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Phenom 100 flight test: building on a Legacy

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When the Legacy 600 was launched in 2000, it would have been easy to dismiss Embraer's first foray into the business jet market as merely an opportunistic adaptation of its prolific ERJ-135/145 regional jet series. Since then, however, Embraer has built the Legacy into a full line of capable super-midsize business jets.

In 2005 the Brazilian manufacturer further cemented its commitment to the business jet market with its launch of the Phenom 100 and 300 executive jets. The Phenom 100 was to be Embraer's entry into the then red-hot very light jet market segment, while the Phenom 300 would take on light jets such as the Beechcraft Premier I, Bombardier Learjet 40 and Cessna Citation CJ3.

Since the halcyon days when Eclipse single-handedly defined the VLJ market, with its $1 million Eclipse 500, much has changed. Eclipse Aviation's assets have been sold under bankruptcy court protection to EclipseJet Aviation International, while its single biggest customer, DayJet, has ceased operations and is also under bankruptcy court protection. Development efforts for the Adam 700 have ceased, and its future is uncertain at best.

However, a number of single-engined VLJs, including the Cirrus SJ50, Diamond D-Jet and Piper Jet have been launched. These single-engined offerings cost less than $2 million and now define the lower end of the VLJ segment. In a marketing presentation Cessna has compared the capabilities of its Mustang with an unnamed competitor. The unnamed competitor whose capabilities the Mustang closely matches is the original Citation 500, one of the first light jets. Cessna calls its $2.7 million twin-engined Mustang an "entry-level jet", floating just above the upper edge of the VLJ market. Embraer originally marketed the Phenom 100 as a VLJ, but as the market evolved, also found that label limiting. The Phenom 100 is now called an "entry level executive jet", a classification perhaps more fitting for its capabilities and aspirations.

CERTIFICATED DELIVERIES

Since the Phenom 100's launch in 2005, Embraer has leveraged its engineering talents and vast experience building regional transport aircraft to field its latest and smallest executive jet. After its first flight on 26 July 2007, four prototype aircraft completed around 1,600 flight hours in the development effort. These efforts were recognised when Brazilian certification was awarded on 9 December, followed by US Federal Aviation Administration certification on 12 December 2008. Initial customer deliveries began in late December, with 10-15 deliveries scheduled before the end of the year. With a backlog of more than 800 aircraft (two-thirds the Phenom 100 and one-third the Phenom 300), Embraer hopes to deliver 100 Phenom 100s in 2009.

While the Eclipse 500 planted the seed for its smallest executive jet, Embraer benchmarked larger and more capable aircraft such as Cessna's CJ1+ to guide the 100's definition. Market forces would dictate an aircraft with an absolute range capability on a par with segment leaders, but Embraer also embraced a concept it calls "bio-range".

Bio-range means designing an aircraft that four passengers would want to ride in for nearly 3h. Central to this is a large cabin. Most fuselages have a circular cross-section, but for the Phenom, Embraer designed an oval fuselage it calls Oval-Lite. This provides more usable room. The class leading cabin's space is further accentuated by eight large windows. Since pulling over for a bathroom break can be problematic at FL410, a chemical toilet lavatory is at the aft end of the cabin.

In addition to delivering a large cabin, Embraer strove to deliver a relaxing interior that balanced a range of customer choices against cost.

Partnered with BMW Group Designworks USA, Embraer has developed seven pre-defined collections and a variety of material choices, allowing for a near custom interior at a mass production price.

PROTOTYPE PACES

Before the first customer delivery, Flight International was invited to Embraer's headquarters to see if the Phenom 100 lived up to its name. As the several available production aircraft were being prepared for customer delivery, our preview aircraft was to be the first prototype, serial number 801, with a Brazilian registration PP-XPH.

