CONCEPTUAL DEFINITION OF A NEW VERY-LIGHT-JET AIRCRAFT CONFIGURATION

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Abstract

Israel Aircraft Industries (IAI) is a world leader in the design and manufacturing of business aircraft. IAI has developed and introduced to the market several biz-jets (Westwind I and II, Astra-AKA Gulfstream G-100, and Galaxy- AKA Gulfstream G-200). All these aircraft have been in the midsize and recently "super-midsize" category.

During the last two years, IAI has been evaluating a new aircraft design, the ProJet that belongs to the new, emerging category of "very-light jets" (VLJ). This lightweight twin turbofan aircraft is characterized by its small size and low target price, compared to existing IAI designs. The ProJet will be certificated to FAR23 normal category requirements, including single pilot operation.

The ProJet exploits newly developed technologies and capabilities, such as: new, small and efficient turbofan engines; advanced low cost and sophisticated avionic systems; advanced low cost mechanical and electrical systems; rapid and efficient development and production methods. All these attributes will provide the capability of introducing a very low cost aircraft into the emerging new VLJ market sector.

The ProJet is a twin turbofan, low wing, T-tail airplane utilizing an all-metal airframe; designed in accordance with damage tolerance requirements. It features a comfortable pressurized cabin with optimized seating for 6 occupants, including 2 pilots, and excellent performance. The ProJet will have a VFR range of 1200nm, a cruise ceiling of 41,000ft, and a cruise speed of 365kt. It will take-off and land on runways shorter than 3000ft. Generous allowance for baggage stowage is provided in the pressurized internal baggage compartment, and in the external rear baggage compartment. The ProJet flight deck features an all-glass cockpit with an integrated avionics package, designed for ease of operation and reduced workload. Composite materials are utilized in flight control surfaces and secondary structures. Two FADEC controlled turbofan engines mounted on the upper aft fuselage supply the ProJet power. Each engine generates about 1300 pounds static installed thrust at ISA +10°C.

State of The Business Jets Industry

Since their emergence in the USA in the early 1960's, business jets have made a major impact as a specialized mode of aerial transportation. Typically powered by twin turbofan engines and boasting airliner-like performance, business-jets came to symbolize an elite form of transportation, offering a reliable, highly comfortable way of reaching any desirable destination on a short-notice, non-scheduled basis. Historically, business-jets were segmented by their Maximum Take-Off Weights (and prices) into three prime categories: Light/Medium/Large. As the industry evolved, powerplant choice and customer demand generated an accelerating segmentation in size, performance and price, to fill almost any possible niche of application - from single-piloted "entry-level" business-jets, that fly a few passengers in relatively crowded and spartan conditions, over distances that may be as short as a few hundred miles, to intercontinental 747-sized airliners modified to yacht-like luxury (private suites, conference rooms, etc.) for the international "jet-set". Distances, business and cultural traits, turned the USA into the domi-

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nant market - more than 85% of worldwide civilian-owned business-jets operate in North America. Government VIP's, large corporations and the "rich and famous" - are still the majority of users. Economies of scale and the ability to offer the largest choice of products (as a "family" of business-jets) have become the driving factors for survival of the players in the industry. At present there are five major business-jet manufacturers, all of them large and established companies, benefiting from comprehensive development and manufacture infrastructure, direct and in-direct government support:

- Bombardier (of Canada), with the Learjet and Challenger (Canadair) brands
- Gulfstream (of the USA), part of General Dynamics, which acquired in 2001 the IAI Galaxy and Astra aircraft and integrated them into it's G-Series
- Cessna (of the U.S.A.) owned by Textron, with it's Citation Brand
- Raytheon (of the U.S.A.), with it's Hawker and Beech brands
- Dassault (of France), with it's Falcon brand

Historically the business-jets market was regarded as a mature and stagnant market, relying on a limited and quite defined pool of customers. From the 1960's until the mid 1990's, annual deliveries stabilized around 300 units (of all size-categories) valued at less than $4 Billion. Then the market exploded -it more than tripled in size within a few years! Deliveries in the record years, 2000 and 2001, reached a magnitude of 800 units annually, worth well above $12 Billion. Of the world total of more than 13,000 business-jets ever manufactured, some 40% were delivered in the last decade. As a by-product - an unprecedented 15 new models of business-jets arrived in the market-place in the second half of the 1990's, in line with the industry's competitive drive for further size-segmentation (super-mid-size, super-light, etc.) and continuous generation of model-derivatives. The market segmentation is shown in Fig.1.

This market growth has resulted from many factors:

- Corporate profits, a key market driver, have increased exponentially since the early 1990's. Typically, demand for business-jets follows a "time-lag" of several years after corporate profits improve.
- Business globalization became a driver for increased mobility. Aircraft are now more identified as business tools and less as "perks". Studies link higher management "productivity" - the efficient use of capital and labor resources - to the use of business-jets to save time and effort.
- The continued degradation in the commercial airlines' service, the delays and security-induced harassments connected with the need to pass thru over-crowed passenger hubs.
- The emergence of Fractional-Ownership, as a popularly preferred alternative to airline-service, was a break-thru, bringing the known benefits of business-jets to within the reach of the "masses" - thousands of customers who never before used a private aircraft.

These fractional-ownership companies have suddenly become the major business-jets industry's customers. At present, fractionals account for 15%-18% of new business-jet deliveries and some 50% of the stated industry backlog. 7% of the worldwide business-jet fleet is already owned by fractionals; this may increase to 15% - 17% by end of the decade.

Forecasts, Trends and Challenges

The market, which has gotten very soft in 2003, with all manufacturers announcing deep production cuts, seems to have bottomed out, and slow recovery is underway. 2003 seems to be the trough year in the current cycle, with slightly more than 500 deliveries worth US$8 B. With a combination of a surging U.S. and Global economy and bonus depreciation, most OEMs report significantly improved order intake and are increasing 2005 build schedules. Purchase expectations remain at high levels for most regions. Forecasts for the decade 2004-2014 average a total of some 8000 aircraft, of all categories [excluding VLJ's (Very Light Jets)], valued at approx. $130 B. Gulfstream is expected to become the market leader, with Bombardier a close second, both at around 24% market share.

Fractional companies will become increasingly dominant in the new and used aircraft markets, as major fleet-operators, but not all them may survive. With some 70% market share, NetJets is best positioned to survive. A small but important market develops for special-missions applications of business-jets. Advances in avionics and sensor technology pose a cost-effective option to replace expensive airliner-size platforms with business-jets for a multitude of para-military remote-sensing duties. This may well become the solution-of-choice for many countries.

Figure 2 and 3 present the forecasts by Honeywell and by Forecast International merely represent the general agreement among manufacturers and independent forecasters that the biz-jet industry is on the recovery track. An important observation is that the entry-level/very light jets segments are becoming dominant in terms of production quantities.

- Technological advances in propulsion, aerostructures and avionics, coupled with the further segmentation of the market, as dictated by the competitive environment, may see the emergence of two new segments at the extremes of the size-scale.
- SSBJ (SuperSonic Business Jet). Demise of the Concorde and continued interest from fractional-operators make this more realistic than in the past. In 2004 there were successful NASA-sponsored tests to prove "Aerodynamic Shaping" as a method to mitigate the sonic boom. In the 2004 NBAA, two programs for SSBJ's were announced, by start-up companies.
- VLJ (Very Light Jet). Derived from NASA's SATS (Small Aircraft Transportation System) Vision, and driven by the sharpening degradation of service to the public using the commercial Hub and Spoke system in the USA, this category has been evolving as the "next hot item" in the market, attracting established manufacturers and start-up companies alike.

