GREENING

AVIATION

FROM THE GROUND UP

GREEN AVIATION STARTS HERE

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Greening Aviation from the Ground Up

Global aviation supports 3.4 percent[1] of the world's economy, enhancing trade, tourism, innovation, and healthy urbanization. But commercial air travel also accounts for about 2 percent of anthropogenic carbon dioxide emissions,[2] a figure that, without action, could rise to 3 percent by 2050.[3] This presents the industry with an opportunity to make a significant contribution to both economic growth and environmental sustainability — an opportunity that major aerospace players have enthusiastically embraced. And the timing is just right. As late as 2004, only 5 percent of the world's population had ever stepped foot on an airplane, a number that likely remains well below 20 percent today.[4] An emerging middle class, expected to reach 5 billion people by 2030, may double the demand for air travel in the next 20 years.[5] This is expected to more than double the number of commercial aircraft in service to approximately 47,000.[6]

In 2008, the United Nations' International Civil Aviation Organization (ICAO) established an industry-wide goal of improving fuel efficiency by 1.5 percent annually from 2009 to 2020. ICAO also called for capping net aviation carbon dioxide emissions in 2020 through carbon-neutral growth, and challenged the industry with an aspirational goal for 2050 of reducing net aviation carbon dioxide emissions to half of its 2005 total.[7] In October 2016, ICAO announced a framework for mandatory carbon-offsetting on all international flights. The United States, China, and 63 other countries in total back the new agreement, which involves voluntary monitoring of pollution on international flights beginning in 2021, and mandatory participation for all nations by 2027.[8] This 15-year agreement is forecasted to reduce carbon emissions by 2.5 billion tons, or the equivalent of taking 35 million cars off the road every year for the life of the agreement. ICAO Director General Liu Fang called the agreement "balanced, pragmatic, and very positive," adding that it will "serve as an important new tool to complement the emissions reduction progress already being achieved."[9]

This is Paper 3 in a series of four.

Click to read Paper 1, "The Modern Silk Road: Aviation in the Age of Sustainable Urbanization,"

or Paper 2, "The Future of Sustainable Aviation: Betting on Jet Propulsion & Lower Net Carbon Fuels."

Much of that progress, at least for the foreseeable future, will depend heavily upon gas turbines. In particular, Pratt & Whitney's (P&W) PurePower Geared Turbofan™ (GTF) engine is poised to transform the single-aisle commercial aviation segment by reducing fuel burn by 16%, particulate emissions by 50%, and noise footprint by 75% overall.

These benefits redefine the sustainability of a jet engine and are so significant that all of the world's single-aisle airliner manufacturers have either announced new aircraft featuring the engine or are re-engining existing models.

In addition to cleaner and greener gas turbine propulsion, aviation's sustainable future is also dependent on continued industry investment and government support of lower net carbon fuels, enhancements to air traffic control, and improvements to aircraft design.[10] One such improvement is UTC Aerospace Systems' Ecological Integrated Propulsion System, or ecoIPS™, which is designed to bundle engine, nacelle, and thrust-reverser technologies to improve fuel efficiency and reduce noise pollution.[11]

However, some of global aviation's best ideas for creating a sustainable future depend on important initiatives happening on the ground for their success. Efforts focused on green (or "carbon neutral") airports, including the support infrastructure for servicing aircraft and moving passengers efficiently, are vital to improved sustainability. So too are green aerospace factories, whose focus on more efficient operations, new production technologies, and green supply chains will make a substantial contribution to the industry's long-term sustainability.

United Technologies, through its business units Pratt & Whitney, UTC Aerospace Systems (UTAS), Otis Elevator (Otis), and UTC Climate, Controls & Security (CCS), is a leader in shaping aviation's sustainable future. Alongside Pratt & Whitney's groundbreaking GTF engine, and UTC Aerospace System's nacelle development work, the company is advancing a host of "on the ground" innovations designed to meet both the growth and sustainability needs of global aviation over the next generation.

