# Case Study 4 HondaJet

Michimasa Fujino


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The HondaJet design team was challenged to deliver 21st century performance with elegance. The result is the business jet shown above. This case study is a personal account of the love affair between the author and the HondaJet design. The story starts three decades ago with the author's passion for airplanes.

*I finally realized that all of my life experiences have worked in concert to bring me here.*

Michimasa Fujino

## CS4.1 Honda's Aviation Challenge

It may be somewhat unique within the very competitive arena of today's global business environment that Honda has always been focused on the future and that the company's top management regularly has its eyes set twenty or more years ahead. From its very beginnings, Honda has remained steadfastly committed to becoming a world leader in providing meaningful forms of transportation for the benefit of people across the globe. As a result, Honda's advancement into aviation can easily be understood as a natural progression of the company's core philosophy to offer products of the highest performance, quality, and value—from motorcycles . . . to automobiles . . . to advanced future technologies—that help to further enhance and expand human mobility.

Honda's aerospace endeavors began in 1986, when top management decided to establish a new research center, named the Honda R&D Fundamental Research Center, and form teams to prepare new products for the 21st century. Several new projects were started, including humanoid robotics, gas turbine engines, ultra-light automobiles, and airplanes. Without any advanced notice, I was assigned to the airplane project. From that point in time, my long journey began—a journey I could never have imagined would find me devoted to the airplane business for more than 25 years.

In 1986, I was working in Honda's automobile division after having graduated from Tokyo University two years earlier. I decided to become an automobile engineer, even though I had earned a degree in aeronautical engineering. I was fascinated by the challenging and dynamic opportunities available within the Japanese automobile industry from both the technical and business perspectives. The very competitive and independent spirit of the Japanese automobile industry fosters a unique environment that encourages the exploration of products encompassing new concepts and technologies. Honda, in particular, has always demonstrated a challenging spirit and independence to penetrate into new markets at its own risk and to boldly expand its boundaries. As I had been independent from my earliest childhood, I joined Honda without hesitation. I was enjoying automobile design and development as a young Honda engineer when I was told by my boss that I was to be transferred to the airplane project. Frankly speaking, I was quite surprised by the announcement.

It is well known that airplane development and certification are not easy tasks. These endeavors require large up-front investments in technology, people, and infrastructure. In addition, the very complex certification process can take a great deal of time to complete. However, if you consider this from a different viewpoint, these challenges are exactly why airplane development—especially development from a clean sheet design—can be such an exciting endeavor and one that not many people have the opportunity to undertake during their lifetime. So, I decided to accept this much larger challenge and join the airplane project team.

Our team was told by top management that we needed to develop from scratch a Honda-original airplane. Complicating our task, the research themes given to us included a forward-swept wing design, Advanced Turbo Prop (ATP) propulsion, all-composite structure, and so forth. Every one of these research themes challenged the limits of available technologies and directly challenged our team as well, because we did not have any experience in aviation technologies.

The first airplane design effort was named MH01. The project was to modify the wing and empennage of an existing single engine turboprop airplane to composite structure in order to demonstrate the advantage of composite application to primary structures. Following MH01, we developed our next airplane for the first time from a clean sheet design. This second airplane, named MH02, was a pure experimental aircraft that consisted of various new technologies [1]. There are pros and cons to applying state-of-the-art technologies to a new airplane design, and some of our goals, such as the ATP, were not realized. However, many things were learned from the challenges we faced. By the end of the MH02 project, we were ready to design an airplane from a clean sheet of paper. Our experience seemed sufficient to fabricate and test an airplane as well. Essentially, we understood the fundamentals of airplane design. We needed computer programs to analyze aircraft performance, aerodynamic characteristics, stability and control characteristics, loads, and vibration and flutter. Many drawings were generated and numerous stress analyses were performed. Actually, our team conducted structural tests, system tests, and ground vibration tests, and I even had to sand tooling molds by hand. Over time we learned and came to understand the theory needed to design an airplane, but also gained valuable practical experience. Through this project, we created the in-house capability to develop aircraft, and all of these experiences would become very important in the pursuit of future airplane designs.

## CS4.2 New Concept for the Light Jet

Although we had developed many airplane design capabilities, the MH02 project ended. Some board members thought we should not continue the airplane project. The automobile industry was very competitive globally, and board members thought we should concentrate the company's resources on automobile research and development. This opinion was driven in part by the fact that the airplane business is very specialized and by the resulting perception that it is very difficult for a new entrant to get into this business. Furthermore, compared to the automobile business, it can take much longer to recoup the investment in aviation. But, most importantly, without unique Honda technologies and concepts that would bring new value to the industry and customers, there would be little meaning for Honda to get into the aviation business.

During the MH02 project, I had numerous opportunities to use commercial airlines, general aviation and business jets. Based on this experience, I envisioned great potential for high performance light jets. I thought if an airplane could be designed having both high fuel efficiency and high speed, without sacrificing cabin volume and luggage space, there would be a potential demand in the business jet market. So, the new design targets for a Honda advanced light jet became:

1. Maximum efficiency—improved fuel efficiency by 20% compared to conventional jets. The target was to realize a direct operating cost per seat mile close to that of a first-class ticket on a commercial airliner under full seating capacity. This direct operating cost should be the lowest among light jets.
2. Maximum cabin space—increase cabin space by 20%. Even though it may be categorized as a light jet, the cabin space should be plush and passengers' feet should never overlap in a club seating arrangement. There also should be a roomy and comfortable lavatory, which passengers do not hesitate to use. Cabin space should be the best in the class.

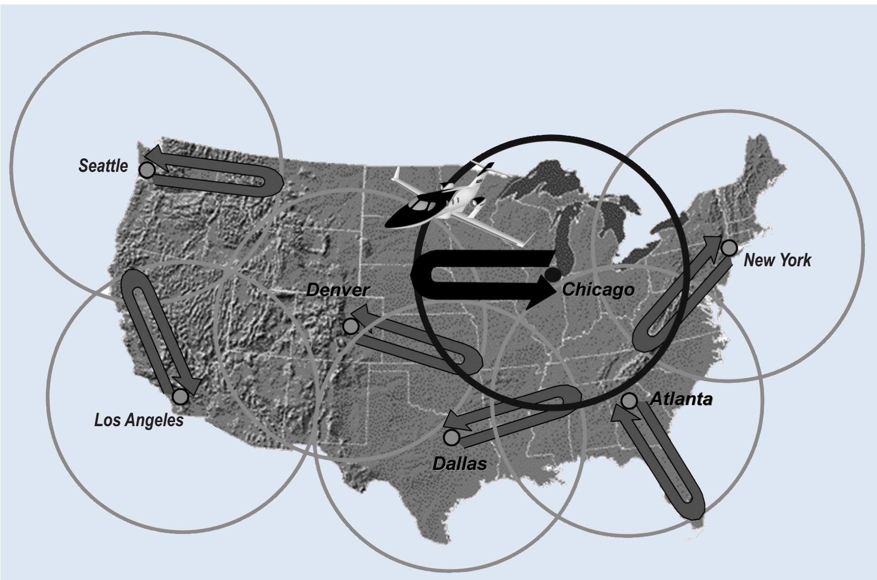


**Figure CS4.1** Round trip range without refueling.

3. Maximum luggage space—maximized luggage space capable of storing six golf bags. Many light jet users would use their jets to go play golf, so this is an important requirement.
4. Maximum speed—cruise speed that should exceed 400 kt, even though it may be classified as a light jet, it should be the fastest in its class.
5. Ownership experience—not only high performance and high efficiency, but also highly attractive to satisfy customers' ownership experiences from quality and aesthetic points of view. The airplane should look beautiful.
6. Optimum range—capable of flying from New York to Miami nonstop and operating out of most major U.S. hub cities via round trips without refueling as shown in Fig. CS4.1.

To achieve these design goals, it is necessary to reduce the overall airplane size as much as possible in order to reduce drag and operating costs, but we also need to maximize space for the cabin and luggage. Achieving these two opposing requirements is a true technical challenge that required the development of various new technologies.

## CS4.3 Development of HondaJet Key Technologies

### CS4.3.1 Over-The-Wing Engine Mount (OTWEM) Configuration

Current business jet designs have engines mounted on the rear fuselage. If we could mount the engines on the wings, the carry-through structure required to mount the engines on the rear fuselage would be eliminated. This would allow the fuselage internal space to be maximized without increasing the size of the fuselage. Since light business jet designs are very close to the ground, it is impossible to install the engine under the wing. Where else could the engines be located? Nearly fifteen years ago the idea of an OTWEM arrangement was sketched on the backside of a calendar as shown in Fig. CS4.2.

