Bombardier's Global Express

Bombardier delivers a pilots' airplane—on time and on spec.

By Richard N. Aarons
Photography by Paul Bowen

Bombardier's ultra-long range Global Express executive transport was conceived in 1991 amid a flurry of superlatives. It would be the largest airplane built specifically for the business aviation market, the Canadian company said. It would have the biggest cabin and the longest legs; it would be the only business aircraft designed from scratch to meet ETOPS standards; it would be the fastest airplane in the fleet; it would be the first business airplane constructed by multi-national, risk-sharing partners; it would have systems synoptics and advanced maintenance tracking systems found only on the latest air carrier designs; and it would have the most efficient wing ever built for a business airplane.

The GEX announcement startled potential competitors into action. Gulfstream rushed to develop and market the G-V, a derivative of its successful family of large business jets. Boeing and Airbus jumped in respectively with the BBJ, a 737 derivative, and the A319CJ, an off-the-shelf transport with executive furnishings.

The sales organizations at Airbus, Boeing and Gulfstream took their best shots as the necessarily slower paced GEX project moved along. Bombardier, some said, would never get all its international partners moving in the same direction in a coordinated fashion. The airplane, they said, couldn't possibly be developed on time. It wouldn't meet its aggressive performance guarantees, and, even if it did, the airplane's systems integration was just too complicated. And certainly, the aircraft's dramatically swept wing with all its moving parts would be too difficult to fly without significant flightcrew compensation.

Now, almost seven years later, the Bombardier sales force has an answer for the project's detractors. The Global Express has been certificated on schedule by Transport Canada and is expected to receive type certificates from the FAA and the JAA within the next 60 days or so.

And, the GEX, aptly described as the most sophisticated airplane ever designed for business aviation, has met all its performance guarantees—it can go farther
The clean, roomy cockpit of the Global Express is a showcase for the latest in avionics and system integration technologies. Honeywell Primus 2000XP EFIS/EICAS six-by-eight-inch displays provide the centerpiece. EICAS and system synoptics pages (normally active on the center tubes) let the crew monitor the state of all aircraft systems. While Bombardier has engineered a high degree of automation into all aircraft systems, the crew can step in at any time to override automatic processes. Dynamic synoptics displays along with logically arranged system controls minimize crew workload. Circuit breaker clutter is minimized by the electrical management system (EMS); each pilot has an EMS CDU (shown at the far right) through which remote breakers can be checked and manipulated. Forward and side visibility is good. Production aircraft will be equipped with AMP 16-g seats.

faster than any other aircraft designed for the business market.

Those folks who suggested the airplane's third-generation, supercritical wing would be difficult to fly, are just plain wrong, in our opinion. B/CA recently flew the Global Express both in simulation at Bombardier's Montreal training center and in flight at the company's Wichita flight test facility. The GEX is one of the best handling airplanes ever introduced to the business aviation market. It's quick, nimble and smart.

All of this is not to say the program has been without problems and challenges. For example, like most airplanes, the GEX is leaving the design phase a bit heavier than its makers would like, and some icing tests and autopilot modes remain to be cleared as additional certification items. But the IOU list is small.

Pete Reynolds, Bombardier vice president-engineering flight test, introduced us to the Global Express at the company's Wichita flight test center. His shop is one of the most modern facilities in the world and one of the busiest with 500 engineers, pilots and technicians working simultaneously on several certification programs in addition to the GEX. They launch and track over 400 test flights monthly. Each of the four Global Express prototypes is putting in two and sometimes three flights daily at the center.

Bombardier provided S/N 9001 for our flight evaluation. It's painted in corporate livery, but remains active in the flight test program and is still stuffed with orange flight test consoles and systems. GEX S/N 9001 has logged more than 900 hours proving the handling characteristics and airport performance of the design.

Our morning with this airplane began with a preflight inspection. My first impression as we approached the aircraft was that the Global Express is, in fact, a big airplane. Measuring five inches short of 100 feet in overall length and standing 25 feet tall at the tail, the GEX dwarfed other Bombardier products parked nearby. In fact, the GEX's horizontal tail surface has about the same span and area as some of the early Learjets.