Efforts focused on green (or "carbon neutral") airports, including the support infrastructure for servicing aircraft and moving passengers efficiently, are vital to improved sustainability

IN BRIEF

- While steady progress is being made in reducing global aircraft emissions, the aviation industry must also emphasize efforts being made "on the ground" to meet its aggressive long-term sustainability goals.
- Green airports are an essential component of long-term success. A focus on becoming "carbon neutral" has ripple effects in greening transport systems and buildings, and improving the quality of life in nearby communities.
- Aerospace manufacturing and supply chain is where green aviation begins, and will also play a critical role in sustainable aviation.
- Just as investment in alternative fuels is important to long-term aircraft sustainability, investment in leading-edge technologies "on the ground," from additive manufacturing to nanomaterials, is essential to the industry's success in creating a sustainable future.

Growing and Greening Airports

Twenty-first century airports are racing to meet the needs of the flying public. New demand is global, but especially high in the Middle East, both as a destination and convenient connection for international flights, and in Asia, where the middle class is growing fastest.

In Qatar, for example, Hamad International Airport opened in 2014, crossed the 30 million passenger mark just two years later, and is now being expanded to accommodate 53 million passengers annually by 2020.[12] Abu Dhabi's International Airport is increasing annual passenger capacity from 23 million to 45 million passengers, which is helping attract new business and tourism.[13] And Dubai International, already among the world's busiest airports with 75 million annual passengers, recently put the finishing touches on a new, $1.2 billion Concourse D that will expand annual passenger capacity at the airport to 90 million.[14]

A large airport consumes as much electricity and thermal energy annually as a city of 100,000 people, with up to 50 percent of that energy used by the airport's heating, ventilating, and air conditioning systems.[15] Ensuring that these systems provide comfortable environments while being highly efficient is vital to the greening of airports around the world.

A large airport consumes as much electricity and thermal energy annually as a city of 100,000 people

Hong Kong International Airport (HKIA) is a leader in meeting enormous passenger growth in a sustainable way. In 2012, airport leadership announced its desire to be the "World's Greenest Airport,"[16] leading to a benchmarking study of 23 other hub-sized airports followed by development of environmental initiatives around carbon reduction, energy savings, air quality improvement, and waste management enhancements.[17] "The underlying objectives go beyond cost reduction and resource efficiency," HKIA's most recent sustainability report noted, "to securing the airport's social license to operate — the public's acceptance and approval of the airport's operation and development."[18] Efforts between 2010 and 2015 resulted in airport-wide reductions in carbon emissions of 25.6 percent per workload unit from a 2008 baseline. An additional reduction of 10 percent between 2015 and 2020[19] will be challenged by forecast growth in passengers from 68.5 million in 2015[20] to 102 million passengers annually by 2030,[21] including construction of a third runway and new terminal.

United Technologies has been a partner to HKIA since the airport opened in 1998, providing energy-efficient solutions and intelligent facilities management systems. UTC's Carrier was chosen as the facility's major HVAC systems supplier, including installations in Passenger Terminal 1, Cathay Pacific facilities and air cargo terminal, the Regal Airport Hotel, Hong Kong SkyCity Marriott Hotel, Hong Kong Aircraft Engineering, and the Midfield Concourse, opened in December 2015. UTC's Chubb services 3,000+ access control card readers at the Hong Kong International Airport. These, along with more than 2,000 cameras to protect facilities and passengers, enhance mobility throughout the airport. Chubb also provides fire safety maintenance services for the terminal and facility buildings.

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Mobility and Green Transport

"Green Transport" is a term used to describe a transportation network designed to minimize its energy use and carbon footprint.[22] A focus on green transport can be especially valuable to airports facing passenger growth but constrained geographically by farmland or housing.

