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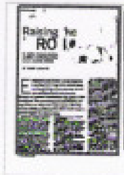

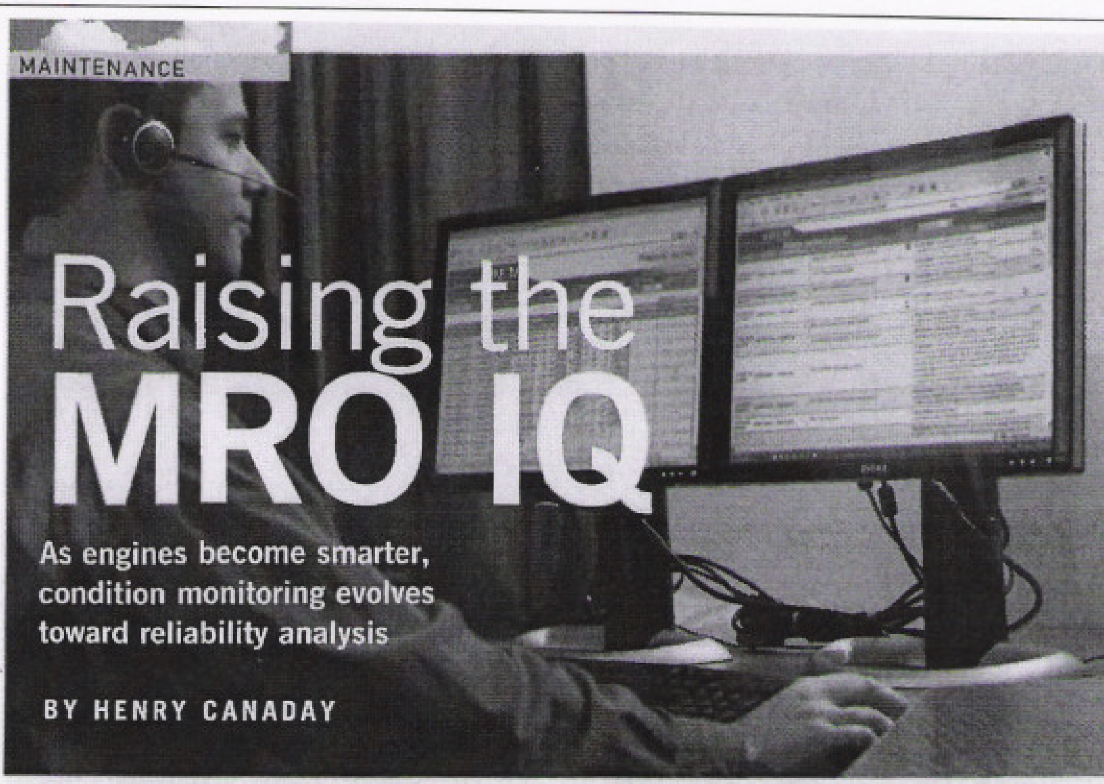

MAINTENANCE

Raising the MRO IQ

As engines become smarter, condition monitoring evolves toward reliability analysis

BY HENRY CANADAY

ENGINE CONDITION MONITORING is moving from diagnostics toward prognostics, pushing at least part way toward true condition-based maintenance. Sensors and systems have become very good at forecasting and thus preventing potential failures, saving money on delays and major repairs. But they cannot reliably predict success: How much longer a part or engine can stay on-wing.

Engines incur very large expenditures during off-wing overhauls, which happen for one three reasons. First, inspection can detect major damage to parts. Engine monitoring can trigger inspections and may prevent major damage. Second, performance can deteriorate. Monitoring continues to improve in tracking and predicting, and sometimes helping to prevent, deterioration, especially of exhaust gas temperature margins. The third reason is that conservatively calculated terms of life-limited parts are reached. Extending the term of LLPs to reflect actual usage more realistically is the next big and very difficult challenge that engine designers and monitors face.

Smarter maintenance will be possible as new airframes and engines are delivered in the next few years and better methods for getting data to the ground and interpreting it are developed. But progress in predicting part life will come only in the middle of the next decade as engines now on the drawing boards come into service.

Much progress already has been made. "On older engines there were maybe 20 variables available," notes Kim Smith, a technical specialist with Delta TechOps. "On the 777 there are over a hundred."