VLJ Market Opportunity

The Problem

The air transport system in the USA, which is based on "hub and spoke" operation, is gradually becoming grid locked causing delays and cancellations, resulting in increased dissatisfaction of the traveling public. Utilization of the system is returning to those levels prior to "Sept 11th." but the greatly increased security arrangements pose a nuisance to passengers. A perfect example of the congestion and difficulties caused to the traveling public is taken from a recent news article published by Avweb.com (Dec. 26, 2004).

***Thousands Stranded on Christmas** : Well, maybe they'll have a happier New Year. **Tens of thousands** of Comair and US Airways **passengers spent a miserable** Christmas*

thanks to foul-ups that may take until Tuesday to clear up. Comair cancelled all 1,100 of its flights on Christmas Day after the computer that manages flight assignments simply threw in the towel after fighting two days of weather delays and cancellations. "There was a cumulative effect with the cancelled flights and trying to get crew assigned that caused the system to be overwhelmed," said Comair spokesman Nick Miller. "It just stopped operating." ***About 30,000 passengers in 118 cities were affected****. Many US Airways passengers encountered another problem altogether: They got where they were going -- but without their luggage. Again, the winter storm that socked the Midwest was blamed for thousands of suitcases being heaped in piles at the airline's hub in Philadelphia while workers tried to sort through them. Naturally, many of the bags held Christmas presents, and some of their owners maintained a vigil to ensure they delivered their holiday cheer. "I can't show up empty-handed," John Price told the Associated Press. "That just doesn't cut it." Baggage problems were also reported at other major US Airways destinations.*

The current air transportation system in the US is growing fast, but congestion and delays in major/hub airports pose an obstacle that threatens to stretch the system beyond its capabilities. The future trends of system development can be shown to exist in the smaller aircraft segments: corporate/air-taxi, and personal/owner-operated business aircraft. Fig.4 shows the market trends and opportunities.

The Solution

One possible solution is proposed by NASA's "SATS" program (Small Aircraft Transportation System), which involves development of technology and aircraft innovation and envisages "personal" jets and other aircraft, which will fly within an "automated" air traffic control system, in an almost unlimited "Free Flight" regime. The SATS view of increasing the speed and efficiency of transportation by Air-Taxi jet services is illustrated in the NASA chart (Fig.5), which compares such a service with cars, airlines and the current prop air-taxi service.

Air-Taxi/on-demand services, which are being developed on a large scale, and which are based on innovative small aircraft utilizing evolving technologies; are the sole reasonable efficient solution for the present-day domestic air-travel problems. The increase in traffic volume will need to depend on the large number of small airfields, which currently are infrequently used, for commercial traffic. Of the more than 14,000 airfields in the US, 10,000 are shorter than 4,000ft and only several hundred airfields are in scheduled commercial use. Moreover, the ~135 major/hub airports which attract most of the traffic, are within 30 min reach of only 22% of the public, compared to SATS-type airports (3000ft) which are within 30min reach of 93% of the population in the USA. Introduction of VLJs, especially with Air-Taxi service, will need to expand into these small, unused airfields. The charts (Fig.6 and 7) depict distribution of airfields surveyed by NASA, and population coverage of those airports.

Engine manufacturers are forecasting the evolving market trends and are developing engines that will eventually facilitate the development of aircraft answering these future requirements. Today, in contrast to the past, the established engine manufacturers (Williams, Pratt and Whitney Canada) are developing small jet engines in the class of 900 - 1500 lb. thrust, which will enable the development of small jet aircraft having a MTOW of 5000 - 8000 lb. These development activities of established and conservative engine and aircraft manufacturers, contribute to confidence in the long term potential for the very small jet aircraft market, in a class below that of business jet entry-level. A new player in this field, Honda Motor Co., has teamed with General Electric A/C Engines, to develop a new 1600lb class turbofan engine.

Market Potential

The current situation of small turbine General Aviation aircraft in the USA is depicted in Fig.8. Some 12,000 aircraft have been operating in the year 2000, the majority of them serving the corporate sector.

The market potential for VLJs, is based on independent sources of information: Teal group, Forecast International, Stanford Transportation Group (STG), US Transportation Research Board- Subcommittee on Business Aviation, discussions with operators, discussions with NASA SATS program director Dr. B. Holmes, and on information obtained from potential customers surveys and engine manufacturers' forecasts. The market can be split into the following segments:

- **Air-Taxi on demand**: Currently, dominated mainly by small operators of propeller/jet driven aircraft - this market segment will transform into "Pseudo-Regional-Jet" (>1200 flight hours per year, short range, operated from small airfields). It is expected to be very sensitive to acquisition cost and direct operating costs. Anticipated nature of operation - large fleets of aircraft, to be operated by sophisticated, capable operators relying on computer technology to optimize efficiency and profitability. The Technological and Operational infrastructure for the Air-Taxi/On-Demand market segment is presently developed in the U.S.A. by:

    * The FAA - JPO Transportation System Transformation
    * Operations' companies (at least 8 companies)
    * Aircraft/Powerplant manufacturers
    * Start-up companies

- **Charter operators**: Currently operating all kinds of jet and prop aircraft, these operators are a significant part of the air transport industry. This sector is expected to benefit from the emergence of VLJs, by consolidating the types of aircraft, and improving their economics of operation.

- **Corporate operators**: The new VLJ category will expand the large corporate market, which today operates 14,000 aircraft into the lower entry-level aircraft. Two sub-segments are expected to be potential source of customers:

    Corporate owners: Small-medium companies which own a fleet of biz-jets and will exploit the added flexibility of equipment. These will be joined by new entrants, who will find the new economics of VLJ attractive and financially justifiable.

    Fractional providers: The fastest developing sector of biz-jet operators, which currently hold a significant portion of the market, have expressed keen interest in the VLJ and will introduce these aircraft into their fleets. This will add flexibility, but most importantly, will draw new customers who currently cannot justify the investment in a share of an entry level biz-jet. The expected low price of a VLJ share would be a major selling point. Least expensive 1/8th share currently costs about $3,600 all-in per hour, whereas an all-in per hour cost for a "personal" jet is estimated at about $1,800.

Currently, about 4,300 entities own fractional shares in the NETJETS, FlexJet, Flight Options and Citation Shares programs. Based on NETJETS' definition of qualifying criteria, the potential U.S. market is around 100,000 entities, or a 2300% growth in terms of A/C numbers.

- **Owner/operators**: This segment is the largest in terms of numbers of general-aviation aircraft, comprising thousands of piston-twins, turboprop singles and twins, and small jets. Thousands of ageing aircraft are in the hands of individuals and small companies, and could be replaced by the new, similarly sized, better performing and more economical to acquire and operate VLJs. Operations will be on a relatively low utilization level and acquisition expected to be single aircraft for both individuals and companies.

- **Special Missions**: e.g. training, aircrew transport, package transport, medical evacuation, etc.

The Air-Taxi segment will expand exponentially within the framework of SATS. A significant part of ProJet launch customers are operating in this developing sector. Fig.9 presents the perceived market segments allocation of the ProJet, based on a potential customer survey conducted last year, covering more than 1,000 respondents, who operate some 3500 aircraft of various types.