With each new generation of aircraft, Embraer has increased composite content, and while the Phenom is predominantly an aluminium aircraft, its structure is roughly 20% by weight composite. Aerodynamically, XPH is production representative, with metallic tape highlighting areas where the design had been tweaked during development. Most prominent of these are wing fences. Wing fences are a boundary layer control devices designed to limit span wise flow, and are most usually found on swept-wing aircraft. Fences are usually physical vertical surfaces or vortex generating notches. Early in the development process two 9cm (3.5in)-high fences were added to each wing to improve take-off and climb performance. To improve lateral directional stability, a fixed ventral fin had been added. On the larger swept-wing Phenom 300, this ventral fin has a "rudder" that acts as a yaw damper to mitigate dutch-roll affects.

The pre-flight walk around inspection was conducted by Embraer test pilot Antonio Bragança Silva, who acted as safety pilot for the flight. Opening the forward nose baggage compartment revealed the first piece of orange-coloured test equipment. In all, the heavily instrumented aircraft had about 250kg (550lb) of test specific equipment. The leading edges of the wing and horizontal stabiliser are de-iced by slick-looking silver pneumatic boots.

Roll control is affected by conventional manual ailerons, outboard of the large 3.9m long flaps. Over-wing refuelling caps are located outboard on each wing. Unlike the 300, the 100 lacks a single point refuelling capability. A single electrically actuated hydraulic pack provides the motive force for retraction of the nose and trailing link main landing gear as well as wheel brakes.

Other than checking the oil level, inspection of the Pratt & Whitney Canada PW617F was without note. Access to the unpressurised large 1.56m3 (54.9ft3) aft baggage compartment was through a door below the left engine. Embraer says two pairs of 1.85m (5.9ft)-long snow skis can also be carried.

Entry to the cabin is via a 1.47m-high by 0.74m-wide door, markedly larger than those of competitive aircraft. The manual counter balanced non-plug door has four integral steps and is secured by eight latches. XPH's passenger compartment was configured for the test and development effort, and was in no way representative of production offerings. The cockpit, however, was with minor exceptions identical to production Phenom 100s. Designed around a quiet and dark concept, the cockpit's centrepiece is a Garmin G1000-based Prodigy avionics suite. I have sampled the G1000 in the Mustang, and continue to be amazed at the level and number of features it offers. Embraer has opted for three identical 12in diagonal displays for the two primary flight displays (PFD) and multifunction displays (MFD), while the Mustang features a larger 15in MFD. Unique to the Phenom's Prodigy system are several system synoptic pages, a feature typically found on more expensive aircraft. In addition a paperless cockpit option and electronic checklist are available. The autoflight guidance control panel is handily mounted on the glareshield, next to the integrated electronic standby instrument.

Once seated and strapped in, I used the visual alignment balls on the centre pillar to attain the design eye position. From the left seat I found the field of view to be quite good, with most of the left-wing leading edge clearly visible. The Embraer signature motorcycle yoke fell readily to hand, as did the thrust levers, mounted on the small centre pedestal. As with the Mustang, I prefer having "real" switches and control panels, as opposed to the virtual ones in the Eclipse.

The only item in the cockpit that felt out of place was the trim control panel, which was mounted forward of the pedestal on the forward instrument panel. After several trim inputs I found its use and location to be intuitive.

Characteristics	Phenom 100	Mustang	Eclipse 500
NBAA IFR range (km)	2,182	2,146	1,900
High-speed cruise (kt)	390	340	370
MMO	0.70	0.63	0.64
Take-off field length (m)	953/1,038 (STD/ADV)	948	714
Price, 2008 ($m)	3.29	2.77	2.15

Before engine start, the tail-mounted vapour cycle air conditioner was turned off and external power disconnected. Pre-start procedures were short and easily accomplished. Internal battery power was used to start the engines, with the dual channel full-authority digital engine FADEC controls in charge. Peak interstage turbine temperature for both engines was roughly 560°C (1,040°F), well below the 892°C limit. Had a hot start been anticipated, the FADEC would have automatically shut off fuel flow. Unlike the Eclipse, whose FADECs are powered solely from the aircraft's power system, the Phenom's FADECs also have dedicated generators as a power source.

