Improving Safety by Integrating Changeable LED Message Signage to the Airfield

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April, 2014

2013-2014 FAA Design Competition for Universities,

Runway Safety/Runway Incursions/Runway Excursion Challenge

COVER PAGE

Title of Design: __Improving Safety by Integrating Changeable LED Message Signage to the Airfield

Design Challenge addressed: __Runway Safety / Runway Incursions / Excursions Challenge_____

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Executive Summary

This report addresses the FAA Design Competition for Universities' Runway Safety/Runway Incursions/Runway Excursion Challenge for the 2013-2014 academic year. The specific problem considered was how current signage could improve crew positional and situational awareness on the airfield. The solution proposed is to introduce changeable LED message signage to the airfield.

The runway environment at major commercial airports is often a confusing and unfamiliar place for pilots. Under clear conditions, the plethora of signs located in various spots is easy to see, as are significant hazards such as closed runways and taxiways. However, an airfield under low visibility conditions can easily become a disorienting place where errors can occur. Under these conditions it is also difficult for the air traffic control tower to have a visual identification of where an aircraft is on the airfield. While pilots are trained to interpret airport charts, listen and repeat movement instructions by ATC, and understand all of the signage on the airfield, catastrophic accidents due to misinterpretation have occurred.

A team of students, both undergraduate and graduate, from The Ohio State University reviewed multiple NTSB accident reports, interviewed past accident investigators, and surveyed the airside environment for various local airports and concluded that there is a significant need in revisiting the way regulations and advisories view the current signage model for the runway environment. The research completed supported the theory that the introduction of LED signage with immediate customization abilities for urgent notifications would provide a feasible and innovative method to increase safety. The customization ability will provide ATC and airport management more opportunities to increase pilot situational awareness, decrease the risk factors associated with airport construction, and decrease the risk of a fatal error.

While the emphasis of this design solution will increase safety and reduce errors, other positive benefits include reduced energy consumption and reduced maintenance costs. Examples of current changeable signage in other transportation modes provide significant data to show the need for various methods of alerting operators of dangerous situations such as upcoming construction or closure. The use of these systems would benefit aviation as well.

Figure 1 Current Photograph of Airfield Signage, Rickenbacker International Airport, 2014

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Problem Statement:

The following report discusses how airports currently use airfield signage and how on-demand, customizable, and changeable message LED signage would make the airfield safer and easier to navigate. This improved signage can increase safety and situational awareness of all individuals operating on the airfield. While researching concerns with signage, the Comair 5191 accident from August 2006 was introduced as an example of the dangers of airfield construction and the inadequate methods used to designate temporary changes. The intention will be to determine whether or not an accident can be prevented by the use of changeable airfield signage, which would have the ability to immediately display warnings and messages from ATC or airport operators.

The report also looks into the possibility of changeable LED signage as a way to display temporary or unpublished modifications to the airfield, such as closed runways and taxiways. The efficiency of signage lit with LED lights, was also researched and compared to current airfield signage to determine how changeable signage could reduce energy consumption and costs for the airport.

Background:

On December 17, 1903, when the Wright brothers took their inaugural flight, they took off against the wind, whichever way it blew (Wilford, 2003). For many years, this method of 360-degree take-off and landing in grass airfields allowed aircraft to utilize any direction as according to the wind. As aircraft became larger and heavier and take-off and landing in all-weather situations became more essential, smoother, paved asphalt or concrete runways were created to handle larger aircraft. Runways were thus permanently aligned to fit with the best wind direction and as a result, to provide for different wind directions, an airport may need a second runway aligned in a different direction. Often, these runways will cross each other and also taxiways to allow aircraft access to parking areas and the runways for takeoff and landing. In some instances, additional runways are added and at some large airports there are several terminals, taxiways, and parallel runways with hundreds of aircraft arriving and departing each day at busier airports. This increase of runways and taxiways on the airfield has grown to become a complex system and therefore airport signage is needed to assist in directing airport traffic.

With the increasing number of taxiways and runways, it is important to know how to identify each taxiway and runway, as well as any pertinent information regarding these areas, by utilizing signage. Airport signage can become cluttered with information which may reduce the ability to interpret signage and also to change information when necessary. For this project, the decision was made to begin with the examination of existing problems with airport signage. Light Emitting Diode (LED) signage is one possible way to reduce cost and increase safety at airports. Consideration will be made of the feasibility of an LED signage plan which examines design, safety, energy savings, implementation, maintenance of new LED signs and the other benefits associated with LEDs.

Existing Airport Signage:

Airfields across the U.S. use a number of signage systems to convey different types of information to aircraft and vehicles on the airfield. The standards for airport signage are regulated and mandated by the FAA and their advisory circular-AC 150/5340-18F, entitled "Standards For Airport Sign Systems". This advisory circular conveys information on the types of signage, size and location of signage, and installation standards that are allowed and must be followed for the best practices and safety at the airport.

Types of Signs and Purpose:

Mandatory Instruction Signs:

These signs are identified with white lettering and a black outline on a red background (see figure 1). These signs consist of letters, numbers, or symbols that help denote taxiway/runway intersections being approached. All vehicles (either an aircraft or ground vehicle) must stop at these signs and receive permission from the airport control tower for permission to continue across the runway or taxiway (Federal Aviation Administration , 2010).

Figure 2- Mandatory Signs

Location Signs:

These signs are identified with yellow letters or numbers on a black background and identify the taxiway or runway upon which the aircraft is located (see figure 2) (Federal Aviation Administration , 2010).

Figure 3- Location Signs

Boundary Signs:

These signs are identified with black symbols that depict the holding position marking on a yellow background and identify the boundaries for the Runway Safety Area, Object Free Zones and other critical areas for pilots and ground vehicles to be aware of (see figure 3) (Federal Aviation Administration , 2010).

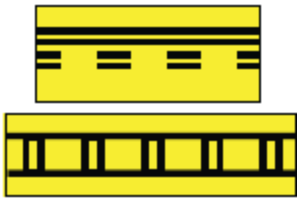


Figure 4-Boundary Signs

Direction Signs:

The signs are identified with black lettering and arrows on a yellow background which depict the directions of taxiways exiting runways or leading out of an intersection of new taxiways (see figure 4) (Federal Aviation Administration , 2010).

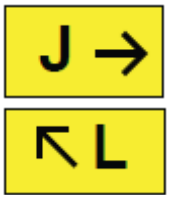


Figure 5-Direction Signs

Destination Signs:

Similar to direction signs, these signs also have black lettering and arrows on a yellow background and depict the general direction to a remote location (far off runway perhaps). These signs come in handy when direction signs alone do not sufficiently guide a pilot to the desired destination (see figure 5) (Federal Aviation Administration , 2010).

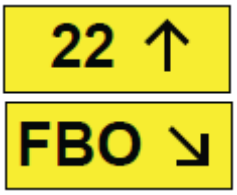


Figure 6-Destination Signs

Information Signs:

Lastly, these signs utilize the direction and destination style of black lettering and a yellow background and are used to convey technical or other specialized information for pilots and airport staff (see figure 6) (Federal Aviation Administration , 2010).

Figure 7

Informational Signs

Sign Materials:

Materials for signs, such as in figure 7, are generally made from high-grade plastic such as acrylic, which provide a similar appearance either in the daytime or at night when illuminated and durability to withstand harsh weather elements (Airfield Guidencesign Manufactuers Inc., 2014). The illumination of the signs comes in either Incandescent, Halogen, or LED lighting. Airport signage manufactures are focusing more on LED signage options because they provide better visibility, power savings, and longer operational life span.

Figure 8 Mandatory Sign and Location Sign at The Ohio State University Airport

Documentation of LED Airfield Signage in use:

Recently, the Federal Aviation Administration (FAA) approved the usage of LED signs for use on airport taxiways. The new signs were welcomed because of their forecasted cost savings, longevity and versatility from message to message without ever leaving the control center. It took nearly two years for construction to be completed, but the Greater Binghamton Airport in New York State was one the first airports to put this new system to use in 2009.

The Greater Binghamton Airport is located near the New York/Pennsylvania border in southern New York, approximately a three-hour drive from New York City. This part of the country is susceptible to heavy snowfall for prolonged periods of time, so this was a big concern for the airport when installing these high efficiency and costly new signs. The airport would have to take into consideration the fact that during snow plowing the signs could possibly be damaged. However, Binghamton took the chance and is pleased with their choice to install the new changeable LED taxiway signs.

The project involved outfitting the existing 7,000 foot parallel taxiway with these new signs. The project also totaled roughly 280 existing lights converted to LED, 40 new lights installed and about 52 new LED signs. LED's do not pose a cheap initial cost, but rather their benefit is in the longevity and lower energy use, thus lower stress on the electricity grid. For this project, the initial installation costs for the lights and signs totaled roughly $1.4 million dollars over the two-year construction duration.

