The University of Illinois at Urbana-Champaign

Imaginary Airport- KMJH

Modern Day Wright Brothers

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The airports of the future provide unique opportunities for innovation. As environ- mentally conscious technologies improve, air travel will grow greener. This technical report will highlight the changes that are expected to occur in the year 2050. The focus of this report is the need to adjust the airport to airlines using less carbon emitting aircraft and their needs. Many changes to infrastructure come from advancing electricity capabilities and using new fuel sources including sustainable fuels and hydrogen powered engines. With this in mind, changes to how the airport operates outside of powering aircraft need to be considered. Creating more technological proposals for building baggage handling, jet bridges, and other operations can provide a wider range of possibilities for a greener future. These changes will enable more blue skies in 2050 and beyond.

The biggest foreseen change will be the emergence of alternative fuel sources. Airplanes are typically powered by the use of jet fuel, specifically either Jet A or Jet A-1. However, looking at the Department of Energy and National Renewable Energy Laboratory projections, we predict that Sustainable Aviation Fuel (SAF), a fuel made from non-petroleum feedstocks, will become more and more prevalent as the future draws closer. SAF must be blended with the regular petroleum-based fuel before it is delivered. Since this is done off-site, it is not in the scope of this project. The blend is compatible with planes that currently take Jet-A as its fuel, which is most. Even if airlines don't make an effort to change their planes, the simple switch to the blend fuel will have a great net positive impact for the environment. Our tank farm for storing the blended fuel will be designed for pipeline delivery and dispersed through a network of pipes to the tanks in the farm. To save costs of fuel trucks, we plan to expand the underground network of pipes to transport fuel to the gates directly. This network is known as the hydrant system. From the calculations in the appendix below, we know that a large fuel truck consumes around 20kWh transporting the necessary fuel to a Boeing 747 for a typical 5 hr flight. This does not include the environmental cost of emissions or the maintenance required for continual use of said trucks. The only main requirement for a hydrant system would be an impeller. High efficiency impellers consume much less energy and so the emissions of this hydrant system will be much lower. Hydrant systems save cost, time, and are overall more organized. Our tank farm will also boast fuel and vapor flow control equipment, volume measuring meters, contaminant removing filters, inlet and outlet pumps, and safety equipment. Besides the blend fuel, our projections allow us to predict the emergence of electrical, Hydrogen, and biofuel energy as more prominent energy sources for the aircraft with electrical leading the transition. NASA is currently investing into all-electric planes and Boeing expects to supply twelve of these "Alice" Planes to DHL by 2024. The main and most important barrier with electrical energy is battery capacity. Most projections estimate that battery technology will have evolved to allow for continental travel within the next 50 years. Battery power will become more prevalent in airplane technology and airports will have to update their systems in order to keep up with the growth of the technology. Countries like New Zealand have already begun the process of switching primary energy sources with their current plans of testing electric planes by 2026. To be compatible with these alternative energy planes, airports would need larger power units for charging and include Hydrogen and biofuel storage tanks. As battery technology continues to increase, the relevance of Hydrogen and biofuel will decrease, therefore the second requirement isn't as necessary. In the current airport model, while the planes are parked at the gate, a Ground Power Unit (GPU) is used to provide auxiliary power while it is being refueled and such. Our airport model proposes that half the gates will only dock planes that still use conventional fuel, for which they will be provided the