It was immediately recognized as a technical challenge, both from aerodynamic and aeroelastic standpoints, to employ an OTWEM configuration for a high-speed jet aircraft. In general, locating the engine nacelle over the wing causes unfavorable aerodynamic interference and induces a strong shock wave that results in a lower drag divergence Mach number. Also, mounting the engine on the wing significantly changes the vibration characteristics of the original clean wing and, as a result, influences aeroelastic characteristics as well. So, initially, it was thought to be a poor idea to mount the engine over the wing from both aerodynamic and aeroelastic standpoints. It was critical to the design objectives that the OTWEM

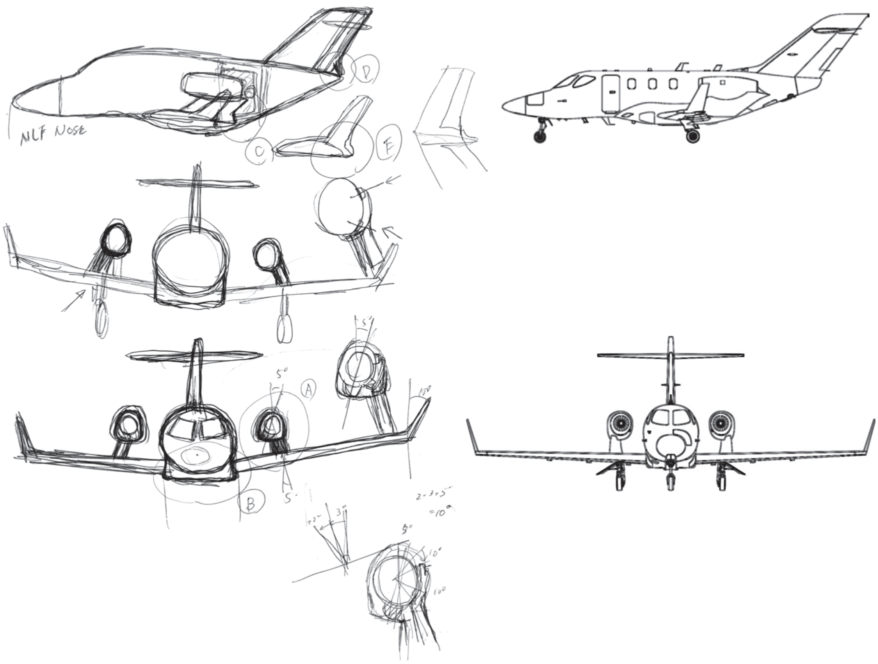


**Figure CS4.2** Original sketches compared to final design.

configuration be part of the design, so the initial research was focused on "how to design an OTWEM configuration that minimizes the wave drag increase at high speeds (high Mach number) and achieves higher cruise efficiency and minimized aeroelastic disadvantage."

## Wave Drag Reduction

Aerodynamic design was initially focused on how to minimize aerodynamic interference from the nacelles and pylons by optimally contouring the nacelle, pylon, and fairing. After several design iterations I glanced at my bookshelf and happened to see an old textbook on aerodynamics authored by Ludwig Prandtl. This book reminded me that when there were no computers for numerical simulation or computational fluid dynamics, aerodynamic flow was analyzed by using analytical methods with complex functions ($x + iy$) to represent the flow around a body. For example, superposition of basic flow functions, such as source-sink, circulation, uniform parallel flow, etc., are used to construct the resulting flow around a body. These theoretical methods renewed the thought process that led to a more evolved design.

The new approach focused on how to "create flow and pressure distribution" that would reduce wave drag rise by superimposing flow fields around bodies, instead of attempting to minimize the interference between two bodies. In other words, an optimum pressure distribution and flow was sought by superimposing two flow fields. I refer to this as "favorable interference." The HondaJet design needed a Natural Laminar Flow (NLF) wing airfoil section to greatly reduce drag. However, an NLF airfoil exhibits high wave drag at high Mach number because of its pressure distribution required for laminar flow. So, it was critical to reduce the upper surface shock wave strength to increase the drag divergence Mach number when we used an NLF wing for high speed aircraft.

I attempted to use a flow field in front of the nacelle to decelerate flow where local wing flow velocity is reaching the speed of sound and a shock wave is formed when an aircraft flies at high Mach number. I thought both (1) that this effect of nacelle flow field to the wing pressure distribution would be smaller at lower Mach number and a favorable pressure gradient could be maintained at most climb and cruise speeds, and (2) that the effect would be larger and could delay shock wave at high Mach number. As a result, we would be able to achieve laminar flow under most flight conditions and, at the same time, reduce the shock wave strength at high Mach number, achieving a higher drag divergence Mach number.

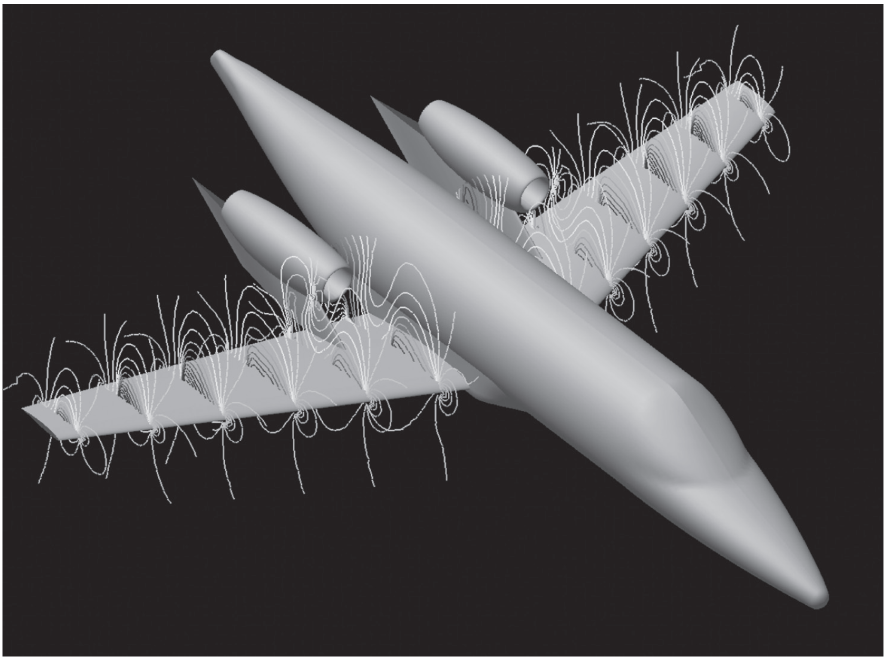

**Figure CS4.3** Off-body pressure contours of the OTWEM configuration.

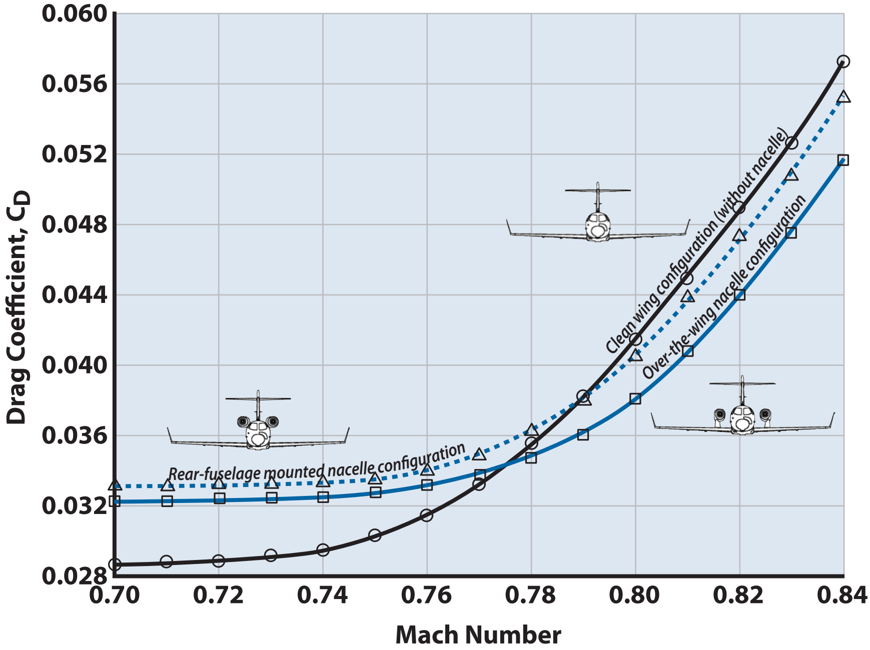


**Figure CS4.4** Comparison of drag divergence for various nacelle configurations.

Based on this approach, hundreds of computer simulations were performed for different OTWEM configurations having different nacelle locations relative to the wing. These runs confirmed that there was an effect of chord wise and vertical nacelle locations on wave drag. The simulation results demonstrated that the strength of the shock can be reduced and that drag divergence occurs at a higher Mach number than that for the clean-wing configuration when the nacelle is located at optimum position relative to the wing (Fig. CS4.3). A transonic wind tunnel test was conducted in the Boeing Transonic Wind Tunnel (BTWT) to validate the simulation results. The optimum over-the-wing nacelle configuration exhibits lower drag than the conventional rear-fuselage engine-mount configuration [2] (Fig. CS4.4). The concept of positive interference of the OTWEM configuration was also confirmed at the NASA NTF (National Transonic Facility) at high Mach number and high Reynolds number testing as well (Fig. CS4.5). Ultimately, shock wave strength was reduced and drag divergent Mach number was increased for the optimum OTWEM configuration while maintaining laminar flow under most flight conditions. The final aerodynamic configuration of the HondaJet's OTWEM is based on these results.