The lights were a costly upgrade, but they would prove to benefit the Greater Binghamton Airport both in the short and long term. Just before the time of the upgrade, Binghamton was being forced to relocate over 20 signs from the taxiway to the runway circuit in order to comply with recently changed FAA standards. If Binghamton would have chosen to use traditional incandescent light fixtures, which was the current status of all the lights and signs of the airfield, the addition of new signs to the runway would have flooded the grid and overloaded the capacity of their electric regulator. Purchasing a new, larger regulator was not desirable because the regulator had just recently been upgraded. This brought forth the idea of using LED signs because their energy consumption rate is so low. A lower energy consumption rate would allow the airport to continue using the existing regulator, and, as a bonus, installing the new LED lighting was approximately $40,000 cheaper than purchasing a new regulator. This proved to be a convenient way for the airport to benefit immediately from the new regulation from the FAA.

As for the long-term benefit, it has been shown that LED bulbs could last nearly 50,000 service hours as compared to traditional incandescent bulbs, which typically last around 1,000 service hours. With the added life span of these new bulbs comes additional savings – longer life of bulbs means less bulbs to replace, therefore significantly lowering costs. However, if and when these

LED bulbs do burn out, or are damaged and need replacing, they are somewhat costly to exchange. This was a big consideration at the Greater Binghamton Airport because of the heavy snow conditions they receive. With regular plowing around the airfield, it is not uncommon to damage signs when snow banks build up around them. Also, the lights use less energy, so naturally they do not heat up quite as much as traditional bulbs. The airport management would have to consider taking the chance that the bulbs do not melt snow as effectively as traditional bulbs. However, the energy savings would be too great for the airport to pass upon. By converting their lights to LED, they could save almost 5 kilowatts per hour. For reference, a typical home would use about 1.4 kilowatts of energy per hour. This was likely the driving factor when considering the changeover to LED's. As another bonus to their case, the lights do in-fact produce enough heat to effectively melt the snow build up upon them – a major positive aspect for an airport in New York.

As a whole, the LED's provide a sufficient replacement to regular incandescent bulbs. The airport is satisfied with the result of their construction project and will even consider implementing the system in coming years with new projects. As discussed above, the new lights certainly present a substantial initial cost that seems very high. But by fronting the cost initially the bulbs can provide great savings in the future because of their efficiency. They also provide superior duration per bulb, which lowers the cost and time spent on frequently replacing bulbs. The major draw-back would most certainly be the cost to replace each bulb should damage occur, but that cost is quite small compared to projected savings and convenience.

LED Cost Analysis:

Life Cycle Comparison AGM LED vs Incandescent				
Size 3, Style 2, 4 Module Sign	AGM LED	T10 45W lamp	Annual Savings	10 years
VA	180	840		
Annual $kw/h	$98.55	$459.90	$361.35	$3,613.50
Lamp Life* (hrs)	100,000	1,000		
Lamps/year @ $6	$0	$312.00	$312.00	$3,120.00
Lamp Changes/year	$0	$2,600.00	$2,600.00	$26,000.00
			Total Savings per Sign	**$32,733.50**

Figure 9 (Based on US Average Transportation $kw/h per US Department of Energy, taken August 2008)
(Lamp changing = $50/labor/vehicle [*Calculated per FAA Order 5100.38c.910.a.2.b])

Table 1 T-10 45Watt Incandescent VA Loads

AGM D-Lux T-10 & Tapswitch (w/incandescent)					
	Style	Sign No. Of Modules	L830 Transformer	Power Factor	Volt Amp - VA Load (INC)
	1	1	100	1	60
	1	2	100	1	87
	1	3	100	1	112
	1	4	200	1	148
	2	1	100	1	87
	2	2	200	1	148
	2	3	300	1	195
	2	4	300	1	243
	3	1	100	1	112
	3	2	300	1	195
	3	3	300	1	275
Size 1	3	4	500	1	370
	1	1	100	1	65
	1	2	200	1	95
	1	3	300	1	117
	1	4	300	1	152
	2	1	200	1	95
	2	2	300	1	152
	2	3	500	1	210
	2	4	600	1	249
	3	1	300	1	117
	3	2	500	1	210
	3	3	600	1	280
Size 2	3	4	800	1	370
	1	1	45	1	35
	1	2	100	1	65
	1	3	200	1	95
	1	4	200	1	122
	2	1	100	1	65
	2	2	200	1	122
	2	3	300	1	166
	2	4	300	1	219
	3	1	200	1	95
	3	2	300	1	166
	3	3	500	1	249
Size 3	3	4	500	1	328

Table 2 LED VA Loads from AGM

AGM D-Lux LED VA Loads					
	Style	Sign No. Of Modules	L830 Transformer	Power Factor	Volt Amp - VA Load (LED)
	1	1	45	1	30
	1	2	65	1	60
	1	3	65	1	70
	1	4	100	1	80
	2	1	65	1	60
	2	2	100	1	70
	2	3	100	1	100
	2	4	200	1	120
	3	1	65	1	60
	3	2	100	1	70
	3	3	100	1	100
Size 1	3	4	65	1	120
	1	1	45	1	30
	1	2	65	1	60
	1	3	100	1	70
	1	4	100	1	80
	2	1	65	1	60
	2	2	100	1	70
	2	3	200	1	100
	2	4	200	1	120
	3	1	65	1	60
	3	2	100	1	70
	3	3	200	1	100
Size 2	3	4	200	1	120
	1	1	45	1	30
	1	2	65	1	60
	1	3	65	1	70
	1	4	100	1	80
	2	1	65	1	60
	2	2	100	1	70
	2	3	100	1	100
	2	4	200	1	120
	3	1	65	1	60
	3	2	100	1	70
	3	3	100	1	100
Size 3	3	4	200	1	120

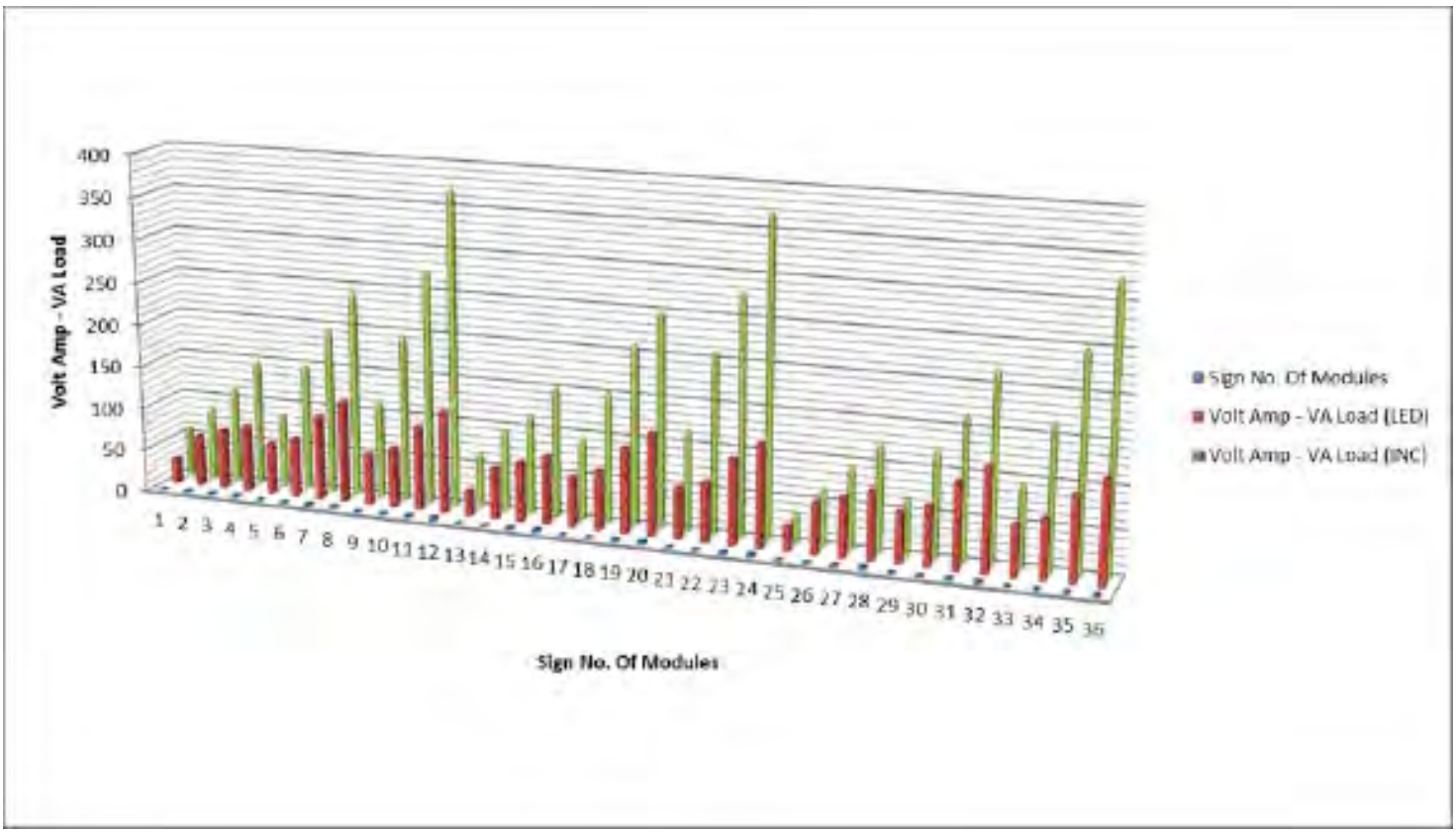


Figure 10- Source: http://www.agmsigns.com/technical.html

According to information provided by AGM, LED lights are easy to acquire, easy to read, reduce maintenance trips, reduce bloom and ground splash. Moreover, LEDs compared to traditional incandescent lights utilize 80% less power based on the fact that each sign using traditional bulbs contains up to 12 lamps and each are rated at 1,000 hours of use which equates to about 50 lamp replacements annually. (Airfield Guidance Sign Manufacturers, Inc., 2014)

