Time Travel

Safety advantages seem understated as remote analysis of turbofan engine parameters helps business jet operators stay on schedule.

BY WAYNE ROSENKRANS

Engine condition monitoring (ECM) like that required for extended range operations (ETOPS) has begun to interest non-ETOPS business airplane operators.[1] Risk reduction, however, may not be what appeals most when they consider subscribing to several new services tailored for them. These services equip engine systems with wireless data-downloading capabilities used on the ground, remotely acquire the data, conduct in-depth analysis at a central facility and rapidly communicate safety-critical information and maintenance recommendations to operators and flight crews.

They take advantage of digital electronic engine controllers, advanced sensors, telematics[2] and remote diagnostics technology, analytical software that compares measured parameters to those of a master model, secure global network communications and handheld computers or mobile telephones with computer functions. Logically, the services could help reduce human factors errors such as failing to remember to manually download data from the aircraft, failing to manually upload data from a laptop computer to a remote database, unintentionally using outdated analysis models or losing critical engine data without backup copies off the aircraft.

The technology reflected, for example, in the Honeywell Aerospace Zing remote diagnostics service for TFE731 engines on the Hawker 750, 800, 800XP, 850XP and 900XP and the programs of Pratt & Whitney Engine Services–Advanced Diagnostics, a unit of Pratt & Whitney Canada (PWC), for the Dassault Falcon 2000EX and

7X have been embraced by a growing number of business jet operators. Honeywell this year has been expanding its service to the Falcon 50, Falcon 900 and Learjet 40/45 fleets.

In 2008, Honeywell published several early operator experiences. In one report, the flight crew of a Hawker observed an "ENGINE FAIL" light during descent, and one engine changed to manual mode. The crew landed in northern Minnesota, U.S., on a Saturday and called the director of maintenance, who instructed them to initiate a wireless data download from the engines to the Zing service. The director of maintenance then contacted the engine manufacturer's technical representative, who reviewed the data on a mobile phone. The review was completed in 15 minutes, and the director of maintenance grounded the aircraft. Within 30 minutes of the download, however, the correct parts had been shipped to the remote airport. Maintenance technicians were able to install them and release the airplane to service the following day.

Maintenance, repair and overhaul (MRO) paradigms are undergoing a significant shift as a result of the application of this new technology compared with relying on maintenance technicians at one shop acquiring knowledge of an engine through first-hand experience, said Maria Mandato, senior advisor–communications of PWC. "Today, any technician who has access to the Internet — from a remote location anywhere, anytime — can have 24x7 access to engine data, including both reports and alerts. They also can have access to watch lists for a visual summary of engine status."

When combined with the TFE731 engine trend monitoring services provided by partner Jet-Care International,[3] "Zing eliminates manual engine data downloads, improves proactive trend monitoring and reduces downtime during unscheduled engine events," said Donna Chase, vice president of Honeywell Business and General Aviation Customer and Product Support. Operators annually save hundreds of hours of downloading time with the wireless engine data download service, which provides fault code, event/exception alerting, automated trend data forwarding to Jet-Care and an Internet Web interface where remote diagnostics link directly to suggested tests, repairs and original equipment manufacturer manuals, she said.

Subscriber flight crews typically shut down the engines after each landing, engage the digital electronic engine controllers and press a green button on the Zing control panel. This action downloads data stored by the engine controllers, encrypts the data and sends it over a Global System for Mobile Communications (GSM) digital mobile phone network in about five minutes. Nine Hawker operators performed more than 500 downloads of engine data with the service at U.S. and international airports while logging 3,500 flight hours in 2008.

Some safety specialists see growing acceptance of this technology by operators but have yet to decide how it will influence their own programs. "We do not have a formal policy or position on this technology," said Eli Cotti, director,

The Internet brings engine data history and remote analysis within reach.