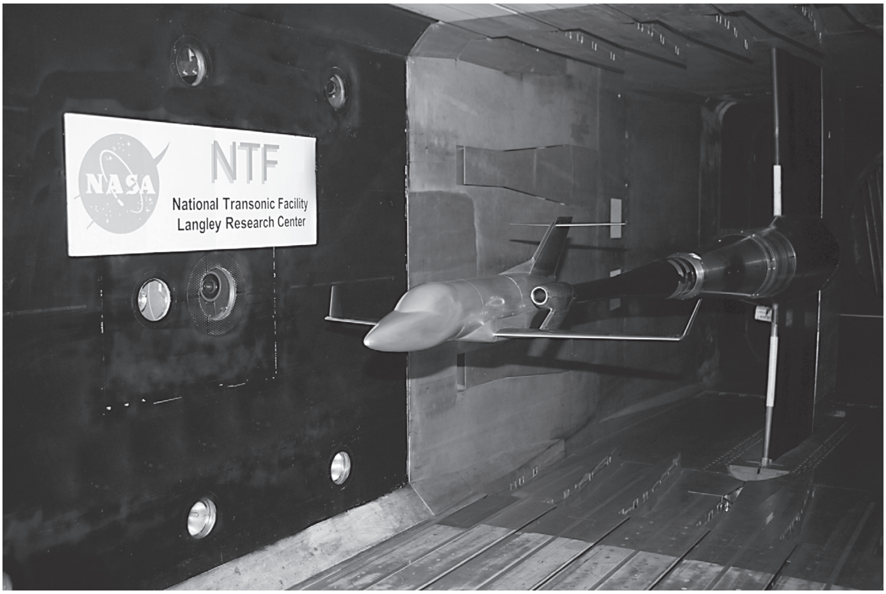


**Figure CS4.5** NASA NTF wind tunnel test.

## Stall Characteristics

Another critical technical evaluation of the OTWEM configuration is to determine its stall characteristics. Docile stall behavior is very important for an airplane. Analytical studies were performed to design wing twist distributions and pylon shapes. Then, wind tunnel tests were conducted to measure the design's stall characteristics. The upper wing surface stall pattern of the OTWEM configuration from a 1/6-scale, low-speed wind-tunnel test is shown in Fig. CS4.6. The wing stall pattern begins at 55% semi-span and separation propagates inboard. At the stall angle of attack, the region of the wing between the fuselage and the nacelle is not stalled, resulting in good stall characteristics. Additionally, there is adequate stall margin over the outboard portion of the wing. The lift curves obtained from the 1/6-scale tests with and without nacelles are shown in Fig. CS4.7. The zero-lift angle and the maximum lift coefficient of the OTWEM configuration are higher than that of the clean-wing configuration. Consequently, there is no disadvantage with respect to the lift characteristics for this OTWEM configuration [3].

## Inlet Distortion Evaluation

I believed it was important to investigate the inlet-flow distortion for the OTWEM configuration at high angles of attack because the separated

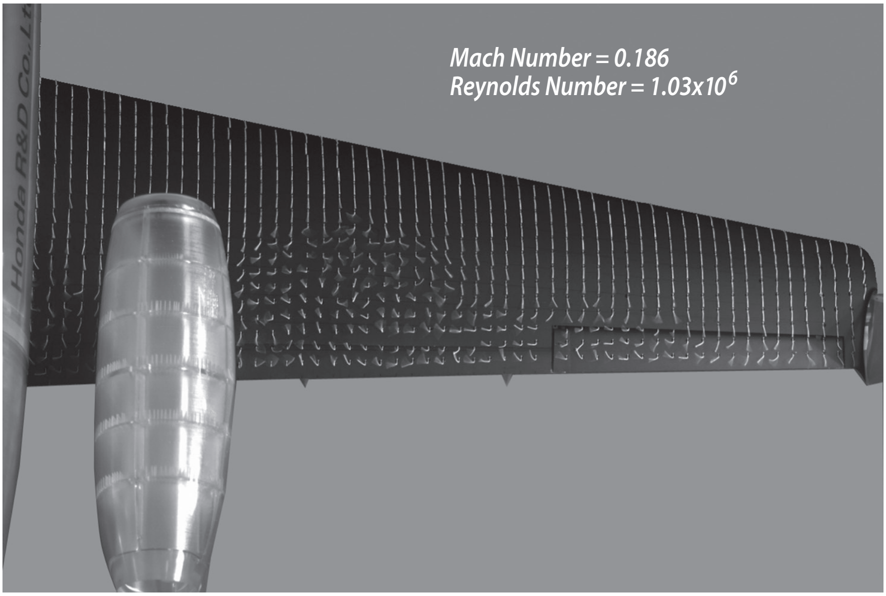


**Figure CS4.6** Stall pattern.

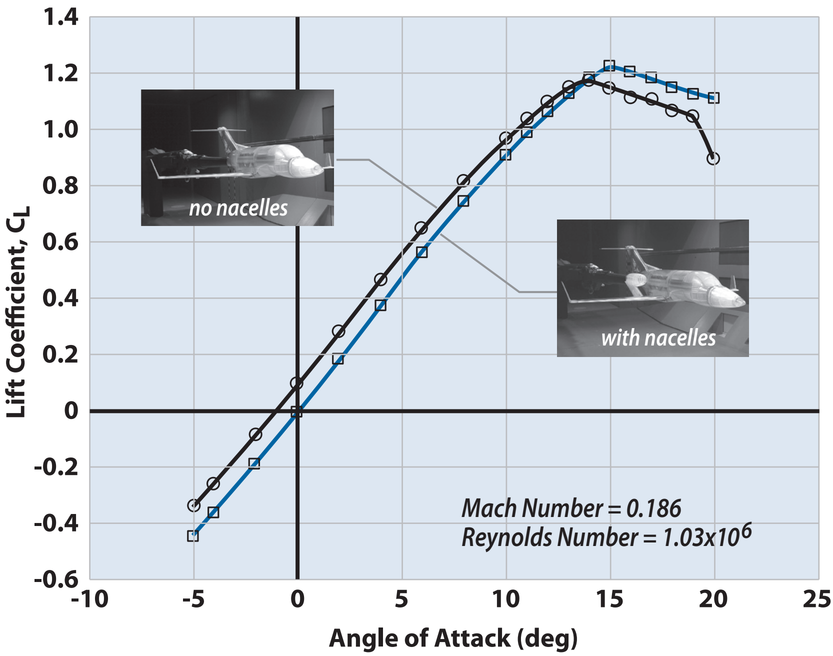


**Figure CS4.7** Comparison of lift curve with and without nacelles.

flow from the wing at high angles of attack could enter into the engine inlet. The inlet shape and length were carefully designed by taking these conditions into account. To evaluate these characteristics, a 1/6-scale, powered-model test using DC motor engine simulators was conducted in the Honda Low-Speed Wind Tunnel. The inlet and duct shapes were scaled from the full-scale nacelles, and forty total-pressure probes were mounted at the fan face (Fig. CS4.8). An investigation was conducted to determine if the measured total-pressure distortion exceeded the limits for high and low mass-flow conditions at various angles of attack and sideslip angles. Examples of the distortion pressure patterns are shown in Fig. CS4.9. The inlet total-pressure distortion is less than 0.1% up to the stall angle of attack and less than 2% at post stall angles of attack. Similar tendencies were obtained from tests with low and high mass-flow ratios. The results demonstrate that the distortion does not exceed the limits specified by engine requirements within the flight envelope.

The OTWEM configuration has a higher cruise efficiency than that of a conventional rear-fuselage engine-nacelle configuration and, at the same time, the cabin volume is maximized. Figure CS4.10 shows the final configuration of the HondaJet OTWEM configuration [3].