SAF/Jet-A blend, while the other half will dock planes that use our list of three alternative fuel sources. For the latter, the gates will not have GPUs, but instead will house what we are proposing as Charging Power Units (CPUs). These CPUs will provide auxiliary power to the planes that are parked while simultaneously charging them. The technology for this will also evolve out of the advancement in battery technology and battery charging capabilities. In regards to the acquisition of the necessary electrical energy for the CPUs, we plan to make use of rooftop solar cells to create a solar farm. Research out of Australia using satellite imagery showed that in 21 airports there were about 2.61 square kilometers of unused area. If this land were filled with solar cells, these 21 airports would cut greenhouse gas emissions by 152 kilotons a year. To best utilize the under tapped energy reservoir solar panels will be strategically placed on the roofs of terminals as well as between pre existing runways. One main challenge with solar panels is the buildup of debris on their surface. By positioning solar panels at the ends of runways, we can expect the jetwash from planes that are taking off and landing to simply blow away any unwanted debris. This creates a simple, passive solution to the debris problem. As mentioned earlier, SAF must be blended with jet fuel and this can be transported to half of the gates that still rely on traditional fuel sources. The other half of the gates will be purely alternative fuel sources. Since each plane will require a different type and amount of power, we propose an electrical microgrid at the airport. This will include a central location for all of the energy to be stored as well as a network to each gate. As a plane lands at a specific gate, the appropriate amount of energy can be transported by this network to the associated CPUs. The appropriate amount of energy can then be used for each plane and losses will be minimized. This is shown in Figure 1 below.

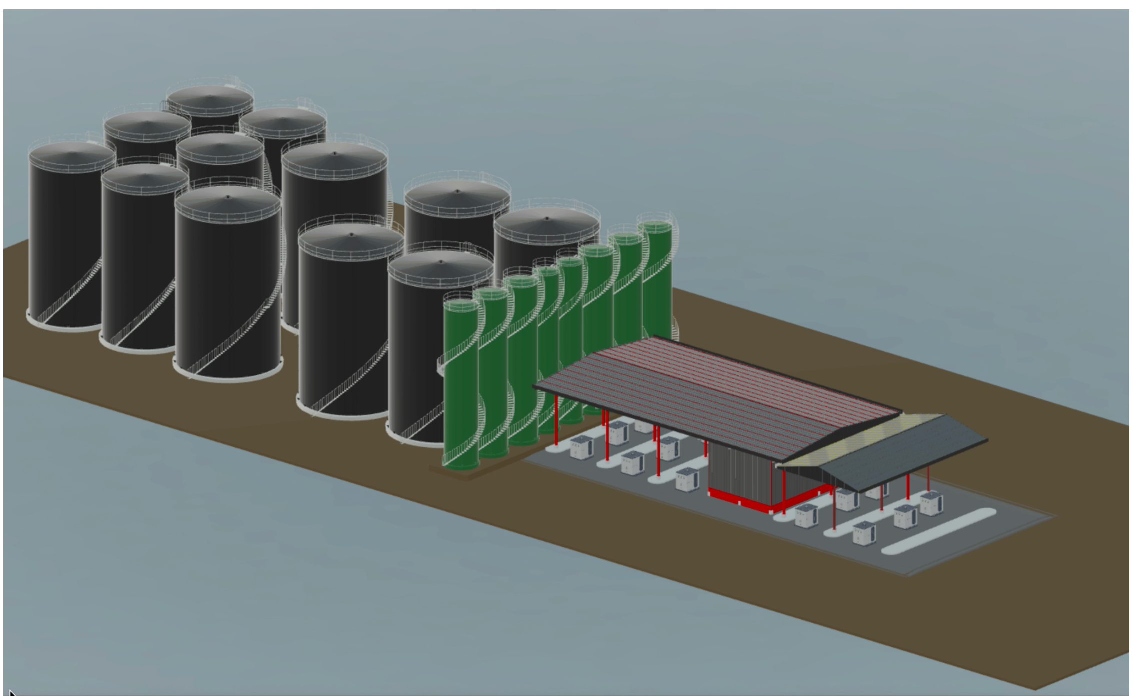

Figure 1: Energy farm split into two sections to store SAF/Jet A blend, biofuel, and house the microgrid