Evidence can be seen in the charts and graphs above (figure 8) – the Life Cycle Comparison chart created by AGM and their Volt/Amp Loads data. The most important numbers are colored in gray, particularly the VA loads between LED and incandescent Red bars show the power usage of LED and the green bars show the usage of incandescent. It can clearly be seen that incandescent bulbs consume about twice as much as LED since LEDs only use one tenth of the amps of

incandescent bulbs. As for cost, the graph is evidence that switching to LED completely has the potential to save any airport a lot of money. This is demonstrated in the top chart, which was calculated by AGM using the data of the cost of kilowatt hour per year collected from the U.S. Average Transportation and the U.S. Department of Energy. The calculation was done "Per FAA Order 5100.38c.910.a.2.b" (AGM) with the assumption that it costs at an estimated $50 for labor (electricians cost – Table 1 below) and the use of vehicles for maintenance. According to AGM, LED bulbs cost significantly less per year based on the kilowatt hour data. This is based on AGM's largest sign (size 3), using 4 modules which equate to more bulbs. It costs about $100 for LED, compared to $500 for incandescent annually, per sign. AGM's LEDs are rated at 100,000 hours of lamp life which is approximately 11 years of usage without replacement. With no LED lamps to replace and a lower kilowatt hour of consumption, AGM calculated a total saving of about $33,000 per year, per sign. For example, according to the Columbus Regional Airport Authority, the new south runway (from 10R/28L) from Port Columbus International Airport (CMH) contains about 200 airfield signs. That is equaled to about a $7 million savings in signs. In addition, CMH had recently replaced about 350 of their metal halide fixtures (at 100W) with LED lamps using a brand named Cree**,** and saw a reduction in energy use at a 60% rate. As a result, CMH "expects to save over $80,000 in the first year alone." (Cree Lightning) Moreover, CMH plans to have LED installed all around the airport terminal in areas such as baggage claim, arrivals, drop-offs, etc.

Table 3 (Depicted in Graphic as Table 1) Estimates taken from the U.S. Department of Labor: Bureau Statistics and Occupational Employment and Wages: GPO.

Table 1: National Estimates: Wage Estimates for Electricians					
Mean Hourly Wage	**Mean Annual Wage**				
$22.41	$46,620				
Percentile	**10%**	**25%**	**50% (Median)**	**75%**	**90%**
Hourly Wage	$12.76	$16.07	$20.97	$27.71	$34.95
Annual Wage	$26,530	$33,420	$43,610	$57,650	$72,700

The purpose of the chart is to pinpoint the cost for the electricians alone, which is a maintenance cost. In this case, an airport can possibly save from $27,000 to $72,000 on each electrician per year and that has not yet taken into account the fact that LED lamps rarely need replacing and with about 11 years of life for each sign, that is a huge amount to be saved by the airport. Overall, an electrician could spend less time on the taxiways and allow themselves to focus on other electrical issues at hand, hence improving the productivity of the operation.

Human Factors and Situational Awareness:

The FAA defines situational awareness in Advisory Circular 120-72 as "Maintaining a complete mental picture of surrounding objects and events as well as the ability to interpret those events for future use. Situational awareness encompasses such concepts as attention, and vigilance" (AC 120-72). The mind perceives the world around us through sight, sound, touch and by drawing on past experiences and memories. Individuals are able to assess the environment around them and what may potentially happen in the future. Pilots and air traffic controllers are consistently drawing on their past experience and training in order to gain a better understanding of what is happening. When there is a breakdown in perception, a pilot does not necessarily have the ability to accurately model the world around them and may make poor decisions which lead to close calls or accidents. Some of the factors that go into these breakdowns include tunnel vision, passive behavior, high workload, distractions or interruptions. The Australian Transportation Authority found a correlation that 70 percent of aircraft accidents where caused by human error while 85 percent of incidents reported, revealed at least some lack of situational awareness. (Flight Operations Briefing Notes) There have been many studies conducted concerning situational awareness. Many of these studies have been focused on the ability and perceptions of individuals with high workloads such as in the maritime industry, transportation, and oil gas industry to name a few. (Stress, fatigue, situational awareness and safety in offshore drilling crews) The FAA has also sighted situational awareness as not only an individual problem, but a

problem that can arise within a team setting. (AC 120-72) The NextGEN technologies have been and will continue to be implemented to better improve situational awareness in relation to aircraft usage. (NextGEN) Although these new technologies help pilots become more attentive to what's going on while in flight and on the ground, other areas such as proper lighting through the usage of incandescent and LED lighting could further enhance pilots ability to visualize any potential hazards they may encounter while operating on the airfield. An area outside of the realm of air travel where these methods are utilized and studied readily are on roadway constructions signs that catch the attention of motorists who may not be paying close attention to their surroundings.

Regardless of profession, all individuals experience difficult and stressful situations typically brought on by complacency and fatigue. (AC-120-72) In a study published in 2013 in Safety Science *Stress, fatigue, situation awareness and safety in offshore drilling crews. "*The effect of stress and fatigue as it relates to situational awareness was observed in reported offshore drilling accidents. The research indicated that as the level of stress and/or fatigue goes up so does the loss of situational awareness of an individual. Stress has a very different effect but similar outcome than fatigue on one's ability to stay aware and comprehend their situations and surroundings in an appropriate manner. In a stressful situation one may experience sensory overload inducing them to tunnel vision, making it harder for them to comprehend complications that may be more urgent within their peripherals. Sleep deprivation or fatigue can induce tunnel vision as well as, increased reaction times, lower vigilance and a decrease in cognitive processes. These types of symptoms brought on by a lack of sleep can be likened to the effects observed by individuals whom have a raised blood alcohol content." (Science direct) Although a lack of sleep can cause fatigue, other causes can include "time on duty" or "time since awake". Another common cause for a lack of situational awareness is that two few things are happening at a given

time. This can cause an individual to become bored with what is actually happening around them and subsequently be less vigilant with regard to their immediate and future surroundings. Tasks between the time of entering and exiting the aircraft may become too routine for pilots and sense of comfort may sink in to the point where pilots may not be as aware of situations requiring their immediate attention. (AC 120-72 section 9-h-e) An example of this could be a taxiway that has been recently closed for construction. If a pilot is too familiar with the typical procedures at this airport it could cause them to go through the actions they typically adhere to without thinking and not adjust to impending dangers accordingly.

In Advisory circular 120-72 Team situational awareness is defined as maintaining a collective awareness across the entire team of important job-related conditions. It is important that a collective group is able to stay focused on the objectives at hand and adjust accordingly to new both minute and severe situations that arise. If the five elements and activities laid out in advisory 120-72 are followed correctly, proper team awareness can be maintained effectively. They are as follows shared mental models, verbalization of decisions, better team meetings, teamwork and feedback and individual situational awareness training. By constantly trying to share similar mental models of the projected outcome and obstacles pilots and crew members can better comprehend the world around them and adjust immediate and future goals accordingly. This goes hand and hand with good communication and the ability to convey to other members any future obstacles. Running team meetings allows everyone to get on the same page and bring up any known obstacles ahead of time to make sure all are aware of the plan to overcome these obstacles. Constantly working on teamwork skills and giving feedback lets other members of the team better understand how those around them create mental models and gives each of them an idea of how to more effectively reach as a single more effective unit. Finally, working on individual situation awareness promotes taking initiative to not rely completely on

other members of the group to notice possible problems. This will in turn give the group a better chance of not missing critical information and analyzing it before it is too late. (AC 120-72)

