NEW TRENDS IN FUTURE AIRCRAFT DEVELOPMENT

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ABSTRACT

This paper reviews the new trends that are emerging in the development of air vehicles of the future. Technological developments in many fields are reviewed, including aerodynamics, propulsion, flight control, structures, materials, production techniques, avionics, communications, computerization, miniaturization and others.

The paper addresses the future needs and requirements of both the military and civil aerospace markets. The needs of military intelligence are expressed in the considerable progress made in the development of UAVs. The transportation needs of passengers and cargo are expressed in the continuous search for greater efficiency and cost reduction in an ever-expanding market place. The review includes examples of developments in the field of civilian aircraft such as Airbus 380, Sonic Cruiser, BWB configuration and supersonic business jet; and discusses technological developments in small business aircraft like the Eclipse 500 and the SATS programs of NASA.

Developments in the sphere of unmanned aircraft are described, including UCAVs, OAV, CRW, solar HALE, micro-UAVs and also sensor craft goals are addressed.

The paper examines the technological goals which industry has defined for the improvement of aviation and air vehicles, highlighting the American and European long term plans as published in the American Aerospace Commission report, "NASA Aeronautics Blueprint" and the European document "ARTE21".

Some examples of IAI's recent activities in aircraft development and the integration of advanced technologies are described. This includes the use of CFD for design and improvement of advanced aircraft and the use of production techniques for composite materials with reference to the G150, Airtruck and the family of Heron UAVs.

This paper contains information published in the press and on the internet. The selection of material and the conclusions and opinions expressed are solely those of the authors . Aviation activities in the USA and Europe are emphasized, and those topics selected for inclusion by the authors represent only a small portion of possible topics of interest.

INTRODUCTION

The paper is structured as follows :- A technology overview which includes computerization, communications, miniaturization, propulsion, manufacturing and materials. It contains excerpts from the American Aerospace Commission report.

The new trends which are reviewed in this paper are as follows :-

- In the field of commercial airliners –, The Boeing Sonic Cruiser and the Airbus A-380. The supersonic aircraft is being developed in the USA in the QSP program and in Europe within the framework of the European R & D program HISAP. Yet another passenger aircraft has a blended wing body configuration in the form of a flying wing.

- The NASA thrust for general aviation is reviewed, highlighting the SATS and Eclipse 500 program.

- Future development trends briefly describes the new programs of the American administration – “The Aeronautics Blueprint for 2025” which was published in February 2002 in response to the European program “A Vision for 2020”, published one year earlier.

- UAV trends - describes a number of interesting new developments which include UCAVs (futuristic UAVs to replace combat aircraft), inflatable wings as presented in the LEWK program, OAV, CRW, solar powered HALE UAV and micro-UAVs.

- Examples of development activities in IAI include the G150 program, AirTruck, Heron-1 and Heron-TP UAVs which are based on new basic technologies in the fields of aeronautics.

TECHNOLOGIES

The development trends in aircraft have been, and will continue to be greatly influenced by the technological revolution. The development of the jet engine and its derivatives with improved performance, reliability and safety was largely responsible for the market impact of long range commercial aircraft from 1980 onwards. More recent developments in the fields of computerization, communications, materials, miniaturization and manufacturing will provide the driving force for future trends in aircraft development.

- Computerization in the fields of engineering, manufacturing and maintenance will shorten processes and improve their efficiency. Advanced neural network algorithms, control systems and fault tolerant reliability concepts will facilitate autonomous operation in the advanced cockpit and for unmanned operation.

- Communications at the human level will improve real time industrial cooperation between physically remote development teams. Automatic communication between aircraft in navigation (ADS-B) provides for safer flight, and DGPS provides more accurate navigation. Intercommunication between onboard computers (IEEE-1394) increases subsystem autonomy. Cellular and internet communications also have potential applications in this sphere.

- Miniaturization of electronics and sensors (MEMS) reduces volume, weight and cost of avionics systems. Fig. 1 shows the UAV avionics produced by Piccolo, an American startup company, on a single plug-in module weighing 100 – 200 grams. Fig. 2 shows the Athena GS-111M, smaller than the palm of your hand and weighing about 120 grams, produced by Aurora – an American company.

Fig. 1 Piccolo (100-200 grms)

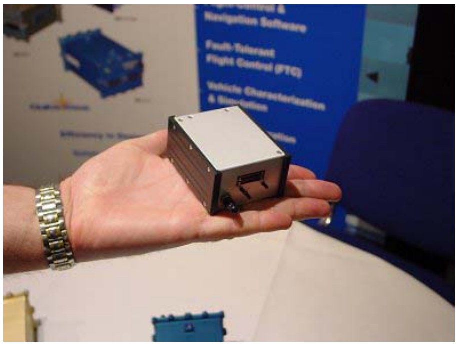


Fig. 2 Aurora Athena GS-111M

- Considerable improvement in jet engines and also in diesel propulsion and fuel cell propulsion.
  Fuel cell propulsion is advancing mainly due to environmental emission requirements in the automobile industry. We are now witness to attempts to employ this technology in aviation. An example is the use of a regenerative hydrogen-oxygen fuel cell by Aeroenvironment in their Helios solar UAV. Fig. 3 shows the Helios Prototype wing alone configuration and illustrates its two energy storage systems which are located inside two of the four landing gear pods.