Another proposed change is located at the gate itself. The two improvements are regarding baggage handling and auxiliary/charging power. Current baggage handling includes automatic and manual transfer of baggage from the start to final location. Baggage will start with check in and begin the journey on a vast conveyor belt system until full security checks of each bag are complete. Batch baggage systems store all the baggage until manually brought to the correct gate using gasoline baggage trucks. Although this is a very detailed process, there is room for improvement. Baggage trucks are part of a large system that keeps the bags, mail, and cargo to the correct gate, however one way to reduce these emissions is to use electric baggage vehicles. One study done by University of Michigan-Ann Arbor provided research for the efficiency of baggage trucks used by United Airlines with a fleet of 300 baggage trucks. The studies proved that each baggage truck from United Airlines in 2017 was running at an average fuel rate 10.4 miles per gallon and using around 25.2 gallons of fuel per day. This statistic is significantly less than the average of an average car sold in the United States that drives at 25 miles per gallon. Truck emissions using these statistics were made to find the daily emissions of these 300 baggage trucks. The calculations provided using EPA Green Vehicle Guide that states that 8,887 grams of CO_2 are released per gallon of fuel used show that 73.47 tons of CO_2 are released per day for these 300 vehicles. With this in mind, electric trucks are an option, however would still need a large amount of electric and man power to use this type of baggage system. One solution is to eliminate a large amount of baggage trucks altogether.

For eliminating baggage trucks, a new form of transportation for the baggage is needed. In order to eliminate this step of the baggage process, eliminating the manual handling of the baggage will help with using an automated conveyor system from baggage check all the way to the gate. First, by eliminating the baggage trucks, manual labor will be reduced. At O'Hare international airport, salaries are raising to 17 dollars per hour for each baggage handler. This money can provide a larger budget for an automated system to send bags directly to each gate. The new baggage handling system will use concepts from amazon fulfillment centers. Honeywell Integrated uses a sorting system constructed in 2018 for a new amazon fulfillment that distributes packages into 187 divert destinations. A transnormal sorting module is used for line splitting and directing packages off the current conveyor belt system. If this modular system is incorporated into the current baggage system, conveyor belts can be extended right from the security screening to each gate by diverting a bag off the main conveyor belt to its final destination. This transfer can include autonomous transfer of layover flight baggage. The problem that would arise would be changing one main batch center within the terminal that stores all bags into individual baggage batch bays at individual gates.

Currently, one large terminal baggage bay is used to store all baggage until the plane is ready for turnaround, shown in Figure 2 below. This provides a great storage space, however is not relatively close to each gate or the cargo's final destination. Instead, the proposal of creating smaller individual baggage bays at each gate would help with storage of baggage.

Figure 2: Demonstration of the crisstore dynamic racking solution created by Beumer Group

Creating a storage bay at each gate would take up space necessary for parking the aircraft, so moving the bays below the pavement would alleviate the ground-level other uses. These baggage bays would be to the right of where the plane parks with a ground level roof made of concrete and Type J-Channel Frame H20 Loading Floor Access Doors. The floor access doors would provide ground storage bay access, while providing enough strength to place service vehicles for the gate above the bay. Provided below is a Fusion 360 demonstration of the concept.

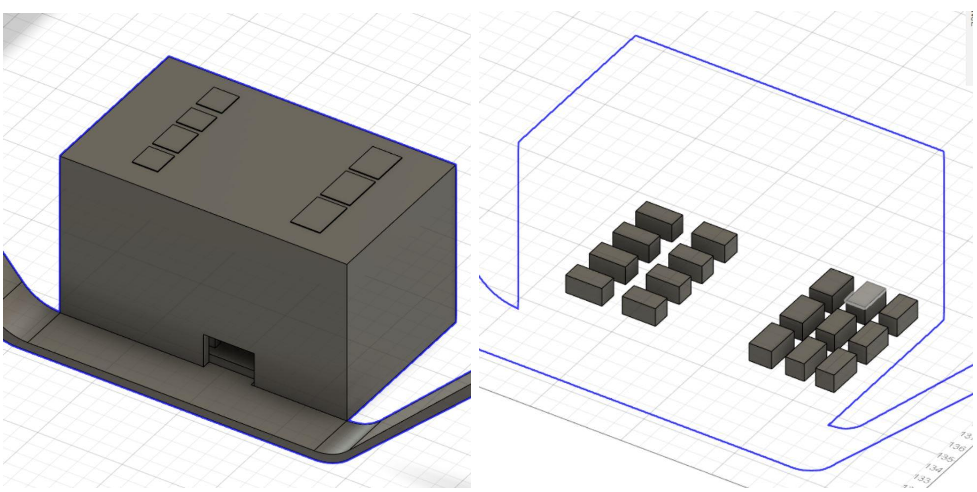

Figure 3: Concept of underground baggage bay

The purpose of the gateside baggage storage is to provide easy access for baggage to be loaded onto the aircraft. Once the aircraft are ready to be loaded, a baggage can extend a Cisco Eagle Flexible Power Roller Conveyor from the storage bay right to the loading bay of the aircraft. Providing this flexibility can provide extra space for when the bags are not being loaded, while additionally reducing the need for luggage carts.

