

Classy Ride

An unusual design gives Honda's first business jet class-leading characteristics

Fred George Greensboro, North Carolina

As a carmaker, Honda is known for the understated style of its vehicles, beneath which lies advanced automotive engineering. But the Japanese giant's first venture into business aviation is a singular design that wears its avant-garde engineering on the outside, with its unusual engine location and low-drag aerodynamics.

Now entering service after prolonged development, the HondaJet is the vision of Michimasa Fujino, an aeronautical engineering graduate who joined Honda as an automotive researcher but was soon moved to aviation research. The unconventional light jet is Fujino's conception, and he is founding president and CEO of Honda Aircraft, established in Greensboro, North Carolina, to develop, certificate and produce the HA-420 HondaJet as the first of an expected family of models.

There is method to the tradition-defying aspects of the HondaJet's design. Over-the-wing (OTW) engines carefully combined with a natural-laminar-flow wing and winglets reduce drag and make the aircraft the fastest of the light jets. Relocating the engines from their normal aft-fuselage location allows for a longer cabin. The bulbous nose promotes laminar flow to reduce the drag penalty from a wide fuselage that, combined with weight-reducing carbon-fiber construction, allows a roomier interior.

Development has taken at least five years longer than expected. The proof-of-concept HondaJet first flew in 2003, and when formally launched in 2006 the aircraft was expected to be certified in 2009-10. The program included development of a new small turbofan, evolved with General Electric from Honda's own HF118. The 2,050-lb.-thrust GE Honda Aero Engines

HF120 was certified in 2013.

The HondaJet's engine location was determined based on computational fluid dynamics (CFD) analysis of dozens of clean-wing/aft-mounted and over-the-wing configurations. Most previous attempts at overwing engines, notably the 1970s VFW-Fokker 614, resulted in a substantially degraded wing performance. Fujino found that positioning overwing engines relatively far aft, and using CFD to shape, size and offset the pylons, actually improved

aerodynamic performance compared to a clean wing by increasing the speed at which shockwave drag begins to rise substantially.

More relevant to everyday operations, he also discovered the overwing configuration increases the maximum lift coefficient by 7%, lowering stall speeds. Other benefits of moving the engines onto the wings include a longer net fuselage section for passengers and baggage because the mounting beams do not pass through the structure, less engine noise and vibration transmitted to the cabin, and lower wing-bending moment.

Fujino's team and a consulting engineer developed a new high-speed, natural-laminar-flow wing design with an 8.5:1 aspect ratio, approximately 15% chord thickness, 9%-span winglets, a 38% taper ratio and 5.1-deg. washout angle. To delay transition to draggy turbulent flow, the SHM-1 airfoil has a favorable pressure gradient to 42% chord on the upper surface and 63% on the bottom surface. Notably, leading-edge contamination results in only a 5.6% reduction in lift coefficient, according to wind tunnel tests, which is impressive for an airfoil that depends upon precise surface smoothness for optimum performance.

For operators, performance of the SHM-1 airfoil, over-the-wing engines and winglets means the wing can be smaller, resulting in less drag, a higher wing loading for ride comfort and better

HA-420 HondaJet Specifications

Seating	1+7
Engines	2 X GE Honda HF120/2,050-lb. thrust ea.
Dimensions (ft./meters)	
Wingspan	39.8/12.1
Length	42.6/13
Height	14.9/4.5
Weights (lb./kg)	
Max Takeoff.....	10,600/4,808
Max Landing.....	9,860/4,472
Zero Fuel.....	8,800/3,992
Basic Operating	7,279/3,302
Max Payload.....	1,521/690
Max Fuel	2,845/1,290
Performance	
Max Cruise (kt.)	420
Max Altitude (ft./m).....	43,000/13,107
Range, 4 passengers (nm).....	1,180
Takeoff Distance (ft./m)	<4,000/1219.2
Landing Distance (ft./m).....	<3,050/929.64



fuel efficiency. The downside of the small wing and relatively wide stance of the HF120 turbofans is higher takeoff V speeds and longer takeoff field lengths.

At maximum takeoff weight (MTOW), the HondaJet's V_2 takeoff safety speed is 120 kt. indicated airspeed (KIAS) versus 98 KIAS for the Embraer Phenom 100E and 111 KIAS for the Cessna Citation M2. Standard-day takeoff field length (TOFL) at MTOW is 3,934 ft. versus 3,123 ft. for the Phenom and 3,210 ft. for the Citation.