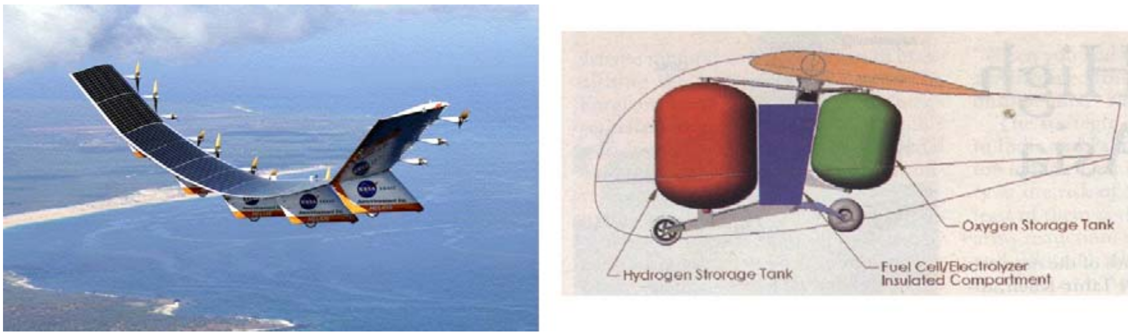


Fig. 3 Helios energy storage system

- In the fields of manufacturing and assembly, advancements in metal welding processes, high speed metal cutting machines and composite materials production. Recent developments in "nano" technologies provide the potential for much stronger materials. Fig. 4 illustrates the phenomenal potential for carbon nanotubes.

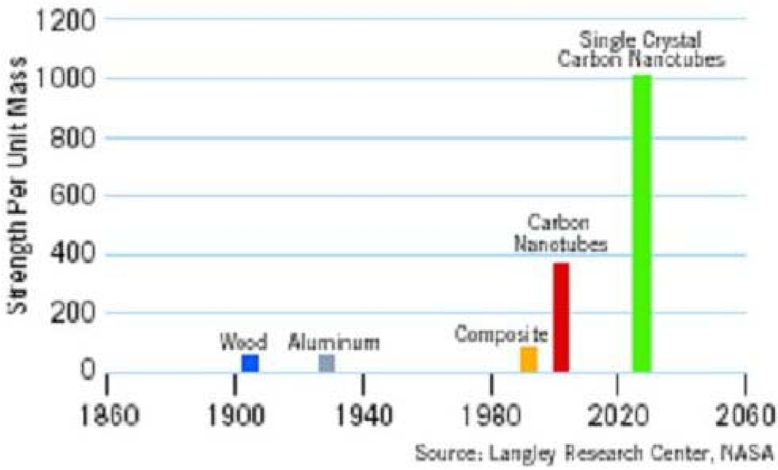


Fig. 4 Past and projected strength of materials for air and spacecraft structures

The recently published American Aerospace Commission report which addresses the future of American aerospace, describes the leading technologies of the future. Selected sections of this report are presented here:-

- ***Information Technology*** – The information revolution will ultimately be as important to transportation as the invention of the automobile and the jet engine. High performance computers will enable us to model and simulate new aerospace vehicle designs, prototype them and field them quickly. High confidence systems and high bandwidth communications will ensure that communication links between space, air and ground elements are secure from cyber attack. Large-scale networks will enable the development of system solutions for moving aircraft around the world when and where needed. Advanced engineering tools will make software more reliable, robust and fault tolerant. Micro and nano computers and sensors will revolutionize flight systems, enabling them to acquire, process and automatically fly aerospace vehicles. New integrated air, space and ground networks will enable us to acquire large volumes of data, process that data and then make it available to decision makers anywhere in the world, in near-real time.

- ***Subsonic and Supersonic Flight*** – Advanced air-breathing propulsion systems will enable a new generation of quiet, clean affordable and highly capable military and civil aircraft. Since the 1950s, aggressive gas turbine engine technology efforts have increased production engine performance by a factor of three and improved fuel efficiency by 70%. Further substantial improvements in the capability and cost of hydrocarbon-fueled turbine engines are being actively pursued under the newly formed VAATE program.

- ***Air Applications*** – In the near term, hydrogen fuel cell technology can be used to provide aircraft auxiliary power, increasing aircraft safety and propulsion system efficiency. The benefits of moving from hydrocarbon-fueled to hydrogen powered aircraft clearly justify an accelerated program to make aerospace a leader in hydrogen energy research.

- ***Human-Centered Design*** – Automated systems can increase capacity and safety of aerospace systems, but not without human factors research. In air traffic management one of the main constraints on system capacity is human cognitive workload limitations. A typical air traffic controller can only maintain awareness of four to seven aircraft at a time. Automation could remove this limitation but would change the controllers' function. Improving safety is possible using automation to compensate for and to assist humans. To achieve this, human factors research is needed to advance our fundamental understanding of how people process information, make decisions and collaborate with human and machine systems. The result will be enhanced performance and situational awareness of the human – in and out of the cockpit.

COMMERCIAL AIRCRAFT

In addressing the new development trends in commercial aircraft, the review will separately consider large aircraft and smaller aircraft.

Large Commercial Aircraft Trends

Nowadays, in the commercial aircraft field, the dominating design of aircraft configurations are as follows :-

Passenger aircraft	Low wing with engines below the wing
Business aircraft	Low wing with rear engines
Turbo-prop aircraft	High wing with engines on the wing
Light aircraft	Forward piston engine

New developments in configurations will be implemented only after proving a considerable advantage in performance, operating costs, noise and pollution and market preference. A number of new directions are currently being examined. Airbus represents a conventional configuration whereas the newer unconventional configurations are represented by the Sonic Cruiser, Supersonic Platform and the Blended Wing Body (BWB).