Market size

Different sources are projecting the size of the VLJ market. Some of the forecast highlights are shown here. Fig.10, adopted by the US Transportation Research Board- Subcommittee on Business Aviation, shows two scenarios of aircraft delivery volumes for the next 15 years. At least 4000 aircraft are expected to be delivered within the next 15 years.

The market forecasts of engine manufacturers are represented by GE's view in Fig.11 and Fig.12, projecting some 3700 entry-level new A/C for the next 9 years, of which 2000 of them are in the Air-Taxi segment.

The Potential Market for the Very Light Jet Aircraft in India

The potential market for the VLJ aircraft in India is generally based on the following types of services, as in the US market. The four types are the following:

A simple sale or lease for the charter companies.
The fractional ownership
The Air Taxi
Owner/operators

The market for the VLJ aircraft in India will mainly depend on the domestic air traffic. The civil aviation market in India and especially the market of domestic flights is demonstrating a continuous growth in the last decade. The growth in the total number of departures during the years 1994-2003 was 70,000, which exhibits more than 50% growth. During these years the number of departures in the private sector was doubled and in the governmental sector was increased by 30% (see Fig. 13).

The need for air taxi service is clearly seen by analyzing the daily domestic traffic in the 65 active domestic airports all over India. The following data is showing the top 20 cities per number of passengers boarding daily domestic scheduled flights for the year 2002-03. In the next 20 cities of the DGCA report the average number of daily flight was 4. The average number of flights for the last 25 ranked cities in the years 2002-2003 was 2. One can expect a reasonable demand for air taxi service when 2-4 flights are available for 2-270 passengers in those 45 cities. Moreover, introduction of such service will definitely develop the demand for the air taxi. Today, the market of the non-scheduled flights mainly consists of charter companies. This specific market is demonstrating a much higher growth rate than the scheduled market (see Fig.14). The number of non-scheduled operators during 1994-2003 increased by 250 % (from 17 to 40) while the number of aircraft endorsed by the same operators has tripled since 1994 (from 42 to 121). The market potential for the VLJ will be materialized by the growing demand of non-scheduled flights all over the operational airports. Today there are 65 operational airports. Yet, the growth potential is based on a higher number of existing airports and the cost effective capability of the VLJ to connect between airports all over India (Fig.15).

ProJet Design Requirements and Goals

The driving requirements were defined at the outset of the program with the potential customers in mind. It was assumed that the most appealing features of the ProJet would be low cost, high utilization rates, and greater passenger comfort (Figs. 16 and 17). The following are the initial goals defined for the design

ProJet Design Goals	
Price	~$2.0m
Utilization	1200-1500 hr/yr
Cabin volume	>250 cu-ft
Range (VFR, LRC, min pld)	~1200 nm
Maximum Speed (35kft)	>350 ktas
BFL (ISA, SL, MTOW)	~3000 ft
Flight ceiling	42 kft
Baggage volume	~47 cu-ft
Separate lavatory	
External baggage compartment	
Comfort Goals	
Accommodation	6 Seats, including pilots
Arrangement	Club or Tandem (36" pitch)
Cabin length	176" (4.470 m)
Cabin width	58.3" (better than the competitors
Cabin height	57" (better than the competitors)
Cabin volume	259 cu-ft
Baggage volume	>47 cu-ft (better than the competitors
Int. baggage volume	19 cu-ft
Ext. baggage volume	28 cu-ft

Advanced Technologies Utilization

Combining new, advanced technologies has enabled the development of new civil "personal" aircraft, with emphasis on affordability. Aircraft prices are expected to decrease to half that of their predecessors, and operational costs to a third of the cost today. An example of this trend is the new generation of Very Light Jets, of which the ProJet, which is currently in the definition phase, is a good example. The ProJet employs new communications and navigation systems which will reduce air traffic over-crowding and considerably reduce door to door travel time by potentially utilizing "un-controlled" airfields that are little used today. The ProJet will respond to the demand for fast, cheap and comfortable transportation for trips of short to medium distance and provide an attractive alternative to both ground and scheduled airline transport.

Propulsion

Manufacturers of small turbofan engine believe that current sales of aircraft powered by engines in the 1,000 to 3,000 pounds thrust range, total 150 to 200 per year. Over the next 10 years, they forecast a potential $3 billion market for jet engines in this thrust class, and this is considered a conservative view. The issue is not whether applications exist today, but rather to produce the best engine for emerging opportunities.

Design goals for engines in the 1,000 to 2,000 pounds thrust range include low acquisition cost (targeted at less than $500,000), low noise and emissions levels, improved reliability with a TBO (Time Between Overhaul) greater than 3500 hours, and increased fuel efficiency. Engine manufacturers believe advanced materials and electronics technology can improve fuel efficiency by up to 30 percent compared with existing engines.

Designing a small turbofan poses a challenge. The two greatest concerns are temperature and pressure ratio. Having a lower mass, a small turbine engine has less material through which to dissipate heat. Also, the gaps between the outer tips of the rotor blades and the casing are critical for keeping low-pressure loss. The smaller the rotor diameter, the smaller the gap must be, and hence the closer the production tolerances need to be. However, with today's computer-aided design and computational fluid dynamics, engineers have more tools to meet these challenges.

Engine manufacturers are introducing new technology concepts into their designs, and the small engines for the VLJ have already benefited from this trend. The future brings more advanced developments that could be inserted to the small engine family. One of those is an "electric engine" - described in Fig.18 by Rolls-Royce, a concept that is shared by other engine manufacturers as well. It is especially suitable for VLJ since it enables weight and cost savings by eliminating mechanical/hydraulic systems, in conjunction with a "more electric aircraft" design concept. Fig. 19 lists several new technology concepts for commercial engines. Some of these have already contributed to the low cost of the engines for VLJs, e.g. all blisk compressor, common core, intelligent controls, etc.

Avionics

An integrated avionics suite should be capable of receiving and processing multiple sensor and sub-system information together with situation awareness data (including weather, air and ground traffic) received via various types of communications channels (satellite and ATC/ATM, e.g. ADS-B). The avionics system will be capable of processing this information using an integrated flight management system, thus allowing the aircraft to be easily integrated into the surrounding air traffic. These features will substantially lower crew workload and increase flight safety. In addition, the more autonomous the system, the greater is the potential for integration into a future network, which will incorporate airborne and ground interoperability (Fig. 20).

Almost all new airliners and high-end corporate aircraft are supplied with integrated glass cockpits, incorporating systems that enhance the capability, reliability and safety of the aircraft. These advanced, integrated flight deck systems have until now been prohibitively expensive for use in light general aviation aircraft. Recent advances in microelectronics and LCD display technologies have reduced the volume, power requirements and most important the cost of these systems to the extent that they can be incorporated in small, budget conscious aircraft. The ProJet will utilize these revolutionary advancements to provide an advanced flat panel display system that will virtually replace all traditional gauges and instruments and dramatically increase situational awareness and reduce pilot workload. The fully integrated system will include attitude direction indicator, horizontal situation indicator, altitude, airspeed, vertical speed, as well as moving map, weather information and traffic avoidance. All this to be displayed on high resolution, sunlight readable colored displays, in a configuration of 2 primary flight displays (PFD) and one multifunction flight display (MFD), each of which can switch roles with any other display. Compared to mid-size business jet avionics, a state of the art avionics package for the emerging "very light jet" market, will cost and weigh about one third, and will be able to perform most of the functions of a large/mid-size business jet avionics package.