The uniquely shaped nose promotes laminar flow for a relatively long distance down the fuselage, thereby cutting drag by 10% compared to a turbulent-flow shape. Composite construction promised a 10-15% weight reduction compared to aluminum, plus a smoother skin conducive to laminar flow. Actual weight saving was about 8%, says Fujino.

GKN Aerospace manufactures the fuselage components in Tallassee, Alabama, and assembles them in Orangeburg, South Carolina. Fuselage halves are laid up by hand in female molds using carbon-fiber prepreg cloth. A carbon-fiber/Nomex-honeycomb sandwich is used for the complex-curved nose and tail sections. The constant-

diameter center section is a semi-monocoque structure using stressed skins, longerons and hoop frames. Entire left and right fuselage halves, including sandwich sections, skins and longerons, are co-cured in an autoclave. Hoop frames are manufactured separately, then glued in place with Scotchweld when the halves are glued together top and bottom. The rear pressure bulkhead is a composite plate reinforced with composite beams. The forward pressure bulkhead is an aluminum structure integrated with the nosewheel strut mount and wheel well.

The wing is aluminum alloy; Honda opted for metal over composites for a better overall combination of strength, weight and volumetric efficiency for fuel storage. Concentrated loads at the engine mounts also favored aluminum construction. Single-piece upper and lower wing skins are milled from solid billets of metal because shot peening could not produce the consistently tight tolerances needed for laminar

Of the current generation of entry-level light jets, HondaJet is the fastest, roomiest, quietest and highest flying.

flow. The T-tail is conventional semi-monocoque aluminum. Engine bleed air is used for wing leading edge and engine inlet anti-ice heating. A separate electro-expulsive deicing system protects the horizontal stabilizer from ice accretion.

Systems design is as advanced as the airframe structure, but elegantly simple where possible. Primary flight controls are manually actuated. The autopilot incorporates a combined yaw damper/rudder boost system. Double-slotted trailing edge flaps are electrically actuated. An optional split-tail speed brake in the aft fuselage is quite effective in flight, but has little effect on runway-stopping performance.

Aviation Week visited Honda Air-



craft's campus at Piedmont Triad International Airport (KGSO) to see the production operation and fly the HondaJet with chief test pilot Ken Sasine. Our first flying opportunity was in a Level D full-flight simulator at training provider FlightSafety International at Piedmont Triad, where there are provisions for a second device when warranted by client demand.

The low pilot workload immediately becomes apparent in the sim. Development delays enabled Honda to upgrade from its originally planned Garmin G1000 to a G3000 flight deck, with a step change in avionics and system integration. Pre-start checks are automated, weight and balance initialization is quick, and flight planning is easy using the Garmin touchscreen control display units (CDU). Operation of external lights, airframe ice protection and transponder is automatic with manual override at the discretion of the pilot.

The system is a little too automated. I would prefer stand-alone taxi and landing light switches that are immediately accessible when crossing runways or when instructed to "line up and wait" on an active runway. Switches for the beacon and strobes would be handy for warning ground personnel of an impending engine start or turning off strobes when penetrating thick clouds at night. Such switching can be selected only through submenus on the touchscreen CDUs.

In single-pilot cockpits, however, the

touchscreens are easier to use and require less head-down time than trackball-based point-and-click interfaces. I spent little time wondering what it was doing and why. As implemented on the HondaJet, the G3000 is iPhone-intuitive because of its easily discoverable user interface.

The touchscreen CDUs provide complete systems control including audio, weather, traffic and terrain hazard warning systems, setting V-speed bugs and displaying waypoint information. Future flight management system (FMS) software versions will include full airport performance computations, including single-engine climb performance, runway lengths and V speeds.

Aircraft system integration into the G3000 enabled us to check external doors, engine oil levels, fuel quantity in each tank, hydraulic system health, air conditioning and pressurization system function, and electrical system status, including battery charge state, from the cockpit. About the only thing missing is an external camera to check that the welcome mat and chocks have been pulled before taxi.

Fujino's team has designed a hands-on-throttle-and-stick airplane. In addition to the standard four-way conical trim switch, there is a left-side on/off

HondaJet's cockpit has the most integrated and advanced version of Garmin G3000 yet developed for a light jet.

checklist control with a scroll and push feature for sequencing through items and acknowledging they have been accomplished. A long push on this control returns the screen to its previous display, such as an approach chart or weather-radar overlay atop a map. The on/off feature enables the pilot to cycle

The standard four-chair club section offers about 14 in. more legroom between facing seats than other light jets.

between the checklist and alternate display almost as fast as picking up or pocketing the hard-copy checklist.