China is a leader in adopting green transport measures, especially important as its middle class booms and total airports grow from 182 in 2014 to a forecast 300 by 2030.[23] Mobility in airports is a multidimensional challenge that involves both horizontal — traditional autos and mass transit — and vertical mobility. No company understands vertical mobility better than Otis Elevator, the world's leading manufacturer and maintainer of people-moving products, including elevators, escalators, and moving walkways. Otis moves the equivalent of the world's population every three days, including people-moving in airports.[24]

A focus on green transport can be especially valuable to airports facing passenger growth but constrained geographically by farmland or housing

The revolutionary Gen2® elevator, combined with a ReGen™ drive, can reduce the elevator's energy consumption by up to 75 percent compared to conventional systems with non-regenerative drive under normal operating conditions. It does this by turning gravity offered by the elevator's descent into energy to power the building systems.

Otis has major projects with Chengdu Metro, supplying 82 elevators and escalators to help connect passengers between Chengdu Shuangliu International Airport and the city center. In Wuhan, Otis will supply 87 elevators and escalators to the new Wuhan Metro Airport Line.[25] And in June 2016, Otis equipped the new Shenzhen Metro Line 11 with 63 Otis Gen2 elevators, helping connect the central business districts of Futian and Nanshan to the Shenzhen International Airport.[26]

These enhancements to vertical mobility mean that commercial air passengers get to their gate on time while the airport reduces energy consumption and greenhouse gas emissions.

Greening Mature Airports

In Europe, the Airports Council International Airport Carbon Accreditation Programme was launched in 2009 and has since expanded into other regions. It focuses on neutralizing airports' carbon footprint by evaluating participants in the areas of mapping, reduction, optimization, and neutrality. Currently 157 airports around the world have been accredited. From 2009 to 2013, European airports' reduction in carbon dioxide (CO_2) totaled 1.7 million metric tons.[27] Gains have come from a variety of projects, including solar electric installations, new electric ground vehicles, and LED lighting.[28]

Heathrow Airport in the suburbs of London is one example of efforts being made "on the ground" in Europe to reduce aerospace's carbon footprint. Already the third busiest airport in the world, Heathrow expects annual passengers to quadruple to 320 million by 2030.[29] "Responsible Heathrow 2020" is a program that targets 70 percent of airport waste to be recycled by 2020, a 5 percent reduction in ground-based nitrogen oxides (NOx) emissions from 2008-9 to 2020, and a 34 percent reduction in CO_2 emissions from energy used in buildings (1990) by 2020.[30] The airport has aggressively embraced green transport as well, encouraging more than 40 percent of passengers and employees to use public transportation, and another 2,300 employees to bicycle to work.[31]

Other ground-based improvements in Europe include "Mobility Concept 2020," an effort by Hamburg Airport, to switch at least 50 percent of its entire airport vehicle fleet to alternative energy sources by 2020.[32] A sustainability program developed by Swedavia, the state-owned company that operates 10 airports in Sweden, targets zero emissions and hopes to be carbon neutral by 2020. This will involve modernizing its vehicle fleet and increasing its use of renewable fuels and synthetic diesel.[33] At Paris's Orly Airport, geothermal power is being used to heat terminal buildings with renewable energy; in 2014, geothermal was responsible for producing 23 percent of the total energy needs of the airport.[34]

From 2009 to 2013, European airports' reduction in carbon dioxide (CO_2) totaled 1.7 million metric tons

In September 2016, Delhi's IGI Airport became the first carbon neutral airport in the Asia-Pacific, a milestone that included achieving LEED® Gold in its Terminal 3, implementing fixed electric ground power units, and the establishment of a solar power plant. These measures resulted in a 51 percent reduction in specific greenhouse gas emissions over five years.[35]

In October 2016, Dallas/Fort Worth International Airport (DFW) became the first airport in North America, and one of only 26 in the world, to achieve carbon neutral status