One large issue that needs to be acknowledged is the price to create underground baggage storage at each gate. Storage bags next to the aircraft that uses advanced conveyor systems stated above will almost eliminate the use of baggage trucks and manual handling of luggage, reducing operation cost and human error. According to SITA, an aviation IT provider, 20% of baggage loss is due to human error. Eliminating the middle ground of baggage transfer using baggage trucks will provide a swift autonomous and errorless transfer of luggage to the final destination at a reduced operational cost.

To combat any errors with autonomous storage, any suitcase or item flown on the aircraft that does not fit the IATA interline baggage standards can still be picked up by an electric luggage truck to be delivered to the aircraft. Even though this system will still need baggage trucks, there will be a large reduction of service vehicles used.

The second improvement at the gate will be with the adoption of the proposed Charging Power Units (CPUs). Currently, airplanes power off their engines at the gate. This reduces engine emissions as well as unwanted noise. However, some systems such as climate control, radio, and lights must continue to stay on. These are maintained by dedicated Ground Power Units (GPUs) which provide auxiliary power to airplanes on the apron. The two types of GPUs are mobile and stationary. If a certain gate does not constantly require auxiliary power, a mobile GPU can be transported when necessary. For smaller airports, this may be preferred so as to reduce the number of units purchased. However, there will be some energy consumption when transported and many of these mobile units rely on gas or diesel to move. A more permanent solution is stationary GPUs. These are mounted underneath the gate and an electrical cable can be plugged into a receptacle on the plane. With the emergence of fully electric planes, we propose CPUs which are capable of quickly charging fully electric planes as well as providing auxiliary power to traditionally fueled planes with a high frequency alternating current. The ITW GSE 2400 GPU is capable of powering two separate planes simultaneously and so it is reasonable to expect the CPU to be capable of fully charging a plane while still having a footprint the size of current GPUs.

Another feature of the gates that would increase efficiency of an airport would be to position two planes at one gate. This is shown in Figure 4 below. Currently, at the corners of terminals, two planes can be positioned orthogonally so as to maximize space. However, each plane requires a distinct gate. Widening the jet bridge will allow for two lanes of pedestrian flow. On the schematic below, the jet bridge protrudes out of the corner of the terminal. From there, Lane A will split off to the smaller plane and Lane B will split off to the larger plane. This will allow for two lanes of motion from one jet bridge. A high capacity CPU can then be placed where these two lanes diverge. This can provide charging capabilities and/or auxiliary power to two different planes simultaneously. Since the CPU is mounted on the underside of the jet bridge - as many GPUs are today - there is much clearance underneath for workers or other objects to move freely. One consideration is ensuring that the planes do not interfere with one another. Based on the size-constraints, only a small plane can be parked as shown in position A. Furthermore, this implementation is only possible at concave sections of a terminal where the tail of the smaller plane will not interfere with another plane beside it. Because of the clearance underneath the jet bridge, baggage conveyors can be maneuvered directly to each individual plane. The single CPU, being in close proximity to either plane, can be used to more effectively transmit auxiliary power to traditionally fueled planes or charging to fully electric planes. Additionally, this will not require a major redesign of existing airport gates. The only major modification to the overall footprint would be to widen the jet bridge by approximately 2 meters. This insignificant change will promote a much more efficient power transmission technique. As the technology advances, the proposed CPUs will be able to charge fully electric planes simultaneously.