Computational Flight Dynamics

In the field of aerodynamics, the relatively new Navier-Stokes CFD (Computational Flight Dynamics) codes, which enable complete configurations viscous drag prediction, have upgraded the aerodynamic design capabilities significantly, allowing shorter and more accurate design/analysis/optimization cycles and saving wind tunnel tests. The IAI in-house developed Navier-Stokes "NES" CFD code was recently upgraded by considerably increasing its parallel processing capability. The IAI "NES" CFD Program now employs 144 processors performing parallel processing. Fig. 21 shows a drag analysis example computed by the IAI "NES" code in the framework of the 2nd AIAA drag prediction workshop. A close correlation can be seen between wind tunnel tests and the calculated values.

Figure 22 shows the IAI "NES" code capability to predict a wing-pylon interference separation bubble, correlating with wind tunnel visualization results.

Enhanced Maintenance and Health monitoring

Other advancements in electro-mechanical systems will be exploited in the ProJet. Advanced microelectronics and MEMS will be utilized all over the aircraft, e.g.: proximity switches, "smart actuators", electronic control of mechanical systems, systems monitoring and crew alerting, maintenance data collection, pre-planning and direct transmission to operator’s base. Health monitoring functions, performed by a dual avionics computer will enhance the future aircraft’s dispatch reliability and safety; as well as contribute to the reduction of operating cost. Improved maintenance methods and the selection of long-life, reliable systems and parts, will allow continuous system health monitoring, reduce unscheduled maintenance activities and increase flight safety.

Configuration Ground Rules and Configuration Selection

The ProJet is a six seat, twin turbofan aircraft that is more economical to own and to operate than most multi-engine pistons and turboprops. The ProJet will cruise at 365 ktas and will have a range of 1200 nautical miles with 4 occupants. Its flight ceiling will be 41,000 ft. The aircraft is able to takeoff from short airfields (less than 3000 ft), and has a stall speed less than 70 knots, which provides excellent landing capability.

Wing loading and wing area have been determined in order to provide for the fuel to be fully contained in the wings, as well as to enable the low stall speed and short field capability. Aerodynamic configuration of a conventional twin-engine biz-jet was selected, after trading off with a forward-canard/aft T-tail configuration. The trade-off study has positively shown that the current configuration, belonging to the "dominating design" breed of biz-jets, is superior to canard configuration in terms of weight, drag, stability characteristics, structural design and pilot visibility considerations.

The T-tail was chosen over a low tail configuration in order to reduce development risk of engine-tail-aft fuselage integration. Although Deep Stall phenomena might be expected, the ProJet flight characteristics and envelope protection design would prevent it from encountering such phenomena in normal operations.

The structural arrangement calls for a tip-to-tip single wing, which will be attached to the fuselage almost round pressure vessel below the contour. The attachment concept will use several discrete links between main fuselage frames and main wing spars. This concept was selected to enable production of the wing as a separate unit, fully stuffed and tested with all its systems before delivery to final assembly line. Another benefit would be fast and simple final wing to fuselage joining.

The cabin is primarily designed to provide first-class comfort for the passengers (seat pitch of 36 inch), aiming to achieve the most comfortable cabin in the emerging very light jet aircraft market. Its oval shape, similar to IAI's production G100 and developmental G150 cross-sections, provides optimum comfort compared to a circular shape with the same width/height, by adding shoulder and leg space. The weight penalty of such a cross section was studied, and determined to be insignificant. The ProJet will be certified to FAR Part 23 normal category, for operation with a single pilot.

Configuration Definition

External Dimensions of the ProJet aircraft are as follows (Figs. 23, 24 and 25):

Overall Height - 3.81 m.
Overall Length - 11.33 m.
Overall Wingspan - 13.3 m.

Internal Dimensions of the ProJet aircraft are as follows:

Cabin Height -57 in. (1.45 m)
Cabin Width -58.3 in. (1.48 m)
Cabin Length -176in. (4.47 m)
Main Entrance Door Height -48in.(1.22 m)
MED Width -24in.(0.61 m)
Passenger Cabin Volume -259ft^3 (7.33m^3)
External Baggage Compartment Volume -28 ft^3 (0.79 m^3)

Seating in the ProJet cabin may be configured either as a "Club" arrangement or as a "Tandem" arrangement according to customer preference, as illustrated in Fig.26.

The cabin interior design takes into consideration the following requirements:

- Seating for five passengers (one passenger in the co-pilot seat). The cross section is designed for improved comfort with adequate head and shoulder room while seated. The cabin is higher, and at waist level is wider or equal to all competitors. The floor is flat and has no aisle.
- Turning and sliding the front row seats can configure a club seating arrangement.
- The entry door is located between the seat rows and entry is eased by sliding the seat backwards.
- A solid divider and door enclose the lavatory and a sideward facing seat saves cabin length and provides comfort and privacy.
- The cabin provides accessible baggage space for five standard carry-on bags with restraint. The baggage area is only a very short distance from the seats.

Weight Targets

Table-1describes the ProJet target weights.

Operating Cost Targets

Direct Operating Costs

Determination of The Direct Operating Costs (DOC) is extremely important since it can be used as a means for comparison. The DOC of the aircraft incorporates only operational costs without any consideration of the acquisition cost and depreciation in value over its lifetime. Components of DOC are :

- Airframe maintenance (spare parts and labor)
- Engine maintenance (spare parts and labor)
- Fuel

Table-1 : Target weight of ProJet configuration

Maximum Ramp Weight	7210lb	(3270 kg)
Maximum Take0ff Weight	7160 lb	(3248 kg)
Maximum Landing Weight	6800 lb	(3085 kg)
Maximum Zero Fuel Weight	5780 lb	(2622 kg)
Empty Operating Weight[1]	4380 lb	(1987 kg)
Total Usable Fuel (6.7 lb/US Gal)	2120 lb	(962 kg)
Maximum Payload (inc. pilot)	1400 lb	(635 kg)

[1] *Empty Operating weight includes typical avionics equipment, and consumables. Pilot is considered payload*

Sometimes crew costs are also included in the DOC calculation when the salary expenses can be expressed in terms of per flight hour and utilization per year. The DOC is also heavily dependent on which block range the calculation is performed. Fig.27 illustrates the DOC comparison as estimated by the manufacturer of the Eclipse 500.

Structural Concept Definition

Airframe

The airplane structures are fabricated from aluminum alloy, alloy steels, stainless steels, titanium and various types of composite material. The selection of material is based on strength, fatigue, damage tolerance, weight, thermal and other physical and mechanical properties of each individual material. The fuselage includes the nose, the pressurized cabin for pilot and passengers and the aft un-pressurized tail cone with baggage compartment (Fig. 28). Drainage is provided at points in the structure where liquids or condensation may collect. The ProJet airframe is designed for a service utilization of 1500 - 2000 hrs/year. The design of the airframe primary structural elements is based on damage tolerance design criteria. The airframe structure meets the FAR23 requirements for flight at 41,0000 feet altitude (Fig. 29).

Wing

The wing is attached beneath the fuselage by discrete attachments that are located underneath the wing fairings.

Empennage

The tail assembly consists of a vertical stabilizer + rudder and a T-tail fixed horizontal stabilizer + elevator. The tail assembly is attached to the fuselage through discrete attachment points.