Many NextGEN technologies are being implemented and further developed that will better enhance the ability for air traffic controllers and pilots to have a better situational awareness of obstacles and potential threats such as other aircraft movement in the air, and on the ground. An example of this would be ASDE-X recently introduced to Atlanta Hartsfield Jackson International Airport. This technology gives the air traffic controllers a view of where each aircraft is within the airport. This technology allows the tower to not only make more efficient decisions with regard to guiding aircraft, but also allows them to offer safer directions for each aircraft (A Better View). Although these technologies if managed properly are safer for air traffic on the ground there may be a time where a breakdown of individual and team situational awareness occurs. For example, what happens if an air traffic controller accidently sends an aircraft down a taxiway closed for construction? This type of situation could potentially have detrimental consequences if the pilots are not vigilant. This gives rise to the importance of having other safeguards such as incandescent or LED lighting with the ability to catch the attention of pilots. Anyone who drives on the highway regularly has passed by a construction site, construction vehicle or maybe even a snowplow. A lack of situational awareness, or highway hypnosis, as it is sometimes referred to, can be a major problem on the roads especially when approaching a construction site. The safety of construction workers and motorists are constantly being reevaluated for roadway construction and held to the highest regard. By following, among other things, proper work zone lighting regulations, the capacity to better ensure the safety can be well met. Some popular traffic lighting configurations with regard to construction include changeable message signs, flashing vehicle lights, steady burning lights, flood lights and warning lights. Warning lights are blinking lights mounted to channelizing devices such as barriers that alert motorists of gradual or abrupt changes in flow

patterns (WSDOT). This alerts motorists who may otherwise not be paying close attention that they are entering a new and potentially dangerous environment. Another example is flashing lights on top of a street sign that alert motorists of any construction down the road. While driving a car is much different than navigating an aircraft at night on an airfield, if some of these techniques are incorporated correctly, mishaps caused by human error can be reduced.

Situational awareness is a very important facet of air navigation that needs to be considered with the utmost respect. By understanding individual situational awareness and team situational awareness, there is a greater chance that accidents can be avoided. Many safeguards such as NextGEN technologies and proper runway and taxiways lighting can help drastically reduce the likelihood of an accident. Ultimately, working to maintain situational awareness both as individuals, as groups, and with both high and low technology accidents caused by the low situational awareness can be reduced.

Safety Risk Assessment

One of the largest priorities of the changeable message signage proposal is the increase of safety on the airfield. Evaluation methods provided by the FAA, including SMS (Safety Management Systems,) allow for ways to emphasize safety management as a business fundamental and a way to promote a safety culture.

Figure 11 The Four SMS Components for Safety

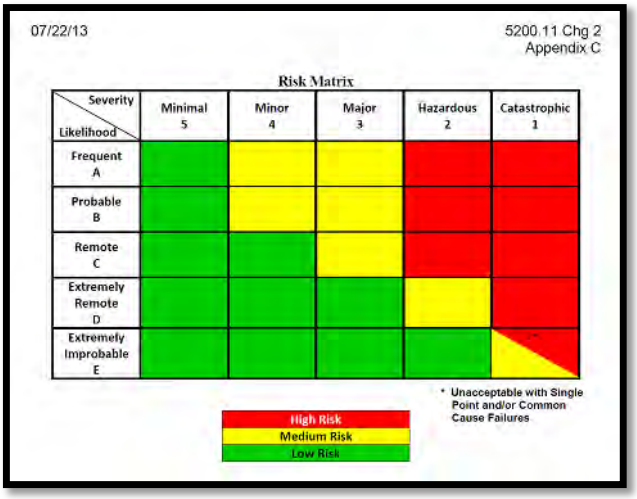
Safety Management Systems is broken up into four main components, each playing a vital role to an over all safety oriented atmosphere. Safety Policy will help management define the structure needed to be in place to meet safety goals. Safety Assurance evaluates the effectiveness of these goals. Safety Risk Management evaluates the risk controls in place based on the assessment. Finally, Safety Promotion is the method management uses to educate their staff and promote the safety culture. (FAA, 2004)

Using SMS as a guide for risk management in regards to airfield signage and the need for improved methods, these four pillars can be applied to provide greater safety protocols.

Table 4 Four Pillars of SMS (FAA, 2004)

Safety Policy	Safety Assurance	Safety Risk Management	Safety Promotion
•Management Evaluates Methods for signage updates •Provides policies for clear useage of changeable message systems	•Monitor effectiveness of signage locations •Reviews and assesses system's performance	•Evaluates major areas of conern, "hot spots," on the airfield for emphasis •Defines levels of risk for these hot spots and designs solutions	•Provides training for staff on the usage of changeable LED signage •Provied communication and training for pilots unfamiliar with the systems •Communicates with industry, other airports, and the FAA on safety updates, concerns, and effectiveness

No changes to the airfield are without possible risks. The introduction of new signage is no exception. To evaluate these risks, possible concerns are documented and levels of risk can be applied to each. The FAA SMS Risk Matrix provides a consistent level of risk assignment throughout the industry. By being consistent with other airports, risk concerns can be addressed on a national and global scale instead of on an individual airport basis.



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igure 12 FAA Risk Matrix for SMS

By using this matrix, levels of risk, whether high, medium, or low, can be assigned to various concerns with the new signage design. Possible risk factors include a learning curve for staff, a learning curve for pilots, the possibility of terminology and design different from airfield to airfield, over reliance on warnings, intentional misuse/hacking, and mechanical failure. By applying the values in the matrix, these risk factors have been determined to be the following risk levels, provided in the figure below.

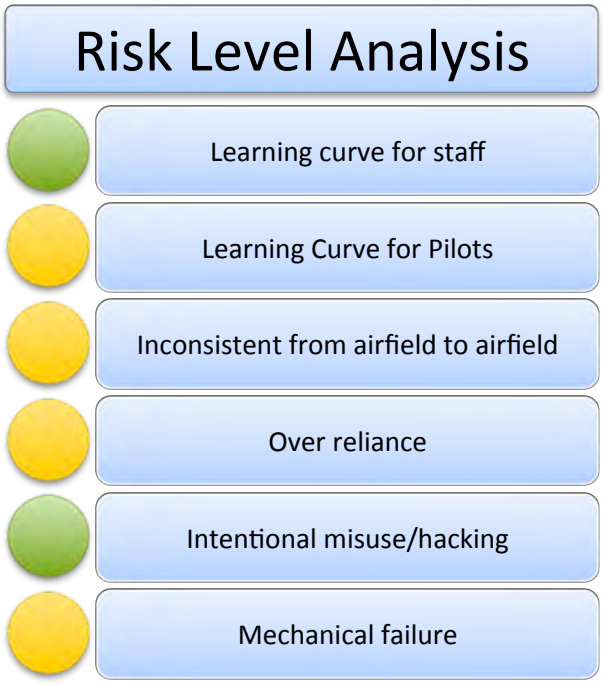

Figure 13 Levels of Risk assigned to concerns in accordance with the FAA SMS Risk Matrix

Despite the list of possible risks that have been identified, there are many more safety and risk concerns with the current structure of signage. An industry expert provided details as to the safety and risk concerns of the current signage structure as well as examples of where the current system has failed.

INDUSTRY EXPERT – SAFETY ANALYSIS

Changeable LED signage would help to enhance the safety of the airfield for pilots, aircraft crews and ground crews. The signage would enhance situational awareness of the flight crew and allow them to have a better understanding of where they are located on the airfield, especially during construction situations. In an interview with Shawn Pruchnicki, former Comair pilot and Air Line Pilots Association (ALPA) investigator, said that the current signage "I think for the most part it's fairly decent, but there is absolutely room for improvement." (Personal communication, April 7, 2014) From Pruchnicki's view, "I'm not really convinced that we need to discard those in favor of a newer design, but rather I think that there are some potentially different things that we can use to help increase positional awareness on the airfield." (Personal communication, April 7, 2014); and changeable LED signage could be one of the improvements that Pruchnicki mentions.

Figure 14 From the ALPA report, shows an example of what changeable LED signage could look like on the airfield.

Improved signage would allow for the correct marking of closed runways, which would improve safety as was seen in the Comair 5191 accident. The following is the Executive Summary from the National Transportation Safety Board's (NTSB) Aviation Accident Report NTSB/AAR-07/05, PB2007-910406:

> *On August 27, 2006, about 0606:35 eastern daylight time, Comair flight 5191, a Bombardier CL-600-2B19, N431CA, crashed during takeoff from Blue Grass Airport, Lexington, Kentucky. The flight crew was instructed to take off from runway 22 but instead lined up the airplane on runway 26 and began the takeoff roll. The airplane ran off the end of the runway and impacted the airport perimeter fence, trees, and terrain. The captain, flight attendant, and 47 passengers were killed, and the first officer received serious injuries. The airplane was destroyed by impact forces and postcrash fire. The flight was operating under the provisions of 14 Code of Federal Regulations Part 121 and was en route to Hartsfield-Jackson Atlanta International Airport, Atlanta, Georgia. Night visual meteorological conditions prevailed at the time of the accident.*

The National Transportation Safety Board determines that the probable cause of this accident was the flight crewmembers' failure to use available cues and aids to identify the airplane's location on the airport surface during taxi and their failure to cross-check and verify that the airplane was on the correct runway before takeoff. Contributing to the accident were the flight crew's nonpertinent conversation during taxi, which resulted in a loss of positional awareness, and the Federal Aviation Administration's (FAA) failure to require that all runway crossings be authorized only by specific air traffic control (ATC) clearances.