After both engines were running, their generators were brought online. The flaps were set to position "1", (10° of deflection) and a control sweep performed before advancing the power to start the Phenom rolling. During the taxi to São José dos Campos Runway 15, I found the pedal actuated nosewheel steering allowed for accurate tracking of taxiway centrelines. Up to 20° of nosewheel deflection is controlled via the pedals, with +/- 35° of castor available with application of differential braking. Before taking the runway, the take-off configuration test button, mounted on the centre pedestal, was pushed. Had either the flaps or trim been mis-set or the parking brake applied, an aural warning would have sounded.

ENHANCED TAKE-OFF

I rapidly advanced the thrust levers to the take-off/go-around detent and released the brakes. Had an unsafe take-off configuration been detected when the thrust levers were advanced, an aural warning would have sounded allowing the take-off to be abandoned. The engines stabilised at 89.5% N1 with Bragança calling "V1" at an indicated airspeed of 102kt (188km/h), followed by "rotate" at 105kt. Roughly 11kg of aft yoke pressure was required to lift the nose wheel.

Unlike the Legacy 600, which requires a definite forward yoke push to stop the pitch attitude from continually increasing, a slight relaxation of aft yoke pressure was all that was needed to establish an 11° climb attitude.

With 980kg of fuel and four occupants (and 250kg of flight-test instrumentation), our take-off weight was 4,734kg, just below the certificated maximum of 4,750kg. Approximate ground roll with calm winds on the 21°C day was 800m. At maximum take-off weight and standard day conditions at sea level, Embraer lists a distance of 953m for our "enhanced" aircraft, and 1,036m for the base aircraft.

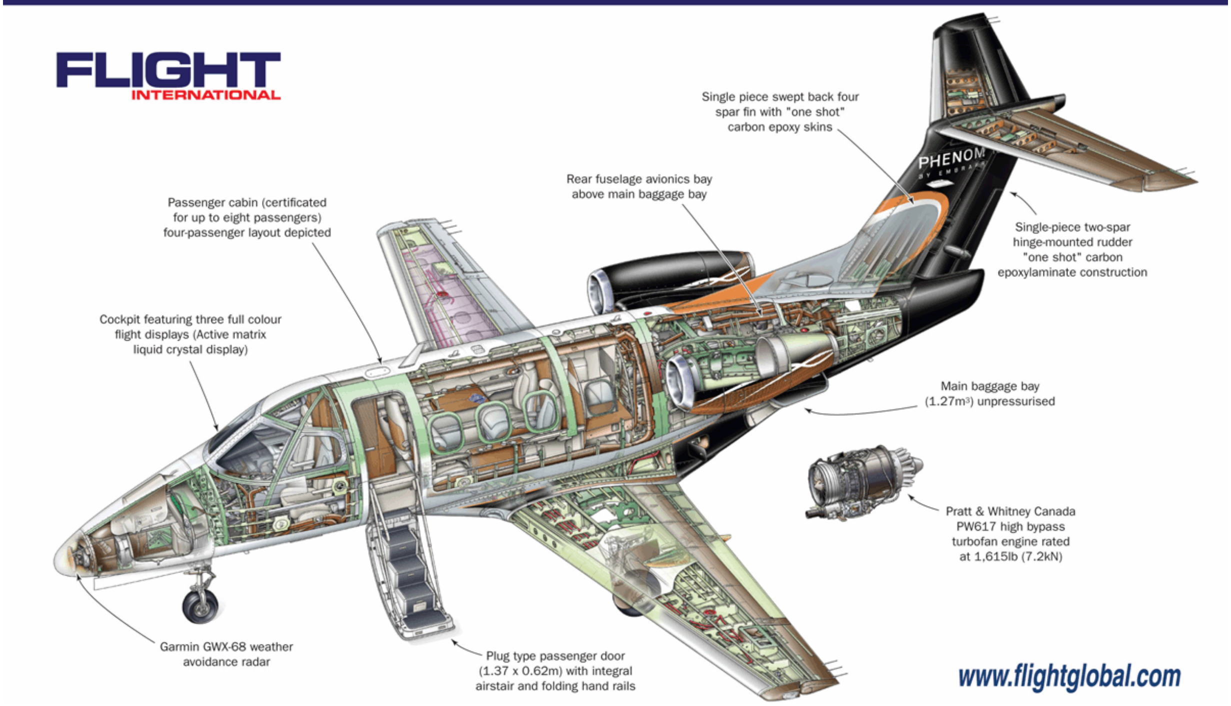
The enhanced option allows the use of the PW617's automatic thrust reserve (ATR) feature. With ATR armed, detection of an engine failure bumps up the thrust of the good engine from 1,690lb (7.5kN) to 826kg, giving better field performance. While the enhanced performance package improvement at sea level and standard conditions is notable, in hot and high conditions it is remarkable. Out of Aspen, Colorado, for example, the base aircraft can only fly 1,049km (761nm), while the enhanced version has a range of 1,933km, a 37% improvement. From Telluride, Colorado the enhanced package ups range from 974km to 1,476km, a 52% improvement.

