Geothermal Heating of Airport Runways

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Problem Statement and Background

Keeping snow and ice from building up on airport runways and taxiways is an essential part of airport maintenance/operations worldwide and requires a large investment of time and money in equipment and operational control, especially in colder climates. Current methods for removing ice and snow from airport movement surfaces consist of spraying large quantities of anti-ice chemicals on the ground and deploying a great number of snowplowing vehicles. Both the chemicals and snowplowing vehicles have adverse effects on the environment as they contribute to pollution. During poor weather conditions, keeping runways open can be a challenge as snowplow crews cannot keep up with the precipitation, causing airport closures, delays and safety concerns. Ice buildup on runways has been proven to contribute to accidents involving runway runoffs. Heating runways with geothermal heat can prevent the buildup of ice and snow on runways and once installed, such a system could pay for itself in as little as 2-5 years. Geothermal heat has been used to melt ice and snow off roads, sidewalks, bridges and other paved surfaces for years in locations around the world. The design is simple; pipes are cut into the pavement that receive a flow of warm liquids, either from direct use geothermal water, where available, or through the use of heat exchanger systems or even hot runoff liquids from local industry or power plants. The most ideal locations to utilize geothermal heat are in areas where high-temperature water wells can be drilled for direct use. Such locations can be found through much of the western half of the United States.

Literature Review
Geothermal Heating of Airport Runways

Keeping snow and ice from building up on airport runways and taxiways is an essential part of airport maintenance/operations worldwide and takes up large amounts of resources and expenditures, especially in colder climates. Every year, very large amounts of pavement de-icing chemicals are dumped on runways, causing potential environmental concerns and inflicting damage to the runway concrete (Hassan, El Halim, Razaqpur, Bekheet, & Farha, 2002; Corsi, Geis, Loyo-Rosales, Rice, Sheesley, Faily, & Cancilla, 2006). Engineers have already developed techniques to heat various pavement surfaces to prevent the buildup of ice/snow on sidewalks, roads and bridges using geothermal technologies (Eugster, 2006; Lund, 2002; Rybach, 2006) and in this following review of literature an attempt will be made to assess the possibility of extending Geothermal technologies to provide runway heating as a viable alternative to existing snow/ice removal methods.

Current snow/ice removal practices have until now been considered the least expensive and most practical solution, but with ever increasing oil prices, snow plows are becoming more expensive to operate, especially in more remote parts of the world. Furthermore with increased public awareness of global warming and environmental protection, interest in reducing carbon emissions is pushing policy makers to seek alternative energy source solutions, including the use of geothermal resources.

The environmental impact of aircraft and runway de-icer and anti-icer chemicals is examined in a research article by Corsi et al. (2006). The researchers took samples from snow banks within a medium-sized airport for four consecutive years and characterized aircraft deicer and anti-icer (ADAF) components and toxicity. The chemicals used at airports today consist mostly of various glycols and urea. While many airports operate collection systems and attempt to treat or recycle spent chemicals, a portion of the chemicals get plowed into nearby snow banks and later flow through storm drains to receiving surface waters and travel to the groundwater system. Where urea or glycols get collected in streams, ponds or lakes near airports these chemicals are known to create undesirable algae and cause various diseases in fish. The U.S. Environmental Protection Agency estimates that 35 million kg of ADAF chemicals are discharged to receiving waters in the U.S. annually. Concentration of these ADAF chemicals in water supplies near airports varies greatly depending on local climates, hydrologic conditions and steps taken to manage chemical spills at individual airports. The research showed that the amount of glycol concentration in snow banks varied from being 0.17% to 11.4% of the amount applied to runways and aircraft or up to 60 grams per liter. The research also showed that while the direct environmental impacts of glycol and urea are fairly well documented, the same cannot be said about the various additives that are mixed with the ADAF chemicals, such as corrosion inhibitors, flame retardants, wetting agents, dies and several binding polymers. Further studies were strongly suggested to examine the impact of these additives.