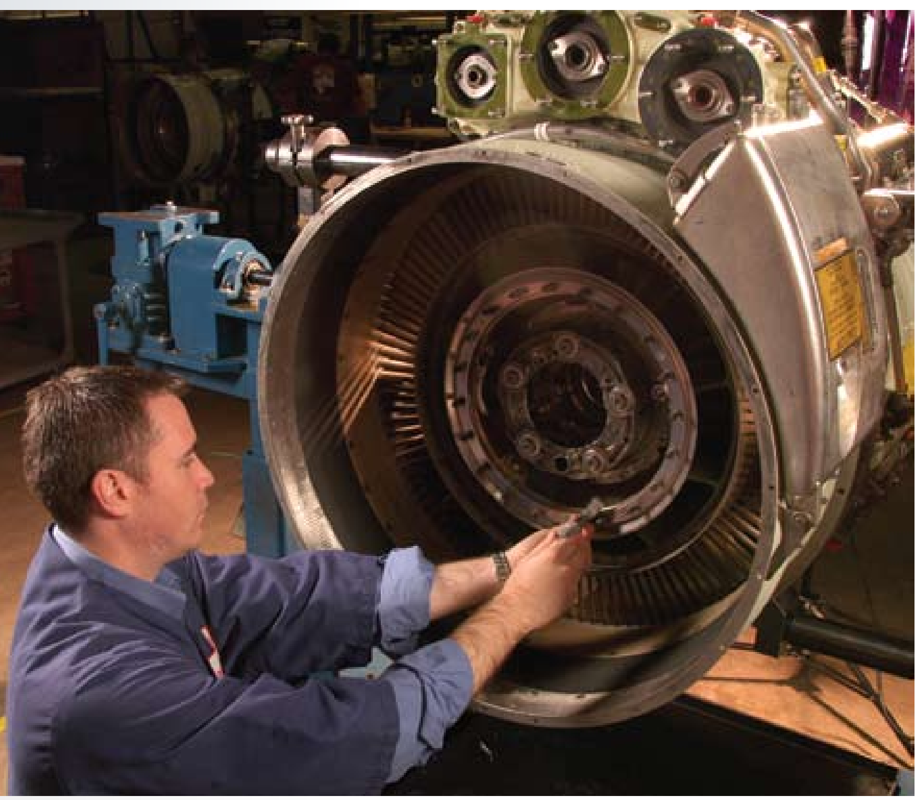

© Pratt & Whitney Canada

technical operations, of the National Business Aviation Association. "Many operators are taking advantage of this service because of the real-time response and logistic support it provides almost immediately upon landing.

"Once a discrepancy is noted in the aircraft records, the aircraft is out of service. The only way to continue operating is to perform corrective action. One of the underlying reasons for Zing, for example, is to allow operators to send their maintenance and support personnel [timely] information about events. Without Zing, the operator requires maintenance personnel attention to accomplish the task of engine data download, usually once every 50 flights."

More than targeting anomalies such as in-flight engine shutdowns or rejected takeoffs, today's ECM services focus on subtle combinations of engine parameter exceedances and events, fault codes, trends and associated flight conditions. Services provide detailed guidance so that operators and pilots can respond appropriately before an issue affects any aspect of flight operations, including airworthiness. Some deviations from normal limits are safety critical.

Consistent, frequent data downloads accelerate work at MRO centers.



© Honeywell Aerospace

"An example of a typical unscheduled engine event would be intermediate turbine temperature (ITT) indication shifts," Cotti said. "This could be as a result of combustion chamber transition ducts or seal misalignment. Another example would be that, if and when exceedance events are recorded, they are typically accompanied by a [digital] date-time 'stamp' of all running parameters.

"Exceedances often have a cycle/limitation penalty — a reduction of total operating hours or a cycle limitation, useful hours or cycles for an hour-limited or life-limited component. Exceedances that go beyond the exceedance record — that is, a limit in the event-recording process — would be followed by an auto-commanded engine shutdown to automatically resolve the problem. For example, if overspeed is the type of exceedance, overspeed beyond a certain RPM or time frame would be followed by an overspeed shutdown."