**Walk Around**

We began at the nose that has standard AOA vanes and air data sensors for dual, independent AOA and air data systems. Additionally the nose provides a platform for dual, independent, ice detection sensors that support the automatic mode of the airplane's ice protection system. Wing anti-ice activates automatically when the aircraft enters icing conditions and switches off when the threat ends. (The wing anti-ice system routes engine bleed air to the leading edge and to the slats.)

The nose wheel is conventional. Steering is electrically controlled and hydraulically powered. A cockpit tiller provides full authority (+/- 80 degrees) steering, while linked rudder pedals provide limited authority directional control.

The Ram Air Turbine (RAT) is housed in the right nose compartment forward of the cockpit bulkhead. It can be lowered into the air stream to provide essential hydraulic and electrical power in the unlikely event of complete failure of the multi-redundant engine driven systems.

Moving to the right wing root, we opened the pressure fueling access panel. This refueling station, located on the leading edge of the forward fairing near the wing root, is easily accessible from ground level. Its control panel includes indicators for total fuel quantity and amounts in each tank. The operator can select fully automatic fueling or control fuel distribution manually. At 300 gpm, refueling to full capacity—all 43,350 pounds—can be accomplished in about 20 minutes. Overwing fueling is possible.
The Global Express wing, manufactured by Mitsubishi Heavy Industries Ltd., is a complex, third-generation, supercritical airfoil with winglets, ailerons, ground spoilers, multi-function spoilers, the latter used to assist roll control and to provide lift dump in the air and on the ground, and single-slotted Fowler flaps. The 35-degree sweep and airfoil shape are optimized for cruise in the 0.80 to 0.85 Mach range. The wing is 90.0 above 35,000 feet. Leading and trailing edge devices tamce airport speeds. Speeds for takeoff at 93,800 lb. gross weight are Vs/Vx, 124 KIAS and Vz, 134 KIAS. Approach Vy at maximum landing weight of 76,900 lb. is 129 KIAS. Aerodynamic refinements to the design have continued during flight test. The flap-gap slots, shown on the left, are an example. Engineers at Bombardier's Montreal structures test lab have completed one life of fatigue testing. Ultimate load came with a 92-inch deflection at the wing tip.

The main gears are massive trailing link structures built for growth. A three-level auto-braking system is certified as standard equipment. Brake temperatures are indicated on the EICAS. The original specification (and initial type certification paperwork) calls for a maximum taxi weight of 93,750 pounds, a MTOW of 93,500 pounds, and a max landing weight of 78,600 pounds. Customer airplanes will get a paperwork change to boost ramp and takeoff weight respectively to 94,250 pounds and 94,000 pounds. You can anticipate additional takeoff-weight increases as the product is refined. There is no plan to increase max landing weight, nor is there a plan to add an emergency fuel dump system for an immediate return after a MTOW departure. However, Bombardier engineers will add a sensor to the undercarriage that will flag an overweight landing in the maintenance data recording system for an immediate inspection.

As we continued the walk-around, Reynolds expanded on the weight situation. (We also discussed this later with Kevin Hoffman, GEX product manager.) Bombardier's manufacturers empty weight target was 41,000 pounds. With a typical outfitting allowance of 6,000 pounds, that generated a manufacturers empty weight outfitted (MEWO) of 47,000 pounds.

The first five production airplanes rolled out of the factory on average about 300 pounds overweight—most of that due to the first BMW/Rolls Royce BR/10A2-20/01 engines arriving in Canada a few hundred pounds heavy.

At the same time, Bombardier has discovered that while it's possible to deliver an interior at 6,000 pounds, a 6,500 pound allowance will allow customers to take advantage of additional nice-to-have options for ultra-long range operations such as a cabin humidification system, a head-up guidance system, a third EMS, electric crew seats, extra communications systems, etc.

BMW/Rolls tells Bombardier it is cutting some weight out of engines (a promise also made to Gulfstream), and, as we've seen, Bombardier is increasing max weight limits where it can.

As we walked around the right wing tip, we got a good look at the striking geometry of this optimized, third generation supercritical airfoil. Shaped by wind-tunnel work and computational fluid dynamics techniques, its 35-degree sweep and 94-foot span put its winglets above the engine nacelles.