Runway de-icers do not only cause environmental threats but do also cause damage to pavement material as shown in a study by Hassan et al. (2002). In order to maintain sufficient traction between aircraft tires and the runway pavement, two distinct strategies are deployed, de-icing and anti-icing. As snow accumulates on a pavement surface and gets compacted by traffic, a bond with the pavement gets created that can be difficult to remove with plows. De-icing is a reactionary operation used to break that bond. Anti-icing on the other hand is a preventive measure used against the formation of snow or ice bonding with the pavement. Both strategies require applying some forms of chemical agents to break or prevent a bond between pavement and snow/ice. While road salts (calcium chlorides) are most frequently used on highways and streets, they cannot be used on airport surfaces as they damage aircraft metallic components and cause severe corrosion. Therefore the most frequently used chemical used on airport pavement surfaces is urea. The problem with urea, however, is that it has been shown to cause damage to asphalt concrete pavements, much more so than ordinary road salts according to this study. The researchers took samples of runway pavement and exposed them to freeze-thaw cycles and found that de-icing chemicals caused weight and density loss in the asphalt and made it more brittle as it affects the viscosity of the cement as well as the gradation of aggregates. It can therefore be stated that alternative means of melting snow/ice from runways should potentially reduce maintenance costs dramatically in terms of longer lifetime of concrete.

In a paper by Lund (2002) several methods of pavement snow melting using geothermal hot water and steam are examined. Currently, sidewalks, roadways and bridges are being heated in various places around the world and most commonly it is done with a glycol solution, hot water or steam being circulated in pipes within or below the pavement, using either heat pipes or geothermal fluids. According to the author, heating requirement for snow melt depends on four atmospheric factors: rate of snow fall, air temperature, relative humidity and wind velocity. The snow melting system must first melt the snow and then evaporate the resulting water film. The rate of snowfall determines the heat required to warm the snow to 32 degrees F (0° C) and to melt it. The evaporation rate of the melted snow from the pavement is affected by the wind speed and by the difference in vapor pressure between the air and the melted snow.

Piping materials used to conduct the hot water are either metal or plastic. Steel, iron and copper pipes were used extensively in the past but have been proved to corrode easily and therefore plastic pipes are now more commonly used. Typical plastic pipes are made from lightweight polyethylene and can handle 200°F hot water at 80 psi of pressure. Expected lifetime of such plastic pipes is over 50 years. Where heat pump systems are used to circulate relatively cool water in a closed system and heated by a heat exchanger an antifreeze solution (ethylene or propylene glycol) is used in the pipes as most systems will not be operated continuously in cold weather and therefore the system must be protected from freeze damage.

Geothermal energy is supplied either through heat pipes or the direct use of geothermal hot water. The use of geothermal hot water is less common in the United States as there are limited numbers of geographical locations in the U.S. where geothermal fluids above 100°F are available. Those areas are mostly found in the the western mountain states inlcuding Colorado, Nevada, New Mexico, Montana, Idaho, Wyoming, and Utah, as well as northern California, Oregon and Washington. Heat pipes can however be used anywhere in the U.S. using typical ground temperatures. Heat pumps are not as efficient as using geothermal waters directly due to the lower temperatures of the circulating fluids. According to this study, geothermal systems can be installed for a cost of around $20/ft^2$ and heat pipe systems for approximately $35/ft^2$.

The author of the study also cited a theoretic study performed by Senser (1982) which indicated that it might be practical to use heat pipe based systems for snow/ice melting for airport runways. A computer simulation was run and the resulting algorithm was shown to be computationally efficient and accurate. The simulation indicated that a practical heating system would require 8.81 Btu/hr/ft^2 °F and water source temperature of 50°F in order to melt the snow as rapidly as it falls. Furthermore during 87% of the time that there was some snow cover, melting at the snow/pavement interface would occur, making manual snow removal a much easier task.

