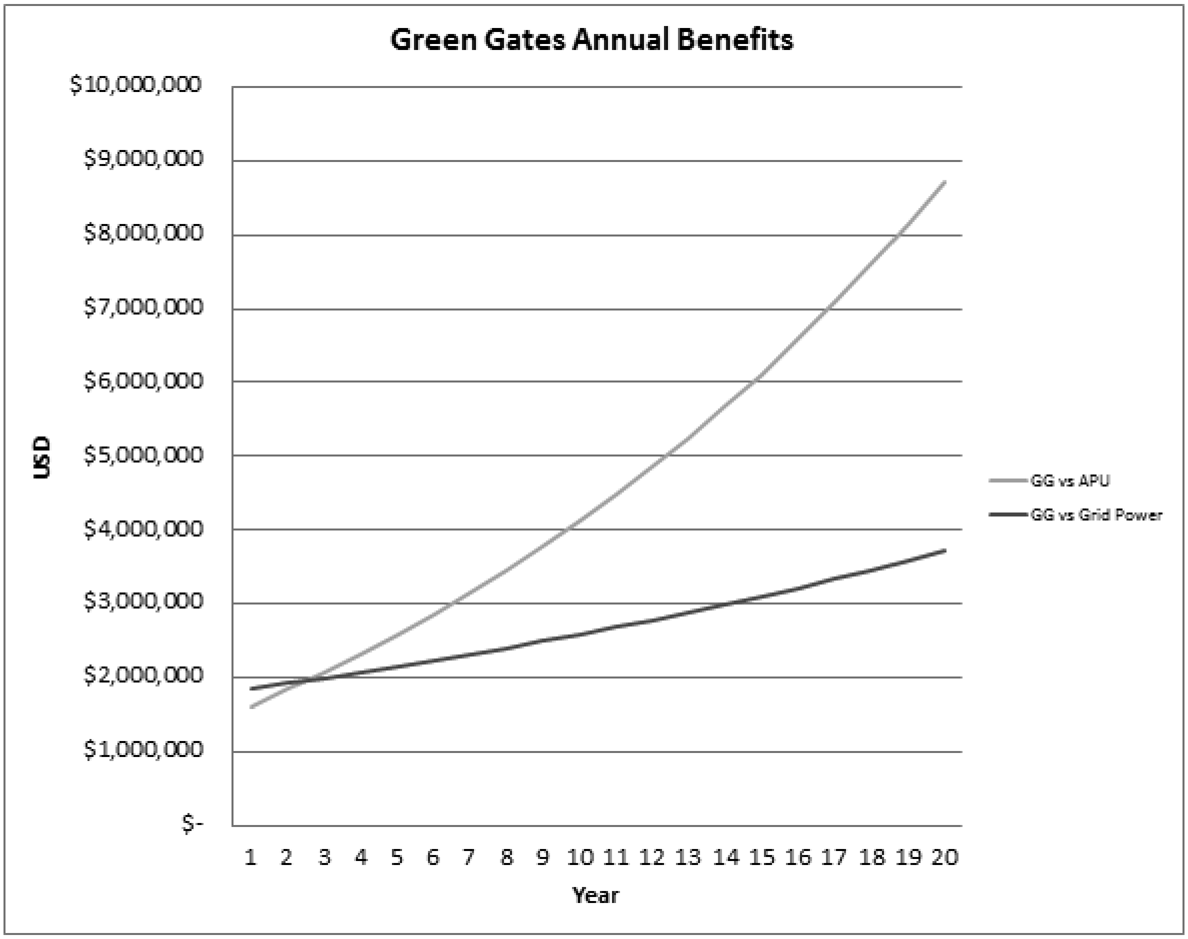

Figure 13: Green Gates Annual Benefits

In the chart above, it is apparent that the Green Gates solution becomes increasingly beneficial each year compared to both APU power and grid power, largely due to the lower appreciation rate of natural gas compared to jet fuel and utilities. What is most significant about the chart is that the annual net benefit is positive compared to both APU use and grid power for every year of the 20 year period. This is a clear indication of the Green Gates better economic performance.

9.2 Ecological Impact

As mentioned above, emissions statistics were calculated based on a per flight basis using equations from the U.S. EPA's Procedures for Emission Inventory Preparation. Using the flight data from Newark, the following annual emissions totals from planes docked at satellites B2 and B3 were estimated to be as follows:

Emission	Lbs.
Hydrocarbons	5,368
CO	61,352
NOx	90,327

Table 4: Current yearly emissions data

The following table shows the projected emissions from the Green Gates solution:

Emissions					
Item	**Operational Time/Day (hr)**	**Emissions (lbs/hr)**	**Total (lbs/day)**	**Total (lbs/year)**	**Percent Reduction**
1.5 MW Generator CO	24	2.506	60.13	21949.06	**63%**
1.5 MW Generator NOx	24	0.626	15.03	5487.26	**94%**

Table 5: Green Gates yearly emissions projection

10.0 Implementation Process

The busy and potentially dangerous nature of terminal activities dictates that a thorough project management strategy must be in place when implementing a complex system like the one described. Understanding the economics of the solution is the first step towards proper implementation. Development of an appropriate project scope is important because the scope assists in accurate scheduling of the project. A detailed technical plan that includes the locations for new infrastructure, installation requirements and instructions, and post-installation test procedures must be created, agreed upon by all major stakeholders, and adhered to throughout implementation. Development of a long term sustainability program describing oversight and maintenance for life of the systems is the final step to the project planning process.

10.1 Project Scope

Expressing the scope of the undertaking can be done through applying a project categorization technique. Using the NTCP framework detailed in Shenhar and Dvir's *Reinventing Project Management* [21], degrees of project intensity can be easily understood through the use of a visual interpretation. Figure 14 shows what, in terms of its novelty to the organization, its technical requirements, complexity, and required pace, a project management team should expect to experience when implementing the system.