Rick Donaldson, manager-diagnostic and prognostics centers at GE Engine Services, says GE is working to expand sensor coverage further on future engines to monitor LRUs and detect mechanical problems with bearings, gears and airfoils. But additional sensors must meet tough economic criteria. Do added weight and cost bring commensurate value? "You have to bring a lot of benefit or make it very cheap to buy your way on," he says.

Donaldson calls the ultimate goal "use-based lifing." Analysts need much more data on severity of engine use and other factors, such as noise or vibrations, to make confident forecasts of how much longer an engine can fly before heavy overhaul. This would be true condition-based maintenance. "It requires the right sensors and other onboard systems, plus further progress in ground systems," he says. "By the time we get to the next generation of narrowbodies, 2015-ish, we should be long way down that road."

More engine variables and more complete coverage of flight phases are available on Rolls-Royce's Trent 900 for the A380, while the Trent 1000 on the 787 will have even more. The Trent 900 already collects five more parameters than the older RB211

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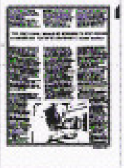

and 4-5 times as much total data, notes Mike Ward, who heads engine monitoring for Rolls' Data Systems & Solutions subsidiary.

The original JT8D reported just four main parameters. Newer Pratt & Whitney engines have added to this figure, including more temperatures and pressures on the gas path. Pratt now is seeking to collect more reliable data on filter pressures and monitor additional engine components, such as lubrication systems. Still further in the future is monitoring turbine top clearance and debris, according to Steve O'Flaherty, GM-service development for Pratt's global partners. These advances could come with the Geared Turbofan, expected to enter service on the Mitsubishi Regional Jet in 2013. O'Flaherty emphasizes that predicting engine life will require getting continuous engine data rather than "snapshots" as at present.

"The holy grail" of monitoring would be sensors to spot cracks in turbine blades, says David Bell, VP at independent monitoring firm SmartSignal. "But that is a long way off."

'THE HOLY GRAIL' WOULD BE SENSORS TO SPOT CRACKS IN TURBINE BLADES. "BUT THAT IS A LONG WAY OFF." — *David Bell, SmartSignal*

Getting Data To The Ground The best aircraft now send engine data to the ground via ACARS, a decades-old system that is limited in capacity and expensive to use. Many small fleets have not even had ACARS. AirTran Airways only recently began using it and some smaller operators still fax engine data to Pratt. ACARS has been a bottleneck. Engine data usually are sent to the ground in snapshots—during takeoff, climb and, every couple of hours, cruise. The bottleneck should be relieved in the next few years in several ways.

A380s delivered after mid-2008 will have a new avionics suite able to download more data. The 787 will have better systems and more bandwidth as well. Older aircraft would need expensive retrofits to match these capabilities, and this may not be economic except for planes like the 777, which will fly for a long time.

SITA has been working on satellite systems for collecting onboard data during flights and will be ready to receive and relay more engine data when the A380s are delivered. Future inflight connections chiefly will use Internet Protocol. GE is working on other solutions involving analyzing data onboard so systems can decide when important data must be sent to the ground rather than simply delivering analyzed data when planes land.

The onboard approach pleases Manfred Paul, who manages monitoring at Lufthansa Technik. "The big change will come with the GEnx on the 747-8," he says. He expects GEnx to reduce LHT's troubleshooting and fault-isolation costs, which now run $2.60 per flight hr., by 40%. "A lot of faults are intermittent, cannot be repeated on the ground and are not covered well in manuals. This will put us in position to do it right the first time."

Both onboard analysis and airport downloads face hurdles. Onboard algorithms must be precise to prevent the frequent false positives that discourage line techs, and it is trickier to adjust systems on many airplanes than on a central system. Waiting until an aircraft lands for downloads may hamper the fast reaction that prevents AOG situations, and some airports have little wireless infrastructure for downloads. Even at hubs, Wi-Fi connections are close to saturation and transmit only a few hundred meters. SITA VP-Aircraft Communications Philip Clinch argues that the newer WiMax standard, which transmits 10Mbps at 10 km., would allow aircraft to begin downloading data before they reach gates.