The full span of each leading edge supports hydraulically actuated slats—four sections on each side. The trailing edge is fitted with an outboard aileron and inboard single-slotted, electrically operated Fowler flaps, three per side. The top of each wing has two inboard ground spoilers and four multi-function spoilers (aileron augmentation, air brakes, and ground-lift dump). The bottom of the airfoil is clean and has the beautiful, exaggerated compound curves characteristic of this class of wing. This wing's sharp sweep and high aspect ratio is necessary for efficient Mach 0.85 cruise. Yet the leading- and trailing-edge devices tame it for low-speed airport maneuvering with takeoff and approach speeds well below the competition for comparable weights.

The APU is in the tail cone. A large equipment bay aft of the pressure bulkhead has a belly door. From the ground position you can make a gross inspection of major ECS, hydraulic and electrical system components. Remote quantity gauges for the hydraulic system reservoirs are located behind an access panel aft of the left wing root. Quick checks of this panel and the left landing gear and wing lead us back to the airstair.

Flying the GEX

Reynolds ascended the steps and took the right seat. I followed and slipped into the left. Scott Runyan, a GEX flight test engineer, sat in the rear at an orange test console to track our maneuvers and compute speeds, weights and CGs. Perry Bradley, B/CA's executive editor, rode jump and kept the log. Photographer Paul Bowen came with us too.

The cockpit of the GEX is wide, roomy and remarkably uncluttered, even with several flight test instruments and controls that will not appear in production aircraft. I settled into the fully articulated seat, strapped in and adjusted the rudder pedals. Reynolds pointed out the seats in S/N 9001 are 9-g units, but production aircraft will be outfitted with 16-g seats from AMP in compliance with the latest FARs.

In terms of switches, dials, knobs, buttons and gauges, the GEX is unquestionably the cleanest airplane in the business fleet. First, the fields of circuit breakers that populate the overhead and side panels of most business jets are missing from the GEX. Instead, each pilot has at his outboard knee an Electrical Management System (EMS) Control and Display Unit (CDU) through which remote solid-state circuit breakers can be manipulated.

Actually, the EMS, as its name implies, takes care of all routine and most non-
Routine switching required to manage the AC and DC electrical systems—four 40 KVA AC engine-driven generators, one 45 KVA APU-driven generator, four 150A transformer rectifier units, a 9-KVA RAT-driven emergency generator, and two nickel cadmium batteries. However, if you want to climb in manually, the EMS-CDUs can display breaker states by the bus or by the system. A push of a button “sets” or “pulls” a highlighted breaker. Only a handful of conventional breakers remain in the cockpit and those are mounted on a small panel behind the right seat.

The accompanying pictures of the GEX cockpit tell much of the story. Each of the six Honeywell Primus 2000XP EFIS/EICAS displays is eight inches tall and seven inches wide. (See the avionics sidebar.) The two outboard tubes are Primary Flight Displays (PFD). The tubes just inboard of the PEDs are usually set to show navigation, radar and traffic information, but can be used for EICAS and synoptics. The left center screen in normal operations shows navigation, radar and traffic information, but can be used for EICAS and synoptic displays. The triple-wide center display synoptic page. Conventional standby facilities while the aircraft is en route. Bombardier anticipates these hourly maintenance costs: airframe, $137; engine restoration, $167; APU $23.

Bombardier’s engineers were able to tap into Canadair RJ airline ground operations experience for ideas in Global Express servicing and maintainability. All service panels are at ground level and provide full annunciation of system quantities and states. Activities directed from these panels are also displayed on the cockpit EICAS. The panels shown here are the AC/DC auxiliary power hookup, the O2 fill station and the pressure refueling station. The all-digital aircraft is equipped with a central aircraft information and maintenance system (CAIMS) that logs selected aircraft system faults and identifies offending LRUs or interfaces. Maintenance technicians access CAIMS using a PC terminal supplied with a special interface. Optionally, CAIMS data can be transmitted to remote service facilities while the aircraft is en route.

Forward, side and aft visibility are excellent, but you can’t see much of the highly detailed aileron/rudder trim, radio control units and display controllers.