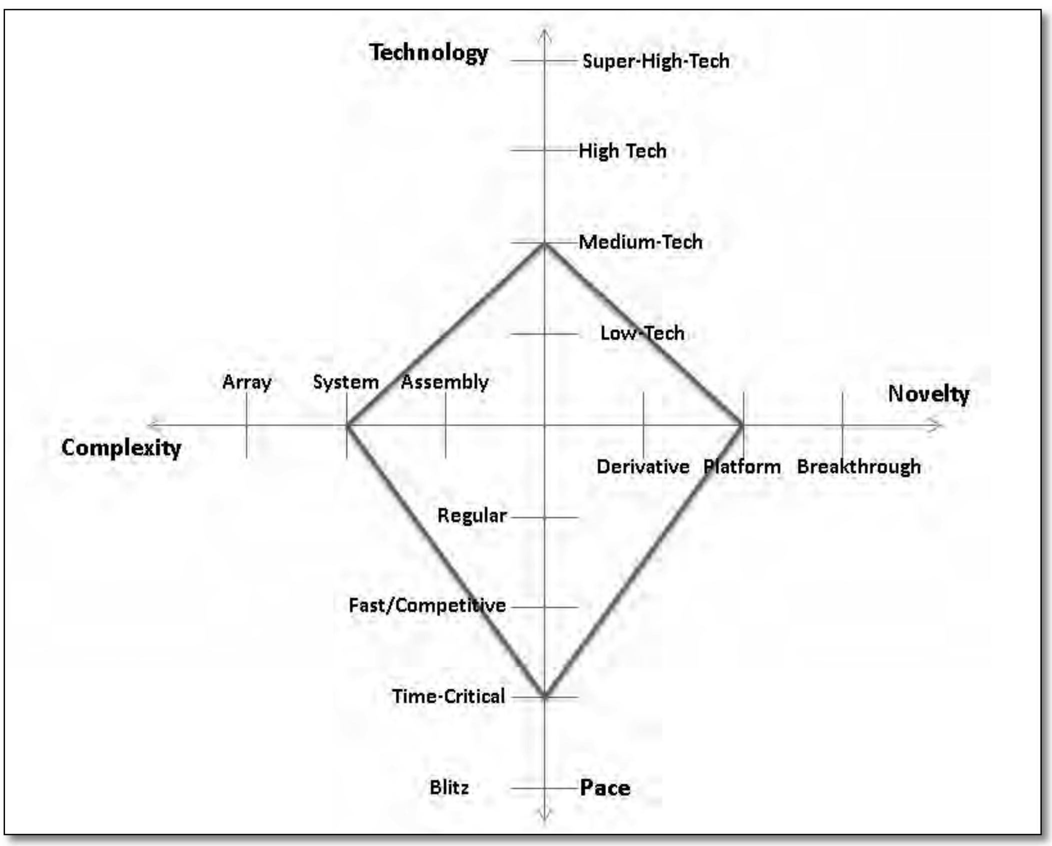

Figure 14: NTCP Framework for Green Gates

The “Platform” designation came with balancing the facts that gate electrification systems are used at airports around the world, but that there is some level of newness to the design. The technology required does not consist of any components that must be invented or drastically changed, but because the design calls for dedicated locally sourced natural gas for electrical power, there are likely no other systems in existence to be compared to. The team ranked the level of technology as “Medium [-Tech]”. All major system components are commercially available and no new technologies are required to be engineered from the ground up. Solutions to the problem at hand are categorized as “System” because of the fact that they deal with a single system assembled out of standalone pieces of equipment. The project objective is to solve a local, rather than widespread, problem. The pace of the project is designated as “Time Critical”. Installing such a system has the potential to temporarily interfere with normal aircraft and handling procedures. The project requires a strategic focus to minimize negative effects on operations by overlapping the implementation steps.

10.2 Implementation Steps

Installation of equipment according to a rigorous schedule is important as to avoid excessive interference to normal airport operations. The gate electrification system is intended to be a permanent addition to Newark’s Terminal B infrastructure. The first step is to tap into the natural gas pipeline for fuel access. Next is delivery and installation of generators, electrical distribution equipment, and wiring to each gate. This should be done in accordance with all manufacturer recommendations for location, orientation, and mounting procedures. Freestanding permanent structures should be surrounded with pylons as per the collision safety recommendations mentioned in section 8. Connection to the gas line should be established and the equipment should be run through a set of preliminary tests. Excavation of the tarmac to install conduit and wiring should take place concurrently with proper termination of cables and connectors at endpoints. Tests should be conducted to ensure power is being safely and adequately delivered to all destination points. The mobile PCAs and GPUs should be delivered to the area and connected. All equipment should be run for a "break-in" period of time per manufacturer recommendations. Lastly, the equipment and surrounding should be checked according to a prescribed safety inspection process. Long term monitoring and maintenance is allocated to the Port Authority's existing maintenance staff which is responsible for facilities management operations. Furthermore, they will oversee qualified vendor personnel when maintenance services are required. Maintenance costs for these new structures will be appropriated in the annual airport operations budget planning in accordance with existing airport planning procedures.

11.0 Conclusions

After discussing operational issues at the Port Authority's Newark Liberty Airport, the team decided to review current ground handling practices with respect to gate electrification. By interacting with airport operators and industry experts, an understanding was reached both about Newark's needs and the ability of current solutions to match them. The current process at Newark was defined and, using operational data, quantified. With this data, the team was able to address the technical aspects of the venture conscious of emissions, costs, and reliability when evaluating alternative solutions. Furthermore, as the FAA is an extremely risk adverse organization, a safety risk assessment was conducted to address the ecological impacts and airport apron crowdedness. With these issues in mind, a three part natural gas powered gate electrification system was chosen. Based on evaluations using industry standard calculations, the system is expected to reduce Newark Airport's carbon emissions by 63% and their NOx emissions by 94% annually, while saving over 2 million dollars in energy and project costs each year. Investing in capital projects that provide both economic and ecologic benefits is an intelligent strategy to allow for the benefits of commercial aviation to be recognized in society.

While we are confident that the proposed solution fits the FAA's goals for the Design Competition for Universities, the team suggests further investigation into a cogeneration application of the natural gas generators. This solution was not explored further due to the fact that it would affect terminal buildings, falling outside the guidelines set forth by the FAA competition guidelines. Based on the increased efficiency provided by a cogeneration solution, further reductions in both emissions and costs could be realized by the Port Authority.

Appendix A – Contact Information

Students

Bradford Antes
bantes@stevens.edu

James Clague
jclague@stevens.edu

Steven Koch
skoch@stevens.edu

Daniel Nuzzetti
dnuzzett@stevens.edu

University Advisors

Eirik Hole
ehole@stevens.edu

Christina Jauregui
cjauregu@stevens.edu

Mark Byrd
HVAC Systems Manager
Stevens Physical Plant
Hoboken, NJ 07030
Phone: (201) 819-3157

Non-University Contacts

Mario Suarez, MBA, CEM
The Port Authority of NY & NJ
Senior Energy Analyst
Office of Environmental & Energy Programs
225 Park Avenue South- 11th Floor
New York, NY 10003
Office: (212) 435-5458
msuarez@panynj.gov

Mike Hyams
The Port Authority of NY & NJ
Energy Analyst
Office of Environmental & Energy Programs
225 Park Avenue South- 11th Floor
New York, NY 10003
Office: (212) 435-5456
mhyams@panynj.gov

James D. Heitmann
The Port Authority of NY & NJ
Deputy General Manager
Newark Liberty International & Teterboro Airports
Phone: (973) 961-6261
jheitmann@panynj.gov

Frank Radics
The Port Authority of NY & NJ
Airport Maintenance Manager
Building 1 – Conrad Road
Phone: (973) 961-6220
fradics@panynj.gov

Vincent P. Antes, P.E.
The Port Authority of NY & NJ
Senior Program Manager
Physical Plant & Redevelopment Division - New Jersey Airports
Phone: (201) 783-4786
vantes@panynj.gov

Christopher T. Perez, A.C.E.
The Port Authority of NY & NJ
International Facility Duty Manager
Airport Operations Division
Newark-Liberty International Airport
Phone: (973) 418-0970
ctperez@panynj.gov

John Clague
Delta Air lines
767/757Captain

Jorge Reis-Filho
The Port Authority of NY & NJ
Aviation Department
Aviation Security and Technology Division
233 Park Avenue south, 9th Floor
New York, NY 10003
Phone: (212) 435-3824
jreis@panynj.gov

Mark Frink
Hobart Ground Systems
Eastern U.S. Sales Manager
Phone: (570) 618-2786
mfrink@itwgsegroup.com

Appendix B- University Description

Founded in 1870, Stevens Institute of Technology is a private institution focused on engineering, scientific research, and entrepreneurship. Prior to his death, Edwin A. Stevens, in his will, arranged for the establishment of an institution of higher learning. Because of the family's involvement the early development of nautical and train transportation technology, it was decided that Stevens would be technology and engineering focused by the institute's original trustees.