In a report made for the European Geothermal Energy Council by Eugster (2007) the author examines the current geothermal projects being deployed in Europe to heat roadways and bridges. A project called SERSO that is being run in Switzerland has been called the “mother of the geothermal bridge or road heating systems.” SERSO collects heat during the summer from the hot road surface and stores the energy in a nearby rock storage, which consists of a concentric field of 91 bore-hole heat exchangers. During winter, heat is extracted from the heat storage and used to maintain a temperature of the bridge surface above 38°F (3°C). SERSO provides a direct use of the geothermal heat and electricity is only used for circulation pumps. The installation has shown that much more heat was collected in summer than needed in winter for de-icing and experts agree that cooling in summer would also extend the lifetime of the pavement.

Geothermal road, bridge or outside surface heating is according to the report “a feasible and approved possibility to increase traffic and public safety.” Several examples were shown to prove that geothermal road heating systems work without problems over years and are completely renewable. Geothermal snow melting without a heat pump is very cheap in operation, independent of the geothermal heat source used but the use of ground source heat pumps makes the system operation more expensive. The installation of a "hydronic" geothermal heating system is rather cost intense, depending upon the geothermal heat source used.

In a report by Rybach (2006) the status and prospects of geothermal heat pumps is explored. Geothermal heat pumps represent the fastest growing segment of geothermal energy utilization as it is not bound to geographic locations capable of producing hot temperature fluids. Heat pumps can raise or lower the temperature of a working fluid and can therefore be used both for heating and cooling. In most cases they are driving by electric power. New technologies like geo-structures ("energy piles"), combined heating/cooling is rapidly progressing on the market according to the report. A prominent example is Dock Midfield, the new terminal at Zurich International Airport. This terminal building is a 30 meters wide new construction and is funded on 440 foundation piles, each 0.9 – 1.5 m in diameter, of which 315 are equipped with heat exchanger tubes. The piles stand at a 30 m depth on a tight ground moraine formation. 1.1 GWh of heat energy is extracted annually through this special Borehole Heat Exchange system for heating in the winter. In the summer, the building heat is deposited in the ground which thus acts as a storage medium. For air conditioning, some 500 kWh cooling energy is supplied by the energy piles.

Snow and ice build up on airport pavement surfaces create a hazard for aircraft operating on those surfaces due to reduced friction for braking. Snow accumulation on pavement also increases the rolling resistance of the aircraft tires resulting in increased takeoff distances and can even make taking off impossible. The current methods for removing and keeping snow and ice off airport surfaces involve a combination of snow plows and chemical de-icers. Snow plows are a problem because they must occupy the runways and taxiways on an airport while they are removing snow; thereby keeping aircraft from using the surfaces while the plows are in operation.

Chemicals are preferred as a means of keeping snow and ice from building up on airport surfaces because chemicals can be applied once and will keep the pavement free of snow and ice for many hours or more, depending on many factors. De-icing chemicals are not without drawbacks, the most widely used chemical for runway deicing is urea, which is toxic to fish and causes bacteria growth in waterways after washing off the airport (Trimbath, 2006). The currently available environmentally friendly chemicals have undesirable side-effects; the Denver, Colorado International airport is experiencing concrete erosion with the use of a potassium acetate based de-icer (Trimbath, 2006).

New de-icing chemicals are being developed, such as calcium magnesium acetate (CMA) for use on highways. CMA is less corrosive than conventional calcium chloride and other salts and therefore may eventually have a use on airports. This new chemical deicer is environmentally friendly and cheap to produce since it can be made from household wastes such as sewage and refuse (Ormsby).

The temperature of the pavement affects how snow and ice adhere to the surface. Canada has a system called Road Weather Information Systems which monitors the conditions near the paved surfaces and has been collecting information to determine the best way to keep the roadways in Canada free of ice and snow (Sheriff and Hassan, 2004). This system could be used to monitor airport conditions and help decide the best way methods or chemicals to keep the pavement surfaces safe for aircraft movement.

Heating pavement is a viable way to keep the surface clear of snow and ice (Ashley, 1997). The main question with heated pavement is whether it can stand up to the abuse from multiple aircraft slamming down on it hundreds of times per day. Heating pavement can be cost effective when the costs of plowing and chemical use are figured into the cost of a non-heated surface. Heated surfaces do not require frequent plowing and chemical application and may not require any at all, depending on the environment and conditions.