The right side of the yoke has a system control shortcut button. When pressed, it takes the pilot to the top level of system controls on the touchscreen CDU. From there, submenus can be used to control exterior and interior lighting, solid-state circuit breakers, certain engine functions, lights, cockpit and cabin temperature, and other systems functions.

Serial No. 11, the first aircraft I flew, is loaded with all popular options and has a 7,381-lb. basic empty weight. With two pilots, 37 lb. of loose gear and 2,000 lb. of fuel, ramp weight was 9,798 lb. Computed takeoff weight was 9,748 lb. Based upon KGSO's 926-ft. field elevation, 27C outside air temperature and near-standard altimeter, V_1 was 110 KIAS, V_r 114 KIAS and V_2 120 KIAS. TOFL was 3,900 ft. and



final segment climb speed 140 KIAS.

With ground power plugged in, all displays and air conditioning were powered as soon as we switched on the batteries. After completing pre-start checks and loading the flight plan, I touched the start button, advanced the throttle to idle and monitored

The over-the-wing engine-mount configuration on the HondaJet reduces high-speed drag and increases maximum lift coefficient.

engine start. Three minutes after engine start, I signaled for the line service technician to pull off the external power cord and I began to taxi to Runway 23L. Wheel brakes were smooth; however, it took practice not to over-control the power steering. But it is as smooth as the system in the Learjet 75. Power steering eliminated the need for differential thrust or braking to maneuver in tight quarters.

Cleared for takeoff, I advanced the thrust levers to the forward stops. Acceleration was impressive at the aircraft's 2.5:1 weight-to-thrust ratio. Rotation forces were heavy for a light jet, as the main landing gear are positioned well aft of the center of gravity. Once the aircraft lifted off the main wheels, pitch control forces were pleasantly light.

Sasine says Honda worked diligently to achieve high handling-quality ratings. In most of the flight envelope,



there is a near-ideal 1:2:4 ratio between roll, pitch and yaw control forces. Roll response is crisp and short-period roll and pitch damping is strong. The yaw damper, though, is required for all phases of flight except takeoff and landing. A weight-on-wheels switch disconnects the damper on touchdown, should the pilot forget.

Atlanta Center was kind, clearing a direct climb to Flight Level (FL) 430 (43,000 ft.). We used the standard 210 KIAS/Mach 0.57 climb schedule. Initial climb rate was in excess of 4,000 ft./min. Time to climb was 18 min., compared with the 21 min. predicted by the pilot's operating manual. In ISA-5C conditions at FL 430, the aircraft cruised at Mach 0.63 burning 560 lb./hr. The manual predicted Mach 0.625 on the same fuel flow at ISA.

Down at FL 330 and in ISA conditions, we cruised at 420 kt. true airspeed (KTAS) while burning 1,000 lb./hr. at a weight of 9,300 lb.—slightly faster than book speed with a slightly lower fuel burn. So the HondaJet makes its advertised speed and fuel efficiency numbers, based upon my observations.

After the long-range and high-speed cruise checks, we descended to 17,500 ft. for visual-flight-rules air work. My first impression was that adding thrust causes a noticeable nose-down pitching moment, as the engines are positioned well above the center of gravity. Also, extending the speed brake at high speed produces a mild nose-up pitching

moment. But the speed brake is quite effective at slowing the aircraft at high speed or adding drag to permit stabilized descent rates of 7,000-8,000 ft./min. or more. That would come in handy during an emergency descent.

Steep turns are a snap if operators opt for the optional synthetic vision system. It includes a flightpath marker (FPM) that indicates aircraft trajectory. Peg the FPM atop the horizon line and the aircraft will not vary from target altitude. Pitch forces in the 45-deg. bank turns are pleasantly hefty, lessening the need to trim the aircraft in pitch. It takes about 5% more engine N_1 (low spool) rpm to hold 250 KIAS during the maneuver.

We then flew a standard series of stall approaches in the clean configuration, with takeoff/approach flaps, and in landing configuration. At 9,140 lb., the stall-warning stickshaker triggered at 109 KIAS, 99 KIAS and 95 KIAS in the three configurations. Stall recovery was immediate as soon as pitch attitude was reduced and thrust increased.

Returning to Greensboro, we flew a couple of approaches in instrument meteorological conditions to full-stop landings. In cumulus clouds, the aircraft provided a ride quality similar to a large-cabin business jet because of its relatively high wing loading. Turbulence does cause some significant nose attitude variations that require control inputs.