Yoke force changes during acceleration and gear and flap retraction were light. Pitch trim speed varies with aircraft speed and easily countered the changing pitch forces. Passing 3,500ft mean sea level (1,380ft above ground level), the aircraft was accelerated to an indicated airspeed of 200kt and thrust levers retarded to the CON/CLB mark on the quadrant for the climb to cruise altitude.

During several turns out of the airport traffic area, I found the Phenom to be responsive in roll and very stable in pitch. Since I primarily fly in the USA, I forgot to select QNE on the altimeter passing the lower transition altitude. But there was no need to worry as the Prodigy avionics reminded me once it was exceeded.

I engaged the autopilot and continued the climb in the flight-level change pitch mode, using heading lateral mode to track air traffic control vectors. The FADECs kept the proper climb power setting throughout the climb, with a climb Mach of 0.55 attained at about FL300. While the Phenom can climb directly to FL410 at MTOW, in the interest of expediency the aircraft was levelled at FL330. Total fuel burn was 250kg and elapsed time from brake release to altitude was about 29min.

EMBRAER PHENOM 100 GIUSEPPE PICARELLA



HIGH-SPEED CRUISE

While level at FL330, the power was left at the climb setting until a speed of M0.60 was attained, then it was retarded to the maximum cruise mark (93.0% N1). The Phenom stabilised at an indicated airspeed of 210kt with a total fuel flow of 337kg/h. With a static air temperature of -39°C, 2.7°C warmer than standard, an indicated Mach of 0.603 yielded a true cruise air speed of 360kt.

When I flew the Eclipse prototype several years ago the maximum cruise true speed attained was 300kt, far below the published figure of 370kt. In the production Mustang on test day a speed of 345kt was attained, slightly faster than the published 340kt figure.

While this brief snap shot of the Phenom's high-speed cruise capability fell short of the published 390kt figure, it lends credibility to the Phenom's relative speed advantage over competitive aircraft. One neat feature I did not try at cruise altitude was cruise speed control (CSC).

This is a kind of a poor man's autothrottle, and when engaged it allows the FADEC to vary N1 within a limited range to hold a constant airspeed. The aircraft was then slowed to a long-range cruise speed of M0.55. At an indicated airspeed of 190kt, a total fuel flow of 300kg/h yielded a true airspeed of 327kt.

Embraer promised an NBAA range with four occupants of 2,148km, but slightly lower fuel burn from the P&WC engines and wing fences has given the Phenom 2,182km legs. Given the nearly linear trade-off between fuel flow and speed between long range and maximum cruise speeds, most Phenom operators may feel the need for speed on less than maximum range stage lengths.