The research team contacted Dr. Burkhard Sanner, President of the European Geothermal Energy Council (EGEC) and according to information he presented at an EGEC workshop conference on geothermal snow melting in Malmö, Sweden on October 2. 2007, geother thermal snow melting and de-icing is currently being used quite extensively to heat roads, driveways, parking lots, sidewalks, railway platforms and even sport arenas using direct heat in Iceland, where geothermal hot water is abundant.

Currently Iceland has by far the largest area using direct geothermal snow melting systems in the world. In 2002 over 3.7 million sq.ft of surface areas were being heated using up 419 TJ/a of energy. The heat came partly from geothermal water already used for district heating (runoff water) at a temperature of about 35°C (95 F) and partly fresh geothermal water at a temperature of 80°C (175 F) for peak loads. In Reykjavik, the captial city of Iceland, warm water storage tanks are located on a hill above the city and local airport, providing an excellent opportunity to utilze hot water to heat the runways at the Reykjavik airport in the future. According to Dr. Sanner, snow melting and de-icing in other countries, such as the USA, Japan, Netherlands and Switzerland motsly utilise Heat Pumps, either ground source (geothermal with) or Borehole Heat Exchangers. In Steamboat Springs, Colorado, a feasibility study for snow melting on walkways at a ski resort area of roughly 100,000 sq.ft. suggested that the construction would pay for itself in 6-24 months, using 3-5 geothermal wells with a 45-60°C (100-140 F) hot water supply. The same operation would provide payback in 3-4 years using 8-9 downhole heat exchangers in geothermal wells containing 60°C (140 F) or warmer water.

According to a presentation by Göran Hellstöm (2007) at Lund University in Sweden there are currently plans to use a Borehole Thermal Energy Storage system to head the runway at Kallax airport in Lulea, Sweden. Waste heat from a local steel plant is stored by pumping the water down into boreholes that are 65 m (210 ft) deep where it can be stored at an average temperature of 50°C with only approximately 10% heat loss in a volume of one million cubic meters. The waste heat from the steel mill blast furnace is approximately 900 GWh and large surpluses are created during the summer that can be used for district heating during the winter months. Kallax aiport has an 11,000 ft runway with a 1.6 million sq.ft. surface area and other paved surfaces of about 7 million sq.ft. surface area. The airport has a 24 hour service and serves 22 scheduled freight traffic flights per day. The plan is to create a “black runway” that would always be free from ice and snow. Current snow removal mehtods include mechanical removal, sweeping, brushing with steel wire brush, and de-icing with urea. The total annual cost for snow/ice removal at Kallax is approximately $3 million. The energy needed to keep the runway surface at +2°C (35.6 F) would be 400 W/sq.m. and a total load of 40 GWh is expected to preheat, melt the snow and dry the entire paved surface area (including ramps, taxiways). Only 7.5 GWh would be required to heat only the runway. The BTES boreholes would be 250 m (820 ft) deep and would consist of approximately 90 holes at a spacing of about 4.6 meters. The volume of hot water they could store would be 460,000 cubic meters and the charged heat would be 8.6 MWh. The drilling cost to install these boreholes is estimated to be around $800,000. The cost of the charged heat would be aproximately $6/MWh so the annual energy cost would be around $220,000 to heat all the surface areas (7 million sq. ft) whereas heating only the runway would cost $41,000. The pipes in the runway would be embedded at a 5 cm (2 in) depth and the pipe spacing would be 25 cm (10 in). The cost of installing the pipes would be around $23/sq.m so the total cost of embedding the pipes for the runway would be around $3-5 million whereas embedding pipes in the entire airport surface areas would cost between $15-25 million. As the current cost of mechanical snow removal is around $3 million this operation would pay for itself in only 1-2 years, if only the runway is heated, and 5-10 years if the entire surface area would be heated.

