B/CA Analysis: Mitsubishi's Diamond I

A lengthy certification process added pounds to the aircraft and 18 months to delivery schedules, but what emerged was a gem for pilots and passengers alike.

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As deliveries of the Diamond I, Mitsubishi Heavy Industries' JT15D-powered business jet, began last month, a touch of deja vu was apparent. It was in the midst of an earlier and deep recession within business aviation that the first Pratt & Whitney JT15D-powered business jet had emerged, much to the may of many shortsighted critics who suggested that there was no market for such an aircraft.

Now, with well over 1,000 Cessna Citations flying and with the United States struggling to pull out of another difficult recession that appears destined to have a more profound effect on the general aviation community than its 1970-to-1972 counterpart, the Diamond I is making its debut with fervent hopes that marketing history will repeat itself.

Mitsubishi's first business jet is aimed squarely at the operator who wants economy and favorable noise characteristics coupled with the performance and operating ease of a fanjet — precisely the market that Cessna eyed when it conceived the Citation 14 years ago. Extensive research by MHI (See " The Diamond I — A Carefully Polished Gem.") conducted between 1969 and 1975 indicated that a need existed for an aircraft that provided more speed and cabin volume per pound of fuel consumed than was available from competing aircraft then.

During the nearly 10 years that separated the start of the Citation program and the first flight of the Diamond I in August 1978, significant advances had emerged in the use of computers for design. MHI hoped to capitalize on those advances, particularly in the area of wing design, to manufacture a faster light jet than the competition, but one that also exhibited fuel economy and offered a favorable interior volume.

With what they thought was a clear understanding of FAR Part 25, MHI engineers massaged their computers, bent over drafting boards, cut metal and produced a 14,030-pound MGTOW business jet that they felt would win swift approval from the FAA.

The new aircraft featured an advanced technology wing with a 20-degree sweep angle and a critical Mach number of 0.84. Its empty weight, with a finished interior and complete avionics, was projected to be 8,600 pounds, and its top speed at FL 410 was estimated to be 434 knots. To provide lower approach and landing speeds, MHI designed the Diamond I wing with nearly full-span Fowler flaps and spoilers for roll control.

Four prototype MU-300s (the official designation of the Diamond I) were built in Japan; two were flown there extensively and then shipped to the company's U.S. subsidiary, Mitsubishi Aircraft International in San Angelo, Texas, for final flight testing in conjunction with initial certification by the FAA. (MHI planned to seek Japanese certification after winning FAA approval.) The other two remained in Japan for static tests.

But a bad break on timing plus a willingness on the part of MHI engineers to abide by nearly every suggestion of the FAA, even if the suggestion was not required by Part 25, caused the certification program to drag on for nearly 18 months, and significantly delayed delivery of the aircraft to customers.

Between the time MHI had finalized the MU-300 design in accordance with Part 25 and the start of the certification flight tests in San Angelo, the now famous crash of a McDonnell Douglas DC-10 occurred in Chicago, claiming 275 lives and causing the FAA to take a critical look at its certification procedures.

As a result of that review, 27 new amendments were issued to Part 25, and stricter interpretations were given to the 17 that existed when MHI made its TC application. Although Mitsubishi's certification bid was submitted prior to the DC-10 tragedy, the FAA Southwest Region required MHI to abide by all the new amendments, thus the DC-10 crash and its regulatory aftermath profoundly influenced the design and certification of the Diamond I.

In addition to suffering the delay in obtaining FAA certification, the Diamond I grew from a ramp weight of 14,100 pounds, with an MGTOW of 14,030 pounds, to a ramp weight of 14,700 pounds with an MGTOW of 14,630. Its typical, factory-equipped empty weight increased by about 500 pounds to 9,100, and the aircraft suffered some loss of takeoff performance during the second segment climb. (Incidentally, the B/CA equipped BOW for the Diamond I as certificated is 9,515 pounds, which includes a crew of two 200-pound pilots plus 70 pounds for stores.)

The Resulting Aircraft

What emerged from the certification process was a well-built, nice-flying aircraft that does not have quite the overall performance that MHI engineers had projected for the original, lighter Diamond I. The aircraft's top speed of 432 knots, however, is only two knots slower than the design goal, and the aircraft meets its sales guarantees.

