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UTC Brings Startup Approach To Electrification Of Regional Aircraft

By Graham Warwick

United Technologies Corp. (UTC) is undergoing its biggest transformation since it was formed, as United Aircraft, by the breakup of Boeing and Pratt & Whitney in 1934. As it prepares to be reborn in 2020 as a focused, $50 billion aerospace supplier, UTC is taking a hard look at its role in enabling the future of aviation.

As a first tangible step, UTC has created a Skunk Works-like organization, United Technologies Advanced Projects (UTAP), to take on disruptive ideas that bring its business units together. The first of these, Project 804, involves modifying a Bombardier Dash 8 Q100 regional turboprop into a 2-megawatt hybrid-electric propulsion X-plane that will fly in 2022.

Project 804 will fly a hybrid-electric Dash 8 X-plane in 2022
The Grid will test 1-megawatt, 1-kilovolt electrical system

The first task for The Grid lab at Collins Aerospace will be to help develop the hybrid-electric system. Credit: Collins Aerospace

At the same time, UTC's Collins Aerospace—formed in November 2018 by the merger of UTC Aerospace Systems and newly acquired Rockwell Collins—has unveiled a $50 million investment in a multimegawatt aircraft electrification and electric propulsion laboratory in Rockford, Illinois. Called The Grid, the lab's first task will be to support development of Project 804.

UTC plans to spin off its Carrier and Otis businesses in 2020, emerging as an integrated aerospace supplier comprising Collins Aerospace and Pratt & Whitney. "This is an important time in the company's history," says Paul Eremenko, UTC chief technology officer. "With the standup of Collins and the spinoff of the businesses, we are reshaping the company into something fundamentally new. And an important part of that is having a 'Skunk Works' organization to more rapidly mature bundles of technology."

The legacy UTC, as a holding company, had no mechanism to do things that required the integration of multiple product lines. "So as we began this transformation toward becoming a more focused, more integrated aerospace company, we started architecting some of these mechanisms for how we do things that are outside of existing business verticals," says Eremenko.

UTAP is one of those. Set up to operate at the speed of a startup, UTAP will take on projects that meet one of two criteria. "It has to be the kind of thing you can't do in a business unit for one of two reasons: either because it requires multiple business units to work together, or it's too disruptive in nature to the existing product portfolio or the existing way of doing things," he says. "Hybrid-electric propulsion meets both of the criteria."

Project 804 is the first to be launched by UTAP because "the most pressing, most obvious need is for UTC to lead in the elec-

trification of propulsion," Eremenko says. The project's name comes from the straight-line distance in miles between the two units involved: Pratt & Whitney Canada (P&WC) in Longueuil, Quebec, and Collins in Rockford. United Technologies Research Center is also participating.

Aircraft electrification is one of four strategic technology focus areas for the new UTC. The others are autonomy, connected aircraft and the connected ecosystem around the aircraft, and advanced design and manufacturing. All four build on existing strengths within UTC. For aircraft electrification, those comprise turbine engines at Pratt and electrical systems at Collins, where they developed the Boeing 787 power system.

The hybrid-electric propulsion project brings the two business units together and provides a startup-like environment in which to develop a demonstrator at convincing scale. "UTAP can move at the speed of a startup, but do it at the heart of the business," Eremenko says.

The hybrid system will comprise a 1-megawatt turbine engine and 1-megawatt electric motor driving the propeller, with batteries under the cabin. Credit: UTC

"One of the constraints on UTAP is that we don't want the demonstrators to run for longer than about 2-3 years and in that time they have to produce something that is productizable," he says. "That means it has retired all the major risks. It doesn't mean that it can be turned into a product overnight. UTAP doesn't make products. But it also doesn't just make technology prototypes."

Under Project 804, a Dash 8 will be reengined—on one side only for safety—with a 2-megawatt parallel-hybrid propulsion system that comprises a 1-megawatt gas turbine and 1-megawatt electric motor. The flight demonstrator will act as both a "technology pull" and an integration platform for UTC.

"One megawatt on the electrical side is hard enough to pull technology versus the 250-500 kW we have today. But 1 megawatt is doable in a couple of years in a certifiable way," says Eremenko. "What 804 does differently is it creates something that can be produced and makes sense for regional airlines."

The 39-passenger Dash 8 Q100 is powered by P&WC's PW121 turboprop, rated at 2,150 shp (1.6 megawatts) for takeoff. In the hybrid system, this is replaced by a new 1-megawatt turbine engine under development by P&WC. This turbine, or "thermal," engine drives a gearbox that powers the propeller.

The 1-megawatt electric motor, powered by batteries installed under the cabin floor, drives the same gearbox. For takeoff and climb, both the thermal engine and electric motor drive the propeller. In cruise, only the thermal engine is used. On descent, the motor operates as a generator, and excess thermal-engine power is used to recharge the batteries to ensure sufficient energy is available for a go-around.

By downsizing the turbine engine, and enabling it to operate at a constant, optimal full-power setting from takeoff through the cruise, UTAP expects fuel savings of about 30% over a 1-hr., 200-250-nm flight. There is a penalty from the extra weight of the hybrid system and lower energy density of batteries versus jet fuel. Empty weight is increased and fuel capacity is reduced by about 50%, cutting range to 600 nm from 1,000 nm. "We shave a little bit off the maximum range, but it is never used," says Eremenko.