Actions to be taken — including whether to notify the operator or await results from subsequent downloads — vary according to the engine parameter exceedance involved and the context of other parameters. "For example, if an over-temperature exceedance is detected, the temperature attained and the duration of the over-temperature condition will determine if immediate action is required," PWC's Mandato said. "Likewise, fault codes can have different levels of required actions depending on the nature of the code. A trend shift … still within the recommended operating parameters of the engine … may merit further monitoring but may not require immediate action if still within limits."

Sometimes, reported events lead the designated analysis center, third-party specialist or the engine manufacturer's representative to give advice to the operator and flight crew that will disrupt the flight schedule. "If sufficiently severe, the recommendation may be to not operate the aircraft until the recommended [maintenance] actions have been undertaken," Mandato said. "This is the extreme-case scenario, but may be the most prudent course of action, depending on the circumstance."

Stress Reduction

Minimizing cockpit disruptions and distractions related to engine anomalies and relieving pilots of routine engine-data documentation tasks — especially freeing up crew time for other operational, safety and mission responsibilities — have been cited as risk-reduction factors.

"In the old days, the crew was obliged to record on paper the parameters of an event or warning signal," Cotti said. "Parameters changed frequently, however, and the crew may not have written down the correct parameters. These new systems capture the information instantaneously so that potential error in engine instrument interpretation is eliminated. This leaves the flight crews free to focus on flying the aircraft rather than troubleshooting." Even when business aircraft crews using these systems receive an in-flight alert, they feel more at ease knowing that recently downloaded engine data give maintenance specialists a head start on diagnosis, and quick problem resolution often awaits them upon arrival, he said.

Virtual "built-in support" has been touted as one of the real-world benefits of remote engine diagnostics, particularly by enhancing the operator's confidence about continuing to fly missions. Although equipment aboard the business aircraft subscribed to these services wirelessly download data to a diagnostic center only after landing — unlike commercial jets performing in-flight downloads — this capability still contributes to in-flight situational awareness.

"From a safety perspective, having in-flight knowledge of an event could help the crew decide if the mission is safe to continue or if an unscheduled landing is needed," Cotti said. "The crew also can plan ahead to meet needs of the unscheduled landing and proceed to a repair facility. Letting the operator's support organization know [about issues] well in advance reduces the amount of time the aircraft is going to be in maintenance or out of service."

Blurred Distinctions

Boundaries between what is feasible in the airline environment versus the business aircraft environment are blurring, PWC's Mandato said. "Significant inroads have been made to assist operators in determining whether an aircraft is 'safe' to fly," she said. "By fully capitalizing on the systems offered, the operator [obtains] invaluable and actionable information for maintenance planning that will assist them in validating their own [aircraft safety] experience and judgment. Operators get immediate confirmation that the engines have been operated within the established limits.

"Visibility of engine events and exceedances also encourages pilots to fly within the specified parameters. The more operators know about their aircraft, the better their decisions. Options available — such as instant-alert notifications in the cockpit and automatic data transfer from the aircraft [engines] to monitoring systems on the ground once a flight segment has been completed — maximize effectiveness."

Illumination of PWC's optional alert light, supplementing engine instruments on the flight deck, tells the pilots to seek immediate maintenance assistance for a serious engine problem.

Services that integrate analysis of engine data and flight data also help operators to make data-driven decisions. "Advanced diagnostics add objective operational, trending and exceedance data to the [operator's] decision-making process," she said. "The Internet-based data management system … automatically accepts, organizes

© G. Schläger/Lufthansa Technik

Devices that add wireless connectivity to engine computers mitigate human factors errors.

and presents trend data for ground-based analysis that would normally take hours to process and tabulate."

Advantages of the services include consistent data collection after each flight; no need for the flight crew or maintenance technician to carry aboard a laptop computer with engine controller cable harness or to handle engine data storage media; and capability of engine troubleshooting from a remote location.

Airplane operators considering a subscription to remote ECM also have to decide whether they will rely on in-house technical expertise to interpret the new data available on a Web site or contract for external expertise. "By having direct access, operators can see [for themselves] how their engines are performing … with data in easy-to-understand format for ground-based analysis," Mandato said. The PWC software suite on the operator's side comprises engineering algorithms, analysis enhancement tools, fleet management information, automatic alerts, data warehousing and data-graphing capability.