In the United States, ground-based sustainability is a priority. San Francisco Airport (SFO) has adopted a series of "Big Hairy Audacious Goals" to guide its sustainability efforts. In 2015, the airport achieved a 38 percent reduction in greenhouse gas emissions from 1990 levels. By 2021, SFO aims to achieve "Zero Greenhouse Gas emissions, Zero Solid Waste, and Zero Net Energy Consumption." Initiatives include the construction of zero net energy buildings, maximizing the use of treated water for meeting non-potable water demands, and embracing a role as an intermodal transportation hub by "encouraging connections among planes, trains, automobiles, waterborne, and human-powered transportation." SFO plans to educate, engage with, and influence its entire ecosystem about sustainability, and has committed that it "will champion health and wellness for employees and passengers in its facilities and operations."[36]

Charlotte Douglas International Airport (CLT) has focused on another important ground-based initiative designed to improve airport sustainability. A new airspace technology demonstration lab is helping to streamline the arrival and departure of aircraft, reducing congestion and fuel use by coordinating schedules between the ramp, tower, terminal, and center control facilities.[37] Alaska Airlines and Seattle-Tacoma International Airport have addressed sustainability in yet another way, replacing fossil-fuel-powered ground vehicles with electric. This involved the installation of an electric charging infrastructure that offered 98 percent carbon-free electricity.[38]

In October 2016, Dallas/Fort Worth International Airport (DFW) became the first airport in North America, and one of only 26 in the world, to achieve carbon neutral status.[39] This included a combination of reduced carbon emissions with renewable energy certificates and carbon offsets from emissions reduction projects at Texas landfills and wastewater treatment plants.

On the Ground: NORESCO

One of the largest energy services companies in the United States, NORESCO is a part of UTC Climate, Controls & Security, a unit of United Technologies Corporation. The company specializes in the development, design, construction, financing, and operation of energy and environmental efficiency projects. It also offers a full suite

of consulting services to integrate sustainable design strategies into new construction and existing buildings. NORESCO has guaranteed more than $3 billion in energy and operating cost savings at more than 7,000 facilities throughout the United States and abroad. Some of its most groundbreaking work has furthered airport sustainability.

In 2014, NORESCO provided project management during the design and construction phases for Terminal 2 West at San Diego International Airport (SDIA), helping SDIA became the first commercial airport in the world to achieve LEED® Platinum certification from the U.S. Green Building Council®. Performance enhancements in the expanded terminal included high-performance glazing, on-site solar power, low-flow fixtures for water conservation, and the diversion of more than 90 percent of construction waste from landfills.[40]

Some of NORESCO's most groundbreaking work has furthered airport sustainability

NORESCO was also a key player in one of the largest public works projects in Los Angeles' history, an extensive modernization of the Tom Bradley International Terminal at the Los Angeles International Airport (LAX). The new facility was designed to replace an older terminal and to accommodate larger planes like the Airbus A380, which can be loaded and unloaded on two levels for quicker turnaround. As project sustainability consultants and energy analysts, NORESCO helped to manage and coordinate the LEED® application and submittal process, and evaluated the design for energy efficiency through the energy modeling process.

"Energy conservation and efficiency are core to how we approach sustainability," says senior sustainability consultant Kristen Salinas. "When it comes to achieving LEED® certification, we are the entity that's squeezing every last ounce of energy efficiency out of the design and pushing for strategic operational and design measures that make a difference for employees and passengers. We draw upon our deep experience across multiple building sectors to provide feedback to teams about how spaces will function over time, and how to incorporate sustainability strategies that meet the ongoing needs of building occupants."[41]

NORESCO's work on the International Terminal project included studies designed to reduce glare for gate agents and examine the use of recycled, regional, or environmentally sustainable materials with low or no volatile organic compounds. The company also undertook process-load calculations for the baggage handling system. "We performed several iterations of energy modeling for LAX. It was a huge project, 1.25 million square feet," she adds. "Los Angeles World Airports calls it the 'crown jewel' of the airport. It's a beautiful space, really like you're in a different place. And because it's an international terminal, the design takes its cues from places all over the world."