As can be noted in the B/CA Comparison Profile, the added weight of the Diamond I negatively affects the aircraft's airport performance and engine-out numbers, since thrust-to-weight ratio dropped as the Diamond I's max takeoff weight increased. The need to increase empty weight contributed to the aircraft's fifth-place ranking in its class for balanced field length for the 600-nm mission. Sea level BFL is sufficient, however, to capture third ranking among the comparison aircraft, and BFL at 5,000 feet and ISA + 20°C ranks second with a reduction in MGTOW. But in each of these cases the Diamond I's principal competitor, the Citation II, ranks first.

The Diamond I does place higher than the Citation II in areas that involve speed, such as normal cruise, long-range cruise and block time for the 600-nm mission. The MU-300's specific range at normal cruise is about 5 percent better than the Citation II because the Diamond I cruises about 50 knots faster using only 84 pounds per hour more fuel at FL 350.

But at long-range cruise, the Citation II offers about 9 percent better specific range in spite of its 42-knot slower speed because the Cessna jet's FL 430 capability results in a 155-pound lower fuel burn than the Diamond I requires at its long-range altitude of FL 410.

When price is considered, the competitive position of the Diamond I comes into sharper focus. Since the MU-300 is the least expensive of the five business jets listed in this B/CA Comparison Profile, and since the Mitsubishi's speed places it only 29 to 56 knots slower (depending upon whether high-speed or long-range cruise figures are used) than the fastest aircraft (the Dassault Falcon 10) in the comparison, the Diamond I offers a very favorable ratio of price to performance.

A graphic presentation of the Diamond I's range payload capability, specific range and airport requirements indicates that the aircraft offers attractive performance for missions typical of those flown by lighter fan jets. However, had the MU-300 been able to complete its certification program without requiring weight-producing structural changes required by the FAA after the DC-10 crash, the numbers would have been somewhat more appealing, naturally.

Good Handling Qualities

B/CA was impressed with the handling qualities of the Diamond I. The aircraft is pleasant to fly, with no apparent bad traits.

For our evaluation flight, we departed the ramp at Westchester County Airport (HPN) in

White Plains, New York with a crew of two plus four members of the B/CA evaluation team and 4,075 pounds of fuel, for a total weight of about 14,400 pounds,

The Diamond I offered excellent cockpit visibility while taxiing and responded nicely to rudder inputs during ground maneuvering, But the power braking system, which has about a one-second delay between the application of force on the toe brakes and the full impact of the 1,500-psi hydraulic pressure on the wheel brakes, requires some familiarity and compensation before smooth decelerations could be achieved. That braking characteristic, however, can be mastered with a little practice.

Should the power braking system fail for some unlikely reason, the Diamond I provides three back-up means of braking: (1) The system's hydraulic accumulator contains about 950 psi of pressure, which is capable of servicing two applications of heavy braking; (2) if the braking capability of the hydraulic accumulator has been expended, the pilot can achieve some stopping capability by stomping on the toe brakes with sufficient force to provide about 50 psi via the system's master cylinder; (3) finally air pressure from a 900-psi pneumatic throttle provides emergency brake pressure which is applied through a separate brake handle. In the event of a total electrical failure, hydraulic pressure for braking is not available, and the emergency system must be employed.

We found the Diamond I's braking to be effective, in spite of the slight delay between initial application of toe brakes and full authority. The system's anti-skid feature also appeared to be effective, although we did not put that aspect of the aircraft's capabilities to a vigorous test.

The Diamond's excellent ground tracking is apparent during the takeoff (as well during landing). As the aircraft accelerates, very little pilot attention is required to maintain a track along the runway's center stripe.

At VR, which for our first departure occurred at 108 knots, the pilot must rotate the Diamond to an attitude of about 15 degrees and eventually maintain a deck angle of between 18 and 25 degrees if he wishes to achieve, a max-performance climb profile at V2 + 10 knots.

Maintaining a final-segment climb airspeed of 200 knots, we made our way through a Westchester One departure and received radar vectors to the Pawling VOR as we climbed toward our initial assigned altitude of FL 350 in ISA+10°C conditions. our rate of climb after takeoff was a solid 2,500 fpm, tapering off to about 1,750 fpm through 15,000 feet and about 1,000 fpm through FL 300.

Although the Diamond I can make an unrestricted climb to its certificated ceiling of FL 410 after a full gross weight takeoff, nearly an hour is needed for the task; however, the aircraft can reach FL 370 in about 37 minutes.