Since XPH's passenger cabin was configured with flight-test equipment, I cannot vouch for its comfort, but I was able to note several features that will enhance the ride. The eight large passenger cabin windows let in a lot of light, giving the cabin an airy feel. Embraer figures show each of the Phenom's windows to be 10% larger than the CJ1+ and 25% larger than those of the Hawker 800XP. Cabin pressurisation is automatically controlled based on inputs of departure field elevation, cruise altitude and arrival field elevation from the flight management system. At FL330, pressure differential was 0.56bar (8.2lb/in2) with a resultant cabin altitude of 5,500ft.

The acoustic environment is also important to passenger comfort, perhaps one of the main reasons passengers do not care for turboprops. Jet engines can also have acoustical issues. Most passengers have no doubt heard the reverberation whine of two engines not quite in sync. The Phenom's FADECs talk to each other and when commanded N1 settings are close to each other, they will match them to prevent the annoying reverberation.

While still at FL330 and an indicated airspeed of 195kt, I performed several 60° angle of bank (AoB) steep turns to explore the Phenom's buffet margin. During all the turns the yaw damper and aileron-rudder interconnect made for smooth co-ordinated flight, and unlike the Learjets of old, no buffet was felt at 2g. Further inspiring confidence was the green dot on the primary flight display airspeed indicator, which showed real time 1.3 VSTALL, 190kt for our manoeuvres.

With the high altitude manoeuvring complete, a descent to medium altitude was initiated. During the descent the aircraft was accelerated to M0.70, MMO. Approaching the limit the airspeed tape showed yellow/red to alert me to the impending overspeed, turning solid red at MMO.

At about 3kt over MMO, an indicated airspeed of 278kt at our altitude, an aural warning was sounded. A series of sharp control inputs in each control axis showed the Phenom's dynamic response to be well damped, all oscillations subsiding within one cycle.

SINGLE PILOT SUITABILITY

The Phenom 100 is certificated for single pilot operations, as are the Eclipse and Mustang. During the several flights I have had in Garmin G1000-equipped aircraft, I have found the large displays and powerful flight management system to be great aids in maintaining situational awareness in all conditions. Coupled with its capable autopilot, safe single pilot operations in instrument conditions are a reality.

While avionics play a major role in single pilot operations, aircraft handling qualities are also critical. Docile slow speed handling characteristics are essential and pilot exposure to this flight region will no doubt increase confidence and safety. Level at 15,000ft MSL, I slowed the Phenom to an indicated airspeed of 115kt, below the green dot speed of 126kt.

Both with and without the yaw damper engaged I was able to precisely capture and track headings from 20° AoB turns. As I had found during the initial climb to altitude, the Phenom was very stable in the pitch axis. Next two stalls were conducted, one in the clean and the other in a landing configuration, gear down and flaps to position 4 (36° deflection).

In the clean configuration the stall aural warning occurred at an indicated airspeed of 104kt for the 4,310kg aircraft. I continued to hold yoke back pressure, slowing the aircraft until the stick pusher fired at 93kt. As the Phenom has a T-tail, the pusher applies over 60kg of force to reduce AoA and prevent entry into a deep stall.

In the landing configuration the aural warning sounded at an indicated airspeed of 82kt, with the pusher firing at 77kt. In both cases I found the Phenom to be responsive in all control axes, with little or no airframe buffet present, nor any tendency to drop a wing. In the slow speed regime I found the Phenom had superb handling qualities, a great aid to safe single pilot operations.

Return to São José dos Campos after the area work was via radar vectors to an instrument landing system Runway 15. En route to the pattern, I engaged the autopilot and further familiarised myself with the Prodigy avionics.

As with other Garmin 1000 applications, I found the PFD's full span horizon line a marked improvement over smaller displays. The large size of the PFD allowed for display of a map inset as well as an inset for crew alerting system (CAS) messages. The standard time in service and optional traffic alert and collision avoidance system information are displayed on the PFD's map inset. Installation of the approach via the flight management automatically tuned the instrument landing system frequency and inbound course.