The safety issues discussed in this report focus on the need for (1) improved flight deck procedures, (2) the implementation of cockpit moving map displays or cockpit runway alerting systems, (3) improved airport surface marking standards, and (4) ATC policy changes in the areas of taxi and takeoff clearances and task prioritization. Safety recommendations concerning these issues are addressed to the

FAA. (National Transportation Safety Board, 2007)

Figure 15 Figure from the NTSB accident report shows the layout of Bluegrass Airport on August 27, 2006

Comair 5191 shows how disastrous confusing airfield layouts and the loss of situational awareness can be for a flight crew. Airfields can be confusing at times to pilots, and sometimes the current signage does not help. Pruchnicki described times when he found airfields to be confusing, " … due to close proximity of multiple runways and multiple taxiways that spider out from a central point, looking at the signage that shows, not only what's straight ahead and left and right ninety degrees, but we start to get into the 45 degree angles and the multiple degree angles. I have found those to be confusing, yes." (Personal communication, April 7, 2014) This was exactly the case for Comair 5191, the taxiway intersection with Runway 26 and Runway 22, which has since been changed, was confusing with a large angle turn for Runway 26 and a smaller

angle turn for Runway 22. Anything that could be used to help the flight crew follow directions by Air Traffic Control (ATC), in poor visibility conditions, would improve the safety of the airfield dramatically. When speaking about changeable LED signage, Pruchnicki states, "Yeah, if you look at several years ago when we did do a study and was looking at [runway incursions], we saw that many of those events, [changeable LED signage] probably could have made it a lot less confusing and a lot easier for air crews to know where they were." (Personal communication, April 7, 2014)

After this accident, ALPA made recommendations to the NTSB in its own report covering the investigation of the accident. Pruchnicki mentioned these in the interview: "That was one of the recommendations that we made to the NTSB that was not acted upon, was that this type of signage should be required. That these flexibilities that we don't have to use these specific codes, right? Not just a P with an arrow, or some red sign, or something, we can just say what the problem is … but certainly you can do better than what we have now, and I firmly believe I still stand behind that recommendation that that should be mandated." (Personal communication, April 7, 2014) Changeable LED signage is not a new concept, as seen by ALPA's recommendation:

> *Expedite development and mandate implementation of variable-message-board technology for use as temporary airport signage to communicate construction details. (Air Line Pilots Association, 2007)*

While changeable LED signage would be extremely useful for construction operations on the airfield, its uses can be expanded for everyday use on the airfield. It would provide an important improvement to safety on the airfield by increasing positional awareness for the flight crew, and by better informing pilots of the dynamic conditions of the airfield.

When asked if changeable LED signage could have provided the pilots with additional aid, Pruchnicki responded with much conviction, "Absolutely." (Personal communication, April 7, 2014) When asked specifically about the intersection of Runways 22 and 26, Pruchnicki said, "Absolutely. All you would have to do is on the other side of 26 just put a sign: 'Warning. Confusing Area.' 'This is Runway 26,' or something to that effect. Or '22 200 meters to the left,' or something like that. Something along those lines, and just clarify to increase that awareness: are you really where you think you are, because that might not be the case." (Personal communication, April 7, 2014) This is just an example of one message that could be displayed on a changeable LED sign. These signs could be used to provide messages to alleviate confusion at confusing intersections, such as the one in Lexington, in non-construction situations; to display departure orders at the hold short lines of runways; or even provide taxi instructions at the

transition point from the ramp to the airfield. The uses are endless, because these signs can display whatever message needs to be communicated to the flight crews. However, there are limitations and other considerations that have to be taken into account, as pointed out by Pruchnicki, "Now there are certain considerations that we have with those types of signs as far as how high they can be above the ground, their exact location, visibility issues, and there is only so much text you can put on there …" (personal communication, April 7, 2014)

The Comair 5191 accident could have been prevented with the use of changeable LED signage to help alleviate the confusion found in the intersection of Taxiway A and Runway 26 and Runway 22. The additional signage would have been able to alert the pilots of construction on the airfield and have allowed them to correct the mistake of lining up on the incorrect runway. When asked if changeable LED signage could have helped prevent the accident, Pruchnicki replied simply and with conviction, "Yes, absolutely." (personal communication, April 7, 2014)

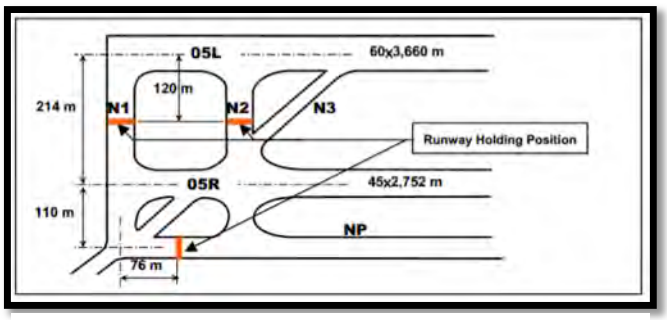

Figure 16 Figure from the ASC accident report shows the distance of hold lines at CSK at the time of the accident.

Another accident in which changeable LED airfield signage could have played a role in preventing the accident was Singapore Airlines 006 at Chiang- Kaishek Airport (CKS) in Taipei, Taiwan, Republic of China on October 31, 2000. This accident was specifically mentioned by Shawn Pruchnicki as an accident worth further investigation, "An accident I would consider you guys should look at, especially when it comes to this type of lighting and construction is the Singapore 006 accident" (personal communication, April 7, 2014). Below is a description of the accident from the Singapore's governmental encyclopedia website:

> *At the time of the accident, heavy rainstorm and strong winds caused by typhoon Xangsane prevailed over Chiang Kai-shek Airport. The aircraft, a Boeing 747-400, started off once the airport cleared its departure from runway 05L at 11:15 pm. However, it took a right turn too soon and entered the wrong runway, 05R, which was closed for repairs.*

Due to the obscured visibility caused by the harsh weather, the flight crew did not see the construction equipment parked on the runway just over a kilometre away from where the takeoff roll began. By the time the pilot noticed the equipment, it was too late to swerve the plane away from speeding towards the obstruction as the nose of the aircraft had already left the ground. At 11:17 pm, about 33 seconds after the takeoff roll started, the plane collided with the parked equipment.

The impact broke the plane into two and caused the filled fuel tank to explode. The large fire that followed destroyed the forward section of the aircraft and the wings, thus killing many seated in the middle section of the plane. Many others suffered burns. It took about ten minutes to bring the blaze under control and the fire was eventually extinguished at 12:00 am.

Of the 179 people on board, 83 were killed, including 12 Singaporeans. The four crew members who died were all cabin crew; the pilot and two co-pilots survived. (Nisha, 2011)

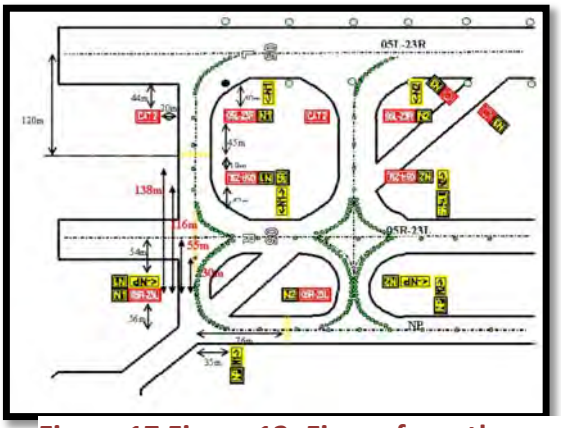

Figure 17 Figure 12: Figure from the ASC accident report shows the airport layout for CSK as well as the location of taxiway and runway signage.

Changeable LED signage could be used to mark a closed runway in poor weather conditions making the closure more visible to pilots and ensuring that they are on the correct runway even if the runway is parallel. As Pruchnicki puts it " … a lot of people in the industry, their knee jerk reaction is well if pilots would just look at the heading when they pull out on the runway … but this is an example and there have been others where that wouldn't have helped because it is a parallel runway; It's more complicated than just checking your heading" (personal communication, April 7, 2014). In the case of Singapore Airlines Flight SQ006, the signage would have been able to inform the pilots that they had turned onto the wrong runway and that there were

construction vehicles ahead. This would have allowed for the pilots to correct the mistake and save the lives of 83 people.