Educating leaders, who create, apply and manage innovative technologies while maintaining a deep regard for human values has been the school's consistent mission. In recent years, many new initiatives to advance innovation in science, engineering, and technology management have been implemented. Stevens is well known for its distinctive external partnerships with business, industry, and government to realize the practical benefits of research for the greater good of society. The School of Systems and Enterprises has graduates directly involved the FAA Next Gen system implementation as part of a partnership agreement between the FAA's William J. Hughes Technical Center and Stevens.

Stevens seeks to develop its graduates as leaders who possess the skills and insight needed to renew American innovation, competitive spirit, and productivity. Stevens currently has 2,234 undergraduate students from 47 different states and 60 different countries. It offers 30 undergraduate majors, 40 Master's degree programs, and 17 PhD programs. Stevens has established its reputation as a premier institute for secondary education being named a National Center of Excellence in Systems Engineering Research by the US Department of Defense and in Information Assurance Research and Education by the National Security Agency.

Appendix C – Partners

Stevens Institute of Technology Physical Plant

The Stevens Physical Plant is the facilities maintenance and management department at the university. It provides day-to-day building support and repair services for the Stevens campus. The Physical Plant plays a significant role in the management and upgrade of Stevens' extensive heating, cooling, and on-site power generation systems.

The Port Authority of New York and New Jersey

Established in 1921, The Port Authority of New York and New Jersey was commissioned to manage transportation infrastructure in the New York City area. With governance jointly allocated to New York and New Jersey, the organization oversees seaports, bus terminals, railways, tunnels, bridges, the World Trade Center, a 1700+ member police force, and five airports: John F. Kennedy International, Newark Liberty International, LaGuardia, Stewart International, and Teterboro. Consistently ranked as some of the highest-volume airports in the United States, JFK, Newark, and LaGuardia collectively serve over one-hundred-million passengers annually. [22] Altogether, the New York City region is the second largest airport system in the world in terms of passenger volume. Newark Liberty International Airport is located within the city limits of both Newark and Elizabeth in Essex County, New Jersey. Opened on October 1, 1928, Newark was the first major airport in the United States.

The Port Authority of New York and New Jersey is an interstate agency given the criticality of aviation to the Northeast region, efficient operations are integral to serving customers effectively. The current economic landscape has, for the past several years, been such that the Port Authority must operate under conditions of zero growth in operating expenses and heavily scrutinize capital intensive undertakings. In order to cope with such constraints, the agency has adopted a stance of sustainability through employing energy efficient technologies in its operations.

Hobart Ground Power

Hobart Ground Power is a premier provider of ground service equipment for the aviation industry. Beginning in 1945, Hobart was consulted by American Airlines to construct a generator specifically designed to start large aircraft engines and operate the plane's electrical systems while it was on the ground. With changes to the electrical needs of aircrafts, the need for specifically designed generators to serve as ground power units grew. With Hobart's experience in battery chargers and DC generators they were able to produce the first generator of this type. Today Hobart has continually developed new products to meet the ever-changing requirements of the aerospace industry. All manufacturing of products is ISO 9001 Certified and Hobart remains the industry leader in quality standard of commercial ground power and preconditioned air units.

Appendix E – The Educational Experience

Student Evaluation:

1. Did the FAA Design Competition provide a meaningful learning experience for you? Why or why not?

The competition provided a valuable means of testing team members' preparedness for working with teams of people from various departments, organizations, and backgrounds in a real-world setting. Whereas all team members participated in either internships or the Stevens cooperative education program, the opportunity to lead a project outside of the classroom was somewhat rare. Real-world experience has been emphasized as being crucial for finding employment after graduation, but the team feels those experiences should be reinforced by leadership opportunities in actual settings where there are real stakes. The competition provided the perfect conduit for the four Engineering Management students to express their skills.

2. What challenges did you and/or your team encounter in undertaking the Competition? How did you overcome them?

The team encountered challenges in two areas: staying on schedule and validating assumptions and calculations. Not being entirely familiar with facilities management and the operations at Newark airport left many questions open-ended for team members. Actively managing the list of inquiries and getting the answers from contacts in a timely manner proved difficult. Furthermore, the team found it challenging to validate equations and figures yielded by them. Not being seasoned facilities engineers led members to sometimes second guess themselves until the conclusions could be checked against the knowledge of contacts.

3. Describe the process you or your team used for developing your hypothesis.

Development of its hypothesis came as a function of heavily researching modern electrical power generation techniques and gate electrification. Solution forming required brainstorming different technologies that would be effective at Newark to avoid the capacity upgrades described in the report body. Knowing conventional grid-tied strategies would not work at Terminal B, the team had to look to alternative power generation methods. The team had to make sure it understood the constraints of the facilities. Members looked to the most sensible solutions, rather than conventional green techniques such as solar or wind. These alternatives were not conducive to Newark, so the team mainly focused on using only what the facility did have to offer; natural gas.

4. Was participation by industry in the project appropriate, meaningful and useful? Why or why not?

Participation by industry proved invaluable. Without the perspectives of all parties that would be involved in the implementation of Green Gates, it would have not been possible to test the economic and ecologic viability of the solution. Understanding the points of view of equipment manufacturers, airport operators, and facilities managers allowed the team to understand the dynamics of each type of individual and the interactions that would take place in design of such a system.

5. What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?

Skills taught in the classroom were strongly reinforced throughout the project. Quality management principles such as the idea of efficient operations through adherence to stringent customer requirements and continuous improvement were heavily emphasized. These concepts have a great deal of real world applicability. Having experienced the competition and project, all team members can say with confidence that strengths gained from the project have complemented the classroom experience and will be of value in professional endeavors.

For faculty members:

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

The opportunity to work on a real world challenge is very valuable. It requires the students to engage with the problem from the perspective of the FAA and other relevant stakeholders and potential vendors, be exposed to real world constraints, not only technical and economical, but also finding and accessing the right people and information, and realize that they are working on something that is of actual interest to several stakeholders.

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

Absolutely. The work fit well into the scope and context of a Senior Design project of the Engineering Management program.

3. What challenges did the students face and overcome?

The main challenge was for students to get the data they needed, which included identifying the right people and being persistent to get on their agenda.

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

Yes. For the reasons under question 1 and the fact that a competition provides focus and additional incentives for the students to apply themselves

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

It seems to have a nice format. One thing might be to assist the students further in finding a first relevant point of contact in the stakeholder community. “Cold calling” is a very good exercise and experience for later, but it can take a lot of valuable time in the beginning of the project.