If the operator does not want to rely on in-house expertise, the external service will provide required engine information and make decisions. "Data review by our designated analysis center assists in the detection of trend shifts, exceedances and events [with] expert analysis of trend data, watch lists, alerts and regular updates on the status of the aircraft engines," Mandato said. "The determination as to whether an alert … necessitates the removal of the aircraft from service would only be made once the aircraft has landed and the data have been downloaded into the Turbine-Tracker data repository for analysis."

Airline Precedents

Lufthansa Technik, which provides services covering about 1,450 engines for more than 50 operators, says that the basic objective of ECM is early failure detection that avoids a severe engine failure during flight. When the company's Frankfurt diagnostic center detects a deviation in engine data compared with preset threshold/limit values, an ECM engineer automatically receives an alert on a computer display.

"At first, we receive an alert e-mail from our system," said Wolfgang Reinert, an international media relations representative for the company. "An ECM engineer then analyzes the trend data and the raw data to find the cause for the alert. If a severe engine failure is detected, the engineer informs the customer via e-mail or phone call and recommends a maintenance action according to the aircraft maintenance manual or troubleshooting manual. The next action — from a visual inspection up to an engine change — depends on the findings."

From a safety standpoint, an ECM engineer usually plays a backup role to the real-time engine status information available to the commercial jet's flight crew. "In case of exceedance of a parameter over a certain level, the crew will get an alert via several displays and acoustic indications," Reinert said. "It is not very difficult for the flight crew to interpret their ECM data — the important parameters such as exhaust gas temperature, fuel flow, N1, N2 — and on Rolls-Royce engines, N3 — oil pressure and temperature, and vibrations."

Many air carriers routinely generate and transmit during every flight several types of engine condition data. "Our ECM uses takeoff, cruise and exceedance reports to detect engine problems," Reinert said. "These reports are generated at specific altitudes, speeds, etc. Takeoff and cruise reports are just snapshots transmitted by VHF radio. An exceedance report, however, will be forwarded immediately via satellite communication."

As a rule, timely rectification averts further problems that could affect airworthiness. "It is better to have a small delay than an engine failure during flight," he said. "The best examples are trouble with the bleed system, fuel metering, sensor and probe failures and engine-control [anomalies] like variable bleed valve or variable stator vane trouble."

Air carriers and business operators alike look to the services to reduce the probability of an aircraft on ground at a remote site because of engine issues. This situation can be extremely costly because of the logistical complexity and additional work, and may entail more risk than engine work performed at major maintenance stations. "Engine removals at stations other than the home base are expensive because the operator has to bring the maintenance staff, tools and the spare engine to the [remote] station," Reinert said. "Special tooling or even a hangar is required for an engine change."

Even when the engine maintenance is performed at the home base or a preferred major maintenance station, knowledge gained from continuous engine analysis often eliminates some steps otherwise required to return the airplane to service. "Inspections and smaller repairs normally do not require an engine run-up," Reinert said. "A run-up is always a consequence due to a part or engine change. Our ECM system does not eliminate these run-ups, but due to early failure detection, we can conduct inspections before we have to change special engine parts."

Practically all decisions about maintenance action for an engine involve a degree of risk, requiring high quality of both data and data analysis. "We try to minimize this risk by analyzing the data very carefully," Reinert said. ECM engineers will not hesitate to advise changing an aircraft, if a spare is available to the operator, or a flight delay for maintenance to ensure that "everything is fine with the engines," he said.

Notes

1. Before 2007, ETOPS referred only to extended-range operation with two-engine airplanes.
2. *Telematics* in this context refers to integrating telecommunication, information systems and autonomous, self-contained electromechanical sensors in vehicles, including aircraft.
3. Jet-Care International. *A Guide to Gas Path Analysis.* November 2008. The company monitors the condition of more than 12,000 engines worldwide, including identification of problems with main engine instrumentation that can cause flight crews to inadvertently operate at off-design conditions that reduce engine component life. Analysis also gives operators advance warning of engines likely to be restricted for power on hot-day operations, Jet-Care said.