This multiyear project resulted in substantial reductions in the use of energy and potable water while creating a striking showcase for arriving international passengers. “Tom Bradley International Terminal at LAX was a landmark project and there were a lot of eyes on it,” Salinas adds. “We really set a precedent for what can be done in terms of scaling sustainability at the highest levels, and how it can be executed from the start. The terminal earned LEED® Gold, the largest commercial airport terminal in the world to achieve that.[42] The Tom Bradley International Terminal is one of the industry leaders for airport sustainability.”

NORESCO’s work also extends to the Federal Aviation Administration (FAA). In 2015, the FAA showcased new renewable energy and water efficiency improvements at its Northern California Terminal Radar Approach Control (TRACON), the third busiest TRACON in the United States. This NORESCO project featured lighting and control upgrades, water conservation through innovative xeriscape landscaping that uses little to no water and requires almost no maintenance, locally recycled tire rubber for hardscape, and a 1-megawatt solar photovoltaic system designed to meet 50 percent of the center’s annual electricity needs. A portion of this power is produced from photovoltaic-covered parking structures, which also provide charging stations for electric vehicles. The site is expected to save $9.3 million over 20 years, reducing water and energy usage by 40 percent, and reducing greenhouse gas emissions by 46 percent.[43]

On the Ground: United Technologies

Green aviation begins long before an airplane ever lifts off from an airport, usually in one of the industry’s green manufacturing facilities

The drive for sustainable aviation can be focused “in the air” with improved engines, aircraft designs, and alternative fuels. It can also be focused “on the ground” as airports work to become carbon neutral. But green aviation begins long before an airplane ever lifts off from an airport, usually in one of the industry’s green manufacturing facilities. Civil aerospace supports 1.1 million workers, more than twice those who work directly in airport operations.[44] The commitment to sustainability of these engineers and office and factory workers — both the kinds of products they make and the ways in which they make them — can have a meaningful impact on the overall sustainability of general aviation. This is illustrated by the progress being made at industry leader United Technologies Corporation (UTC).

Because of its size, capabilities, and global footprint, UTC is uniquely positioned as a corporate leader to drive aviation sustainability. The company believes that "Green Aviation Starts Here," and since 1997, despite a tripling in business size, UTC has reduced greenhouse gases 34 percent and water consumption 57 percent through facility and manufacturing operations improvements at UTC facilities, all with pay-backs that made good business sense. Every five years the company re-establishes aggressive new sustainability goals for greenhouse gases, water consumption, solvent air emissions, recycled waste, hazardous waste, and hazardous substance use, among others. These goals are approved by the board of directors and have the highest level of engagement and support among senior managers.

"We don't normalize our results by hours or revenue," explains Lisa Szewczul, who served as United Technologies' first director of Environment, Health & Safety (EH&S) from 1988 to 1991, and is today vice president of EH&S for Pratt & Whitney. "We have a footprint—and we go by the absolute footprint. In other words, at P&W we expect our waste, greenhouse gas emissions, and water usage to decline despite our current forecast ramp in the Geared Turbofan™ business. We're expecting to double production by 2020, and double again by 2027. But over that period, we also expect our absolute footprint will be lower. We pursue big goals," she adds, "and we're public about it. It's not easy, but this is how we establish leadership."[45]

In 2015, UTC extended sustainability into its supply chain. The company has requirements for suppliers to achieve "Supplier Gold" status, which, if met, allows vendors and partners to be eligible for improved commercial terms. Achieving Supplier Gold also contains requirements around sustainability — which means these suppliers would have a sustainability program that looks and works like UTC's in terms of improving water efficiency, energy efficiency, and other board-level policies. Because some 80 percent of UTC's products are supplied by vendors, extending sustainability throughout its supplier ecosystem is critical.