Once the localiser (LOC) was captured, I disconnected the autopilot and hand flew the aircraft. Pitch changes due to gear and flap extension were once again easily countered by the variable speed pitch trim. I found the flight director provided excellent guidance to track both the LOC and glidepath. I retarded the thrust levers to idle at roughly 20ft above the runway and initiated the flare by raising the nose very slightly at about 5ft above the runway. The Phenom gently settled on the runway and was allowed to roll out to a mid-field taxiway, 1,800m from the approach end. Very light braking force was needed to slow the Phenom to 5kt before turning off the runway.

SINGLE ENGINE QUALITIES

Rather than taxi back to the ramp, the Phenom was configured for a Flaps 1 take-off. Once airborne off Runway 15, the left thrust lever was retarded to idle to simulate an engine failure at V2+10kt - an indicated airspeed of 112kt in this instance.

Over 50kg of pedal force was needed to maintain co-ordinated flight with take-off/go-around power, 89.5% N1, set on the right engine. Application of full right rudder trim reduced the pedal force to about 20kg, a welcome reduction, but I would have preferred to have had more trim available in case an extended climbout was dictated.

Once level on downwind with flaps at position 1there was sufficient rudder trim available to zero out pedal forces with the reduced N1 setting. A visual circuit was flown, again to Runway 15. On final with flaps to position 2 (26° deflection), rudder trim was centred. At the Flaps 2 approach indicated airspeed speed of 113kt, about 15kg of pedal force was needed to maintain co-ordinated flight. Flare and runway touchdown were much like the first landing, the Phenom again gently alighting.

Once on the runway, Bragança reset the pitch trim and selected the flaps to "1" for the take-off portion of the planned touch and go landing. The last circuit was again a visual one to Runway 15, but with both engines this time. With flaps set to "4" (36° deflection), our approach indicated airspeed was 103kt for the 4,124kg aircraft. Pitch attitude on final was roughly 3° nose up, with the FADEC controlled engines allowing me to keep the aircraft right on speed.

With idle power selected, a slight flare again ensured a smooth touchdown. After lowering the nosewheel to the runway, I applied what I felt to be moderate wheel braking.

The initial deceleration rate was slow, causing me to put even more pressure on the pedals. This increased pressure had no real effect, as 100% of brake pressure had been applied with only 25% deflection of the toe brakes, the cycling of the anti-skid system confirming a maximum effort stop. The deceleration rate increased markedly as decreasing aerodynamic lift put more weight on the wheels, the Phenom slowing to make a turn-off less than 800m from the approach end of the runway.

While the Phenom offers competitive landing field performance, 823m at maximum landing weight and standard conditions, I had found maintaining runway alignment while applying maximum braking to be a fairly high-gain task. The brake-by-wire system performed as advertised, and its anti-skid system should allow for maximum effort stops regardless of runway conditions. Upon reflection, this was most likely the result of my inadvertently making small nosewheel steering inputs while applying the wheel brakes. The geometry of the rudder pedals/their angle relative to the floor boards (not near enough to vertical) required somewhat excessive rotation of the feet to actuate the wheel brakes. The Phenom's toe actuated wheel brakes obviously meet current certification standards, but with a few minor adjustments they might be even better.

WHAT'S IN A NAME

With its Phenom 100, Embraer had set out to establish the gold standard for VLJs. As the design process evolved and the competitive landscape changed, it ended up fielding what may be the definitive entry-level executive jet. Its 390kt cruise true airspeed eclipses that of the CJ1+, while offering a slightly wider cabin. You can go 179km farther in a CJ1+ with four occupants, but at a cost of nearly $1.5 million more.

The Phenom 100 is a robust aircraft designed for 35,000 cycles, more than twice the design life of its closest VLJ competitor. Embraer has developed a strong customer support reputation with plans for 28 worldwide executive jet service centres. With more than 500 orders in the books, the Phenom 100 is a commercial success, and my brief flight in it assured me that those lucky enough to fly it will not be disappointed.