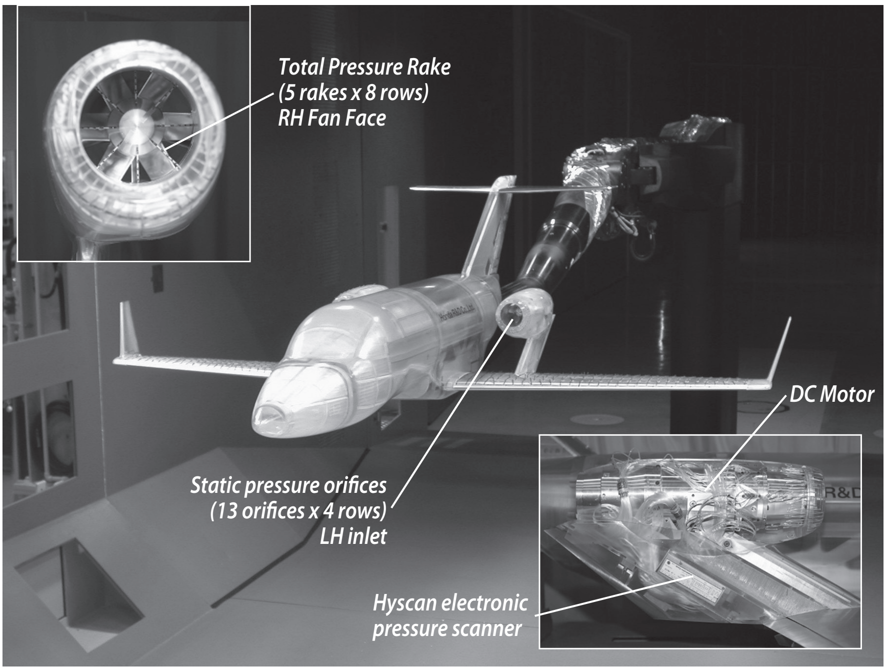


**Figure CS4.8** 1/6 scale engine simulator.

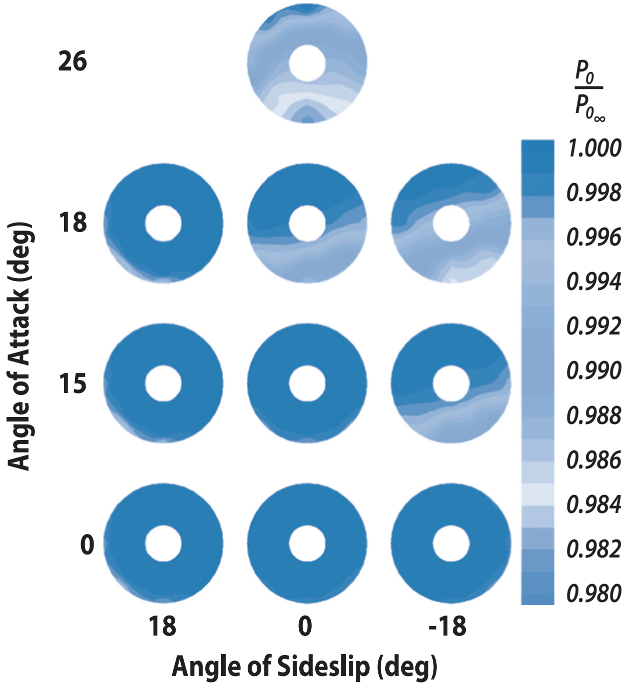


**Figure CS4.9** Pressure distribution pattern obtained from powered model test.

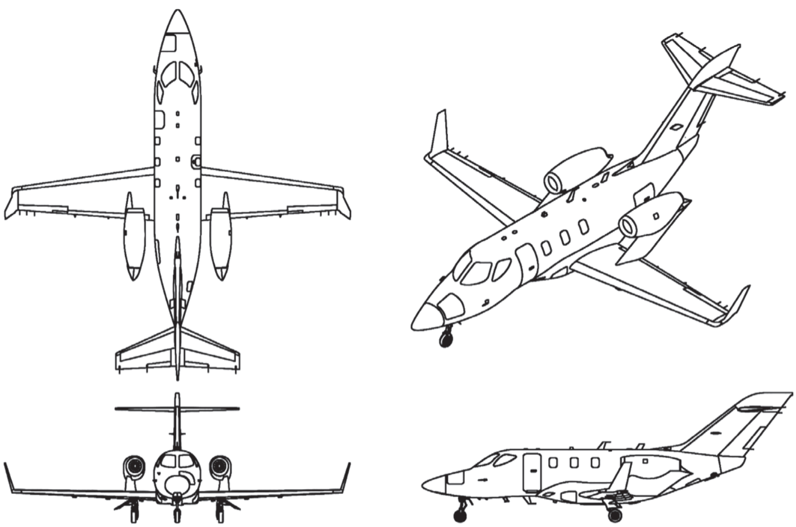

**Figure CS4.10** General arrangement.

## Aeroelastic Characteristic

Mounting the engine on the wing, however, significantly changes the vibration characteristics of the original wing and, as a result, influences the aeroelastic characteristics. In addition, the nacelle aerodynamic load and interference will affect the flutter characteristics. Positioning the engine ahead of the elastic axis of the wing to increase the flutter speed is a well-known design rule, which has a marked effect on the configuration of modern transport aircraft. For the present OTWEM configuration, however, the engine is positioned aft of the elastic axis of the wing, and the aeroelastic characteristics must be carefully calculated. Also, the aerodynamic effect on the flutter characteristics induced by having the engine nacelle positioned over the wing must also be included, especially in the transonic flight regime. It is necessary to validate flutter characteristics for the over-the-wing engine nacelle configuration.

The flutter characteristics of the OTWEM configuration were determined using extensive theoretical studies and numerous wind-tunnel tests. The location of the engine mass and the stiffness of the pylon relative to that of the wing are also important parameters for wing-flutter characteristics. Theoretical analyses were performed using the ERIN code and NASTRAN, and substantiated with low-speed and transonic wind-tunnel flutter tests at the National Aeronautical Laboratory Transonic Flutter Wind Tunnel. The study shows that the symmetric flutter mode is more critical than the anti-symmetric mode for the OTWEM configuration [4].

The effects of the aerodynamic load and the interference due to the engine-nacelle installation over the wing were studied as well. The result showed that the effects are small for this OTWEM configuration. Furthermore, the engine-pylon vibration characteristics influence the flutter characteristics. The study showed that the flutter speed is highest when the engine-pylon side-bending frequency is close to the uncoupled first wing-torsion frequency (about 0.9 to 1.0 times the uncouple first wing-torsion frequency). The flutter speed is also lowest when the engine-pylon pitching frequency is about 1.25 times the uncoupled first wing-bending frequency (Fig. CS4.11). Based on these results, spanwise location of engine, wing stiffness and mass distributions were designed to satisfy the flutter-clearance requirements.

## CS4.3.2 Natural-Laminar-Flow Airfoil (SHM-1)

To maximize the performance of the HondaJet, a new natural-laminar-flow airfoil, the SHM-1, was designed using a conformal-mapping method [5]. The pressure gradient on the upper surface is favorable to about 42% chord,

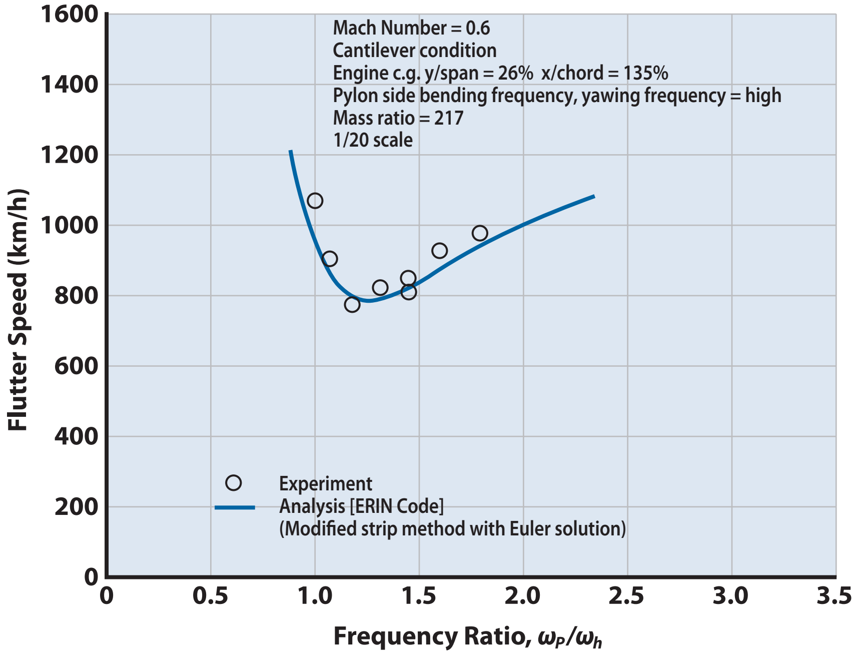


**Figure CS4.11** Correlation of the flutter analysis with experimental data.

followed by a concave pressure recovery, which represents a compromise between maximum lift, pitching moment, and drag divergence. The pressure gradient along the lower surface is favorable to about 63% chord. Wing leading-edge geometry was designed to cause transition near the leading edge at high angles of attack to minimize the loss in maximum lift coefficient due to roughness. The upper-surface trailing-edge geometry was designed to produce a steep pressure gradient and, thereby, induce a small separation. By incorporating this new trailing-edge design, the magnitude of the pitching moment at high speeds is greatly reduced. The SHM-1 airfoil and its associated pressure distribution are shown in Fig. CS4.12. The airfoil has been tested in both low-speed and transonic wind tunnels, as well as full-scale flight testing using a gloved T-33 aircraft (Fig. CS4.13, Full-scale flight testing validated the performance of the airfoil at full-scale Reynolds number and Mach number. The laminar-to-turbulent boundary-layer transitions were visualized in real time using an infrared (IR) camera during the T-33 flight tests (Fig. CS4.14). As designed, the airfoil exhibits a high maximum lift coefficient, and yet, has docile stall characteristics and a low profile-drag coefficient.