The Diamond I exhibits excel stability during all phases of flight, including the climb, once trimmed for the pitch attitude for 200 knots, the aircraft held its airspeed as if a mystical autopilot were providing assistance. Roll and yaw stability were equally solid, thanks to a yaw damper that uses a separate control surface in the aircraft's vertical stabilizer with the yaw damper off, the Diamond is still quite well-behaved and can be dispatched up to FL 280.

Roll control was a pleasure with none of the uncomfortable lag or adverse yaw that normally is apparent with roll spoilers. The blending of wing sweep, a good yaw damper and effective roll spoilers result in a crisp and precise means of establishing turns.

Stall characteristics were benign, with good aerodynamic and mechanical warning. The Diamond I incorporates a stick shaker that does its dance about 10 knots prior to the pitch break. Recoveries were made with no significant roll-off and with effective pitch control.

Used as speed brakes, the roll spoilers are deployed symmetrically to 36 degrees; roll control then is provided by differential deflection between 14 and 72 degrees of the right and left wing spoilers. When using the spoilers as speed brakes, we observed an initial pitch up followed by a return to an attitude that produced little change in trim airspeed as the rate of descent at flight-idle power built to better than 6,000 fpm at Vmo or Mmo.

The Diamond's good speed stability, pleasant overall handling qualities and hefty gear combine to provide an easy aircraft to land. A pilot will look good as he touches down after a well-mannered approach. Pitch changes with flap and gear deployment are not particularly noticeable or objectionable. Visibility on the approach and during the flare and touchdown is good.

Cabin Comfort

The Diamond I B/CA flew had a comfortable cabin that was nicely finished in the fine leathers and fabrics that are usually found in corporate jets. The general level of workmanship, both in the interior and throughout the entire aircraft, reflected a quality and experience one expects from a manufacturer of sophisticated aircraft.

Subjectively, the interior noise level seemed typical for this class of aircraft, but we measured an average dB value in the cabin of 81.5, which is several dBs higher than most other jets that we have mapped for sound. The noise level, however, was quite consistent throughout the cabin, indicating good seals and uniform soundproofing throughout most of the aircraft. Subsequent Diamond Is may be somewhat quieter since the aircraft B/CA flew (MAI's first demonstrator, serial number 05) lacked insulation within the cabin door.

During our flight, we observed that the cockpit became slightly warm, while the cabin stayed at a comfortable temperature, thanks to the Diamond's air-cycle environmental system (which is an MAI design built by Garrett AiResearch). On all aircraft after serial number 12, an optional dual-zone environmental system is available, and it is being specified by nearly all customers. The air vents were not only effective but were quiet as well, even when fully opened.

A maximum pressure differential of 9.1 allows the Diamond I to maintain a sea level cabin up to 24,400 feet and a 6,400-foot cabin at FL 410.

The Diamond I, while 18 months behind schedule, has retained most of the 120 or so customers who placed orders for the aircraft to date. When they receive their sparkling gem, which will depend upon how soon MAI in San Angelo gears up to its anticipated production rate of eight units per month, the boss as well as his pilots should be pleased with this nice flying, commercial and comfortable business jet. B/CA

THE DIAMOND I — A CAREFULLY POLISHED GEM

A protracted certification effort that saw production schedules for the Mitsubishi MU-300 Diamond I slip by nearly 18 months may have caused some prospective customers to believe that business aviation's newest fanjet was brought along too hurriedly by a company whose only previous business aircraft manufacturing experience lay in a successful twin turboprop airplane. Nothing could be farther from fact.

First, the experience level of Mitsubishi Heavy Industries, Limited in the design, engineering, development and production of a broad range of aircraft rivals that of any major airframe manufacturer in the world. Its Aircraft Works Division in Nagoya, Japan had its genesis in the Mitsubishi internal Combustion Engine Company in 1921. From 1928, when Mitsubishi Aircraft Company was established there, through 1945, it produced more than 18,000 aircraft of over 100 different models, including the famous Zero fighter. Since its rebirth as MHI's Aircraft Works in 1962, the division has increased its total production count to more than 30,000 aircraft. It has been involved in the manufacture of reciprocating engine and turbine powered aircraft both under license and of its own design since 1965.