The intersection of the taxiway and Runway 5R could be confusing to pilots given clearance to taxi and immediately take off. The location of the hold short lines and signage did not accurately inform pilots of which runway they were approaching, as the signage and hold short lines were located across Runway 5R and further down Taxiway NP, as shown below in Figures 1.10-2 (hold short lines) and 1.10-9 (signage) of the accident report (Aviation Safety Council, 2002). If changeable LED signage had been located at CKS, the range of visibility of the pilots would increase greatly, allowing the pilots to maintain positional awareness while on the airfield.

Effective Interaction with Airport Operators, Practicality, and Feasibility

A very important segment of research for this project was to visit an airfield that would benefit from changeable message LED signage. Upon evaluation of the airports available within the region, the team decided to review The Ohio State University Airport (KOSU,) and visit Rickenbacker International Airport (LCK.)

The Ohio State University airport provides significant opportunities for confusion and concern. There are 4 major hot spots, according to the FAA, on the airfield that either are expected to cause confusion or already have. (FAA, 2014) These include:

COLUMBUS
OHIO STATE UNIVERSITY (OSU)

HS 1	When holding short of Rwy 09R, acft must clear Rwy 05 hold short line on Twy A, west of Rwy 05.
HS 2	Rwy 05 hold short line close proximity to west ramp on Twy A .
HS 3	Wrong rwy departure risk: Rwy 32 is not visible from hold short lines on Twy D.
HS 4	Successive hold short lines on Twy A east of Twy D define Rwy 32 apch zone. Pilots confuse the apch hold markings with the Rwy 27L rwy holding position markings

Rickenbacker International Airport is part of the Columbus Regional Airport Authority in Columbus, Ohio. The airfield was once strictly a military facility but now currently provides significant cargo traffic, few commercial flights, and military training activities.

Rickenbacker airport operations coordinator, Joseph VonBargen gladly provided the opportunity to tour the airfield, review locations that may benefit from signage, and provide valuable feedback regarding design and function.

Upon visiting, the weather provided low visibility and wet conditions. The METAR for that time showed rain, a visibility of 4 miles, and a low ceiling.

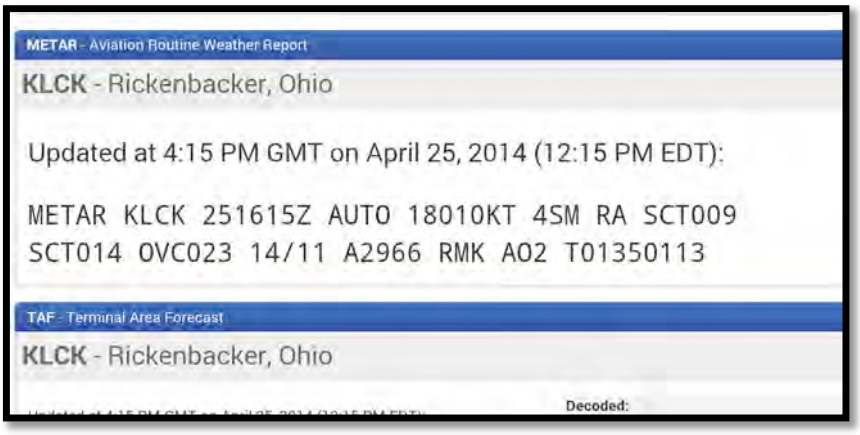

Figure 18 METAR for LCK on day of final review of the airfield

The benefit of the weather this day was that when stopped on the and of runway 23L, the visibility did not allow a clear view to the end of the runway. If an aircraft would line up there for takeoff, they trust that ATC knows that the runway is clear. As seen in the Singapore Airlines accident, confusion in poor weather can have fatal consequences.

Figure 19 Photograph taken of low Visibility at Rickenbacker

The opportunity to visit and speak with Joseph VonBargen provided valuable feedback regarding the application and design of the signage systems. He explained that about two times a day, a 747 with cargo lands at LCK. Due to the wingspan and size of this aircraft, there are only three taxiways on the airfield that this aircraft can use, taxiways alpha, bravo and golf. Provided below is the airport diagram for LCK with these locations designated.

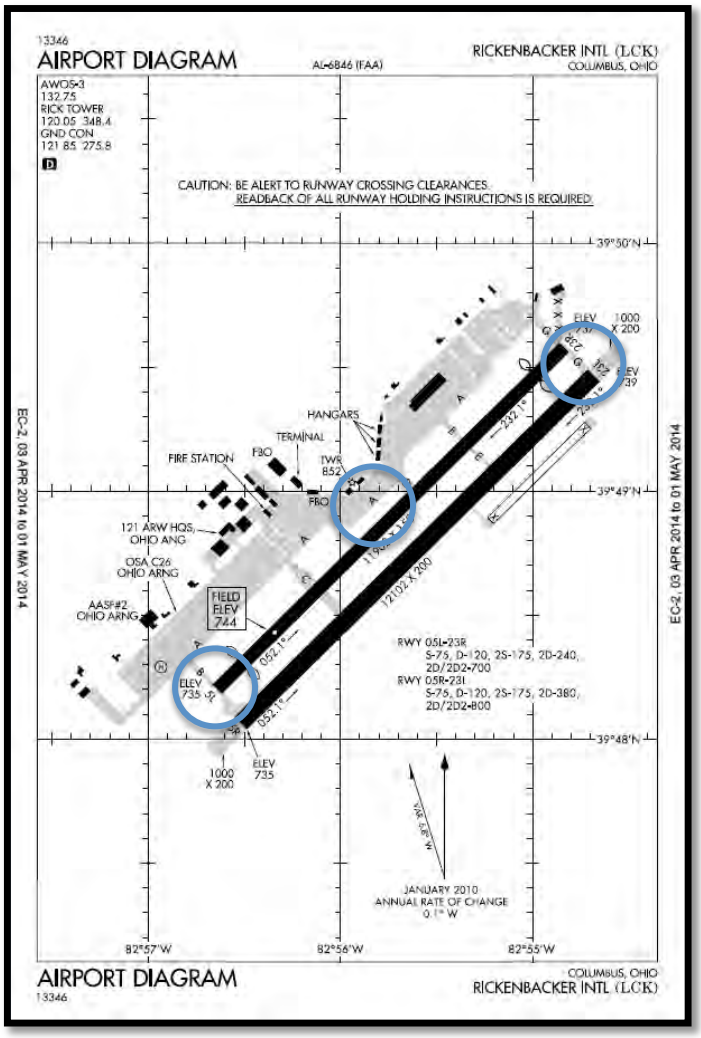

Figure 20 Airport Diagram with Taxiways Noted for example

The opportunity for this type of signage would be beneficial for this situation. The ability to have a configuration prepared that provided notices on taxiways Charlie, Delta and Echo of "No Entry" or "Proceed to taxiway Golf," could prevent an incident on the airfield. Then once the aircraft is safely on the ramp, ATC could return the airfield to the original configuration of all taxiways open.

Other important design characteristics discussed with Joseph were the need for scalable brightness due to different weather conditions, the ability for the signage to display graphics that are identical to current signage when not displaying an urgent message, bust be able to display multiple colors in order to match appropriate sign categories, and innovative heating designs.

Some uses of the changeable message signage would be for runways that are closed or sections of the airfield that under construction. See the two images below for examples of how signage would change during various conditions.

Figure 21 Example of "Closed Runway" signage

Figure 22 Example of "Under Construction" Signage

The energy cost savings were also a benefit, he said. Not only would they save on the use of LEDs, but the variable heating as well. He informed us that currently the incandescent lighting on the airfield was heated constantly and that an airport operation does not have the ability to turn off the heater. If the LED signage provided a system that would sense the temperature, or obtain it from on-field weather sources, and turn on the heater at a pre-programed value, this would save the airfield significant funds especially during the summer months when heating is unnecessary.

The lighting design suggested includes all of these features as well as the ability to remain within the FAA regulations and standards of current signage heights, frangible, and colored design. Below is a sketch of the proposed design based on current signage, requested features, and variable message signage studies in other transportation modes. Changeable message LED signage has been used for many years to protect users and workers on roads during confusing or poor weather situations. This technology could easily provide similar life saving effects to aviation.

Conclusion:

In conclusion, the use of changeable LED signage on the airfield could enhance the safety of the airfield environment. Through the enhancement of situational awareness and more descriptive signage, flight crews will be able to better comprehend and navigate through confusing airfield layouts, resulting in less runway incursions and other accidents that result from a loss of situational awareness. Changeable LED signage will also be more efficient than current airfield signage by saving energy and money, as well as the ability to display written messages as needed. While the current signage does not need to be completely replaced, supplementing it with technology such as changeable LED signage will benefit both the airport and the flight crews by enhancing safety and navigability of the airfield, and increasing situational awareness of flight crews leading to potentially less accidents or runway incursions.