The student research team contacted Dr. John Lund, director of the Geo-Heat Center at the Oregon Institute of Technology at Klamath Falls, OR, and asked him a few questions as a leading expert in geothermal heating in the USA. Dr. Lund said that he was not aware of any new strategies to implement geothermal airport runway snow-melting systems in the United States at this time. Implementing such a system in the US would require some interest from the US Department of Energy; however the present administration has been working to “zero out” the geothermal budget in favor of other renewable energy sources, such as ethanol production, solar, wind and nuclear power. Currently there does not appear to be any leadership being provided for the future of geothermal power within the DoE according to Dr. Lund. It is conceivable however that interest in geothermal could be revitalized under a new administration and with some lobbying the Department of Transportation might become increasingly interested in the use of geothermal energy. Asked about the technical implementation of runway heating, Dr. Lund said that pipes can be embedded in the concrete and do not have to be placed under the pavement. All that is required is about 2 inches of concrete to cover the pipes and they should not be damaged by the stresses of landing aircraft. The temperature of the fluid required to heat the surface would depend on the flow rate and temperature difference (delta T) that is taken out of the water. Generally about 125 Btu/hr/sq.ft. is needed. Thus for 1000 sq. ft of pavement using a 20 degree F delta T (say from 125 to 105 degrees F), about 12.5 gallons per minute would be required to provide the 125 Btu/hr/sq.ft. Asked if using Heat Pumps to heat pavement was a viable/economically feasible alternative to direct geothermal heat in areas that lack hot water sources he pointed to the Steamboat Springs ski area in Colorado that has been deemed economically feasible, however where direct geothermal heat is available it is much more economically feasible and environmentally friendly as heat pumps require electricity input to run the compressor. Based on the cost of implementing highway pavement heating, Dr. Lund estimated that the installation cost (just for the piping) would run one to three dollars a square foot, depending upon the local market for labor and materials. Asked about the main advantages/disadvantages of implementing a runway heating project using geothermal resources, Dr. Lund said that the main disadvantage was the high up-front cost associated with the geothermal systems (wells, pipes, heat exchangers, etc.). However the advantages are that the annual operation cost is low and eliminates the need for expensive snow removal and that certainly safety is improved as the snow melts as it falls and ice does not build up on the runway.

Team's Problem Solving Approach to the Design Challenge

To meet the design challenge, the team utilized an engineering design process that included the ten following steps.

1. Identifying a Need. The first step was to brainstorm ideas individually for each of the three areas of the Design Competition. Those three areas were Airport Operations and Maintenance, Runway Safety/Runway Incursions, and Airport Environmental Interactions. After the team came up with a list, the field was narrowed down by voting. After the voting the group agreed to work in the area of Airport Environmental Interactions. The agreed upon topic was improved methods of snow/ice removal on airport runways.
2. Defining the Problem. The group discussed the current situation and why there was a need for an improved system and continued brainstorming towards new solutions.
3. Conducting Research. The group conducted an extensive review of literature found in online articles and scholarly journals.
4. Narrowing the Research. After reviewing literature the group decided to focus its research on geothermal heat as a means to prevent snow/ice buildup on runways. Furthermore the group compiled a list of industry experts that were then contacted and their input was sought to further our understanding of the topic.
5. Analyzing set criteria. The group generated a list of topics to explore further and formulated follow up questions for our industry experts.

6. Finding alternative sources. A list of possible solutions was made and the pros and cons of each solution were discussed.
7. Analyzing possible solutions. Alternative solutions to runway heating were discussed (geothermal vs. electrical) and the pros and cons of each were weighted.
8. Making a decision. After weighting the strengths and weaknesses of different solutions and conducting a SWOT analysis the group decided to go ahead with a proposal for geothermal runway heating
9. Presenting the design. The group presented the design idea to the aviation capstone class utilizing a powerpoint presentation and received constructive input from fellow classmates and the professor.
10. Communicating the design idea. Finally the team organized this written report following the FAA Airport Design Competition for Universities Guidelines for Design Submission and the assistance of Professor Aceves.