Airbus A380

Airbus' future passenger aircraft the A380 has a conventional configuration and will be capable of carrying 555 passengers on two cabin levels up to a range of 15,000 kms. At a maximum speed of 0.89 mach. Examples of new technologies incorporated in the aircraft are:-

- Composite materials are used to a much greater extent, graphite and also GLARE. Use of composite materials in the rear of the fuselage reduces weight by30% and cost by 40%.

- Use of laser welding employing regular rivets at a rate of 10 meters per minute, instead of 15 to 25 cms. per minute. This reduces weight by 5 – 10% and cost by 10 – 20%.

Fig. 5 shows a model of the Airbus A380 and Fig. 6 illustrates the future potential for the application of composite and hybrid materials both in the near future and in the next 15 to 20 years.

Fig. 5 Airbus A380

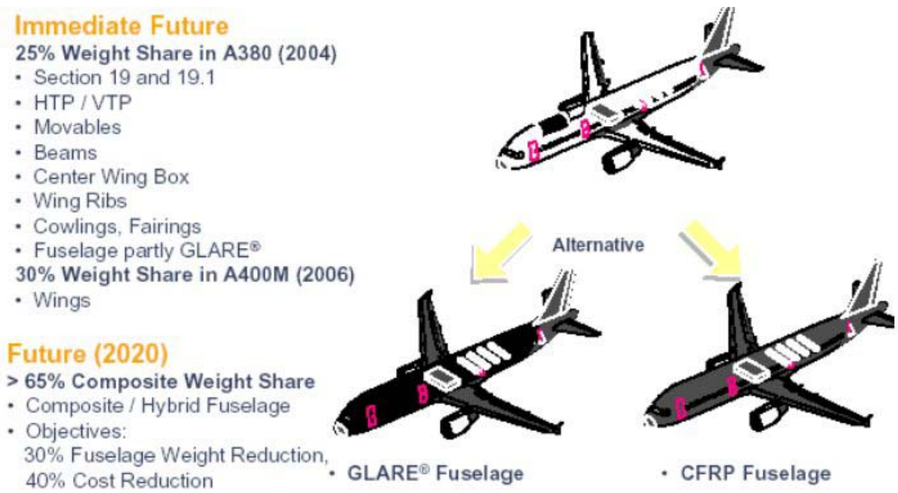


Fig. 6 Future application of composite / hybrid materials

Airbus envisage that by the year 2020, 65% of an aircraft weight will be due to composite materials. They predict a 30% weight reduction in the fuselage and a 40% reduction in cost. The Airbus A-380 “Anti-Weight” strategy is depicted in Fig. 7.

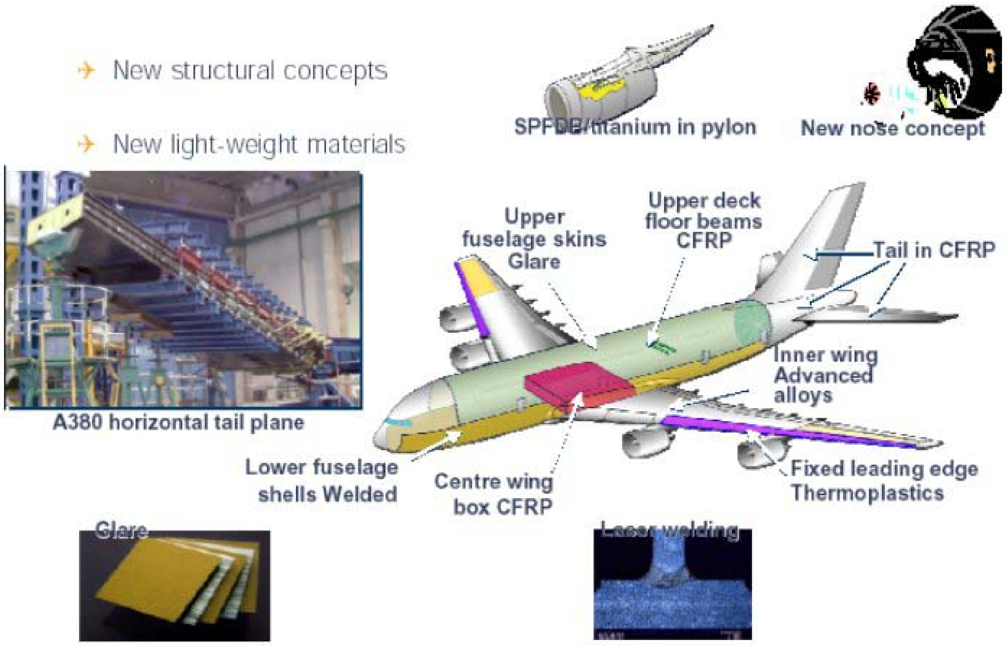


Fig. 7 A-380 - Anti-Weight Technology

Boeing Sonic Cruiser

Boeing’s sonic cruiser announced in March 2001 and recently cancelled, was supposed to enter service in 2008. The aircraft was defined with the aid of the latest CFD capabilities, which enabled the analysis of 25 wings, 50 engine nacelles and 60 different fuselages all in a period of 16 months. The market for the aircraft was never clear, but with a price tag of $M150, it was designed to fly with 225 – 250 passengers at 0.96 mach, at an altitude of 45,000 ft. and a range of 9,000 NM. Operating costs of the sonic cruiser were expected to be 50% higher than those of the A380.

During the design phase Boeing developed new technologies including the extensive use of composite materials and manufacturing and assembly techniques to reduce the assembly time of the entire aircraft to only several days, compared with the Boeing 737, which now takes several weeks.