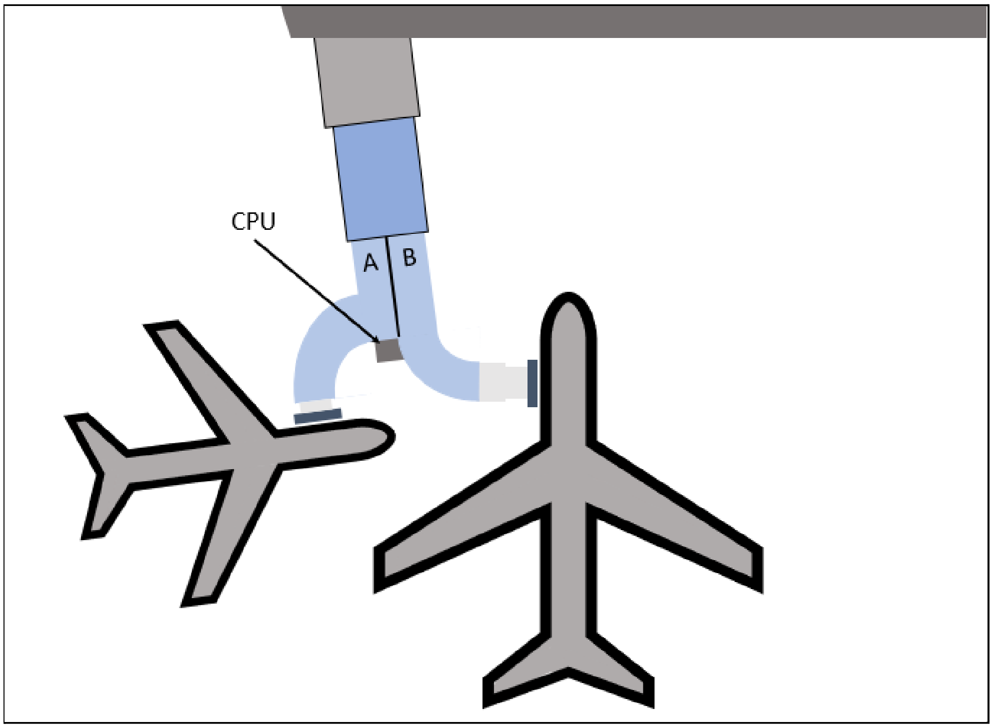

Figure 4. CPU design on the jetbridge

The timeline of each of these implementations is highly dependent on the advancement of electrical technology. There are many plans in place to achieve fully electric continental flight by the year 2050. However, current technology will still be preferred for intercontinental flight. Furthermore, the cost of phasing out all of the standard fueled planes may exceed the payoff from switching to fully electric. In this way, airports of 2050 must accommodate both the emerging technologies of the next few decades as well as the current technologies. Because of this, the designs introduced can be adapted to suit old and new airplane technology.

As presented in this report, there are many current and emerging technologies that can be implemented in the coming decades. Designing our airport around the emergence of SAF/Jet A blend as well as electric planes will allow forward thinking companies to invest more into alternative energy and give motivation for others. The current baggage handling system consists of emissions from the transportation of the cargo that are unthought of by the large public. Creating autonomous baggage bays at each gate underground using a more advanced scanning and conveyor system will reduce human error during transportation and almost completely eliminate truck emissions. Lastly, a redesigned gate configuration can be used to boost the efficiency of the power transmission to planes.

APPENDIX

Calculations

1) Calculations for emissions for gasoline powered baggage trucks

Total Emissions for 300 United Airlines Baggage Trucks

$= (Emissions\ per\ gallon\ of\ fuel) * (Gas\ consumed\ per\ day) *$ (# of trucks) * (1 ton / 907185 grams)

= (8887 grams of CO2/gallon) * (25 gallons/day) * (300 trucks) = 73.47 tons of CO_2 emitted for 300 trucks per day

2) Calculations for costs of a fuel transport truck vs fuel hydrant system

Total energy to fuel a 747 for a 5hr flight

$= (Gallons\ per\ flight)\backslash(Gallons\ transported\ in\ one\ trip) * (distance\ per\ trip) * (energy\ per\ km)$

$= (18,000\ gallons)\backslash(8,000\ gallons) * (3km\ roundtrip) * (3kWh\ per\ kmm)$

$= 20.25kWh\ for\ each\ refueling$

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