Safety Risk Assessment

Although, implementing a geothermal runway heating system does not impose immediate safety issues two important factors need consideration.

The first is the potential area of concern however is the possibility of buildup of surface water on the runway if proper drainage is not ensured. Precaution would have to be made to ensure that runoff melt-water would have easy access to drainage and or reservoir pools and that drainage access points and pipes would not get clogged during heavy snowfall/icy conditions. It should be noted that 1 foot of snow equals approximately 1 inch of water. Most runways are already designed to handle that amount of water which can occur during heavy rain.

The second and a major concern is utilizing geothermal energy as an environmentally clean, alternate method of snow/ice removal will dramatically improve safety to the environment, by reducing the carbon footprint of airports and therefore contributing to the prevention of a catastrophic damage to the environment on a global scale.

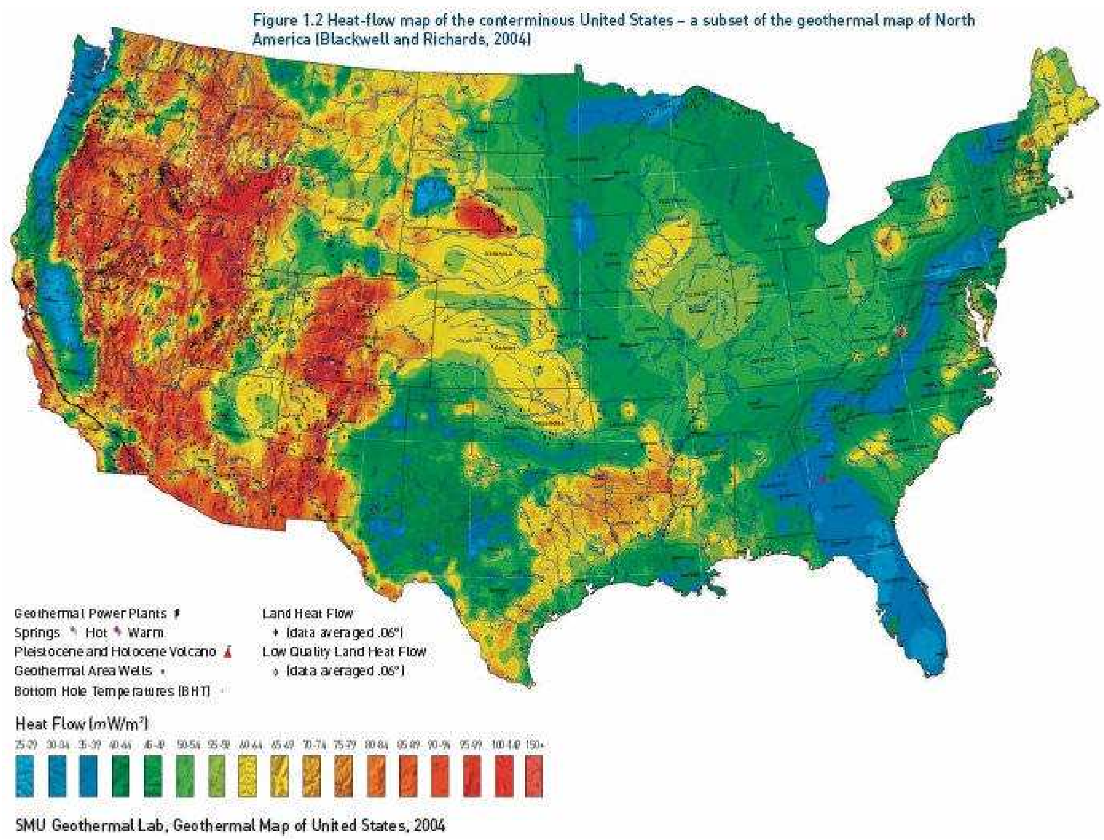
Heated runways should fall under the concept of a Safety Management System (SMS) for airport operators as described in FAA Advisory Circular NO: AC 150/5200-37 which states that the application of a systematic, proactive, and well-defined safety program allows an organization producing a product or service to strike a realistic and efficient balance between safety and production. SMS plans will provide additional safety measures at airports already under existing requirements of 14 CFR Part 139 and the FAA has determined that contract costs incurred for development of an initial SMS at an airport are eligible for AIP (Airport Improvement Program) planning grant funds.