Boeing has presented four different possible alternatives:-

- The familiar Sonic Cruiser configuration shown in Fig. 8 With the aft wing.
- A central wing shifted forwards with engines at the leading edge and a regular rear tail.
- A forward wing with engines mounted in front and below the wing (767 style), and a fuselage designed using area rule method, which is more difficult to manufacture.
- A configuration similar to the B777 but restricted to 0.85 mach.

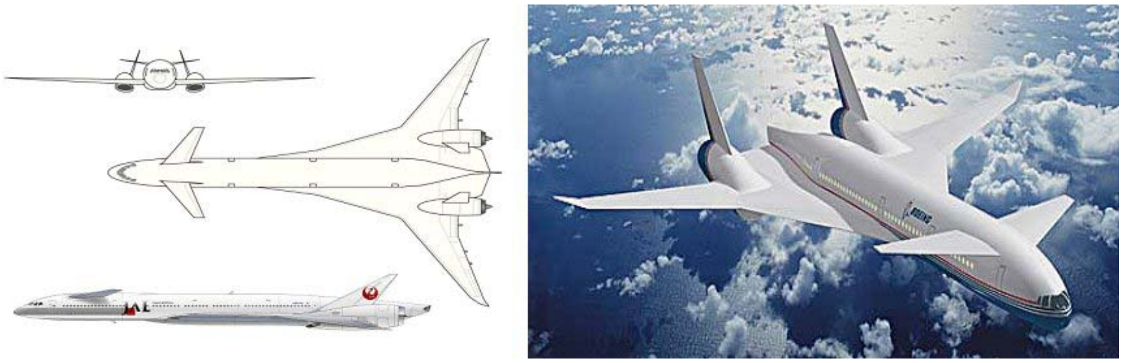


Fig. 8 Boeing Sonic Cruiser

QSP – Quiet Supersonic Platform

The main problem with aircraft cruising at supersonic speeds is the noise of the sonic boom produced. This in fact considerably limits their viability for commercial applications. Developments in computational capabilities in the field of CFD now facilitate the search for new supersonic designs that will reduce the volume of the sonic boom. Fig. 9 illustrates the new targets for noise reduction. The new design point for supersonic flight is directed towards aircraft of 50 tons, compared to the famous Concorde supersonic airliner which is in the 200 ton class; and a sonic boom intensity 7 times lower (0.3 psi instead of 2.0 psi). This trend will drive the development of new supersonic aircraft (mach-2) for business jets, and it also has a potential for future small supersonic bomber aircraft (DARPA vision).

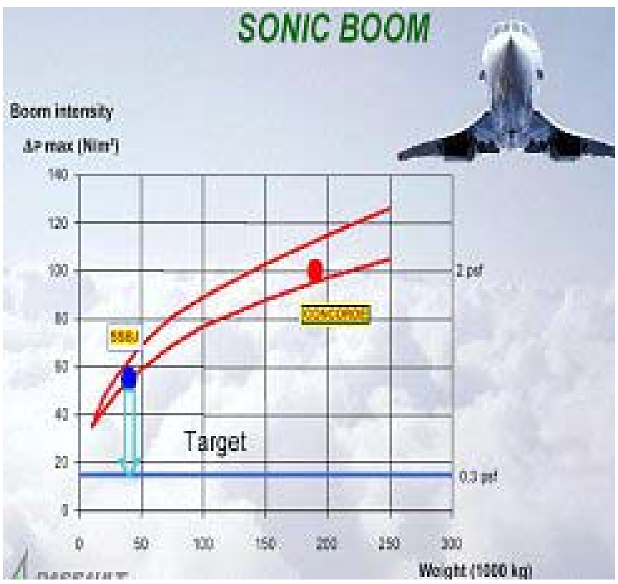


Fig. 9 QSP – Targets for noise reduction

The QSP configuration proposed by Northrop-Grumman and developed within the QSP DARPA funded program, is illustrated in Fig. 10. It has a span of 58 ft. and a length of 156 ft. with a range of 6,000 NM. and is to be demonstrated in conjunction with NASA-Dryden at 2.2 mach with a takeoff capability of 7,000 ft. (BFL).

Fig. 10 QSP – Quiet Supersonic Platform

Fig. 11 shows Dassault's configuration which will be developed within the aegis of the European Framework 6.

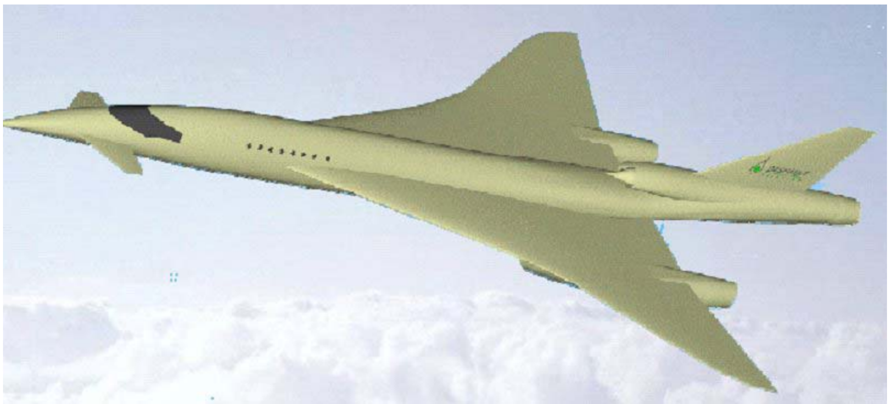


Fig. 11 HISAC – High Speed Aircraft

BWB – Blended Wing Body

Another non-conventional configuration that has been studied fairly extensively in the past few years is the BWB (Blended Wing Body). The BWB aircraft is a flying wing configuration which is being promoted by the aerodynamics engineers of R.H. Liebeck (Boeing) McDonnel. The concept is a 450 – 800 passenger aircraft with a range of 7,000 NM at 0.85 mach. It will require 20 – 27% less fuel than the Airbus A380 due to a 15% lower takeoff weight and a L/D improvement of 20%. The aircraft configuration is still at the study stage, and is being analyzed by universities, research institutes and industries, including Boeing, Airbus, ONERA, DLR, NASA, TSAGI etc.