In 2015, UTC extended sustainability into its supply chain

"In many instances, our footprint is only as good as what our suppliers can do," Szewczul says. "So we're real partners with our supply chain, and we try to help them do the right thing as well. Within our Supplier Gold program, for example, we've added questions that get to ethics, environmental metrics, social compliance — and not just compliance, but questions like 'Do you give your employees an opportunity to volunteer,' and 'How do you interact with your community?' So we're showing leadership — we're not just saying we're a leader."

Within UTC, goals set at the corporate level flow down to each business unit. These provide the framework to drive specific projects within and across manufacturing facilities.

"When five-year goals are set by UTC," Szewczul adds, "it's a collaborative process. But we never have the pathway figured out in advance. We rely on the creativity of our people and their commitment, and the commitment of senior management. Once you get through the low-hanging fruit, the kinds of facilities improvement where you change out light bulbs," she says, "it becomes more and more challenging. It's necessary to look at changing out chemicals, at major facilities improvements, and process changes. And there's a lot of conversation in the field about what can and what should be done. There's always a stretch element too — at Pratt & Whitney, for example, we want to do more with renewables, whether it's with solar or wind or electric vehicles. So it's really a lot of flow down, and flow up, and once we have agreement, it all flows across to employees, contractors, and suppliers."

Hazardous waste presents a special kind of problem, and opportunity, for UTC. "At one of P&W Canada's facilities in Poland," Szewczul says, "their largest waste stream was potassium hydroxide, a caustic. The facility used cross-functional teams and came up with a cross-flow filtration technology, a way to purify and then reuse the caustic. This reduced cost and improved product quality. This is just one example of how we go about achieving our strategic sustainability goals. It truly is a team effort."

UTC Aerospace Systems (UTAS) provides another good example of how this effort works. With over 40,000 employees operating in 150 locations across 26 countries, UTAS is one of the world's largest suppliers of advanced aerospace and defense products for business, military, and international customers. The goal of UTAS is to be the safest, healthiest aerospace company with the smallest environmental footprint on the planet.[46] This means that every facility around the world identifies opportunities to improve sustainability based on the UTC framework. Once identified, projects are created, launched, and tracked through to completion.

In 2015, UTAS set a goal to reduce water consumption by 41 million gallons

Results to date are impressive. Since 2006, UTAS has reduced greenhouse gas emissions by 20 percent, water consumption by 16 percent, air emissions by 46 percent, and industrial process waste by 26 percent.[47]

In 2015, UTAS set a goal to reduce water consumption by 41 million gallons. This is especially important because 39 of the unit's sites are located in water scarce regions. One, Chula Vista, is in California, a state experiencing its fifth year of drought. Headquarters of the unit's Aerostructures business, the Chula Vista facility removed 51,000 square feet of lawn and replaced it with water-smart plants and a walkway of decomposed granite. The expected water savings at this site alone is around 2 million gallons per year.[48] In November 2015, UTAS hosted its first Sustainability Symposium on water conservation at the unit's Santa Fe Springs, California, facility to discuss best practices and incentives with local businesses and government.

The UTAS site in Dijon, France, installed a rainwater tank to collect water for use in sanitary equipment, reducing consumption by 10 percent. "Water conservation is a challenge for many businesses, including those within our company," said Jean-Philippe Verhelle, general manager of the Dijon facility. "We are sharing our insights to help our businesses install similar tanks to save even more water." A number of UTAS sites are evaluating this process for their facilities, and a site in Bangalore, India, now recycles 100 percent of its water through an on-site treatment facility and rainwater collection.[49]

Efforts to improve both water and energy conservation are continuous. To date, UTAS has completed 112 projects with low-flow fixtures, 111 projects focused on process wastewater recycling, 50 cooling tower management projects, and 68 “zeroscaping” initiatives. In addition, 270 lighting efficiency, 241 compressed air leak management, and 145 HVAC efficiency improvement projects have contributed significantly to reductions in energy usage.