Second, the MU-300 was a full 12 years in planning and development before it was finally anointed with an FAA type certificate in November 1981. its evolution began In 1969 with an exhaustive market study that continued until 1975 when product planning was launched in earnest. The survey, made among corporate flight departments already operating business Jets, indicated that 45.3 percent of the respondents believed that speed was the most important feature to be considered in development of a new aircraft; 26 percent cited cabin size and comfort; 19.7 percent mentioned price; 6-8 percent stated economy and 1.2 percent said range was the most important factor.

Feeding survey results and the company's own preliminary design parameters into their thinking machines, Mitsubishi engineers came up with more than 3,000 computer aided design models that might fill the bill. Fifteen were selected from among these , based on price versus performance, estimated cost to develop and build, and technical feasibility. Finally, one design, which reflected the best potential for profit in the opinion of Mitsubishi management, was selected. Preliminary design work on the Diamond I began in November 1976, and a design mockup was completed six months later. In August 1978 their first prototype was successfully flown.

Project engineers both in Nagoya and at Mitsubishi Aircraft International's new Diamond I assembly, facility at San Angelo, Texas contend that the aircraft's design concepts reflect a straightforward, traditional technological approach . During a tour of MHI Aircraft Works facilities in Japan last April, however, B/CA was impressed not only with the firms modern and well-equipped design, engineering and fabrication resources but by the technical and marketing sophistication of its management. The obvious intent and ability to play competitive hardball in the business aviation marketplace was also apparent.

The Diamond I program reportedly represents an independent research and development effort, funded on entirely by MHI with no direct infusion of Japanese government support. Such an undertaking might have taxed the, resources of the Aircraft Works and MAI. But the parent company, MHI, with 1980 gross sales of $6.29 billion, ranks as the world's 28th largest industrial corporation outside of the United States. And the company is committed to making a success of the Diamond I.

To achieve a design that would deliver the speed that prospective customers had asked for, MHI Aircraft Works engineers developed a special transonic wing section, designated MAC 510. Based generally on Whitcomb supercritical wing (SW) design criteria, the airfoil was developed with attention not only to drag characteristics but to lift, pitching moment and stall characteristics at low speed.

Requirements were set for a wing planform that would permit a 435-knot maximum speed, a 4,000-foot balanced field length, an FL 390 cruising altitude and a 1,300-nm range (later increased to 1,565 nm). The final wing design — which incorporates 86 percent of full-span Fowler flaps with the inboard halt double-slotted and the outboard half single-slotted — has a 13-percent of chord maximum thickness, a 20-degree back-sweep angle, spoilers for primary roll control and roll trim tabs for secondary control. Besides meeting design requirements, the airfoil reflects a 2- to 3-percent improvement in critical Mach number over the NACA 64 and NASA-SW designs and a 36-percent improvement in pitching moment characteristics over the NASA-SW design, MHI engineers claim. The prominent flaps provide the Diamond's wing with a maximum lift coefficient of 2.24 at a 30-degree landing position and 1.8 at 10-degree takeoff and approach settings.

A basic design goal of the Diamond I, as its numerical designation implies, was growth capability, at least from the standpoint of propulsion. Its elliptical fuselage, with a 400-cubic-foot interior volume, is among the largest available in the class of business jets. Company officials will not divulge when an up-powered Diamond II may be anticipated on the market. An educated guess is that it may follow closely after delivery of Diamond I serial number 500.

That may be little more than five years downstream. MAI now has about 120 firm orders for the Diamond I on its books, and by late June had received 37 units at its San Angelo assembly plant. New sales made today bring a delivery promise of late 1983 or early 1984. MAI officials apparently want to extend their security blanket beyond the present backlog, however. They have leased back the first five customer delivered Diamond Is to be used as sales demonstrators. Meantime, MAI and MHI engineers — the latter group on temporary assignment in San Angelo — continue to fine tune the Diamond I's anti-icing and thrust reverser systems, full certification of which is expected by late this fall.

Don't expect Mitsubishi to limit its business aviation market interests to the high-performance MU-2 turboprop series and the Diamond I and II. From the market study that spanned a six-year period, MHI analysts determined that there are four definable classes of business jets that are eitherin use or in demand. "Eventually we may have at least one entry that we believe is a cut above any competitive aircraft in each of these classes," a company spokesman disclosed.