Engine manufacturers increasingly collect engine data and report it to their customers over the Internet. OEMs get a global view of their products. Customers get highly sophisticated tools but still need non-OEM data on and a deep knowledge of their own engines. Monitoring provides two kinds of reports: Alerts to problems and analyses of performance trends, which help plan removal schedules.

GE monitors 15,650 engines for 250 operators. The GE system combines physics-based modeling of how engines should work with statistical analysis of how engines do work and when problems are likely.

Snecma Services monitors engines including EGT, fuel flow and vibrations using centralized CFM diagnostics. It aims to have 8,000 engines on the system by 2010-12. VP-Engineering Gerard Rebeyrol wants to customize the system more for individual engines.

Pratt's Advanced Diagnostics & Engine Management monitors 3,000 civil engines, about half of which belong to fleet-management cus-

GE Engine Services

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tomers. Data Systems & Solutions monitors more than 7,000 engines, mostly Rolls and IAE models, receiving 14,000 packets of engine data each day. Half these engines are under Rolls' Total Care contracts.

LHT began using GE's system for all its engines last summer. Employing different manufacturers' solutions was difficult for information specialists. Technik now takes a "fingerprint" for each model on GE's system during the first 10 takeoffs and retrieves this benchmark for later analysis. It supplements reports with the engine data that GE lacks. "We have the complete engine history available, time-on-wing and shop visits," Paul says.

Hawaiian Airlines uses Pratt's ADEM for the PW4060s on its 767s and Rolls software to monitor BR715s on its 717s. "Both report the same data in real time, but ADEM is quicker and easier to interpret," says Senior Engineering Director Yesso Tekerian. ADEM has been especially important in maintaining Hawaiian's ETOPS status.

Delta uses the independent SmartSignal to monitor the bulk of engines that it maintains in-house. Bell says SmartSignal is very good at modeling each engine individually and can be adjusted rapidly when new problems arise. And Delta did not want to run different software packages for engines made by four manufacturers. It does run GE software "in the background," Smith says. He notes that no manufacturer possesses all the engine data DL has.

Donaldson agrees that manufacturers lack critical operating data such as engine configurations, part numbers installed, service bulletins implemented and results of borescope inspections. GE field teams try to gather this information from operators. Electronic sharing of this critical data would be more efficient and improve recommendations to operators.

Avoiding Disruptions, Damage Dealing with alerts is crucial. Delta can send alerts out within 5 min. of receiving engine data. Serious warnings are e-mailed or sent to pagers of the engine analysts 24/7. Messages also go to the maintenance coordination center for troubleshooting decisions. The reaction process can divert aircraft to base stations, but that remedy has not been necessary yet.

For troubling events, Hawaiian gets performance data from ADEM for 10 sec. before and 10 sec. after each event. E-mails and pagers alert the right engine specialist. Trend data help schedule engine washes and pick up malfunctions, such as dislodgement of O-ring spinners on the PW4060.

OEM systems work similarly. GE sends customer notice reports for non-urgent events such as fan vibrations and EGT problems. Indicators of potentially costly failures, such as turbine distress and stator vane defaults, prompt an urgent CNR. Airline staff, who have all the data available, make the final decision whether to inspect or investigate.

About 30% of the alerts LHT receives from its GE system require maintenance actions. "The more experience you have, the better you get at deciding if action is needed," Paul says. Alerts can save the cost of repairing secondary damage from a small problem that is not remedied promptly and avoid losses from service disruptions. Paul estimates a couple days of delay at an outstation costs an airline up to €200,000.

During the first nine months of 2007, GE spotted 186 indicators of significant events on its engines, such as turnbacks or major delays. Operators were alerted and no problems developed. Not all the problems would have arisen, and operators would have caught some, Donaldson acknowledges. "But a significant portion of these events would have happened." GE avoided warranty liability and operators saved their costs, which can be three times warranty value.

O'Flaherty says ADEM's primary benefit is preventing secondary damage. Rebeyrol agrees that avoiding high-cost failures and increasing time on-wing are the big gains. He estimates Snecma monitoring saves customers 4% of engine maintenance costs alone, excluding disruptions avoided.

Data Systems & Solutions marketer Nick Godwin estimates his customers receive a 300% return by using centralized instead of in-house monitoring. So the centralized approach is producing results, not least by collecting data worldwide and concentrating the expertise to analyze it. Further progress, however, will require much more than centralization.