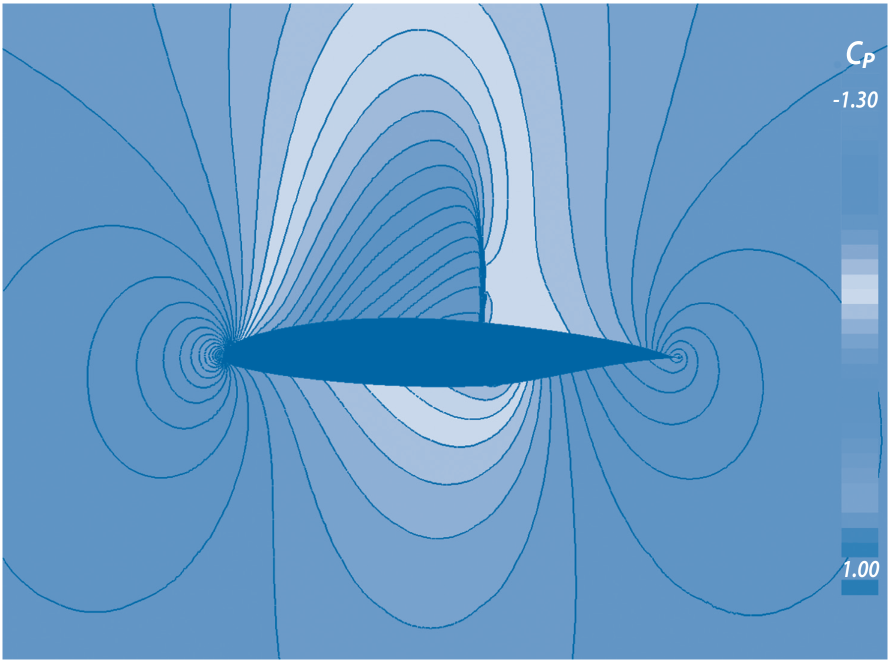


**Figure CS4.12** Airfoil pressure fields showing location of upper surface shock.


**Figure CS4.13** T-33 flying testbed.

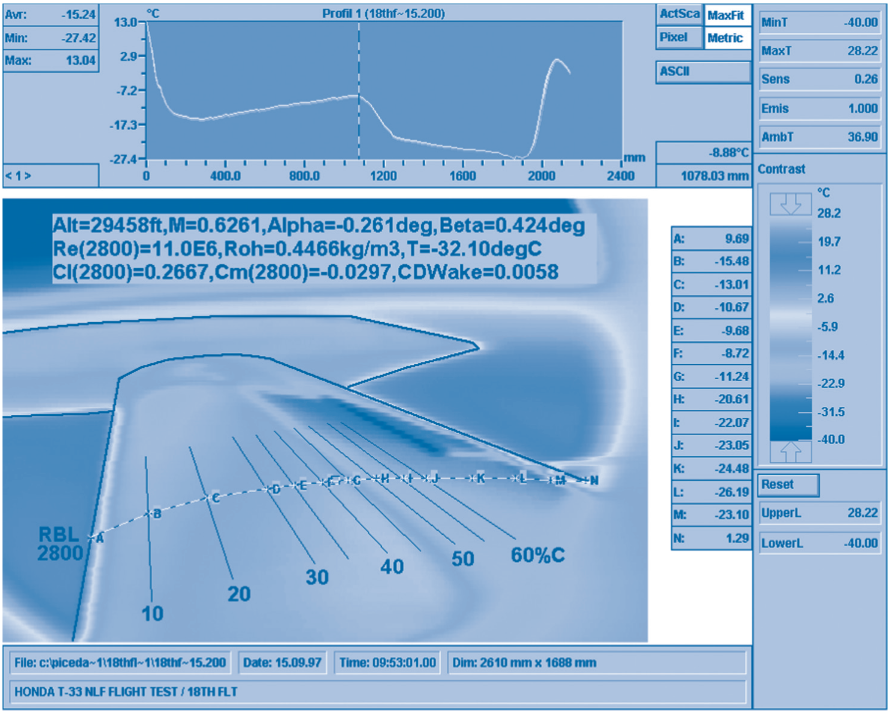


**Figure CS4.14** Boundary layer transition.

## CS4.3.3 Composite Fuselage

Composite material is now widely used in the aviation industry to reduce structural weight by taking advantage of its superior mechanical properties such as specific strength. However, careful evaluation is needed especially for composite material application for light jets because of its cost and the relative size of the aircraft. The weight benefit is often limited by the necessary minimum gauge of the structure and other design constraints. As a result, it is not always easy to take advantage of the characteristics of composite material for aviation applications. In addition, unique characteristics of composite material, including strength "knock down factor" for hot wet conditions, compression after impact (CAI), and inter-laminar shear strength, etc., are design constraints that must be considered, which have negative impacts on actual weight reduction. For the HondaJet structure, composite material is applied mainly to the fuselage taking into account all of the design aspects and constraints described above.

The HondaJet's fuselage is constructed entirely of graphite composites. The material is a 350-deg-F cure epoxy pre-preg reinforced by carbon fiber. The matrix is Cytec 5276-1 high-damage-tolerance, epoxy resin, while the reinforcement is TOHO G30-500 high-strength, intermediate-modulus fiber. As shown in Fig. CS4.15, the cockpit and tail sections are a honeycomb sandwich construction to maintain the compound curves, which are especially important for the laminar-flow nose. The sandwich structure also has the advantage of reduced cost due to the ease with which it can be fabricated into complex, three-dimensional contours. An integrally stiffened panel structure is employed for the constant cross-section portion of the cabin. The stiffened panel structure reduces weight because of its high efficiency structure and also maximizes the cabin volume. The general frames and stringers have identical dimensions in the constant cabin section, so the numbers of molds for the frames and stringers are minimized. The constant fuselage section can be easily extended to satisfy future fuselage stretching. A feature of the fuselage fabrication is that the sandwich panel and the stiffened panel are co-cured integrally in an autoclave to reduce weight and cost. It was a technical challenge to cure the honeycomb sandwich structure under the pressure (85.3 psi) required for the stiffened panel, but a new method called the "picture-frame stabilizing method" prevents core crushing.

Another feature of the HondaJet composite fuselage is the buckling tolerance design that has been adopted to the stiffened panel. Shear buckling is allowed under limit load. The skin thickness and ply orientation of each structural skin bay were designed for optimum stress level and contribute to weight reduction as well (Fig. CS4.16).

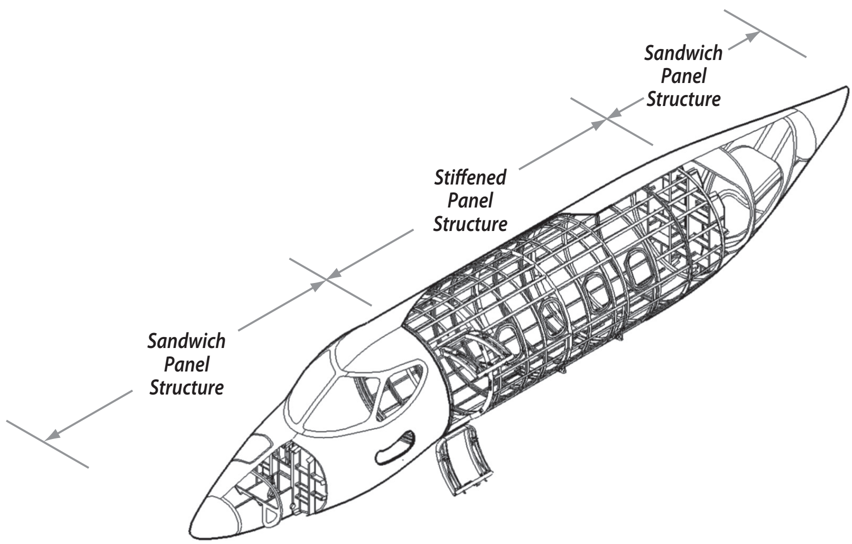


**Figure CS4.15** Fuselage structure.

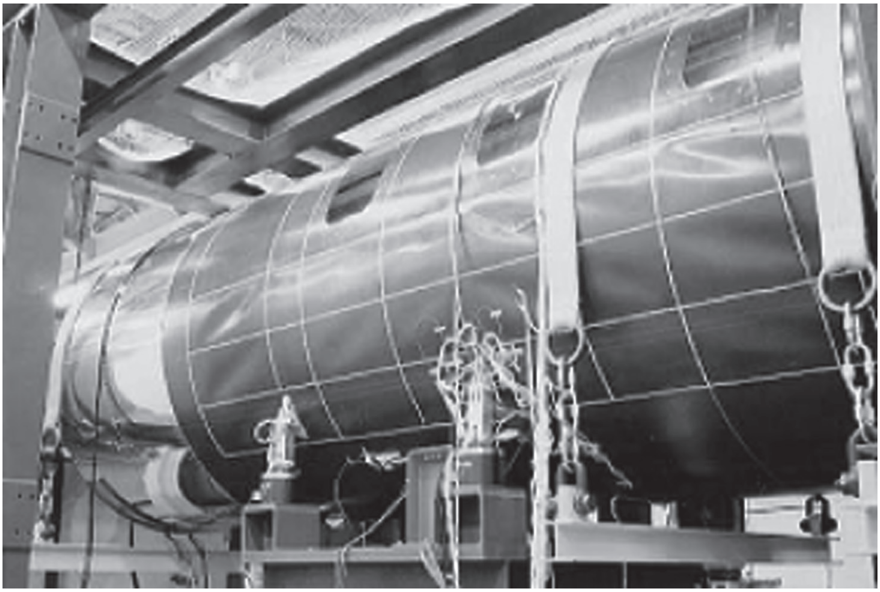

**Figure CS4.16** Fuselage skin.

Through the application of composite material for the HondaJet's fuselage, we have achieved lower weight along with both an affordable fabrication cost and the best contour for aerodynamics (Fig. CS4.17).