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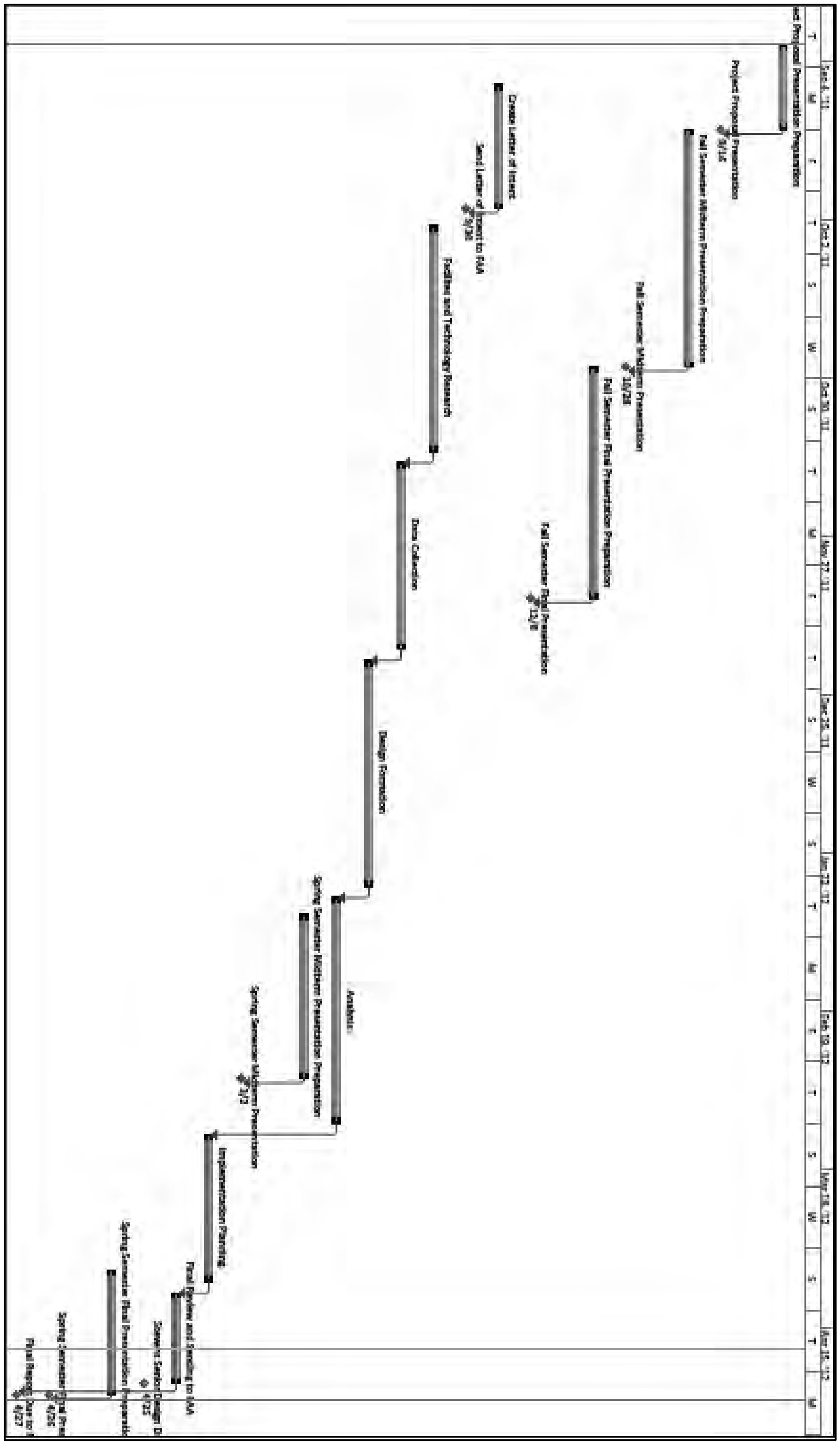
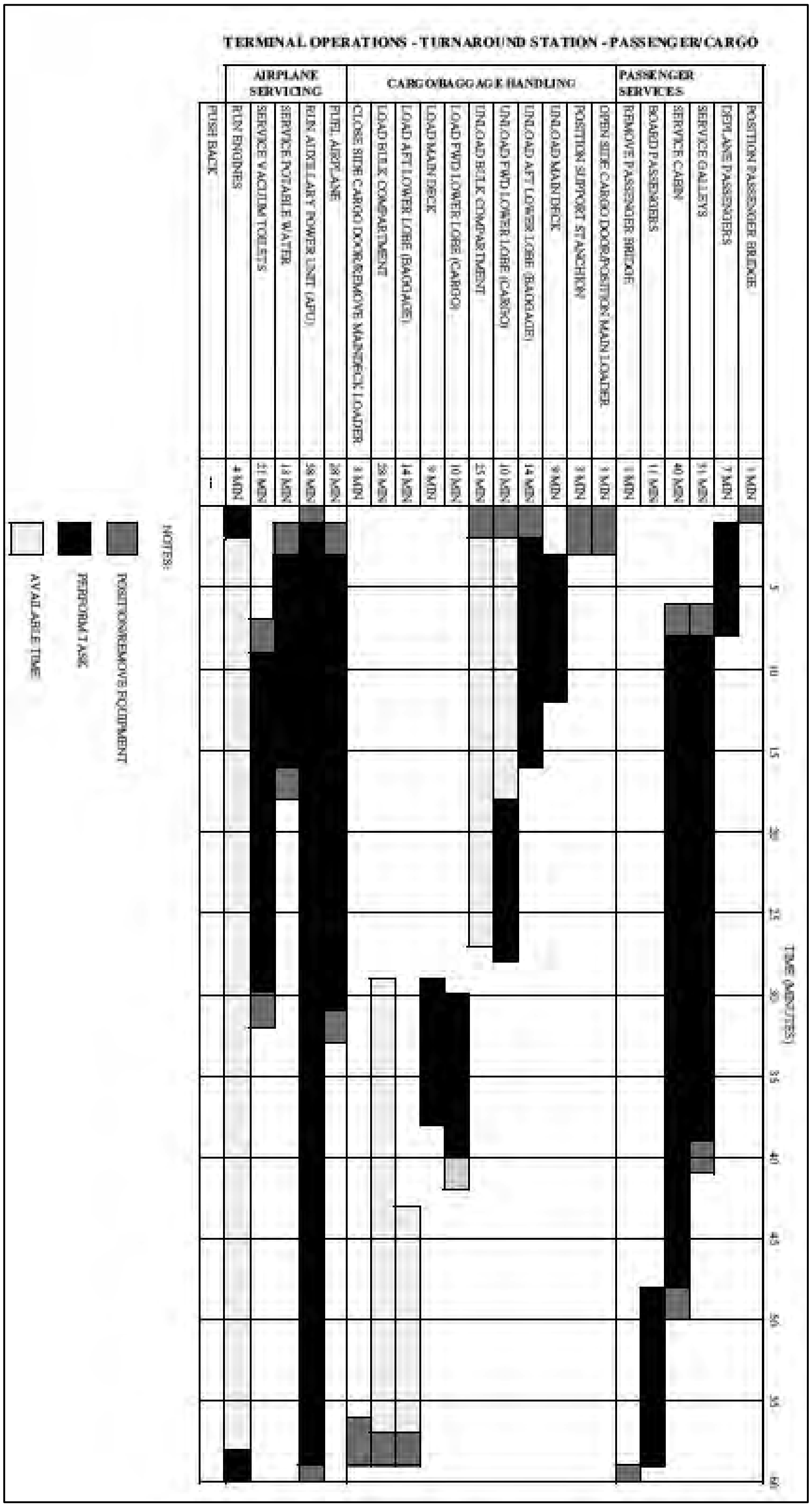
Appendix G – Gantt Chart



Appendix H – Terminal Servicing Requirements



Appendix I – DATAM Guidelines

<u>Guidelines for E423 Consulting Projects</u>

<u>Instructions:</u>

This report is prepared by combining information from the DATAM model and from the Consulting Model

Use it as a guideline to complete your E423 project report – provided you have a consulting project ONLY!!!!