Appendix A – Contact Information

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Appendix B – Description of University

The Ohio State University (OSU), located in Columbus, Ohio is a public land-grant university supported by the State of Ohio Board of Regents. Founded in 1870, OSU is currently the largest single-campus university in the United States with more than 60,000 undergraduate and graduate students. Ohio State is ranked among the top 20 public universities in the United States according to U.S. News & World Report. The university offers more than 160 academic programs, through 20 colleges and schools.

Ohio State is considered to be one of the most comprehensive and diverse research institutions in the United States. In 2007, OSU ranked 7th of all public universities in research expenditures with more than $650 million in funded research. Ohio State University ranked 10th in engineering research in 2006, according to the U.S. News and World Report.

The Ohio State University College of Engineering supports academic programs in Aviation. The OSU Center for Aviation Studies offers undergraduate programs in aircraft systems (flight education) and aviation management. The Center also works across the College of Engineering to foster graduate research. OSU Aviation operates an FAR Part 141 Flight School and The Ohio State University Don Scott Airport, and associated fixed based operations and FAR Part 145 Repair Station.

The Ohio State University is accredited by the Higher Learning Commission (HLC) of the North Central Association of Colleges and Schools (NCA).

Appendix C – Description of Non-University Partners Involved

Airport Operator

Our non-University partner was Joseph P. VonBargen, Airport Operations Coordinator, Columbus Regional Airport Authority, Rickenbacker International Airport. Joseph was a very valuable asset to our project. The ability to research lighting and signage at an airport like Rickenbacker allowed us to view how a 12,000 ft runway looks in low visibility. He also provided us with examples of daily usage for our design as well as features that are needed on an airfield such as this.

Joseph P. VonBargen
Airport Operations Coordinator
Columbus Regional Airport Authority
Rickenbacker International Airport
jvonbargen@columbusairports.com

Industry Contacts

For our participation with industry professional we interview Shawn Pruchnicki, faculty member at The Ohio State University, as well as a former Comair pilot and Air Line Pilots Association (ALPA) investigator. Mr. Pruchnicki experience as an ALPA investigator gave us a great insight into aviation safety involving airfield signage, citing many investigations where changeable LED signage could have helped prevent accidents (i.e. Comair 5191 accident).

Shawn Pruchnicki
The Ohio State University, Center for Aviation Studies

Student Evaluations:

Brandon W. A'Hara

The FAA Design competition did provide me with a meaningful learning experience. The competition allowed me to learn about the different ways that airfield signage can be updated and improved. These updates and improvements can help improve the safety and efficiency at airports. A challenge faced by our team during the project was finding examples of where changeable LED signage is currently used and how it can be implemented. Since this technology is not used on the airfield currently in the capacity we are thinking. The only example we were able to find of our exact product was from the ALPA accident report for Comair 5191 where they recommended changeable LED signage be implemented on the airfield.

The process we used to develop our hypothesis was to first brainstorm among the group how changeable LED signage could be used and implemented on the airfield. Next we divided up the research among each member of the group so that every aspect of our hypothesis was covered. The participation by industry was very beneficial for our project. We interviewed Shawn Pruchnicki about how changeable LED signage could help increase safety on the airfield. Pruchnicki pointed us to a couple of accidents that could be studied and used to show the benefits of the technology and how it could have helped to prevent these accidents and save lives.

During the project, I learned that the current airfield signage, while not needing to be replaced entirely, can be improved upon by the use of changeable LED signage. This improvement will allow for better situational awareness of flight crews, therefore increasing safety on the airfield and at the airport as a whole. I also learned that changeable LED signage will allow airports to save money because the LED lights are more efficient than the currently used incandescent lights.

This project was definitely beneficial and allowed me to learn about how the airport can always continue to be improved.

JOSHUA K. CRUMP

The FAA Design competition has provided me a quality educational experience and exposure to aviation and airport-related careers. With the assistance of classmates, and professors, I have learned a great deal on airport safety and risk management.

One particular challenge our team faced understood the different airport signage systems. Aside from the FAA standards for signs, each airport has different configurations and uses for signage, designed respectively for their particular airport. By getting a basic understanding of sign standards for airport, we were able to get an understanding of how a particular airport would utile signage and compare that with other signage systems.

During our hypothesis development and using our teams multi-disciplinary background in Planning, Engineering, and Aviation, we came up a topic that fit best with our areas of expertise and interests and ultimately decided on exploring the topic of changeable LED signage use at airports.

For our participation with industry professional we interview Shawn Pruchnicki, faculty member at The Ohio State University, as well as a former Comair pilot and Air Line Pilots Association (ALPA) investigator. Mr. Pruchnicki experience as an ALPA investigator gave us a great insight into aviation safety involving airfield signage, citing many investigations where changeable LED signage could have helped prevent accidents (i.e. Comair 5191 accident).

Through this project, I have learned changeable LED signage is in its infancy at airports across the country. With more research and testing, I believe this concept of signage could be utilized in communicating information regarding airfields and airports, making airports more efficient and

safe into the future. Participating in a project and competition like this has given me a great deal of knowledge and skills to be proficient for the field airport planning and design.

JIMMY DETER

The design competition was a great learning experience. As a civil engineering student, I have never had any exposure to airports/airplanes/FAA and this case study and class allowed me to gain some important working knowledge of the aviation field. I learned a good deal about new improvements that could benefit the aviation community from not only my own personal project, but also from the other presentations we attended. The course had four groups of students all put together research to possibly present to the FAA, and I learned a great deal about some of the new techniques that are currently being researched.

The major challenges with the group project were mainly clerical issues. The group was composed of two aviation students, two city & regional planners and two civil engineers. The challenge was to divide work into sections so that each different person could provide some expertise on their topic. Overall, we as a group effectively managed to bring together our specialties and contribute to the project equally.

Our hypothesis was generally based around the case studies we had in mind. We used the two accident cases displayed in the report as motivation to get this changeable sign technology into the forefront of the aviation community. If changeable warning signs were available, it is feasible to assume that the accidents could have been avoided.

We consulted with an expert who had some direct experience to one of our accident cases. He was able to give his professional opinion about the value of these changeable signs, and drew the same conclusion we were going for – that the signs would definitely have been a good extra line of defense for these pilots using wrong taxi/runways.

I learned about the possible treachery of the airfield. Previously, I thought that almost everything was completely computerized, and that the pilots were basically there incase anything went wrong. I wasn't aware that the airfield could also be so confusing and dangerous. I think the project helped give me a deeper insight view to issues that surround pilots and the airline industry. I feel very comfortable that if I were to enter into this workforce that I would be better off now after completing some real, in depth research and design on certain scenarios than I would have without having put extra work into the class.

VICTORIA HAKY

Being a part of the FAA Design Competition is a very valuable experience. The project allows you to work on a real world issue while being part of a team. It also provides the opportunity to interact with airport staff, researchers and professionals in the field. This has been my second experience with the FAA Design Competition and again I learned so much more about airport operations.

One of the big challenges was the short time we had to work on our entry. The team did not come together until February in the Airport Design course, which did not leave a lot of time. This group, however, was very hard working and did an amazing job. Luckily, the hypothesis was created pretty quickly. The idea came out for the changeable signage and everything else just took off from there.

Our industry professional, even though he is part of Ohio State, was the perfect person to talk to regarding the runway environment, accident causes, and human factors/ situational awareness. He was vital to our safety and risk evaluations. His experience as an ALPA accident investigator provided a critical key to understanding how things can go wrong so quickly and easily on an airfield.

This project taught me a lot about human factors and situational awareness. It showed how easily something can be missed and how easy it is to ignore things when seen every day. It also taught me the importance of not only considering initial and physical cost but the possibility of unintentional benefits of adding additional safety features to an airfield. The teamwork needed on a project such as this is one of the most important skills learned in college. I have learned that almost nothing happens in "the real world" individually and that teamwork skills are a necessity.

Andrew Macpherson

I found the FAA design competition stimulating because it required a more focused perspective on one facets of airport design, and all the things that can go into something as "simple" as signage. The portion of the project I primarily worked on was researching situational awareness, and how it has been classified and studied not only in air travel, but across multiple disciplines. As an engineering student it was interesting to look at the psychology behind situational awareness and how it affects pilots and air traffic controllers, but also how properly implementing different technologies such as Nextgen and LED lighting can make key personnel in and around an airfield more aware of what's going on giving them a better cognitive map to make decisions.

At first it was difficult to research subject matter that was both meaningful and relevant to situational awareness, airports and LED lighting. After meeting with Shawn Pruchnicki regarding the accident that he had helped investigated I was able to get a better feel for the types of problems that arise from a lack of situational awareness and different areas to pursue with my research. This was also the point where as a team we were able to come together and hash out the direction we wanted to take with this project. We were then able to more effectively divide up the work while staying on the same page.

After graduation this year I will be starting a career as a structural engineer designing buildings. As far as my career is concerned I don't believe I truly gained much from this project. However, I will say it was a worthwhile endeavor and peeked my interest.