## CS4.3.4 Advanced Cockpit Design

Within the automobile industry, design cycles are very short and the number of models is very high compared to the aviation industry. As a result, the automobile design process from concept to 3D definition is not only very sophisticated, but also very short and efficient. For the HondaJet, the primary goal for the cockpit design was to achieve a high degree of flight safety while incorporating automobile interior and cockpit design processes. This approach achieves a high degree of integration of cockpit functionality, human factors consideration and interior aesthetics. In order to realize this objective, we conducted several systematic design studies for cockpit layout, machine human interface to define basic dimensions for seating, flight controls and switches, and visibility pattern assessment (Fig. CS4.18). Then, several concept sketches were drawn, and, based on the sketches and defined geometry, very high fidelity 3D surfacing data was created. At this point virtual design studies for aesthetics, including

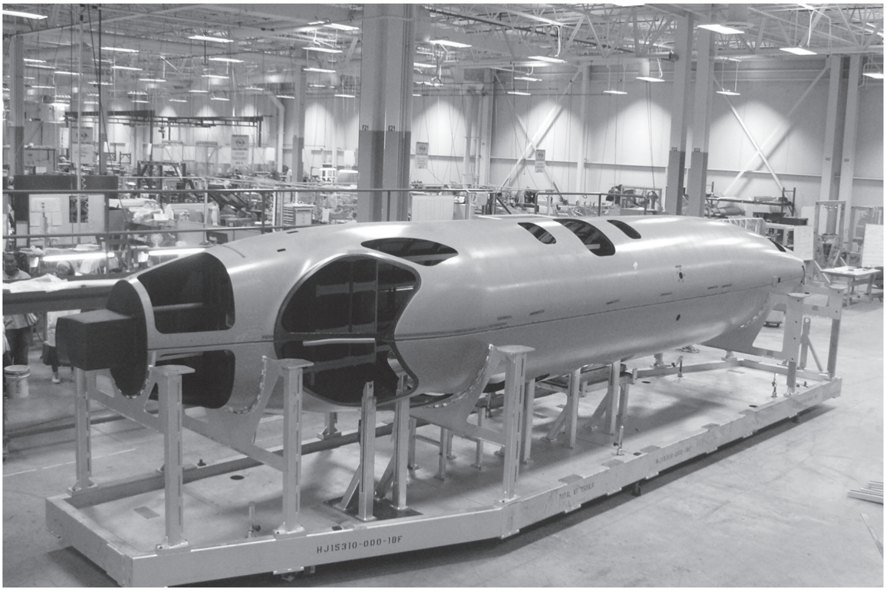

**Figure CS4.17** Composite fuselage.

evaluation of textures were undertaken. These studies utilized high-performance workstations and software that projected images on what is called a "powerwall," which offers four-times higher resolution display than a standard high-definition display. In addition, more detailed simulation analyses, such as ray tracing analysis of the instrument panel display's reflection on the windshield, etc., were conducted to define and verify glare shield geometry.

When the original concept of the HondaJet was started in the 1990s, cockpit and avionics systems on light business jets were not very well integrated and still relied heavily on conventional instruments. The goal was to incorporate a highly integrated system with large Primary Flight Displays (PFDs) and a Multi-Function Display (MFD) presenting all flight information. The HondaJet flight deck features a Honda-customized Garmin all-glass avionics system incorporating an advanced layout with three 14-in. landscape-format displays and dual touch-screen controllers for overall avionics control and flight plan entries. The cockpit is shown in Fig. CS4.19. All information from flight and engine instrumentation to navigation, communication, terrain, traffic data, and the like is uniquely integrated and digitally presented on the large-format, high-resolution, dual PFDs and single MFD. The PFDs have optional Synthetic Vision capability and the

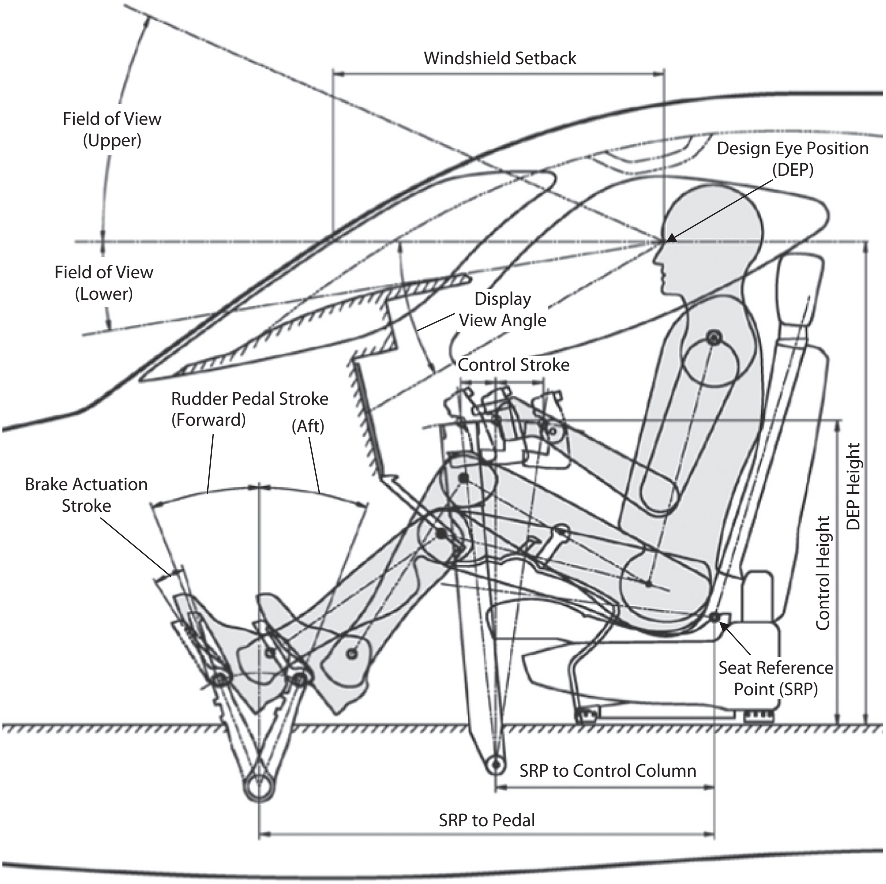


**Figure CS4.18** Pilot geometry.

MFD features split-screen capability with satellite weather, graphical synoptics, etc. Intuitive touch-screen multi-function controllers provide a low-workload user interface that is ideally suited to our high-performance light jet aircraft. The HondaJet Avionics Suite, integrated into our human-centric cockpit design, represents a significant enhancement in both capability and user experience.

## CS4.3.5 Innovative Interior Design Concept

A challenge for the interior design of light business jets is that the cabin volume is limited by the fuselage dimension, and it is very difficult to achieve adequate space to satisfy passengers' comfort requirements. The volume desired for each passenger depends on the trip duration, and an example is shown in Fig. CS4.20. Based on the HondaJet aircraft's designed

Figure CS4.19 Actual HondaJet cockpit.