Certain problems however are inherent in this configuration – acceptance by the public of an aircraft without windows, emergency escape access, relatively high forces on passengers seated far from the aircraft axis and rather steep inclines during takeoff and landing, susceptibility to gusts and a somewhat complex flight control system.

A wind tunnel model of the Blended Wing Body illustrating a typical configuration being investigated by NASA, is shown in Fig. 12.

Fig. 12 BWB – Blended Wing Body

Small Aircraft Trends

In parallel to the development trends in large commercial aircraft, there is also extensive activity in advanced technologies, promoted by NASA, in the field of general aviation. This activity is reviewed in the first part of this section. Emerging from these technologies is a whole new concept of "AirTaxi" pioneered by the Eclipse-500, which is described in the latter part of this section

NASA's Thrust for General Aviation

NASA set itself the target of influencing the development of flight worldwide by establishing in 1994 the AGATE and SATS programs in the USA. The goal is to create a revolution in air transport similar to that of the automobile revolution in the fifties – an airplane for every individual !. The revolution to be based on advances in computerization, communications, satellites, new materials and production techniques.

As illustrated in Fig. 13, air transportation in America will be developed in four layers, hub service between major international airports, regional jets between hub airports, corporate and air taxi services, and owner operated light aircraft for personal and business use.

Specific objectives of the revolution include a low cost light aircraft for two to four passengers at an affordable price, operated autonomously and integrating with other traffic by means of automatic navigation aids such as ADS-B.

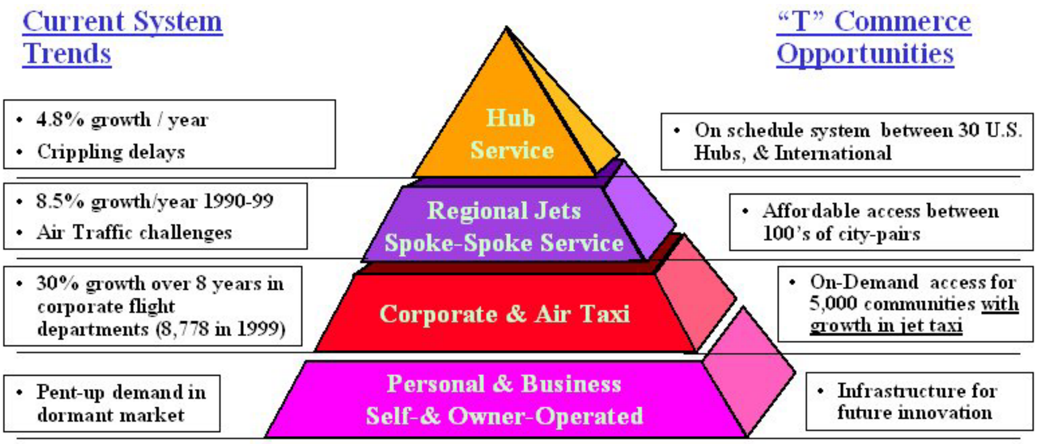


Fig. 13 Air transportation in USA

SATS

The Small Aircraft Transportation System (SATS) which is a NASA program, is envisaged to be a safe travel alternative freeing people and products from transportation delays, by creating access to more communities in less time. The target is to reduce public travel times by half within ten years, and by two thirds within 25 years, at a cost equivalent to highway costs; thus increasing the nation’s mobility by providing on demand, an advanced air transportation system. SATS facilitates higher volume operations in non-radar airspace and at airports without control towers and with minimal equipped landing facilities. It provides en-route procedures and systems for integrated fleet operations. It also increases crew safety and mission reliability.
An up-to-date roadmap for general aviation is illustrated in Fig. 14.