During the installation of a geothermal runway heating system at an operational airport the Airport Safety Manager would consult with a designated Construction Safety Committee and follow the guidance outlined in the FAA Advisory Circular 150/5370-2, *Operational Safety on Airports during Construction*, as per instructions found in the SMS.

Description of Technical Aspects

Figure 1 shows a geothermal loop system used to melt ice and snow from a sidewalk in Klamath Falls, Oregon. A similar system on a larger scale could be used to heat airport runways.

Figure 2 shows areas in the United States (in red) where direct use of geothermal heat is feasible.



Description of Industry Interactions

The team made contact with two industry leaders and experts in the field of geothermal heating, Dr. Burkhard Sanner, President of the European Geothermal Energy Council and Dr. John W. Lund, Director of the Geo-Heat Center at the Oregon Institute of Technology. The team interacted with Dr. Lund and Dr. Sanner via telephone and e-mail communications and received invaluable information and advice, including data and powerpoint presentations from a recent geothermal conference in Sweden attended by Dr. Sanner. Also Dr. Lund and Dr. Sanner provided us with their personal opinions on our project and encouragement for further studies and development of our idea.

Projected Impacts of the Team's Design and Findings

Using various geothermal technologies, the team believes it is feasible to implement the idea of heating runways and other airport surfaces. In conclusion the team believes that the ability to keep snow and ice from building up at airports can become a reality, increasing safety, saving money and benefiting the environment by reducing the need to use snowplows and chemicals to clear runways and other airport surfaces thus meeting the FAA design competition goals of implementing a system that uses alternate energy sources to increase the efficiency in the management and safety of airfields.

Contact Information
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University Description
(Appendix B)

An Overview of St. Cloud State University

Located alongside the Mississippi River in St. Cloud, Minnesota, St. Cloud State University was established in 1869 as a teachers college. Recognized as an official university in 1979, St. Cloud State University has expanded over the years and is currently the second largest university in Minnesota as well as the largest member of the Minnesota State Colleges and Universities system.

Now a four year university, St. Cloud State currently offers the 16,000 students attending over 175 academic programs of study, with colleges of Education, Business, Science, and Engineering as well as Fine Arts and Humanities. St. Cloud State University is also internationally recognized for its exchange program, with more than 1000 students from over 80 nations currently attending. Although currently offering various masters degrees, St. Cloud State University will, along with the University of Minnesota - Mankato, be the first state university to offer a PhD degree.

St. Cloud is a city of 65,000 residents and is located in central Minnesota, 65 miles northwest of the Twin Cities, Minneapolis and St. Paul. St. Cloud Regional Airport is located 4 miles southeast of the city's central business district. Owned and operated by the city of St. Cloud, the airport averages over 200 daily operations and receives commercial air carrier service through Northwest Airlink, operated by Mesaba Airlines.

Non-University Partners
(Appendix C)

This project did not involve any non-university partners.

FAA University Design Competition
Design Proposal Submission Form (Appendix D)

Note: This form should be included as Appendix D in the submitted PDF of the design package. The original with signatures must be sent along with the required print copy of the proposal.

University: St. Cloud State University, St. Cloud MN

List other partnering universities if appropriate: N/A

Proposal Developed by: ■ Student Team

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Competition Design Challenge Addressed:

Geothermal Runway Heating

I certify that I served as the Faculty Advisor for the work presented in this Design Proposal and that the work was done by the student participant(s).