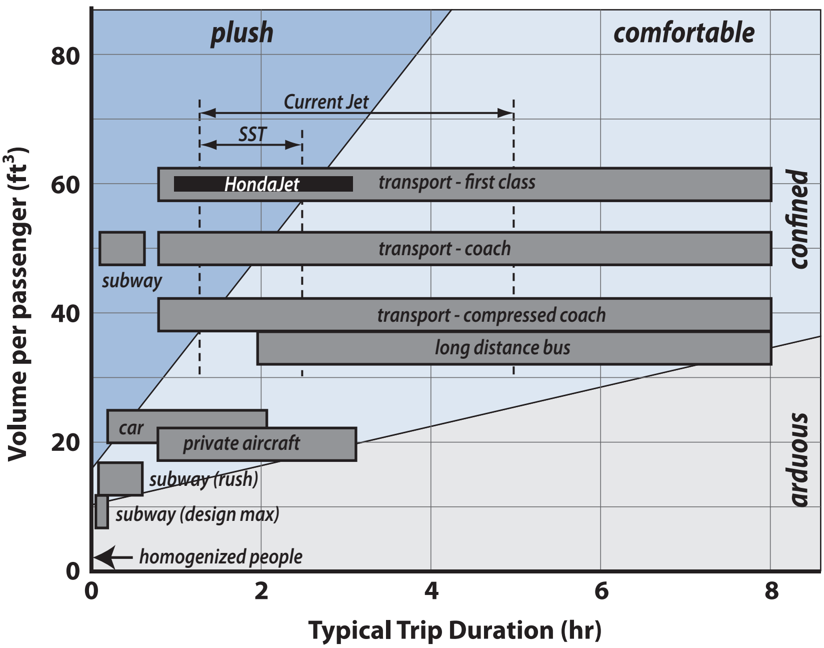


Figure CS4.20 Passenger volume.

trip duration passengers were allocated 60 $ft^3$ [6]. This volume is somewhere between that available in a commercial airline's business and first class cabin area. These are plush accommodations for light jets. By applying the OTWEM configuration, it is possible to maximize the HondaJet cabin volume without increasing the outside dimensions of the aircraft and, consequently, airplane drag and weight. The HondaJet cabin volume is approximately 20% larger than similarly-sized business jets. By virtue of the OTWEM design, cabin length can be much greater and hence, seat-pitch increases significantly compared to conventional light jets. As a result, extra leg space has been realized. Within the HondaJet cabin, passengers' feet do not overlap each other—a common discomfort in many light jets and a definite advantage for the HondaJet (Fig. CS4.21).

The private lavatory was one of the more important interior design attributes for the HondaJet. Research indicated there was a true hesitation for many light jet passengers to use a lavatory in flight. Therefore, designing a lavatory that passengers would not hesitate to use would further enhance the passenger's overall comfort. The result is a lavatory that is very spacious. Taking this one step further, two sky light windows were installed on the ceiling to provide a source of outside light into the lavatory to enhance an already spacious environment (Fig. CS4.22). By offering this

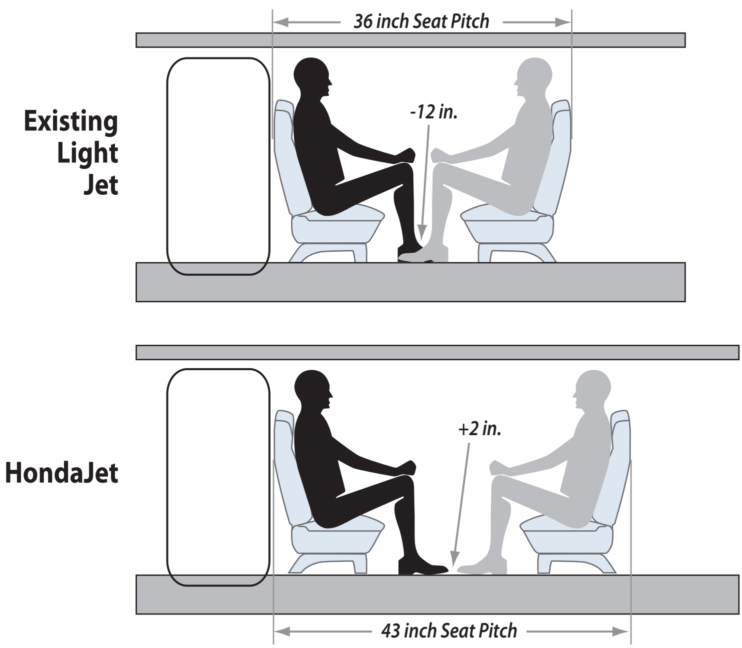


**Figure CS4.21** Seat foot and leg room.

**Figure CS4.22** Lavatory.

roomy and bright lavatory, the emotional hesitation to use the onboard lavatory is eliminated and the overall level of passenger comfort and relaxation is increased substantially. Considering that the purchase decision and the desired use of light jets are often based on emotional reactions to, and interactions with, the aircraft, I believe the lavatory design is a definite selling point that results in a positive HondaJet ownership and user experience.

Important improvements in the HondaJet interior design in the areas of aesthetics and human factors have been realized by utilizing Honda's automobile interior design expertise. It likely can be said that the HondaJet is the first business aircraft to fully utilize automobile interior design processes. My general impression is that the typical current business jet interior design philosophies and its design processes are still not as refined as those in today's automobile industry. The character of most current business jet interiors is expressed by the use of high-end materials, such as walnut wood or gold plating. However, compared to modern luxury automobile interior designs, there would seem to be many potential areas for improvement in business jet interior aesthetics and ergonomics.

By creating high fidelity 3D surfacing computer models, we have employed highly realistic computer graphics to make virtual material selections for the HondaJet interior. In addition, a precise, full-scale interior mock-up—both cockpit and cabin—was fabricated, and many design parameters were assessed and finalized using production design parts. Integration of aesthetics, human interface, and ergonomic considerations gives the HondaJet interior a more modern, yet timeless, image. The original interior concept sketch and final production interior are shown in Fig. CS4.23 respectively.

A very important design consideration is the ease of installation of each interior part during the completion phase of aircraft final assembly. Automobile designers use sophisticated techniques to design each interior part to have exceptional fit and finish in final assembly by using each part's overlap or gap to achieve high tolerance management. This cost-effective design technique takes into account slight variations that may occur with each installation and results in a consistent, high-quality look and feel. Furthermore, as the installation time for aircraft interior parts generally is much longer than for automobiles, such business aircraft parts historically

**Figure CS4.23** Interior layout.

may not be well designed for a mass production concept. To improve parts installation time—as well as the quality of fit and finish—automobile interior design experience and expertise has played a crucial role in HondaJet interior design.

## CS4.3.6 Paint Scheme

Paint is as important as other technologies for automobile manufacturers. The paint scheme of the HondaJet is significant because this is my final "art work" contribution. Generally speaking, aeronautical engineers are not usually concerned with colors and paint schemes, but to me they are just as important as they are for cars. I wanted to indicate physical phenomena and forms through colors. We came up with more than 150 proposals and finally decided to use the paint scheme shown in Fig. CS4.24. I wanted to reflect the movement of air flowing over the fuselage—dark blue on a white background with silver edges making for vivid contrasts. The coloring is a bit eccentric for this kind of business jet but matches very well its shape. I wanted to use a blue that seems to swallow you up. Many airplane designers may not pay much attention to paint, but I put a lot of thought into choosing a design to express both my passion and effort that I have put into this aircraft.

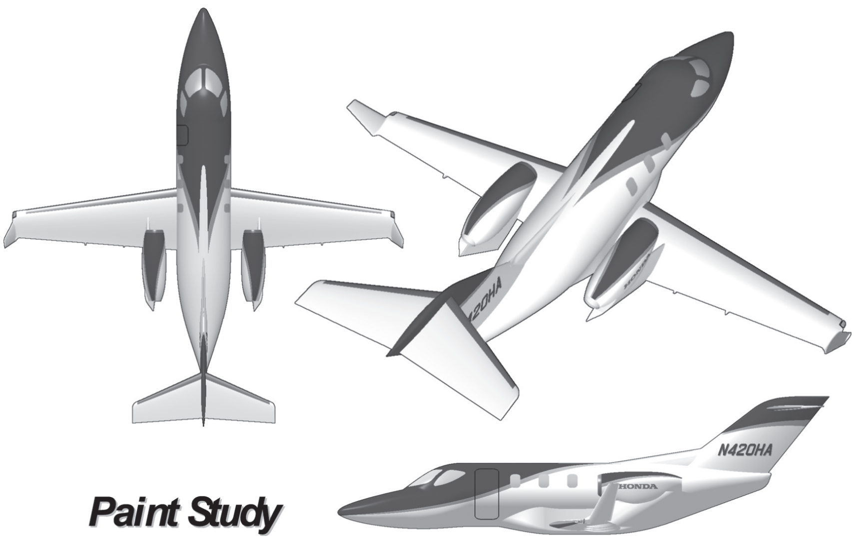


**Figure CS4.24** Paint scheme.

# CS4.4 HondaJet World Debut

## CS4.4.1 First Flight

It took almost six years from the original proposal to completion of design and fabrication of the HondaJet. There were many discussions and arguments about the HondaJet concept—and even skepticism about the project—but we finally reached the point of being able to prove the aircraft's concept was valid. Our resources were limited, but everyone on our very small team worked hard to make the HondaJet a reality [7]. After completing the final assembly and all ground tests, the HondaJet was pulled out of the hangar and appeared on the ramp under the sunlight. It was the first time for the HondaJet to appear under the sky. During its steering test, the HondaJet ran on the ramp as if a figure skater were making "figure-eights" on the ice. I must admit I became rather emotional when I saw the HondaJet taxiing under its own power. It looked like it was moving under its own will. At last, I felt as if my "daughter" would become independent of me as she tried her wings for the first time. Following steering tests and low- and high-speed taxi tests, the HondaJet made a successful maiden flight on December 3, 2003 (Fig. CS4.25).