Jake Nguyen

The FAA design competition has provided me a meaningful experience, as I was able to gain more useful skills to add to my knowledge of aviation. I had the chance to work in a team environment, which could have been interpreted as a real-life job. The team had gone through all the aspects of the design and each person was given a category to do more research on his own. I was given the task of cost analysis. It was difficult at first to go online and look for a general cost of incandescent and LED. There were many other costs that I had to take into consideration as well. I kept looking at other places and came upon an LED manufacturer's website (AGM) where they had comparison charts of energy usage using their data of Volt/Amp of both incandescent and LED bulbs. I thought I could combine the Volt/Amp data of both types to see how much energy each uses. The rest of the team also had their own problems; however, they were able to interview Shawn Pruchnicki, an aviation safety professor at The Ohio State University who has ALP experience. Professor Pruchnicki was useful in obtaining information as he is an expert in safety and the fact that he himself investigated an accident at an airport he formally work at where many were killed due to the pilots taking off in the wrong runway which was under construction.

The team easily came up with the hypothesis to use LED signage as an alternative because of the fact that LED lights are much more cost effective with their high life rating (as high as 100,000 hours) and that providing clear instructions to pilots taxiing to the runway to prevent another accident like the one Professor Pruchnicki investigated. Professor Pruchnicki 's inputs were

extremely useful as he is someone of a professional who has been involved in the industry for so many years, so he would know exactly what is going on at the airports. As a result, the team and I were able to learn much about the industry. I would say doing this hands-on project allowed me to see aviation in another perspective, more deeply involved than just by learning in the classroom. We get to see the costs of the lightings and the normal operations of the airport beyond the terminals. What is greater is we know a way to improve and make the airfield safer and less cost. We believe if given more time, this project can go beyond our reach and become something that airports could potentially implement, with much more success.

JOSEPH SCHRANTZ

I do believe that the FAA Design Competition for Universities provided me with a meaningful learning experience. I was able to experience work as a member of a cross-disciplinary team for the first time, and found that experience to be extremely valuable. Also, the ability to work on a project that could enhance safety in the Aviation industry is also very meaningful to me.

A major challenge that our team faced was that not all members of the group were Aviation-related majors, and not all members had strong aviation knowledge. We solved this by assigning parts that either did not require much aviation knowledge to complete, such as the background on airfield signage, or current usage of LED signage; or were of interest to the team member.

Our team knew that we wanted to study the use of changeable LED signage on the airfield, much like the use of this signage on highways and roadways. Once we had this general topic, we were able to provide a more specific hypothesis.

Participation by the industry was extremely appropriate, useful, and meaningful. Mr. Pruchnicki's experience and expertise agreed with the design and usage that we are proposing. He even mentioned in his experience that ALPA suggested this technology be used 8 years ago. His guidance was extremely valuable to the group, and was much appreciated.

I learned a great deal about the usage of LED signage and lighting on the airfield. I feel that this experience helped prepare me as I attempt to make a career in airport operations.

Seth Young, PH.D., Faculty Adviser

As part of the course I teach in Airport Planning and Design at The Ohio State University, I ask students to team up for their final projects, involving the investigation of an issue of importance to airports, and to hypothesize a solution to the issue at hand. It is within this course that the team of Brandon A'Hara, Josh Crump, Jimmy Deter, Victoria Haky, Andrew MacPherson, Jake Nguyen, and Joseph Schrantz, came up with the issue of attempting to create a form of changeable signage that would help reduce spatial disorientation, and hence improve airfield safety.

The team's consideration of using LED technology towards the creation of LED-based changeable airfield signage seemed intriguing to me, and showed worthy potential for a product that may be marketable. Thus, was the motivation for the work described in this entry to the FAA Airport Design Competition.

This project team was comprised of a unique combination of student majors, ranging from civil engineering, to city & regional planning, to aviation, on both the graduate and undergraduate levels. Each student brought their own strengths to the team, and in turn learned about issues that weren't part of their core academic programs. As an adviser, it was exciting to see this multi-disciplinary group work so well together.

As part of their research, the team met directly with management at The Ohio State University Airport and Rickenbacker International Airport, and made site visits to these airports to conduct research. For several on the team, it was their first visit on airfield visit, a wonderful learning experience in its own right.

I am proud have advised the OSU student team on their entry, and am grateful to the FAA and the Virginia Space Grant Consortium for the opportunity to allow our students to participate in such a worthy program.

Appendix F - Bibliography

Airfield Guidencesign Manufactuers Inc. (2014, April). *DLUX Incandescent Product Sheet.* Retrieved from Airfield Guidencesign Manufactuers Inc. Web site: http://www.agmsigns.com/images/DLUXIncandescentProductSheet.pdf

"ALPA's Submission to the NTSB on Comair 5191 Accident." *ALPA's Submission to the NTSB on Comair 5191 Accident*. Air Line Pilots Association, International, 23 Mar. 2007. Web. 08 Apr. 2014.

Attempted Takeoff From Wrong Runway Comair Flight 5191 Bombardier CL-600-2B19, N431CA Lexington, Kentucky August 27, 2006. Rep. no. NTSB/AAR-07/05. Washington, D.C.: National Transportation Safety Board, 2007. NTIS No. PB2007-910406. *Aircraft Accident Report*. National Transportation Safety Board, 26 July 2007. Web. 8 Apr. 2014.

Crashed on a Partially Closed Runway During Takeoff Singapore Airlines Flight 006 Boeing 737-400, 9V-SPK CKS Airport, Taoyuan, Taiwan October 31, 2000. Rep. no. ASC-AAR-02-04-001. Taipei, Taiwan, Republic of China: Aviation Safety Council Taiwan, Republic of China, 2002. *Aircraft Accident Report*. Aviation Safety Council Taiwan, Republic of China, 2002. Web. 8 Apr. 2014.

Faber, J. (2009, March-April). *Greater Binghamton Gives LED Runway Signs the Nod.* Retrieved 2014, from Airport Improvement.com: http://www.airportimprovement.com/content/story.php?article=00070

Federal Aviation Administration. "A Better View of Operations at World's Busiest Airport." *Federal Aviation Administration*. N.p., 04 Apr. 2014. Web. 09 Apr. 2014.

Federal Aviation Administration (09/28/200) Advisory Circular 120-72, *Maintenance Resource Management Training.* Retried from HYPERLINK "https://www.hf.faa.gov/docs/508/docs/AC120-72.pdf" https://www.hf.faa.gov/docs/508/docs/AC120-72.pdf

Federal Aviation Administration . (2010, 08 16). *STANDARDS FOR AIRPORT* . Retrieved from Federal Aviation Administration : https://www.faa.gov/documentlibrary/media/advisory_circular/150_5340_18f.pdf

Flight Operations Briefing Notes. Blagnac Cedex France: Airbus, 2007. *Airbus*. 01 July 2007. Web. 09 Apr. 2014.

Nisha, Fatimah M. "Crash of Singapore Airlines Flight SQ006." *Singapore Infopedia*. National Library Board Singapore, 2011. Web. 8 Apr. 2014.

Pruchnicki, Shawn. Personal Interview. April 7, 2014

Port Columbus Int'l Airport – Columbus, OH." Cree Lighting Case Studies: Port Columbus International Airport. Cree, Aug. 2013. Web. 17 Apr. 2014.

Sneddon, Anne, Kahryn Mearns, and Rhona Flin. "Stress, Fatigue, Situation Awareness and Safety in Offshore Drilling Crews." *Safety Science* 56 (2013): 80-88. *ScienceDirect*. Elsevier B.V., July 2013. Web. 09 Apr. 2014.

United States. Washington State Department of Transportation. Maintenance and Operations Programs. *Washington State Department of Transportation*. N.p., Aug. 2013. Web. 09 Apr. 2014.

Wilford, John. BIBLIOGRAPHY Takeoff! How the Wright Brothers Did What No One Else Could. (2003, December 9). *New York Times*. http://www.nytimes.com/2003/12/09/news/earliest-days-takeoff-how-the-wright-brothers-did-what-no-one-else-could.html

Images:

Figure 2- Mandatory Signs- Source:
http://www.faa.gov/airports/runway_safety/news/publications/media/QuickReferenceGuideProof8.pdf

Figure 3- Location Signs- Source
http://www.faa.gov/airports/runway_safety/news/publications/media/QuickReferenceGuideProof8.pdf

Figure 4-Boundary Signs- Source
http://www.faa.gov/airports/runway_safety/news/publications/media/QuickReferenceGuideProof8.pdf

Figure 5-Direction Signs- Source
http://www.faa.gov/airports/runway_safety/news/publications/media/QuickReferenceGuideProof8.pdf

Figure 6-Destination Signs- Source
http://www.faa.gov/airports/runway_safety/news/publications/media/QuickReferenceGuideProof8.pdf

Figure 7-Informational Signs- Source

http://www.faa.gov/airports/runway_safety/news/publications/media/QuickReferenceGuideProof8.pdf