The overhead panel provides controls for the engines and systems, each arranged physically to match the EICAS synoptic displays. Thus, the “picture” on the overhead for any system matches the “picture” on the synoptics page making manual selection wholly logical and intuitive. GEX systems were designed from the start to meet or exceed Extended Twin Engine Operations Standards (ETOPS), the rules for system reliability and multiple-level redundancy required for air carrier operations on extended over-water routes. To this end, the airplane has four independent electrical systems with six AC power sources, and three independent hydraulic systems with seven power sources. The hydraulically powered flight controls are triple redundant and the flaps/slats subsystems are powered by dual motors.

Bombardier was pushing for a marketplace advantage with this design, and, in fact, got it. While the GEX systems are rich with redundancy, pilot workload in managing them is light due in large part to an extraordinarily capable Engine Indication and Crew Alerting System (EICAS).

Reynolds tuned the radios and toggled through the pre-start checklist on the EICAS. The basic cockpit configuration is “dark and automatic,” that is to say that all lights and EICAS messages should be extinguished and all switches should be in the AUTOMATIC position.

Waking up the airplane is a simple matter. First the AlliedSignal RE220 APU is brought on line by holding its switch in the spring-loaded START position for two seconds and allowing it to drop back to the RUN detent. Reynolds fingered the display controller to bring up the electrical and hydraulic system synoptic screens along with the default engine status screen. It’s the best way, he said, to get a feel for system health during the start sequence. The entire process plays out visually as the APU starts powering primary pneumatic, electrical and hydraulic circuits (as it would in an inflight-emergency) and later as the redundant engine driven electrical, pneumatic and hydraulic accessories come on line and share loads. Not only is system configuration automatic at power-up, but system reconfiguration to handle abnormal situations is automatic as well. The pilots get notification on the EICAS whenever an automatic subsystem does something that otherwise would not be entirely obvious.

Normal pneumatic (APU or GPU) engine start is controlled by the BMW/Rolls BR710’s FADECs, and is fully automatic. A guarded push-button FUEL CUTOFF switch is located just aft of each throttle. Pushing a button initiates the automatic engine start/stop sequence. The sole crew task is to monitor the EICAS—a quick acceleration of N2 to 15 percent, ignition icon at 20 percent, a gradual ITT rise, ignition off at 42 percent, starter off at 45 percent and acceleration to 65 percent where the engine stabilizes. Each start took less than 65 seconds.

Engine Pressure Ratio (EPR) is primary for setting power. The engines can be controlled by reference to N1 in the event of failure of an EPR sensor or EPR FADEC channel. As I moved the EPR/N1 switch, the EICAS indicators changed to indicate the selection.

Costs: engine restoration, $137; APU $23.
Bombardier Global Express

These graphs are designed to be used together to provide a broad view of Global Express performance. Do not use them for flight planning.

For a complete operational performance analysis, consult the flight planning and cruise performance manuals, as well as the FAA-approved flight manual.

Range Payload Profile — The purpose of this graph is to provide rough simulations of trips under a variety of payload and airport density altitude conditions, with the goal of flying the longest distance at high-speed cruise. The payload lines, which are intended for gross simulation purposes only, are each generated from several points. Fuel burns and times can be approximated using the Block Time and Fuel Versus Distance graph or the Block Fuel graph. Balanced field lengths have been recomputed to reflect the most recent flight test data. Range and fuel burn numbers are still preliminary pending verification during F&R flight test.

Block time and Fuel Versus Distance — This graph shows two missions. The upper line represents high-speed cruise and the lower line represents long-range cruise. The numbers and the hour lines indicate cumulative miles and fuel burned for those two cruise profiles, the intermediate points only are accurate for the full trip. They can, however, provide a rough approximation of the time and fuel required for trips of intermediate length. The chart assumes an eight-passenger, 1,600 pound payload.

Ground control cleared us to Runway 1L. Wind was 110 at 13, giving us moderate right crosswind. Runyan computed takeoff speeds for our ambient—V1/Vr 104, V2 118, VFTO 156 and VREF for an immediate return 122. Reynolds plugged these into the FMS performance pages to set the vertical tape display bugs. In production aircraft, FMS software will do this automatically as soon as the crew confirms payload weight. The system also will be able to compute flex takeoff.