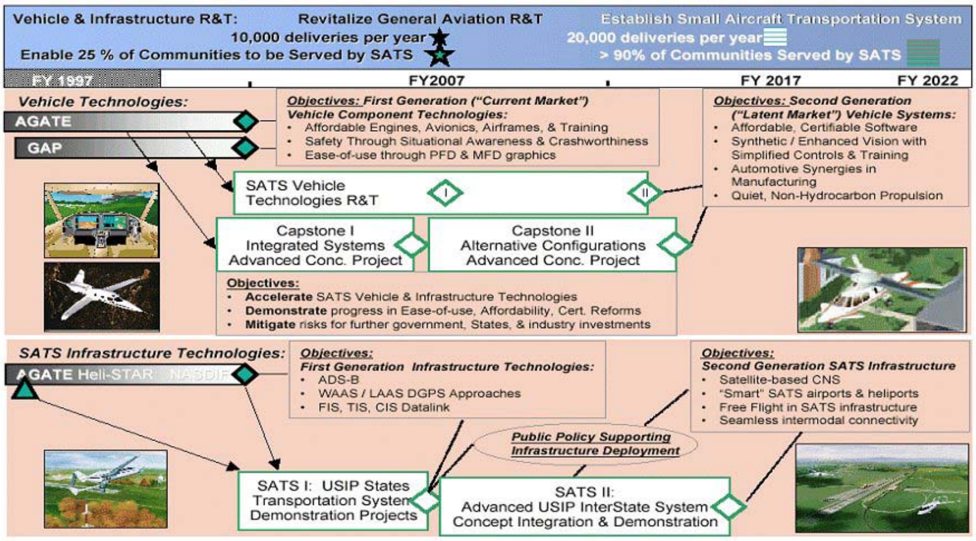


Fig. 14 National general aviation roadmap

SATS features :-

- “Smart” airports with highway in the sky approaches, airport databus, virtual terminal procedures (TerPs) and synthetic control tower or towerless- radarless operations.
- Ultra-propulsion employing non-hydrocarbon fuels with low noise and emissions.
- Integrated vehicle and air traffic services automation.
- Satellite based communications, navigation and surveillance for air traffic management functions in all airspace.
- Simplified flight controls and autopilot functions integrated with displays to reduce complexity of interactions between aircraft attitudes, power settings and rates of motion.
- Enhanced vision, by means of sensor based and database generated depiction of the terrain and obstacles in artificial or synthetic vision formats.
- Simultaneous non-interfering (SNI) approaches at class B airports for runway independent aircraft.
- Affordable manufacturing employing thermoplastics and aluminum with composites automation for integrated airframe systems design and manufacturing.
- Wireless cockpit using open standards for on-board systems and architecture.
- Cyber-tutor and internet based training systems utilizing embedded and on-board training and expert systems.
- Extremely slow takeoff and landing by means of aerodynamic configuration for slow and vertical flight.

- Emergency autoland for fail-safe recovery of aircraft and occupants following pilot incapacitation or other emergency situations.

Precision information makes new airspace available by virtue of knowing the relative position of the aircraft and its intentions, and any potential hazards such as terrain, weather, vortices etc. The new airspace can be exploited by improving the traffic flow and increasing separation.

Fig. 15 Toyota Advanced Aircraft – POC (proof-of-concept)

An example of this new trend is Toyota's advanced aircraft which is shown in Fig. 15. and which first flew in May 2002 in California by a Scaled Composites' test pilot. Its Lycoming engine may eventually be replaced with a new a/c-qualified diesel powerplant. The wing, which is a proprietary Toyota design, and the fuselage are each manufactured as single-piece units using carbon-winding techniques, greatly reducing production time and cost. Toyota has a vision of becoming a major general aviation manufacturer, bringing its successful automobile production techniques to the light aircraft industry.

Air Taxi

The creation of the third layer "Air Taxi", of the diagram in Fig. 13, is supported by the development of a new line of aircraft lead by the Eclipse 500, which is expected to be a market leader in its class. As a result of the interest shown in the Eclipse 500, interest has been aroused by other contenders such as Cessna Mustang, Safire S-60, Adam-700, Honda and Cirrus.

Eclipse 500

The Eclipse 500 shown in Fig. 19 on its first flight in August 2002, has a price tag of around a million dollars. It can carry five passengers in addition to the pilot, at a speed of 355 knots and a range of 1350 miles. It has an empty weight of 4,700 lb. and a maximum takeoff weight of 4,700 lb. with a ceiling altitude of 41,000 ft. It was designed to be powered by the Williams EJ-22 engine, which delivers over 770 lbs thrust. The flight control system incorporates a dual channel, three axes autopilot and auto-throttle and is managed by an aircraft performance computer and a flight management system. The basic avionics system is dual redundant and additionally available is an active route moving map, flight path predictor, weather radar, ADS-B, traffic information service (TIS) and terrain avoidance warning system (TAWS-B).

Fig. 16 shows the Eclipse 500 cockpit, and Fig. 17 its avionics architecture.

Fig. 16 Eclipse 500 cockpit

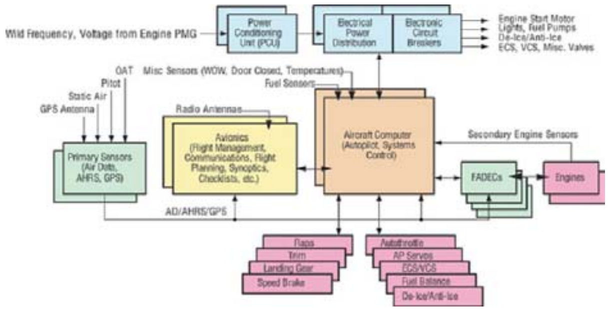


Fig. 17 Eclipse 500 avionics architecture

The panels of the Eclipse 500 will be assembled to form the pressurized fuselage. On the exterior, the metal joining process of friction stir welding produces a smooth finish (no rivets or edges to fill, just a smooth easy-to-paint surface) – see Fig. 18

Fig. 18 FSW (friction stir welding)

The revolutionary aspect of the Eclipse 500 is the ability to reduce operating costs and its price to about a third compared with similar business aircraft like the Citation-CJ1. The basis for this achievement is the advanced low-cost technologies employed in its production and assembly (FSW welding), advanced avionics and low cost propulsion system. The intended price of the Eclipse 500 is around $M1 and its market potential in the role of air taxi is estimated to be between 15,000 to 50,000 aircraft in the coming years.

The Eclipse program has now been slowed due to the limitations of the Williams' EJ-22, and its inability to provide the required performance. The engine will be replaced by a higher thrust engine for which the Pratt & Witney and Honeywell engines are contenders.

Fig. 19 Eclipse 500

FUTURE DEVELOPMENT TRENDS

This section gives a brief overview of the long-term roadmaps for technologies, and the directions under consideration for the development of air vehicles. The overview includes highlights from NASA's Aeronautic Blueprint and the European Aeronautics Plan – ARTE21.