This document will help you fill out the sections of your E423 (Senior Design) Final Report. The sections you will be assisted with are mentioned before the explanation provided for each section.

<u>Introduction:</u>

Explain in this section your overall project in a nutshell. 1 sentence for the problem statement and then maybe 1-2 lines explaining possible solutions that you think MIGHT be feasible.

<u>Problem/Opportunity</u>

Always remember that a problem for the client could be (and most likely is) an opportunity for your consulting firm.

Model the current process that your client is undertaking and obtain metrics to measure the process outcome.

Examples of these metrics are:

- Cost / Unit
- Time / Unit
- Selling price / Unit
- Actual number of units produced

Based on these metrics you can find out the annual costs and the annual revenue for the client --- taking into consideration the current process that they are implementing.

In order to get a more accurate estimate of the total costs associated with the process, include the deployment costs for this current process being employed by the client.

Strategies for Identifying & Reducing Costs of Processes:

For any consulting project to be successful, there are two approaches that you can adopt.

One way is to identify costs and device strategies for reducing those costs. In fact, to control costs and enhance profitability, building a viable business strategy is the most effective action any organization can take.

The second option is to conduct a benefit cost ratio for the process because in some situations higher costs can be justified provided the benefits are greater in the long run, i.e, over the total life of the process.

Why do you want to reduce costs?

- Increase Profits
- Waste Reduction
- Increase Productivity
- Competitive advantage
- Resource Conservation

In order to identify and reduce process costs, first you need to address the following essential elements:

1. Know your team and its expertise
2. Know the client
3. Always keep options for solutions and do not narrow it down to one pick right away.

Keep in mind that cost reduction is a broad program where everyone is focused on reducing cost from each area of the process. Cost reduction can be achieved through reduction, elimination, modification, substitution or innovation. All cost drivers should be taken into account and with a thorough analysis the best and least cost path is adopted for each activity.

Where to implement cost reduction in your process:

Since this is a consulting project, the most common areas where you can reduce the cost of your process are:

- Logistics – inbound and outbound
- Energy
- Human Resources -- you need to do a cost analysis and see if it is beneficial to carry out a certain process (or part of the process) in house or to outsource it to a vendor who has expertise in that particular task.

Benefit Costs Ratio analysis:

A **benefit-cost ratio** (BCR) is an indicator, used in the formal discipline of cost-benefit analysis that attempts to summarize the OVERALL value for money of a project or process. A BCR is the ratio of the benefits of a project or proposal, expressed in monetary terms, relative to its costs, also expressed in monetary terms. This methodology should particularly be used in consulting projects if the costs outweigh the benefits in the short run. It is used to show the client that if the overall benefits are greater than the costs, then it is worth while investing in this consulting project.

Possible Cost Reduction Strategies:

A. Cost Reduction by Design:

• Product development determines 80% of product cost. The concept/architecture phase alone determines 60% of cost! Cost is very hard to remove later after products are designed

How to reduce Product Cost by Design:

- Practice Concurrent Engineering with early and active participation of manufacturing, purchasing, vendors, etc.
- Implement Design for Manufacturability (DFM), Design for Lean, and Design for Quality
- For dramatic cost reduction - *half cost to order-of-magnitude* - optimize the concept/architecture phase

- To convert ideas, research, or prototypes into viable *products,* use commercialization techniques to ensure success.

B. Lean Production Cost Reduction:

Cost Reduction Opportunities through Lean Production:

- Lean production benefits include doubling labor productivity, cutting production throughput times by 90 percent, reducing inventories by 90 percent, cutting errors and scrap in half errors.

C. Overhead Cost Reduction:

Implement Just-in-time production methodology which reduces inventory costs

Procurement costs can be reduced by deciding to do a particular part of the overall process in-house or to outsource it to an outside contractor who can do it for cheaper.

D. Standardization of Processes:

If you are working on a number of different processes for the same organization, try to implement a minimum level of standardization between the various processes. This will help your client take advantage of economies of scale.

At the end of implementing your cost reduction strategies, you need to make sure that you MEASURE the improvements. In order to be able to measure the improvements there have to be parameters to do so.

E. Tool and Technology Support:

Better tools and technology should be implemented. This implementation of information technology can lead to higher automation and correspondingly higher productivity. This in turn can reduce process costs and increase the value being provided by the process to the stakeholders.

Suggested parameters to measure reduction in costs:

- Cost per unit ($/unit)
- Man-hours/unit
- Units produced/ unit time
- Number of defects
- Power Consumption
- Inventory Turnover Rate

Typical classification of projects as Small, Medium & Large

For **Small Projects –** Projects with 0-10 Man Months of labor for the consulting group or which are less than $100,000 for the cost of the solution.

For **Medium Projects –** Projects with 10 – 50 Man months of labor for the consulting group or which are between $100,000 and $500,000 for the cost of the solution.

For **Large Projects –** Projects with more than 50 man months of labor for the consulting group or whose solution cost is > $500,000

Proposed Solution:

For the cost of the proposed solution, you need to re-measure the same metrics that you obtained for the before process. This way you can set up a comparative table to show the gain to the customer based on the new process.

Deployment Costs:

In order to implement the cost cutting strategies for the processes under consideration, there has to be some equipment bought as well as corresponding software (as well as license fees). This can add up to a considerable amount of money and hence it needs to be taken into consideration. Fill in the table given below and estimate the cost to your client for implementing the new process.

Item	# (Units)	$ / Unit	Total ($K)
New Equipment Required			
New Software Required			
Software Licenses			
Design Cost			
PRIMARY DEPLOYMENT COST			

In the table below, the guidelines provided will help you estimate the costs for other aspects of deployment of your project. Fill in the table below to estimate the deployment costs for the new process to your client.

Item	Cost
Cost of Training	
Opportunity Cost of sending	
Transportation Costs	
Additional Deployment Costs	

Working Capital Estimation

This is the amount of money needed to keep your business going. It may be a few months before you start earning revenues. Until then you need to pay your employee salaries, bills and other day to day expenses from working capital. Please fill in the given table as required.

Item	No. of months	$ / month	Total ($K)
TOTAL WORKING CAPITAL			

TOTAL DEPLOYMENT COST TO CLIENT TO IMPLEMENT NEW PROCESS

= PRIMARY DEPLOYMENT COSTS + ADDITIONAL DEPLOYMENT COSTS + TOTAL WORKING CAPITAL

Conclusions and Recommendations

It is important to keep in mind that the bottom line (main reason) why your client has hired you is so that their process can be done in a more efficient manner so that it can save them money.