We moved into position at 1130 hours and the tower cleared us for an immediate takeoff. I pushed the throttles forward to swept wings—just the tips, and that requires a healthy over-the-shoulder stretch. Ramp personnel pulled the chocks and waved us ahead and I advanced the throttles to get us moving. (GEX crews will want to use wing watchers when maneuvering on crowded ramps.)

Tight ground maneuvering requires use of the tiller on the left cockpit side-panel. The full-authority hand wheel is sensitive but easily mastered. Minimum pavement width required for a 180-degree turn is 68 feet, so you can swing the airplane on a standard width taxiway.

I threaded our way through the crowded Test Center ramp complex, getting used to the steering and brakes. The carbon brakes are nicely modulated by their electronic control unit but they require a gentle touch.

Aircraft 9001 weighed just over 71,000 pounds as we moved down the taxiway. That included 1,000 pounds of crew, 7,500 pounds of flight test equipment and 12,100 pounds of fuel. Putting that weight into perspective, we could have flown four passengers 3,300 nm with NBAA IFR zero wind reserves in a corporate-equipped Global Express departing at that weight.
the stop—the FADEC accelerates the BR710s to max computed takeoff power keeping EPR and other parameters within limits. Engine spool-up and aircraft acceleration where quick. I found the low-authority, rudder-pedal, nose-wheel steering provided plenty of control, even with the crosswind. I held slight aileron into the wind; Reynolds called 80 knots for a crosscheck then V1/Vr. I rotated to 12 degrees nose-up—rotation forces were surprisingly light—and S/N9001 sprang off the runway.

We were off the ground in a little under 3,000 feet (a rough estimate based on runway markers) and accelerated instantaneously to V2. Initial climb rate was about 2,000 fpm quickly accelerating to 3,000 fpm as Reynolds retracted gear and flaps. After a short delay at 3,000 ft. msl, deparway markers) and accelerated instantly to 4,000 fpm. Vertically speed increased through 4,000 fpm as Reynolds retracted gear and flaps. I found the low-authority, rudder-pedal, nose-wheel steering surprisingly light—and S/N9001 sprang off the runway.

Climbing through the nose and to the sides was excellent.

For high altitude work. I established climb at Mach 0.80 and we were seeing 2,000 fpm to 2,200 fpm and about 2,400 pph per side. First step for max gross weight departures will be FL 430. Bombardier flightcrews plan 30 minutes to TOC under these conditions. We leveled off at FL 440 about 25 minutes after takeoff with two ATC holds and our handling characteristics checks thrown in.

B/CA's introduction to the GEX began in Montreal at the Bombardier Aerospace Training Center where all flightcrews and maintenance technicians will be trained. "We are gearing up to handle 450 pilots and 550 maintenance techs a year," said Terry Yaddaw, the center's business aircraft training director. Included in the $32.2 million price of each aircraft is training for four pilots, two maintenance technicians and one flight attendant.

Prices for training beyond that included with the aircraft are as follows: initial pilot, $31,000; recurrent pilot $23,250; full service initial (initial plus one recurrent), $38,500; full service recurrent (two sessions per year), $31,000; initial maintenance technician $16,150.

The initial pilot training program includes 16 hours in a flight training device (FTD), 24 hours in a full function simulator (FFS) and about 60 hours of classroom sessions. The program is expected to require three weeks.

The five-week maintenance tech program includes basic operational presentation of aircraft systems and avionics and an optional additional two days for engine ground runs and taxi procedures.

The EICAS in the all-digital Global Express is the best systems instruction device available—better than any classroom because its synoptic pages give you real-time graphics of subsystem states as you manipulate cockpit switches. So, time in the FTD replaces classroom time in more traditional aircraft, accelerating learning. The training center has one fixed-based GEX flight training device and one full-function GEX simulator, the latter with the entire size replica of aircraft S/N 9007’s flight deck. The six-axis simulator provides complete fidelity of sound and motion along with a superb daylight/dusk/night visual system.

Built by CAE in Montreal, the simulator obtained interim FAA Level C certification last month and is expected to receive Level D certification in 1999.