Doors and access

A 24 x 48 inch entrance door, is installed on the left hand side of the cabin immediately aft of the cockpit .The door is a "non plug in" type air-stair. Around the door, seals will maintain cabin pressurization. Access to the cabin will be by a foldable stairs integrated in the door. Additionally, there is one removable plug-type emergency exit on the right hand side of the passenger cabin. Access doors provide access to the external baggage compartment and to the forward and aft fuselage equipment compartments.

Systems Conceptual Definition

Avionics

ProJet avionics system is based on an integrated avionics suite, which centralizes almost all avionic functions. The suite completely integrates flight instrumentation, engine indication, crew alerting, autopilot, communications, navigation, weather radar, and other equipment to provide a highly reliable system designed for ease of operation and reduced cockpit workload. The Avionics System is made up of the following major subsystems and functions (Fig. 30):

- Electronic Flight Instrument System (EFIS)
- Engine Indication and Crew Alert System (EICAS)
- Flight Control System (FCS)
- Attitude Heading System (AHS) and Air Data System (ADS)
- Communication, Navigation and Surveillance System (CNSS)
- Advisory and Information Systems (AIS)
- Systems Control and Synoptics
- Recording Systems
- Emergency Locator Transmitter (ELT)
- Other systems

Standard Avionics Package

The ProJet baseline avionics equipment, functions and instruments comprise are as follows:

*** Electronic Flight Instrument and Engine Indication and Crew Alert System (EFIS and EICAS)**	
EFIS and Engine Displays	3
Engine and Creq Alert Computer	1
Electronic Checklists	1
*** Flight Control System (FCS)**	
3-axis dual channel Autopilot System	1
Flight Control Panel	1
*** Attitude Heading and Air Data System (AHS and ADS)**	
Attitude and Heading Reference System	2
Air Data System (RVSM certified)	2
*** Communication, navigation and Surveillance System (CNSS)**	
VHF Communication (25 and 8.33 kHz spacing)	2
VOR/ILS Navigation (incl. Glideslope/Localizer and Marker Beacon Rx)	2
DME	1
ATC Transponder Mode-S	2
Integrated Radio Tuning	2
GPS receiver	2
FMS control	2
Colour Weather Radar	1
Cockpit and Cabin Audio Control	2
*** Advisory and Information Systems (AIS)**	
Terrain Aviodance and Warning System - Tupe B (TAWS-B)	1
Traffic Information System - Broadcase (TIS-B)	1
Automatic Dependant Surveillance	1
Broadcast System (ADS-B capability	1
Traffic and Collision Avoidance System (TCAS I/TAS)	1
* Other Systems	
Systems Control and Synoptics	1
Digital Clock	1
Emergency Locator Transmitter (ELT)	1
Standby Flight Instruments	1 set

Optimal and Complementary Avionics Systems

The following avionics and instruments may be installed in the ProJet as optional or complementary equipment:

Stormscope ^{R}	1
ADF	1
HF Communications with Selcal	1
EGPWS	1
ELT with position update	1
Electronic Charts	1
Electronic Flight Bag	1 or 2
CVR	1
FDR	1
Entertainment System with or w/o enhancements	1
Radio Telephone System	1

Electrical System

The electrical power supply system is a 28 Volt DC system, which includes two 28VDC starter generators driven by the engines and two NI-CD batteries operated in parallel mode. The batteries are used for aircraft engine starting and to provide emergency power supply to essential flight instruments and emergency equipment. A 28 VDC external power receptacle is also provided on the aircraft. Each engine is started with its starter-generator by one of the following methods:

Aircraft batteries.
External Power and batteries.
One engine generator and batteries.

Environmental Control System

The Environmental Control System (ECS) will provide air for pressurization, ventilation, cooling and heating to the passengers and flight crew cabin. The system consists of a hybrid Heating, Ventilation and Air Conditioning (HVAC) system, featuring a single zone cabin/cockpit temperature control and is based on the following:

- A Vapor Cycle Air Conditioning System is used, to provide cooling and air circulation for ground static operation and low altitude flights on hot days. The system is designed as a split system, with the condenser and compressor modules being installed in the un-pressurized section of the aircraft, while the two evaporator heat exchanger units are installed in the cockpit area and passenger cabin respectively.

- An Engine bleed air management system providing pre-cooled and temperature modulated bleed air extracted from the two engines which is used to provide fresh air to the occupants and heating in flight and on ground as required. The system will be designed so as to fully meet the fresh and ventilation air requirements of FAR 23.831.
- The ECS operates in conjunction with a Cabin Pressure Control System (CPCS), with a conventional, automatically controlled cabin pressure schedule. The CPCS complies with requirements of FAR 23.841, and the cabin pressure altitude will reach 8000 ft at the maximum flight altitude of 41000 ft. The system will provide back-up in the event of a failure of the auto control. Indications of cabin altitude, cabin altitude rate of change and cabin pressure differential will be continuously provided at the flight crew level.

Airflow and Temperature Control System- airflow and temperature control system will be provided, to be operated from the flight deck.

Propulsion System Alternatives

Williams International (WI), with its FJ44 versions have dominated the last ~10 year market for engines in the lowest commercial thrust range. Pratt and Whitney Canada (P and WC) is making a run with its developmental PW600 series. Cessna has chosen the P and WC engine for its developmental Mustang, as has Eclipse for its proposed Eclipse 500 after severing ties with Williams. All the new entrants to this low-end turbofan market are controlled by a dual channel FADEC (Full Authority Digital Electronic Control).

The WI FJ33, a new small turbofan engine in the 1300-1500 lb. thrust range, is a potential engine for use in the ProJet six-seat, twin- engine turbofan jet, intended mainly for the air taxi market. The WI FJ33 is a simple, rugged 1500 lb thrust class turbofan that will power small, fuel efficient, light, entry level jet business aircraft of the future.

The FJ33-4 thrust is rated at 1,350 lb take-off thrust, up to ISA+7°C. It is a 2-spool turbo-fan engine controlled by a dual FADEC. The engine has a built-in growth capability to 1536 lb thrust. The FJ33-4 is scaled version of the FJ44-2A with a bypass ratio of 2.2:1 with high reliability and durability.

The PW615F, which is a P and WC's (Pratt and Whitney Canada) small turbofan engine in the 1300-1415lb. thrust range, is also a candidate engine for use in the ProJet. The PW615F is P and WC's new generation turbofan rated at 1,350 lb. take-off thrust up to ISA + 10°C. It is a rugged 2-spool turbo-machine controlled by a state-of-the-art robust, reliable dual channel FADEC. The PW615F is scaled version of the PW625F demonstrator with a bypass ratio of 2.7:1.

General Electric Aircraft Engines and Honda Motor Co. of Japan last year announced that they have entered into an alliance to develop, certify, market and support Honda's 1,670-pound-thrust HF118 turbofan engine. The HF118 would represent GE's first foray into turbofans of this thrust range. The two-spool turbofan has a one-stage fan, a two-stage compressor and a two-stage turbine. With a fan diameter of 17.4 inches, its bypass ratio is 2.9/1. The HF118 is also a candidate engine for use in the ProJet aircraft.

Production and Assembly Concepts

The aircraft production concept is driven by decisions to outsource manufacturing of major elements such as wing, tail, landing gear and systems, in order to produce a light jet aircraft at an attractive cost.