<table>
<tr><td></td><td>Year</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Revenue (R)</td><td></td><td>R1</td><td>R2</td><td>R3</td><td>R4</td><td>R5</td></tr>
<tr><td>Cost (C)</td><td></td><td>C1</td><td>C2</td><td>C3</td><td>C4</td><td>C5</td></tr>
<tr><td>Δ (R-C)</td><td></td><td>ΔB1</td><td>ΔB2</td><td>ΔB3</td><td>ΔB4</td><td>ΔB5</td></tr>
<tr><td colspan="7">NPV of Process (ΔB1 through ΔB5), that is NPV before the change has been implemented</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Revenue (R)</td><td></td><td>R1</td><td>R2</td><td>R3</td><td>R4</td><td>R5</td></tr>
<tr><td>Cost (C)</td><td></td><td>C1</td><td>C2</td><td>C3</td><td>C4</td><td>C5</td></tr>
<tr><td>Δ (R-C)</td><td></td><td>ΔA1</td><td>ΔA2</td><td>ΔA3</td><td>ΔA4</td><td>ΔA5</td></tr>
<tr><td colspan="7">NPV of Process (ΔA1 through ΔA5), that is NPV after the change has been implemented</td></tr>
</table>

Appendix J – Equipment Documentation

See attached documents.

Kawasaki
Co-Generation system

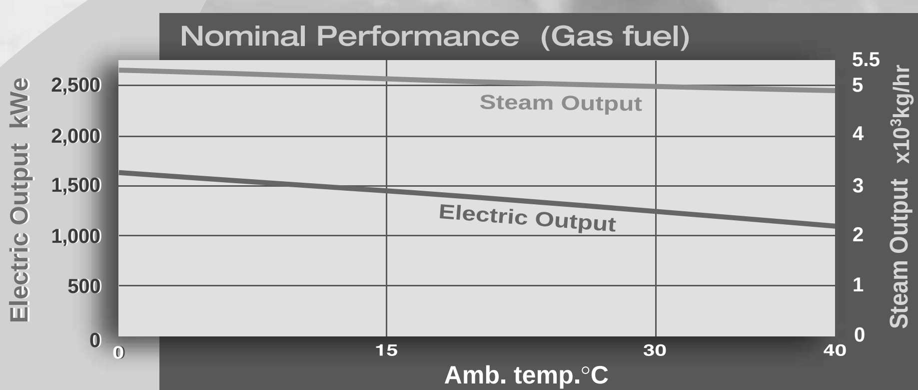
GPB15D

Electric Power 1.5MWe, Steam 5.1t/h, Dry Low Emissions

High efficiency : electric 23.6%, overall 79.7%

Dry low emissions : NOx 25ppmv, CO 50ppmv (O_2 =15%)

High reliability & easy maintenance



Amb.temp. °C (°F)	Electric Output kWe	Heat Rate kJ/kWe-hr	Steam Output $\times 10^3$kg/hr	Electrical Efficiency %	Total Thermal Efficiency %
0 (32)	1,630	14,810	5.3	24.3	77.8
15 (59)	1,450	15,280	5.1	23.6	79.7
40 (104)	1,116	17,140	4.9	21.0	82.8

Nominal Performance

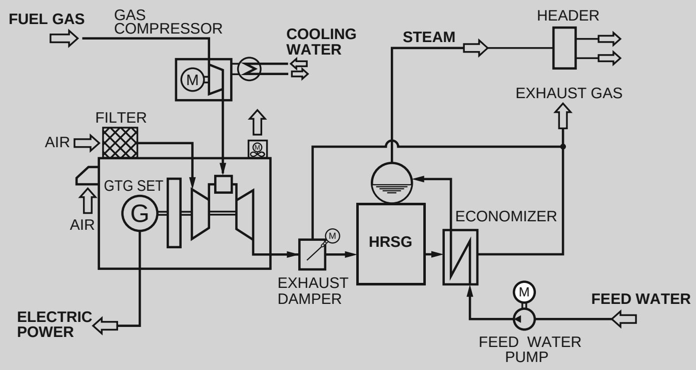
Elevation	: 0 m
Inlet Air Temperature	: 15 °C
Inlet Air Pressure Loss	: 0.98 kPa
Exhaust Gas Pressure Loss	: 2.45 kPa
LHV of Natural Gas Fuel (100% CH_4)	: 35.9 MJ/Nm^3

Typical Steam Condition

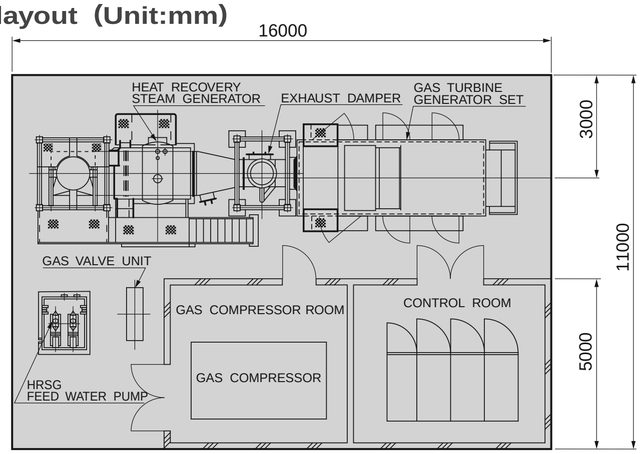
Steam Pressure	: 0.83 MPaG
Steam Temperature (Saturated)	: 177 °C
Feed Water Temperature	: 80 °C
Blowdown from HRSG	: 0 %

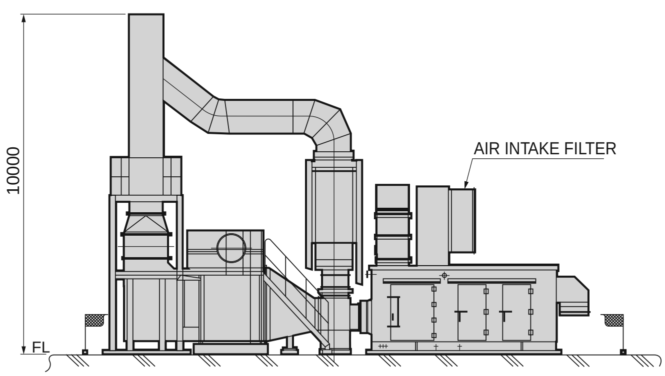
GREEN
Gas Turbines

Typical system flow (IN CASE OF GAS FUEL)



Typical layout (Unit:mm)





Kawasaki

www.khi.co.jp/gasturbine/index_e.html

Kawasaki Heavy Industries, Ltd. Gas Turbine Division
Phone: +81-3-3435-2232 Fax: +81-3-3435-2592

Kawasaki Machine Systems, Ltd. (Asia Division)
Phone: +81-3-3435-2977 Fax: +81-3-3435-2592

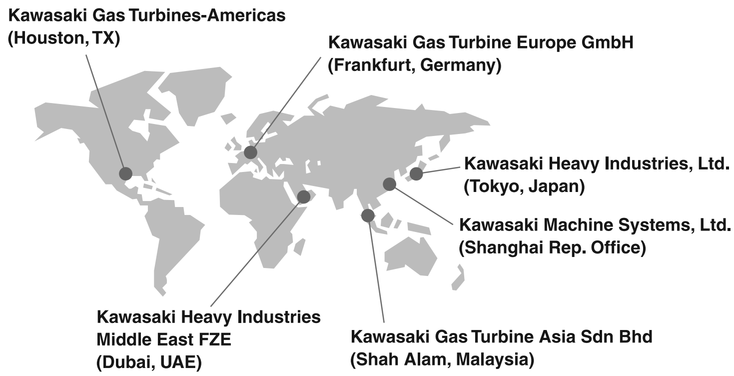
Kawasaki Gas Turbine Asia Sdn Bhd : (KGA)
Phone: +60-3-5569-2882 Fax: +60-3-5569-3093
www.kga.com.my