The evolution of flight and and the future development of aircraft is influenced by the fierce competition between the two blocks of the United States and the European Community. On the one hand Europe, in January 2001, presented its plan entitled "A Vision For 2020", and continues investing in its own research and development programs. On the other hand the USA, in February 2002, presented its plan entitled "NASA Aeronautics Blueprint" which describes its developmental directions through 2025.

The NASA Aeronautics Blueprint illustrated in Fig. 20 has four major elements – the airspace system, revolutionary vehicles, security and safety, and education of the workforce. This review addresses only revolutionary vehicles.

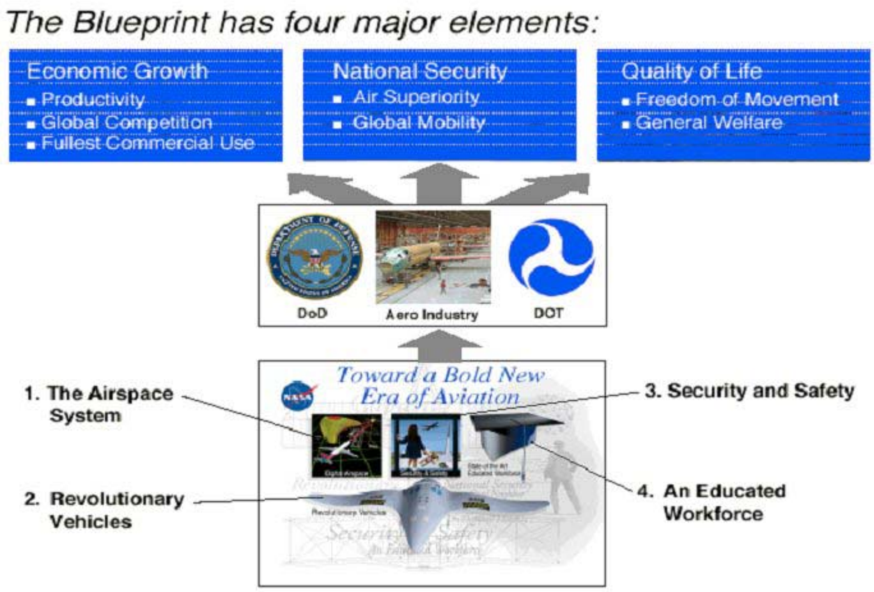


Fig. 20 Organization of the aeronautics blueprint

The challenges facing us today are:

- Long duration and large, long-haul transportation to provide months aloft at high altitudes and covering long distances.
- High speed commercial transportation to provide quiet, efficient and affordable supersonic flight.
- Quiet and efficient, runway independent aircraft having extremely short takeoff and landing, to provide door to door service.
- Autonomous operation capability for a whole range of aircraft from micro-vehicles to heavy transports.
- Noise reduction to eliminate airport restrictions. This can be achieved by integrating the airframe and propulsion system and by active flow and noise control.
- Lower exhaust emissions to reduce greenhouse gases and improve local air quality, by means of intelligent propulsion systems and fuel efficient vehicles.
- Improve safety and reduce accident rates by means of integrated health monitoring, fault tolerant systems and more robust flight control systems.

- Develop light, strong and structurally efficient air vehicles by using nanostructures which are 100 times stronger than steel and one sixth of its weight.
- Improve aerodynamic efficiency by means of active flow control.

The ten greatest challenges for revolutionary vehicles are considered to be:-

1. Processing and fabricating nanotube reinforced composite structures.
2. Damage tolerance of load bearing structures with embedded sensors and actuators.
3. Certification technology for morphing aircraft structures.
4. CFD codes to accurately model the complete flight envelope
5. Control of "designer aero" vehicles.
6. Autonomous control of personal air vehicles.
7. Robust vehicle health monitoring with 0.99999 reliability.
8. Fuel cell efficiency sufficient to power aircraft.
9. Mastering complexity in design, manufacturing and certification of revolutionary new vehicle designs with new technologies.
10. Software reliability.

The four diagrams depicted in Figs. 21, 22, 23 and 24 are taken from NASA's Aviation Blueprint, to illustrate the principle issues involved. The examples cover the issues of materials and structures, propulsion, aerodynamics, flight control and structural certification.