- The major structural components will be manufactured by subcontractors
- Those structural components will include stuffing of airframe systems.
- Joining of airframe major components (fuselage, wing and tail) will be performed via discrete points and quick connections of sub systems (flight controls, hydraulics...)
- The produced largest structural components could be transported using standard marine containers.
- The aircraft final assembly will take place close to the main market region.

Figure 31 illustrates the major aircraft assembly components.

Design for Manufacturing and Assembly (DFMA) methods will be used to reduce parts count, enhance assembly procedures, and optimize production and assembly time and cost.

- Small number of subassemblies
- Small number of detail parts
- Monolithic structures
- Lap Joints
- Extensive usage of blind rivets

The program will be dedicated to enhance short Cycle Time and Just In Time (JIT) deliveries

Assembly Principles

- Short Cycle
- Jigless Assembly
- Friendly operations (most jobs done by one mechanic)
- Automation in riveting process
- Stuffing of systems
- Moving line of major components
- Advanced logistics (JIT)

Fabrication Principles

- Well proven technologies
- Accurate parts with coordination holes to facilitate Jigless Assembly
- High Speed Machining
- Technological Working Cells

ProJet Performance Summary

Preformance Figures

Cruise Speed - At 35,00 ft (10668 m)	365 KTAS
FAA Takeoff Field Length (Balanced field length, Maximum Takeoff Weight	3000 ft (914 m)
FAA Landing Distance (Unfactored distance, Maximum Landing Weight)	3000 ft (914 m)

The performance figures are based upon ICAO Standard Atmospheric Conditions; level, hard surface, dry runways and zero wind conditions.

Range VFR (45 min reserve)

Long Range Cruise	1200 nm (2222 km)

Based on the maximum Takeoff Weight of 7160 lb (3248 kg), the ProJet can fly 1200 nautical miles at 300 kt with 3 passengers.

Limit Speeds

Maximum Operating Speed 9VMO) - From Sea Level to 28000 ft (8530 m)	250 KIAS
Maximum Operating Mach Number (Mmo) - Above 28,000 ft to 41,000 ft (12,497 m)	.66 MI
Stall Speed - At Maximum landing Weight	68 KIAS ±5%

Maximum Altitude

Maximum Operating Altitude	41,000 ft

Fig.1 Business jets market segmentation
Source : (Rolls-Royce)

Fig.4 Air transportation system trends in USA

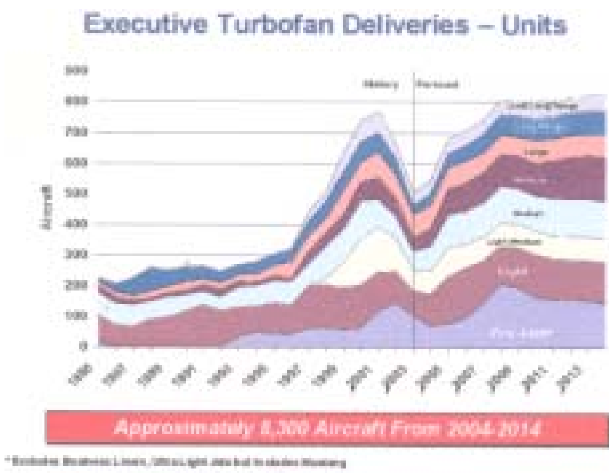

Fig.2 Business jets delivery forecast 2005-2014 by Honeywell (Excluding very light jets)

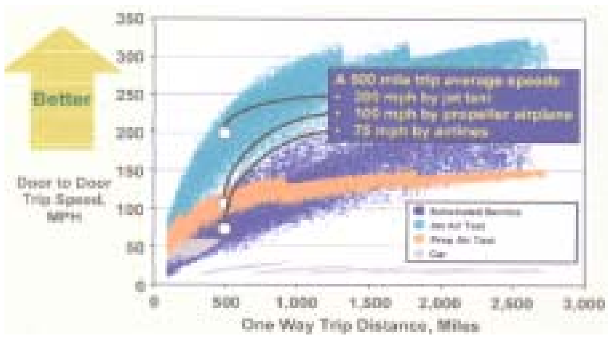

Fig.5 Impact of Jet air-Taxi : Potential to triple door-to-door travel speeds on trips up to 1,000 miles)

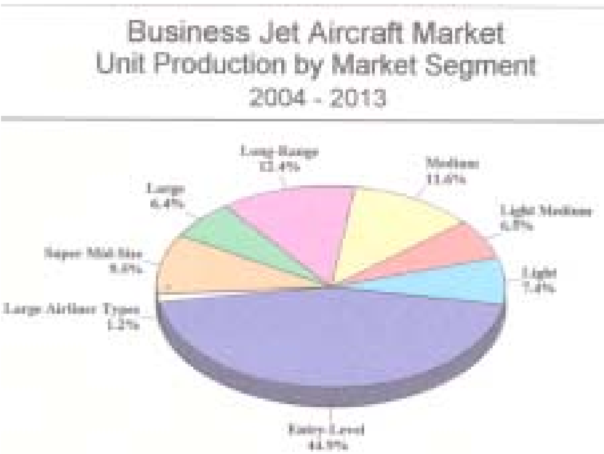

Fig.3 Business jets production segmentation forecast 2004-2013 by Forecast International

Categories	—Airport Type—		
	Public Use	Private Use	Total
Total Number of Airports	5,023	9,433	14,456
Paved Runways (%)	77	9	33
Lighted Runways (%)	73	8	33
Without Paved or Lighted Runway (%)	15	84	65
Number with Longest Runway of Length:			
< 3,000 ft	1,181	6,855	8,036
3,000 to 3,999 ft	1,393	1,163	2,556
4,000 to 4,999 ft	914	364	1,278
5,000 to 5,999 ft	776	152	928
6,000 feet and more	764	57	821

Fig.6 Distribution of airfields in USA

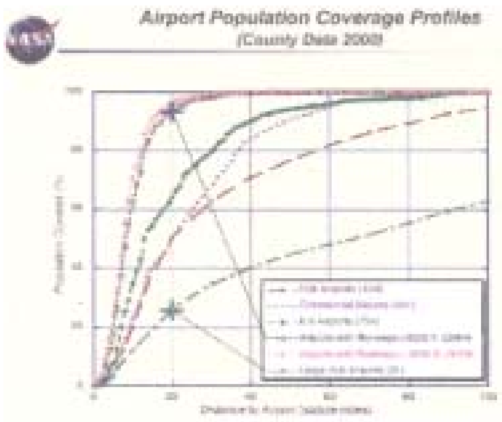

Fig.7 Airport population coverage

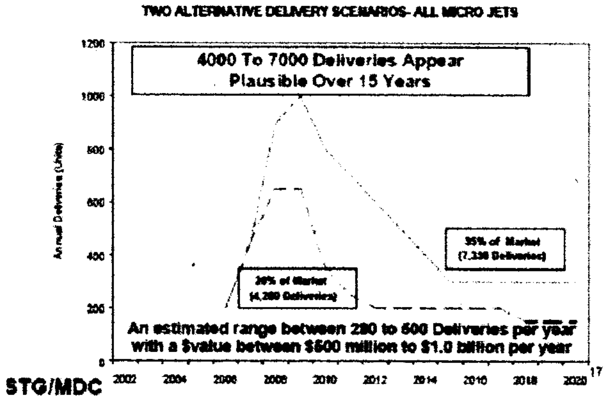

Fig.10 VLJ (micro-jet) market size forecast by Stanford Transportation Group

FAA Year 2000 GA and Air Taxi Activity Survey

Primary Use Category	Jets (2-eng)	Turboprops (all)	Total
Corporate	4,529	2,831	7,360
Business (Owner-Pilot)	441	1,145	1,586
Air Taxi (Charter)	638	536	1,174
Personal	496	520	1,016
Instruction	33	21	54
Other	78	709	787
TOTAL ACTIVE	*6,215	5,762	11,977