Kawasaki Gas Turbine Europe GmbH : (KGE)
Phone: +49-6172-7363-0 Fax: +49-6172-7363-55
www.kawasaki-gasturbine.de

Kawasaki Gas Turbines-Americas : (KGT-A)
Phone: +1-281-970-3255 Fax: +1-281-970-6465
www.kawasakigasturbines.com

Kawasaki Machine Systems, Ltd. (Shanghai Rep.Office)
Phone: +86-21-3366-3500 Fax: +86-21-3366-3505

Kawasaki Heavy Industries Middle East FZE : (KHI-ME)
Phone: +971-4-214-6727 Fax: +971-4-214-6729



Cat.No KTK-0020A '10-05 (71) Printed in Japan

HOBART®
GROUND POWER

DATA SHEET: 209
INDEX: 022008
REPLACES: 082307

PoWerMaster® EV
120/150/180 kVA Solid State Frequency Converters

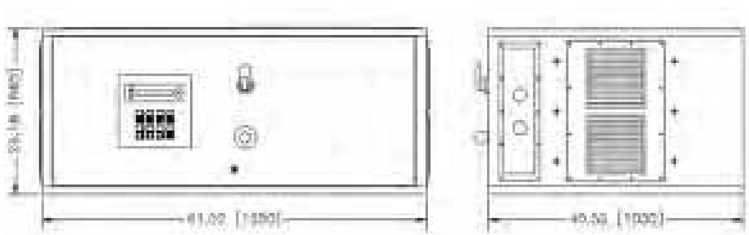
DESCRIPTION
The Hobart PoWerMaster® EV converters are the latest addition to the Hobart line of 400 Hz frequency conversion products. The flexible design allows for the GPU to be set up for either bridge, fixed, or trailer mount configurations. With our continued user-friendly controls and a superior diagnostic system, the converter is easy to use and requires minimal training. With a wide array of output ratings available, an optional 28.5 VDC output, and a broad choice of input voltage configurations, this unit has the versatility to provide power to all aircraft from the wide-body aircraft to the large jumbo aircraft. State-of-the-art design, ease of use, and proven reliability are among the many reasons the PoWerMaster® EV design has set a new industry standard.

OPTIONS
- 28.5 VDC Output (600 A continuous, 2400 A peak)
- Vertical, Bridge and Trailer Mounting Kit
- Remote Control Box
- Lost Neutral Protection
- Lockable Doors
- Remote Control Capable
- 600 V Input

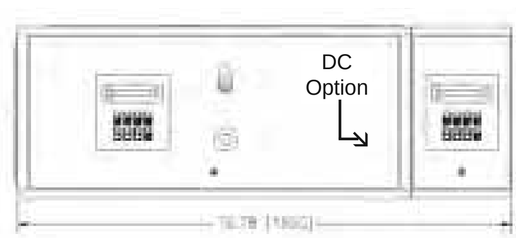
Contact factory for other available options.

FEATURES
- Compact and Lightweight
- Low noise levels < 65 dbA at 1m
- Individual phase regulation at output
- 12-pulse rectification at input as standard with input current distortion < 10%
- Harmonic elimination at output with total harmonic out < 2%
- User friendly controls for simple daily operation
- All user information available via digital display
- Modular design throughout for easy access to all parts
- CE Compliant
- RS232 and RS422 / RS485 Communication Port
- JBUS or Siemens Protocol
- Simplified fault reporting troubleshooting and maintenance
- NBPT Compatible
- ETL (UL 1012) Certification

Dimensions in inches (mm)



Without DC Add-on Option



With DC Add-on Option

Hobart is an ISO9001 Certified Manufacturer

PoWerMaster® EV
120/150/180 kVA Solid State Frequency Converters

Specifications

Inputs

Model	Amperage & Voltage	Hertz
120SE200	151 @ 400 VAC ±15% 131 @ 460 VAC ±15% 126 @ 480 VAC ±15%	50-60 ±5%
150SE200	189 @ 400 VAC ±15% 164 @ 460 VAC ±15% 158 @ 480 VAC ±15%	50-60 ±5%
180SE200	227 @ 400 VAC ±15% 197 @ 460 VAC ±15% 189 @ 480 VAC ±15%	50-60 ±5%

- Configuration: 3 wire with ground service
- Input Power Factor: 0.96
- Overall Efficiency: 0.93
- Load Power Factor: 0.8 @ 100%

Outputs
- Continuous Power Rating:
  120 kVA (96 kW)
  150 kVA (120 kW)
  180 kVA (144 kW)
- 115/200 VAC, 3 Phase, 400 Hz. ±0.1%
- Overloads: 100 - 125% – 10 minutes
  125 - 150% – 30 seconds
  150 - 200% – 10 seconds
  200 - 210% – 1 seconds
- Short Circuit Protected
- NBPT: Specifically designed to service present and future aircraft no-break power requirements.

Protections
- Input Over/Under-Voltage Overload
- Output Over/Under-Voltage
  Over/Under-Frequency Overload
  Short Circuit
- Physical Internal High Temperature
  Internal Voltage Error

Environmental
- Relative Humidity: 10 - 95%
- Operating Temperature: -40°C to +52°C
- Noise Level: < 65 dbA @ 1 m

Output Voltage
- Voltage Regulation: < 0.5% for balanced and 30% unbalanced loads
- THD (total harmonic distortion): < 2% at linear and non linear loads
- Phase Displacement:
  120° ±1° for balanced load
  120° ±2° for 30% unbalanced load
- Transient Performance: Meets MIL-STD-704F
- Crest Factor: 1.414 ± 3%
- Voltage Modulation: < 1%

Maintenance
- No preventative maintenance required (other than filters)
- MTTR: Maximum 20 minutes
- MTBF: 100,000 hours

Enclosure
- Standard protection: IP55
- Ventilation: Filter forced air
- External circuit breaker handle with lock-out capability
- Emergency Stop Button

Codes
- MIL-STD-704F
- SAE ARP5015A
- DFS400
- ISO 6858
- BS 2G 219
- EN50091-1
- EN 61000-6-4
- EN 61000-6-2
- UL 1012

Control / Indicators
- 400 Hz. On/Off: each output
- Mains/Lamps Test
- Common Error
- Digital Display (default mode):
  Year / Month / Date
  Hour / Minute
  Output Voltage
  Output Current
  Output Frequency
- Alternate Display Modes (User Initiated)

Efficiency
- Overall Efficiency:
  > 0.93 at 100% load, P.F. = 0.8
  > 0.92 at 50% load, P.F. = 0.8
- Standby Losses: < 100W

Weights
- Bridge: 1,808 lbs (820 kg)
- Fixed: 1,808 lbs (820 kg)
- Trailer: 2,400 lbs (1,089 kg)

Specifications subject to change without notice.