**Figure CS4.25** First flight.

## CS4.4.2 HondaJet World Debut at Oshkosh AirVenture

Although we could prove from the flight test results that the HondaJet met performance goals and showed potential [8], it was the opinion of some of Honda's top management that it was difficult to get into the airplane business. In order to gain a better understanding from the board of directors of the commercial potential, a HondaJet would be displayed publicly to get reactions from industry people and potential customers. The airplane was still experimental and there was no plan to commercialize the HondaJet at that time. This being the case, the perfect venue for displaying the HondaJet was AirVenture Oshkosh, which is primarily an experimental aircraft show.

On July 28, 2005, in the clear morning air and under the strong summer sunlight, the HondaJet landed at the Oshkosh airport. During taxiing to the ramp, thousands of airplane enthusiasts stopped to stare at the HondaJet. In an instant, the HondaJet was surrounded by people in AeroShell Square, and everybody was very excited by this dynamic new airplane design. I still cannot forget the pride and excitement I felt seeing the beautiful HondaJet painted in deep blue and bright white under the clear sky in Oshkosh. It was the first time the HondaJet had appeared in public (Fig. CS4.26). Although I had been working on the airplane project within Honda for


**Figure CS4.26** Oshkosh 2005.

almost twenty years, I really could not have imagined that this moment would be realized.

Many airplane fans at Oshkosh talked to me and said, “I have never seen such a beautiful airplane.” It was the most wonderful compliment, and one that I had never experienced before. In my heart, however, my emotions were more complex at that time, as there was still much debate within Honda’s top management as to whether the airplane program should be terminated or proceed. Some in Honda’s top management still felt it was difficult to commercialize the HondaJet. I worried that this showing of the HondaJet at Oshkosh might be both the plane’s public debut and the closing ceremony on the project. However, I was determined not to give up. I was hoping that I could commercialize the HondaJet and deliver it to customers by changing the general opinion of the board of directors.

At Oshkosh, the HondaJet surprisingly attracted many people and drew tremendous interest. I was asked many questions about Honda’s plan for commercialization of the HondaJet. Even though we did not have any plan at that time to manufacture the HondaJet, someone sent a $50,000 deposit check to purchase a HondaJet. Many media wrote positive comments about the design and performance of the airplane, and the reaction was overwhelming and much more positive than even I had hoped. Based on these overwhelming reactions, Honda’s top management gradually changed its opinion and realized the great potential for the HondaJet in the market. I could feel that both the internal and external atmosphere in support of the HondaJet project was growing positively after the Oshkosh debut.

## CS4.5 Decision to Commercialize the HondaJet

Following Oshkosh and armed with the tremendously positive public and industry feedback to the HondaJet, I approached Honda’s board of directors with a proposal to commercialize the airplane. After several discussions with the board about the HondaJet and the proposed business plan, the decision to commercialize the airplane was finally made in March 2006. The president of Honda Motor Company at that time, Mr. Fukui, made his final decision after a few minutes of silence. He spoke as if he were convincing himself, “Honda is a mobility company. We should pursue the future through the HondaJet.” For a moment I could not even believe what I had just heard. Using a Japanese expression, it was the moment the “mountain moves.” Based on this decision, we finally could make a formal announcement of our commitment to commercialize the HondaJet at Oshkosh AirVenture in July 2006. It was exactly twenty years after I joined the airplane research project (Fig. CS4.27).

In October 2006, Honda formally started to take orders for the HondaJet at the National Business Aviation Association (NBAA) annual convention


**Figure CS4.27** HondaJet news conference 2006, Oshkosh, WI.

in Orlando, Florida. I prepared as best as I could, but still I could not sleep the night before the event. On October 17 at NBAA, in front of the actual HondaJet being displayed on a slowly rotating turntable in the center of our exhibit, we held a press conference and formally announced sales of the HondaJet. Nearly 1000 people attended the press conference, and the exhibit was filled to capacity with customers eager to purchase the airplane (Fig. CS4.28). With so many guests, our exhibit certainly stood out within the convention hall. On the first day of NBAA, more than 100 HondaJets were sold. There were many customers who actually signed a contract on the spot after seeing the HondaJet displayed at our exhibit and experiencing the cabin mock up, which highlighted Honda's design innovations for light business jet. Customers were literally waiting in long lines to put down a deposit to purchase the HondaJet, and it was an absolutely unbelievable scene. Many NBAA attendees said that the HondaJet aircraft were "selling like hotcakes" and that such a scene had not been witnessed before in the history of NBAA. Salesmen and Honda associates, including me, were very excited and running around to take care of customers.

It was 1986 when I attended NBAA for the first time. It was held that year in Anaheim, California. I was a young engineer and had just joined Honda's airplane project. In Japan, there is no comparable event to NBAA. I vividly remember the moment when I entered the NBAA exhibition hall. I was struck by the gorgeous exhibits and was in awe of the stunning business


**Figure CS4.28** Press conference 2006, NBAA.

jets. Ever since that first NBAA, it has been my dream to bring a jet I designed to this magnificent show. However, I did not really ever imagine that such a moment would be realized in that wonderful way in 2006.

## CS4.6 Reflection on Mr. Honda

In the summer of 2009, I had the opportunity to go to the home of and speak with Mrs. Sachi Honda, the wife of Honda Motor Company founder Mr. Soichiro Honda. When I presented a HondaJet model to her and reported the commercialization of HondaJet, she mentioned to me that, "If Mr. Honda were still alive, how happy he would be to see the HondaJet launched." Mr. Honda always had a special passion for airplanes, and it was his dream to build an airplane from his youngest age. After he graduated from school, he joined a small automobile repair shop as a technician. He was an exceptional individual with a passion for engineering, and he eventually established Honda Motor Company, which became one of the world's most pre-eminent engineering companies.

I have one memory of Mr. Honda that I will never forget. I had an opportunity to see Mr. Honda only once when I was in my late twenties. I was a young engineer working at Honda R&D Japan. At the office, all Honda associates wear white uniforms, but one morning when I went into the restroom, I came across a gentleman with thin hair in a Hawaiian Aloha shirt. He looked very different, so I immediately recognized him as Mr. Honda. Although Mr. Honda had already retired from the company, he made occasional visits to various parts of the company see what was happening. At that time, I was working for the airplane project, which was very confidential . . . even internally . . . and it was not allowed for me to discuss anything about my job with anyone. My boss told me that the airplane project was so confidential that company management did not even let Mr. Honda know that Honda R&D was undertaking the airplane project. According to my boss, if Mr. Honda knew that Honda R&D was working on the airplane project, he could not resist returning to the company because of his strong passion for airplanes. So, we had to be very secretive with him as well.

When I looked at Mr. Honda, he looked at me as well, and our eyes met each other for a moment. I was about to say, "I am now working on the Honda airplane project!" But I was so young, and I did not have the courage to speak to him. I just bowed slightly, and he bowed slightly as well, and we passed each other without a word. After a few years, he passed away, and there was no opportunity to see him again. When I am facing tough challenges, I always think that, if I had spoken to him at that time, what would he have said to me? Would he have encouraged me to continue with the airplane project? Was he really looking forward to seeing the HondaJet fly? Unfortunately, I will never know. I am sure that he had a passion to achieve his dream to create an airplane. However, he probably did not imagine that his intention would be realized with the establishment of a company in the United States rather than in Japan. And, he probably did not expect his dream would start with the most advanced light business jet instead of a single-engine propeller aircraft.

I will never forget Mr. Honda's clear and bright eyes. I want to keep alive for the future his vision and challenging spirit, and I hope we will see many HondaJets flying all over the world.

## About the Author

Michimasa Fujino (CS4.29) is the founding president and CEO of Honda Aircraft Company, the Honda subsidiary responsible for Honda's overall airframe business strategy, and the further development, marketing, sales, and production of the innovative HondaJet advanced light business jet. Prior to leading the formation of Honda Aircraft Company, Fujino rose through the engineering ranks to become a vice president with Honda R&D Americas Inc. and the large project leader for the HondaJet. In this capacity, he led all engineering tasks from design through experimental verification, fabrication, and flight testing of the HondaJet. Fujino created the unique Over-The-Wing engine mount (OTWEM) configuration for


**Figure CS4.29** Author.

the light business jet. Fujino also developed a new natural laminar flow (NLF) airfoil and fuselage nose for the HondaJet. Not only did he design, build, and sell his concept, HondaJet, he also drove the formation and development of a new airplane manufacturing company, Honda Aircraft Company. Fujino, who joined Honda R&D Co. Ltd. in Japan in 1984, graduated from Tokyo University with a degree in aeronautical engineering. He now resides with his wife and three children in Greensboro, North Carolina.

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