Signed Robt Aceves ______________________ *Date* *15 Mar 2008*

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Appendix E

Project Evaluation (Advisor): Dr. Robert I. Aceves

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As I look forward to the dynamic future of aviation, I see that we, the academy of aviation educators, are preparing aviation students for aviation careers in technologies that don't yet exist…in order to solve problems that we don't even know are problems yet. Albert Einstein wrote, "We can't solve problems using the same kind of thinking we used when we created them", so *Planning Today, for Tomorrows Issues with Tomorrow' Technology* was set at the onset of the semester as the project mission. As my students and their ventures developed, I noticed that ten outcomes emerged and how their projects amalgamated the education strategy at St. Cloud State University. That upon project accomplishment, the following **ten** frameworks of **Competences** and **Challenges** that were *Outstandingly* achieved and *Successful* overcome. 1) *Communication* is the ability to read, write, speak, and listen and to use these processes effectively to acquire, develop, and convey their creative ideas; 2) *Critical thinking* the ability to examine aviation issues of airport operations rationally, logically, and coherently; 3) *Environmental, Cultural and Diversity* an understanding of the societal context or environment and where the aviation industry is now existing and working; 4) *Professional identity* a concern for improving the knowledge, skills, and values of the aviation profession; 5) *Professional ethics* an understanding of the ethics of the aviation profession as standards that guide professional behavior; 6) *Adaptive* anticipating, adapting to, and promoting changes important to a the airport operation profession's societal purpose and the professional's role; 7) *Leadership capacity* exhibiting the capacity to contribute as a productive member of the airport operation profession and assuming appropriate leadership roles as a research in the aviation industry; 8) *Scholarly concern for improvement* recognizing the need to increase knowledge and to advance the aviation industry and profession through both theoretical and applied research; 9) *Motivation of continued learning* exploring and expanding personal, civic, and professional knowledge and skills through a lifetime; and 10) *Globalization and technology* an understanding of the forces driving globalization and technology in aviation.

Recommendations: The Competition is the basis for a Senior Capstone and a graduate course due to the excellent real world experience involvement, so please maintain the completion in upcoming years.

Student Evaluation:

Travis Athmann
Robert Bjornsson
Paul Borrell
Patrick Thewlis

This project involved many new educational experiences for the student team. Throughout the course of this design competition the team received personal experiences in ten competencies that the College of Science and Engineering at Saint Cloud State University and Professor Aceves set up for the team to experience. . Firstly the team members exercised and improved their *communications* skills by effectively developing and conveying their creative ideas, both internally and to leading industry experts. Additionally the team members exercised *critical thinking* and reasoning while examining the issues of airport operations as well as put into context the *Environmental, Cultural and Diversity* factors that exist within the aviation industry. The group examined the *Professional Identity and Ethics* of the aviation industry to understand the values and professional behavior of the aviation profession and *Adaptation* towards promoting changes important to the aviation industry and society as a whole. The group received an opportunity to expand *Leadership* skills by approaching the project from a professional standpoint and by recognizing the need to increase knowledge and to advance the aviation industry and profession through both theoretical and applied research the group gained increased *scholarly concern for improvement* and *motivation for continued learning* as a lifelong quest to expand personal, civic and professional knowledge and skills. Finally, one of the most important issues the team explored and received a better understanding of was the ever increasing impact of *globalization and technology* on the aviation industry.

Without this project the student team would not have been able to make contact with and learn from two of the Geothermal Industry's leading experts in the field of Geothermal Heating. Those individuals being, a Dr. Burkhard Sanner, President of the European Geothermal Energy Council and a Dr. John W. Lund, Director of the Geo-Heat Center.

Participating in the FAA Airport Design Competition provided a meaningful learning experience for the group as it involved making contacts outside of the university setting and combining interdisciplinary fields. Participating in the competition also gave the group a better insight into the FAA safety regulations and standards.

The student team believes that participating in this competition has helped build a knowledge base in the fields of aviation and airport safety, environmental issues and engineering which should prove beneficial for further studies or entry into the workforce.

For these reasons we strongly recommend the FAA Airport Design Competition be continued. This competition allows student competitors the ability to start using their education and ideas to assist the industry they are studying in the classroom.

References
(Appendix F)

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