Fig. 8 Year 2000 survey of GA and Air-taxi activity (Source: STG)

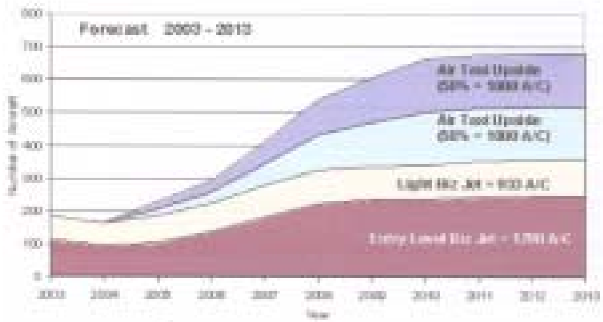

Fig.11 Entry level/light business jet market potential, considering emerging air taxi segment (Source : General Electric Aircraft Engines)

Fig.9 ProJet market survey - segmentation of expected VLJ market

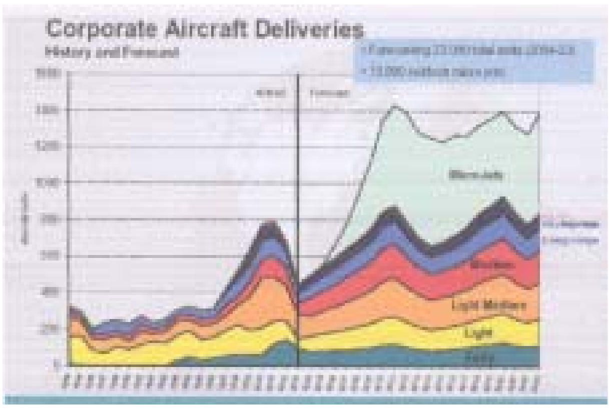

Fig.12 Micro-Jet (VLJ) market potential (Source : Rolls-Royce)

Fig.13 The annual number of departures in India (Source : DGCA statistical report Table-4.21)

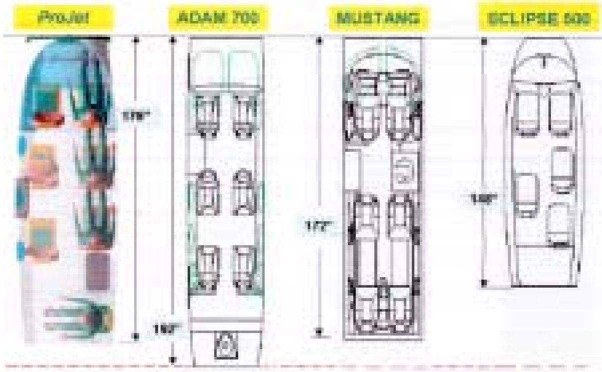

Fig.16 Cabin length comparison

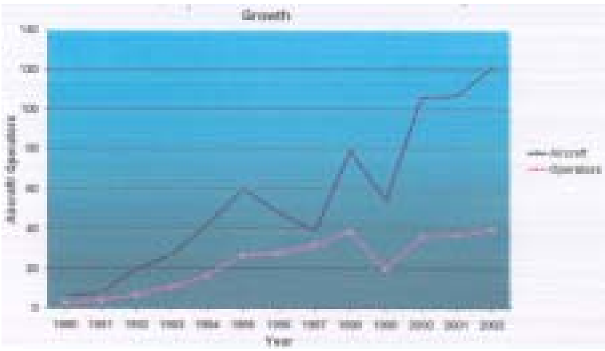

Fig.14 Growth of non-scheduled operators (Source : DGCA report Table-6.1)

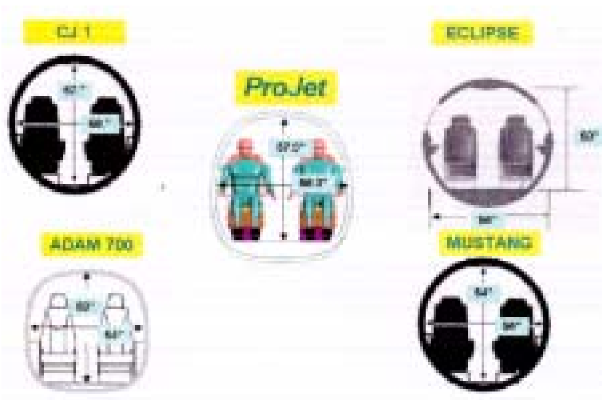

Fig.17 Cabin cross section comparison

Fig.15 Airports in India and the VLJ radius of operation (Source : Airport Authority of India)

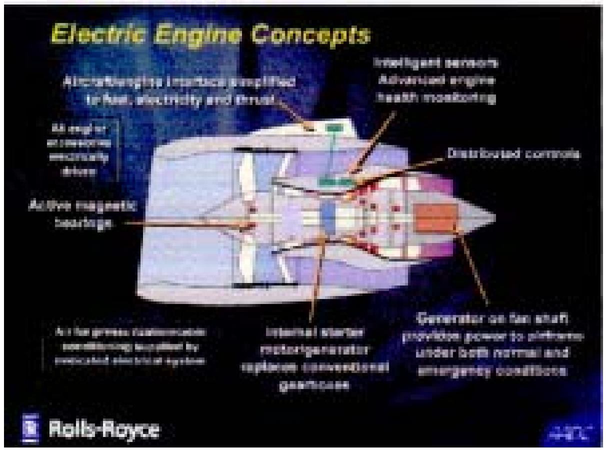

Fig.18 Electric engine concepts (Source : Rolls-Royce-AADC)

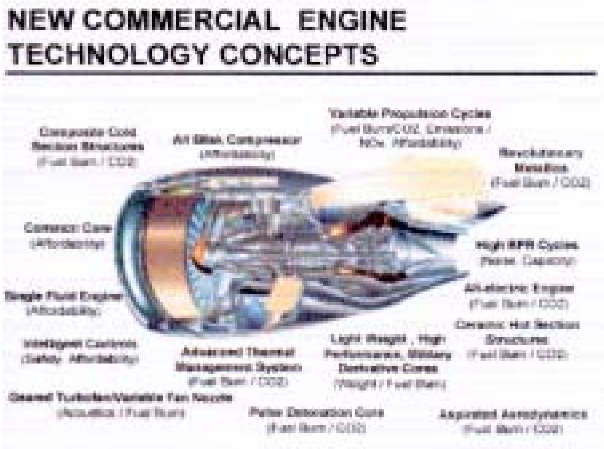

Fig.19 New commercial engine technology concepts (Source : Pratt & Whitney)