At 9,200 lb., approach speed was 114 KIAS and V_{ref} 109 KIAS. The air-



craft was easy to hand-fly on approach, with linear thrust response to throttle movement. Crossing the threshold, I slowed to V_{ref} , pulled the thrust to idle at 50 ft. above the runway and settled into the flare. I encountered some float, as the wing sits low to the runway surface with weight on wheels.

During the second landing, I slowed the aircraft more aggressively when crossing the threshold, and there was little float—a technique similar to that used in the Eclipse 500, which similarly lacks ground spoilers. It is essential to slow the HondaJet well below V_{ref} in the transition to flare to prevent float.

We used the simulator to practice a one-engine-inoperative takeoff. Center manager Eric Dixon “failed” the left engine at V_1 . This caused a pronounced left yawing moment, easily countered with a large amount of right rudder input. Pedal force, though, was impressively moderate because of the effectiveness of the rudder bias system.

The HondaJet sets a new standard for cabin comfort in entry-level light jets. The OTW configuration provides about 14 in. more legroom between facing chairs than its competitors do. Both times I flew the aircraft I was impressed with cabin sound levels. This is the quietest light jet I have yet flown by wide margins. The air-conditioning system is the loudest sound in flight.

The HondaJet raises the bar in entry-level jets for passenger comfort, cabin quiet and baggage capacity. Optional luxury features, such as an externally serviced toilet and lavatory with running water, are not available in other light jets. The aircraft also has the best ride quality in turbulence of any entry-level jet in production, in my opinion.

Fit and finish are unsurpassed in its class. Exterior surface tolerances are tight, doors fit precisely and paintwork is superb. Interior furnishings also are



st rate, befitting an aircraft that sells more than \$5.1 million with options.

But the entry-level jet market is far more competitive than when Fujino began design in 1997. Today there are more than 400 Citation CJ1, CJ1+ and M2 aircraft in operation and nearly 300 Phenom 100/100Es. The latest versions of these aircraft are more competitive than their original models. Moreover, this end of the market has suffered one of the strongest declines since 2009.

All this is a small dip in the long-term plans of Honda Aircraft, say

industry consultants. Honda, a company with enduring patience and deep pockets, is likely to be in the aircraft business to stay. The HondaJet’s development path has yielded technologies and experience that could benefit a range of future aircraft with the performance and comfort to earn sizable

shares in several segments of the business aviation market. ☒



Check 6 Fred George discusses flying the HondaJet in our podcast with other editors from the European Business Aviation Convention & Exhibition: AviationWeek.com/podcast

Honda Aircraft’s plant is a paradigm of Honda’s ultra-clean, ultra-calm and ultra-disciplined manufacturing standards.



JOINT POWER

Honda Aircraft’s \$120 million, 680,000-sq.-ft. campus is clearly sized to accommodate future HondaJet models. The hangar doors are nearly twice the height of the HA-420’s 15-ft.-high T-tail and open more than twice as wide as its 40-ft. wingspan. And there is ample open land available for future expansion on the 130-acre parcel at the east side of Greensboro, North Carolina-based Piedmont Triad International Airport.

Inside, the work environment is similar to Honda’s massive automotive plant at Marysville, Ohio. Ceilings, walls and floors are bright white and abundantly illuminated with overhead LED arrays. Workers all are clad in white coveralls embroidered with their names for easy identification. Mid-shift breaks are provided for calisthenics.

Activity on the assembly line is proceeding slowly for now. More than 40 airframes are in various stages of completion, but fewer than three a month are being produced. Honda is in the final stages of earning its production certificate, and currently each aircraft must be individually inspected for approval. Full-scale deliveries to customers will begin midyear.

The HF120 engine is manufactured at separate company Honda Aero’s 86,100-sq.-ft. plant in Burlington, North Carolina, about 35 mi. east of the Greensboro campus. Ground has been broken on a 50,000-sq.-ft. plant extension that will enable the facility to produce well over 100 engines a year. Similar to Greensboro and other Honda factories, the work environment is all white, brightly illuminated and immaculate.

General Electric and Honda formed the engine joint venture in 2004 to capitalize on GE’s materials and 3-D-aerodynamic expertise, particularly with titanium fan and compressor alloys, and Honda’s aerodynamic design capabilities. One of the most advanced engines in its class, with a 4.5:1 thrust-to-weight ratio, 2.9:1 bypass ratio and 24:1 pressure ratio, the 2,000-lb.-thrust-class HF120 is also one of the quietest and cleanest.

With a time between overhaul (TBO) when mature of 5,000 hr. and no requirement for a midlife hot-section inspection, the HF120 is expected to remain on wing 40% longer than other engines in this class and thus have far lower operating costs. Current TBO is 2,500 hr. ☒