Efforts to improve both water and energy conservation are continuous

In May 2016, the UTAS facility in Riverside, California, became the first recipient of the City of Riverside's Green Business award under the Green Business California program. The Riverside facility produces composite bond components for the world's newest airplane platforms, such as the Airbus A350 XWB and A320neo, the Boeing 787 Dreamliner, Bombardier CSeries, the Mitsubishi Regional Jet and the Embraer E2. In order to be recognized, the Riverside facility needed to meet an extensive list of criteria for environmental focus and resource reduction. Among the projects that helped earn the award was a system for recycling rinse water used in chemical process lines. The recycling system saves 1.2 million gallons of water per month. Since its inception, the site has saved more than 215 million gallons of water through its use. The Riverside facility has also begun softening the water used in six cooling towers, which reduces mineral buildup and enables the towers' holding tanks to be flushed and refilled less often. That change is expected to save about 4 million gallons of water per year. Other measures include the introduction of LED lighting where possible and replacing toilets with high-efficiency ones.[50]

Another UTAS project, this one focused on greenhouse gas reduction, included newly installed solar panels at the unit’s Singapore site. These panels are expected to reduce greenhouse gas emissions on the island by over 2,000 metric tons annually – the equivalent of 2.2 million pounds of coal burned.[51]

Sustainability also happens in the community outside UTAS and P&W in a way that impacts both present and future. Lisa Szewczul notes, "I chair the Industry Advisory Board of the Academy of Engineering & Green Technology," an institution that educates high school students in Hartford, Connecticut, in engineering principles.[52] "Pratt & Whitney, United Technologies Aerospace Systems — our people work with these students and it goes beyond robotics. We just built a windmill to generate power for a little village in Nepal. This is outreach, all under the umbrella of sustainability. It's outside the four walls of our facilities," Szewczul concludes, "but it's an important part of our mission. These students are future engineers who are going to be thinking more sustainably when they enter the workforce."[53]

Green Technology: Materials and Process Engineering

Additive manufacturing can produce an overall component much faster, and at a lower cost

UTAS is involved in aircraft manufacture from nose to tail, including electrical systems, air conditioning systems, landing gear, brakes, sensors, cockpit equipment, and flight-attendant seats. UTAS also makes the nacelles for a number of large aircraft engine manufacturers. Recently, the company opened its Materials and Process Engineering (MPE) laboratory, a 20,000-square-foot facility in Windsor Locks, Connecticut. MPE was created to support UTAS business units around the world by developing advanced materials and advanced manufacturing technologies. MPE works with technologies that involve high-temperature materials, ceramics, metals, composites, and multilayer coatings for corrosion and wear resistance.[54] When UTC says that "Green Aviation Starts Here," MPE is a shining example.

One focus of the lab is **additive manufacturing**, sometimes called 3D printing, with an emphasis on transitioning new manufacturing techniques into UTAS's core business. Additive manufacturing can produce an overall component much faster, and at a lower cost. "If you look at some of the more complex parts, like fuel injectors and nozzles, we have anywhere from 12 to 18 piece-parts that are individually brazed and welded together," explains Venkat Vedula, director of MPE. "With additive manufacturing, we're able to produce the part in one operation. We can eliminate a number of energy-intensive and complex chemical processes like brazing and welding, contributing to the overall sustainability of the new process."

Another key benefit of additive manufacturing is a reduction in material intensity, a metric that measures how much starting material is required to make a final part. A conventional process might start with a forging that is then machined, resulting in a final "buy-to-fly" ratio as high as 10 — a 10-pound block yielding a one-pound part, a waste of 90 percent. "With additive manufacturing, you can achieve a buy-to-fly ratio of one," Vedula says. "This material savings is another component of sustainability."