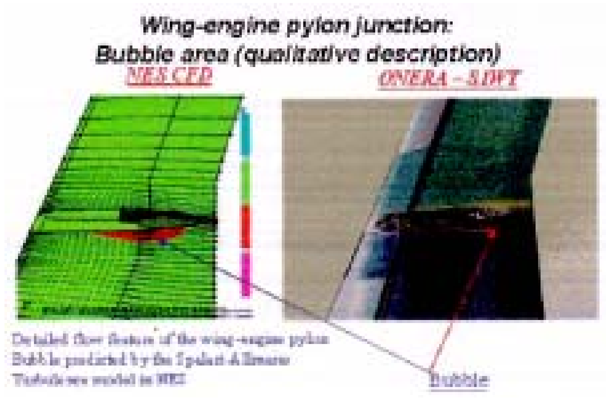

Fig.22 IAI Navier-Stokes separation bubble prediction compared to wind tunnel

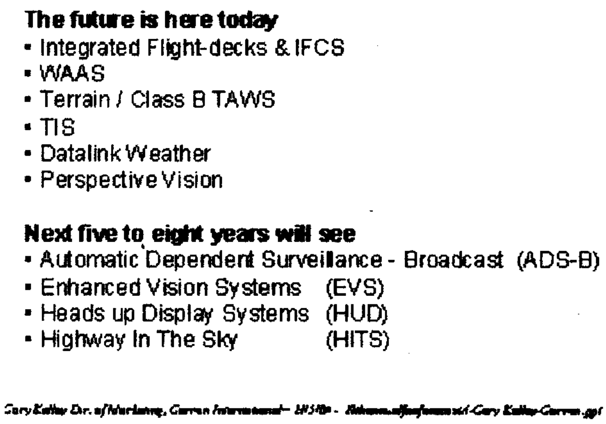

Fig.20 Near future trends in avionics

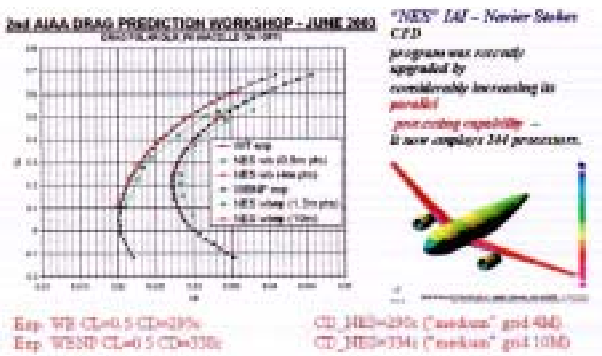

Fig.21 Drag polar prediction capability

Fig.23 ProJet external dimensions

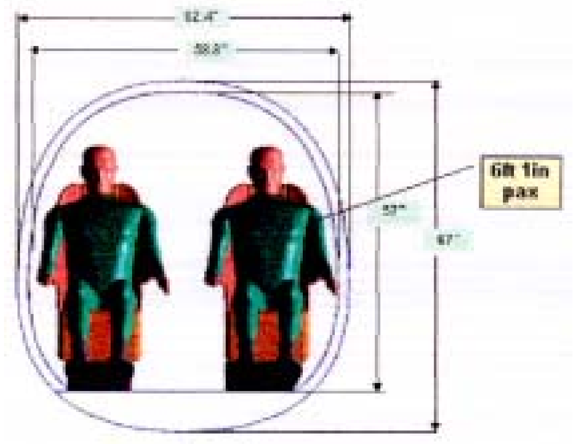

Fig.24 ProJet cabin cross section

	Eclipse 500	Cessna Mustang	Adam A-700	Safire Jet	Avocet ProJet
Published Price	$1,175,000	$2,395,000	$2,100,000	$1,395,000	$2,100,000
Month & Year of Published Price Point	June 2000	September 2002	August 2004	April 2003	January 2004
Projected Price for Delivery in March 2006	$1,346,303	$2,651,463	$2,209,202	$1,507,201	$2,253,619
DOC/Statute Mile (estimated)	$0.69	$1.36	$1.03	$0.96	$1.31

Fig.27 Acquisition and operating cost comparison (Prepared by Eclipse, not all the assumptions are known)

Fig.25 Aft baggage compartment

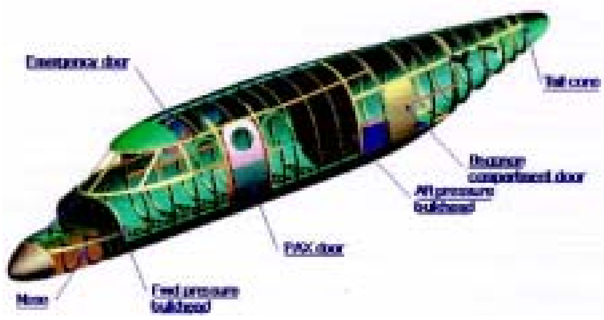

Fig.28 Fuselage structural arrangement

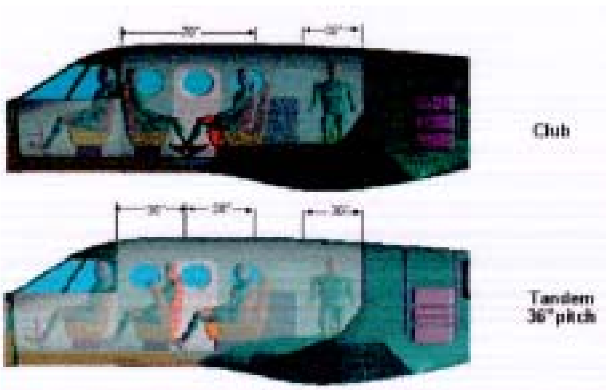

Fig.26 ProJet cabin seating arrangements

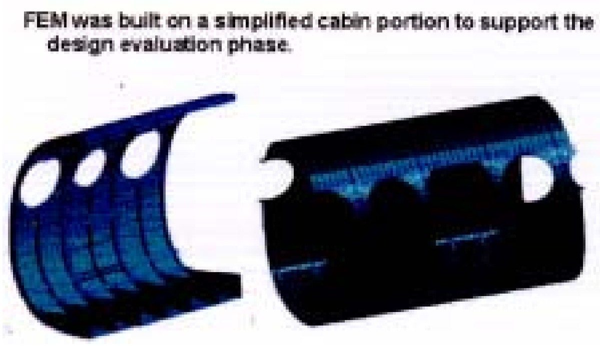

Fig.29 Nastran structural analysis

Fig.30 Avionics installation - cockpit

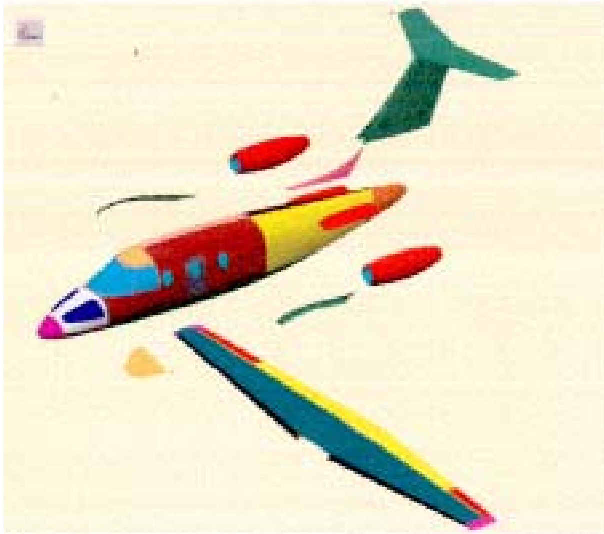

Fig.31 Major aircraft assemblies