The visual system, called “Maxview,” has a 210-degree horizontal field of view, a 40-degree vertical field and five-channel projection that enables cross-cockpit viewing.

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At 1204 hours we started down. I pulled the power to idle, deployed the boards, and let the airplane have its head. There was no vibration and very little rumble from the spoilers. Descent increased to 6,000 fpm, then gradually to 9,000 fpm. Then I pushed forward on the yoke to MMO; the required deck angle was a comfortable 10-degrees nose down. The vertical rate pegged at its 9,900-fpm indicating limit. (Of course, in normal operations TOD begins some 100- to 120-nm out. You pull back to idle, and the descent works out. Completion of icing certification flight test series in actual conditions awaits cooler weather, however, preliminary data suggest the engines produce plenty of bleed air at idle to keep the wings warm during descent.)

We slipped into a cloud layer a few thousand feet thick, emerged at 15,000 feet and continued down to 12,500 feet for a stall series and additional configuration checks. We ran out slats at 223 KIAS followed by six-degrees flaps approaching 200 KIAS, then slats-plus flaps 16 degrees. The airplane pitched up slightly, but that trim change was swallowed quickly by its continued deceleration. We lowered the gear at 200 knots and then went to full flaps at 185 KIAS. Once again, I was able to handle all trim changes with fingertip pressures.

I allowed S/N 9001 to decelerate to a VREF of 119 KIAS, leveled off and executed a series of turns. Roll control is responsive and brisk right down to stick shaker. Reynolds pulled the right engine, VREF for engine out operation is five knots higher than that for two-engine operation. No configuration change is needed. Rudder pedal pressures are reasonable. Reversing a 30-degree roll into the dead engine was smooth and without hesitation.

A simulated go-around in the engine-out configuration proved uneventful. The flight director commanded a wings-level 13-degree nose up attitude when I hit the go-around button on the throttle. With one engine running we got about 2,200 fpm climb at 13,000 feet as we cleaned up. Next we configured the airplane for a clean stall. Flight engineer Runyan's computer predicted we would feel the shaker at 125 KIAS and that the pusher would fire at 118 KIAS. We actually got the shaker at about 127 KIAS, and got some buffet and the pusher at 119 KIAS. The aircraft rolled off slightly to the left as it nosed over, but the roll was easily controlled.

Reynolds told us that stall extension provides the largest increment in stall speed. We repeated the stall with just slats extended and it came at 98 KIAS. Each notch of flaps thereafter reduced the stall speed about five knots. I detected no rolling tendency at stall with slats deployed.

We returned to Wichita for pattern work weighing about 65,000 pounds. Our first approach was a manual ILS to Runway 19 for a touch-and-go. VREF was 117 KIAS. We popped back up into the pattern, maneuvered for a visual at 180 KIAS with slats/flaps 6 degrees and touched down for a full stop with deep reverse and full breaking. The FADEC modulates the reverse thrust automatically so the engines begin to decelerate as the aircraft slows below 65 knots. This means you can keep some reverse selected down to 35 knots.

We taxi’d back for a final pattern circuit, this one with a simulated engine failure. At our weight, computed speeds were V1/Vr 98, V2 113, VREF for immediate return 116. As it turned out, Reynolds chopped the engine at 93 knots and told me to continue. We accelerated, climbed out and negotiated the pattern with an intentionally flat approach on final—VREF was 121—to feel rudder control. There was plenty.

During all our pattern work we had a 10- to 12-knot crosswind. The GEX was easy to handle in the air on two engines or one. Aircraft control on the ground was positive and precise using the rudder-pedal linked nose wheel steering, and automatic ground spoiler deployment never left a doubt about the airplane sticking to the ground once both main gear were compressed on touch down. All of our distances were well inside computed performance figures.

Reynolds is justifiably proud of the Global Express. After all, his people have managed to fly test and certificate on time and on performance an aircraft that is arguably the world’s most sophisticated business jet. “It seems like its too big to go as fast as it does and too big to go as slow as it does, but it does them both beautifully,” he said as we unbuckled. I have to agree with him.

Usually, we have the opportunity to