Additive manufacturing can also have a significant impact on aircraft repair. "Today, you might have an aircraft on the ground in Europe or Asia with the primary manufacturing facility in the U.S.," explains Vedula. "Imagine having additive-repair machines at different MRO sites all over the world. When you need a particular part, it would be made then and there — closest to where it was required." This has the potential to reduce the delivery of parts from weeks to days, and eliminate the time and cost of shipping. "We're able to build a part — with quality standards and an approved process," Vedula adds, "where we need it. And we can eliminate inventory when we are able to build parts quickly. That's our vision. We have a ways to go to realize the full potential of this technology."

MPE also focuses on the development of advanced **high-temperature composites**, like those found in carbon brakes. Carbon composites are about one-third the weight of steel brakes, and on a commercial aircraft like a 747, the use of carbon brakes results in 1,400 to 1,500 pounds of weight savings. Carbon brakes are produced using chemical vapor infiltration (CVI), where reactive gas decomposes on a porous preform to yield a fully dense product. CVI process is very energy-intensive, and the typical manufacturing process time exceeds 1,000 hours. MPE, through fundamental physics-based modeling, has been able to bring this manufacturing time down to a few hundred hours. "That's an example," Vedula says, "of how we're improving production sustainability. We can enhance the performance of the brakes and the sustainability of the aircraft while reducing the overall time and energy required for manufacturing."

A third major focus of MPE is **nanotechnology**, with a fully dedicated lab for research on nanomaterials. One of the applications of this technology also involves aircraft brakes. For instance, at about 600 degrees Fahrenheit, carbon begins to oxidize, significantly reducing the life of the brakes. MPE is developing advanced coating systems that ensure greater resistance to everything from these extreme temperatures to deicer fluids, ice, and water.

The fuselage and components of modern aircraft like the 787 and A350 are 50 percent to 55 percent composite by weight, and more than 70 percent by

volume. “The opportunity for a company like UTAS is for additional advances at the component level — how can we reduce weight,” Venkat says. Less weight means less energy to fly the airplane. There is significant activity going on now in terms of metals to composites, and related work going on with smart materials. “For example,” Venkat asks, “how do we know when a composite part has formed a defect? We are looking at ways to incorporate sensors into the composite manufacturing process to do more diagnostics and address critical defects.”

Nanotechnology has many applications — most still in the early stages — everything from lightning-strike protection to corrosion protection. Being able to incorporate composite materials in these traditional processes will result in both weight reduction and better performance.

Ground Support: A Positive Ripple Effect

Passenger demand is on a steady rise. The challenge of meeting the new ICAO regulations of capping carbon emissions in 2020 and reducing them by 2050 to half of the industry’s 2005 levels will require creativity and a concerted effort by the entire aviation industry. Focus must continue on reducing aircraft emissions in flight. But achieving sustainable commercial air travel is also a function of what happens on the ground, at airports and in manufacturing locations. These earthbound efforts often have positive ripple effects, greening transport systems, buildings, and supply chains, and improving communities where aviation players are located. In fact, “ground support” for aviation can have an impact well beyond reducing greenhouse gas, on other components of sustainability like water consumption and hazardous materials. New technologies such as additive manufacturing and nanomaterials have the potential longer-term to transform the aviation industry in ways we cannot yet anticipate.

Healthy urbanization and a strong global economy require that aviation grow rapidly and sustainably. Michael Gill, executive director of the Air Transport Action Group, recently addressed the issue, writing, “Here, then, is the delicate line between two responsibilities that the industry treads: the responsibility to protect the environment and the responsibility to help the global community enjoy growth and prosperity and create opportunity. No one said it would be easy,” Gill concluded, “but it is possible.”[55]

Our chances improve dramatically if we support ground-based measures as a vital component in aviation’s sustainable future.

[1] "Aviation Benefits Beyond Borders," Air Transport Action Group, April 2014, Web October 13, 2016, http://aviationbenefits.org/media/26786/ATAG__AviationBenefits2014_FULL_LowRes.pdf, 4.

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