Hybridization is suited to short commuter flights where aircraft spend a lot of time in climb and descent, he says. "With a 1-megawatt electric system we can downsize the thermal engine and get a significant efficiency improvement. The economic case closes, and we can productionize it in a relatively small number of years. This is a technology and a product demonstration," Eremenko says. "It delivers something that has looked at the major regulatory risks, the market opportunity, the business model and retired the top risk in each of those areas."

A key part of Project 804 is the safety of the hybrid-electric propulsion system. "We're looking carefully at the safety if this or that component fails and are thinking through how the electrical system would be certified. And to the extent that certification bias does exist, we want to work with the regulators to help develop it." UTAP will not certify the system, but by the time Project 804 is finished, certification will not be high-risk, he believes.

Project 804 not only opens up the possibility of a hybrid-electric product for the regional market in the near term, it also lays the foundation for other avenues of aircraft electrification. "A key role for UTAP is to provide a technology pull. We wanted to develop 1-megawatt, 1-kilovolt-class electrical components, so we explored the set of possible concepts we could fly and identified this one as having a potential commercial off-

ramp," says Eremenko.

"It was an opportunistic play, and if it works, we will certainly explore this regional market. But we also get this technology pull so that we master this megawatt-class category of components, and we can move on from that," he says. "It's a hedge because I think it is not clear which way the industry is going to go in the longer term. But the fundamental technology base we are developing is applicable to pretty much any one of those futures."

Pratt has said that megawatt-level power is an enabler for different types of propulsion electrification, from boosting a turbofan by bolting a motor to its shaft, powering a tail thruster for drag-reducing boundary layer ingestion or driving multiple smaller fans for distributed propulsion. "Megawatt [scale] opens up all those possible architectures," says Eremenko.

Collins was already moving to multi-megawatt electrical systems before the project was launched. "What 804 is doing is driving a time line and an impetus to do it quickly, and providing a concrete set of system-level set of requirements," says Eremenko. "It was clear from the perspective of our Power & Controls business that we need to improve power density and move up power levels. Project 804 provides an additional pull: an early application of actually integrating the components onto an aircraft and flying."

Part of a larger, $150 million investment Collins expects to make in electric systems over the next three years, The Grid builds on $3 billion the company says it has spent over the past decade advancing more electric architectures for aircraft. The 25,000-ft.^{2} lab incorporates lessons from the Airplane Power Systems Integration Facility, where the 787's 1.5-megawatt electric system was tested.

"Some key investments we had made a little more than 15 years ago got us ready for the first phase of aircraft electrification, like the 787 and military platforms that use high-voltage DC and electro-hydrostatic flight controls like the [Lockheed Martin] F-35," says Tim White, head of Collins' Power & Controls division. "What was key during that phase was early investment we had made in lab capability."

The Power & Controls business was formed before Collins Aerospace was created in November, bringing together the electric power, thermal management and engine controls groups "because we see those discipline areas as being critical to the next phase of aircraft electrification . . . as we look at electric propulsion integrating those electrical and thermal aspects with the engine controls," White says.

"We wanted this lab to be modular and scalable to test multi-megawatt capability, extremely high voltages and be able to test and validate not only the power and loads but integrate them and inject faults," says White. "It's important that we can be flexible and able to test various sources of power, whether it's aircraft generators or battery systems, and couple those with high-demand users of that power, whether it is an electrically driven environmental control system or a motor with simulated loads for electric propulsion."

The 1-megawatt motor for Project 804 will be the aerospace industry's most power-dense and efficient, Collins says. "Just as important, we have to think about the control and protection of that amount of power as it gets integrated into an air vehicle at altitude," White says. "The way we have designed the lab will allow us to collect data and inject faults into the electrical network, and design the algorithms and distribution system to be able to detect a fault condition and repair it, to make sure we're not putting a significant amount of power into a short circuit."

Construction of The Grid will begin by laying in the power generation capability at the megawatt level, which White says involves making the right connections between the local utilities and the lab. "Then we have the machinery component which is consuming that power, the rotative capability such as dynamometers, and then the power supplies that allow us to vary the voltage," he says.

"After we put in those foundational elements that allow us to disburse the power from the utilities, the infrastructure to distribute that within the building, and the power supplies that can set the voltages at the kilovolt level, [then we can] start component-level testing," he says. Collins will then build out the lab with multiple channels, duplicating the initial setup so it can test systems with four or more channels. "We will have the full modular capability and multiple channels that we envision in 2021," White says.

Skepticism abounds over electric propulsion, but White believes UTAP is aiming at the right spot with Project 804. "The industry expectation is that every new generation of propulsion will provide a double-digit performance improvement," he says. "In the propulsion class that 804 is focused on, the math alone for the level of improvement with a hybrid-electric architecture would say it is worth pursuing."

UTAP and Project 804 are just some of the company's strategic changes. "We're a different UTC," says Eremenko. "We want to help the industry and our customers, including our military customers, think through the future and help shape that future as a partner, not just a supplier."