Operator Control Panel

Hobart Ground Power • Headquarters & Factory: 1177 Trade Road East, Troy, OH 45373 U.S.A.
Phone: 1-800-422-7253 or 937-332-5080 • Fax: 937-332-5799
E-mail: hgpsales@itwgsegroup.com • www.hobartgroundpower.com
Hobart Asia Office • Phone: + 853 288 81 891 • Fax: + 853 288 81 891
Hobart International (UK) • Phone: 44-1723-370437 • Fax: 44-1723-370125

An Illinois Tool Works Company

MOBILE PCA (ALL-ELECTRIC)

MAE320 Series

Data Sheet: 350 REV: 02/17/12

HOBART GROUND SYSTEMS
Your Total Systems Provider

Hobart Ground Systems combines ***Hobart Ground Power***, ***Trilectron/Air-A-Plane*** and ***ITW Military GSE*** and their world-renowned engineering, design, sales, and service teams to provide a total systems solution for the commercial and military aviation ground support industries. Our user-friendly designs, superior performance, and proven reliability, provide our customers the best value in the industry.

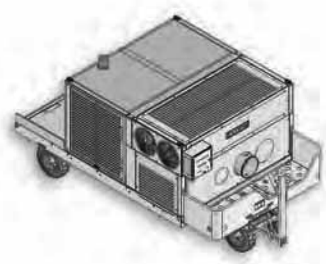
New All-Electric Compact Design:

This newly designed ***MAE320 Series*** air conditioning system was developed, tested and optimized to take advantage of the latest generation of high efficiency, zero ozone depleting refrigerant to cool any aircraft type under the most demanding of ambient conditions. New fail-safe controls enhance the efficiency of the air conditioning system to provide faster cool down of the aircraft and ensure more consistent aircraft cabin temperature for passenger comfort. The compact, lightweight package allows the units to be easily moved when assembled on a trailer for mobile applications.

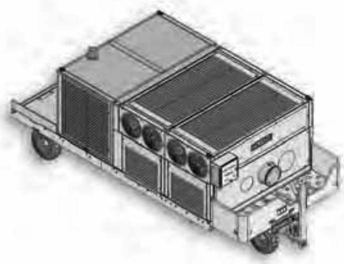
The MAE320 Series is available in various sizes to provide the optimal delivered air temperature, volume and static pressure to cool or heat any commercial aircraft. It is reliable, efficient and environmentally friendly in a compact package.

Performance Features:

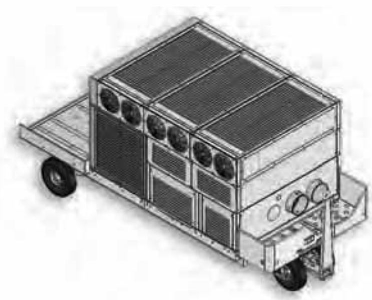
- ***Zero ODP R-410A refrigerant***
- ***Higher capacity refrigerant compared to R-22, R-134a and R-407C resulting in up to 75% less charge per system***
- ***Tested for high performance output at high ambients***
- ***Provides faster aircraft cool down times***
- ***Highest efficiency micro channel coils***
- ***Smallest package size in the industry***
- ***Fail-safe, patent pending controls***
- ***Auto/Manual operating mode selection***
- ***Patent pending modular building block design***
- ***Low mean time to repair***
- ***Easy service, maintenance and training***
- ***Common spare parts inventory across all models***



MAE321



MAE322



MAE323

new

MOBILE PCA (ALL-ELECTRIC)

MAE320 Series

SPECIFICATIONS

Construction ~

- Formed steel frame construction
- Aluminum body access panels and doors with stainless steel hardware
- NEMA 4 Electrical enclosure and wiring conduit
- Large operational switches, buttons and latches for cold weather operation in heavy gloves
- ETL Listed

Protective Finish ~

- Anti-corrosive polyester powder provides excellent weather resistance, flexibility and adhesion, plus a strong resistance to chemical agents such as glycol and skydrol
- Standard color is high gloss white
- Custom colors require a paint chip or swatch for accurate color match

Environmental ~

- Operating Temperature: -40°F to 128°F (-40°C to 53°C)
- Relative humidity 0 – 100%

Electrical ~

Blower Motor

- MAE321: 15HP (11.2kW)
- MAE322: 40HP (29.8kW)
- MAE323:75HP (55.9kW

Condenser Fan Motor

- MAE321: 4 @ 3HP (2.24kW)
- MAE322: 8 @ 3HP (2.24kW)
- MAE323:12 @ 3HP (2.24kW)

Control ~

- Industrial grade PLC controller
- 24V control voltage
- Laptop interface port for troubleshooting
- Blower outlet damper airflow control
- Remote mountable operator interface with large lighted momentary push buttons and fault indication

Protection ~

Air Conditioning

- High discharge air temperature switch (with heat option only)
- Low airflow indicator
- High refrigerant pressure switch and transducer
- Low refrigerant pressure switch and transducer
- Input voltage phase monitor
- Circuit breakers and overloads on all motors

Displays/ Instrumentation ~

- Discharge air temperature, hour meter
- Communication Interface: Output data for maintenance via serial ports to computer or live reporting to BMS
- Indicator Lights: Lighted pushbuttons, summary faults
- Buttons: start, stop, aircraft class selection, unit mode selection, dual hose (optional)

Available Options ~

- 14”D insulated, flat air delivery hose
- External emergency stop
- Heat
- Operation indicator beacon
- Corrosion resistant coil coatings

Model	Input (V*/PH/HZ)	FLA Cool/Heat	Max Fuse	Blower Moter	Condenser Fan Motor
MAE321	460 / 3 / 60	85A / 91A	100A	15HP (11.2 kW)	4 @ 3HP
MAE322	460 / 3 / 60	169A / 141A	200A	40HP (29.8 kW)	8 @ 3HP
MAE323	460 / 3 / 60	284A / 226A	300A	75HP (55.9 kW)	12 @ 3HP

Model	Airflow Range (min/max)	Air Static Pressure @ Max Flow	Air Discharge Temp*	Max Heat Capacity	Length**	Width	Height	Weight
MAE321	75 - 210 PPM	19 in WG	38°F	60 kW	171.5” (4,356 mm)	92.4” (2,347 mm)	85.6” (2,174 mm)	4,835 lbs (2,193 kg)
MAE322	90 - 310 PPM	31 in WG	36°F	90 kW	211.5” (5,372 mm)	92.4” (2,347 mm)	85.6” (2,174 mm)	7,016 lbs (3,182 kg)
MAE323	100 - 600 PPM	30 in WG	37°F	120 kW	219” (5,563 mm)	96” (2,438 mm)	110" (2,794 mm)	11,656 lbs (5,287 kg)

*Temperature at maximum airflow on 100°Fdb/80°Fwb **Unit length measure to end of hose basket (not including tow bar) *Specifications subject to change without notice.*

HOBART® GROUND SYSTEMS

www.HobartSystems.com

Headquarters: 11001 US Hwy. 41 North Palmetto, FL 34221 U.S.A.
Phone: 941.721.1000 • Fax: 941.721.1087
E-Mail: Sales@HobartSystems.com

Asia Office: Phone: +65 6645 3668 • Fax: +65 6645 3669
International (UK): Phone: +44 1723 370437 • Fax: +44 1723 370125

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