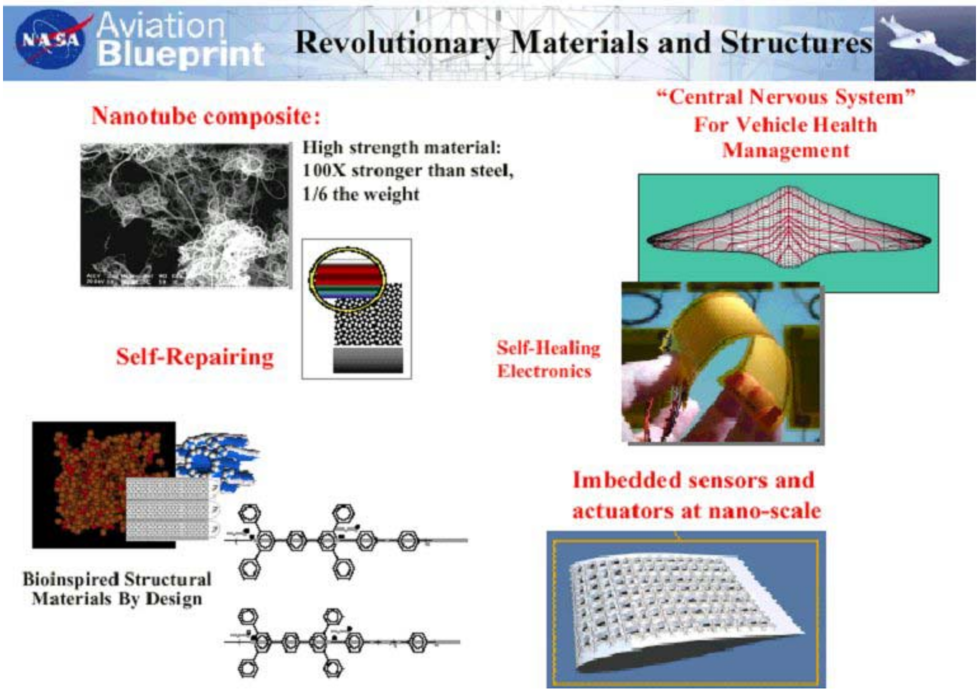


Fig. 21 Revolutionary materials and structures

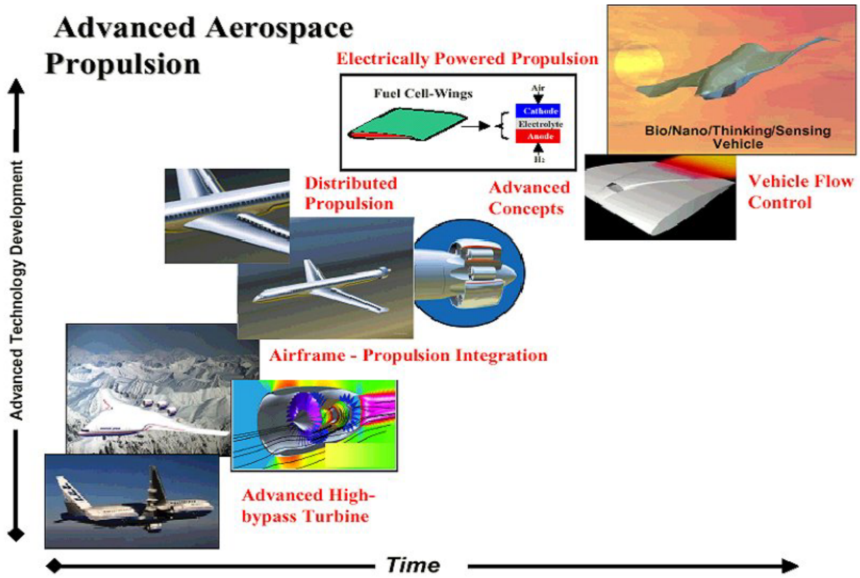


Fig. 22 Advanced aerospace propulsion

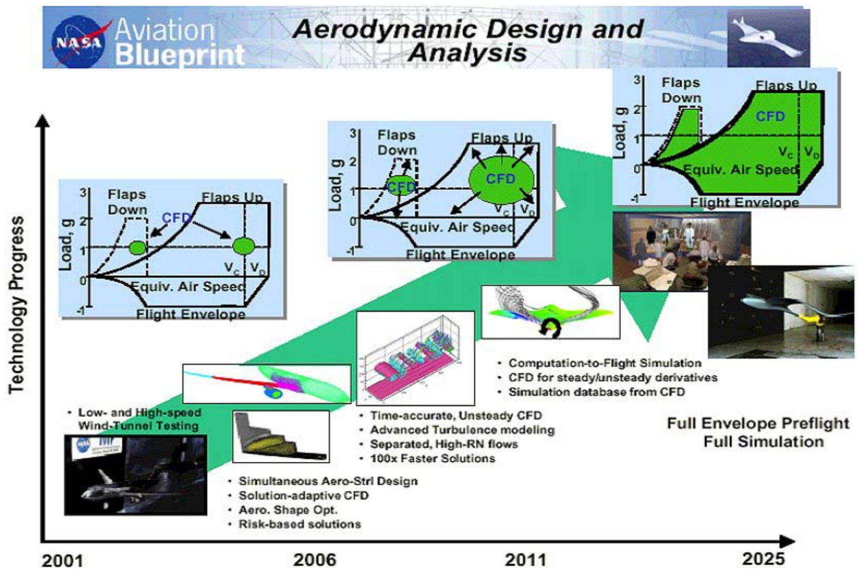


Fig. 23 Aerodynamic design and analysis

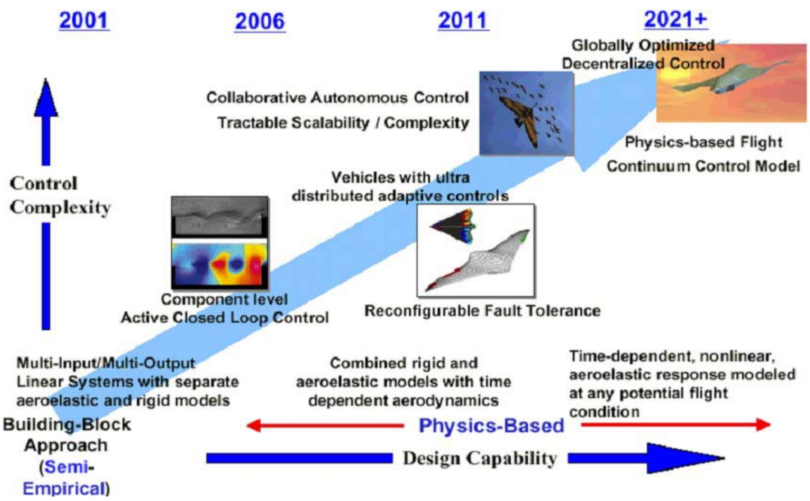


Fig. 24 Advanced control system - analysis, design & development

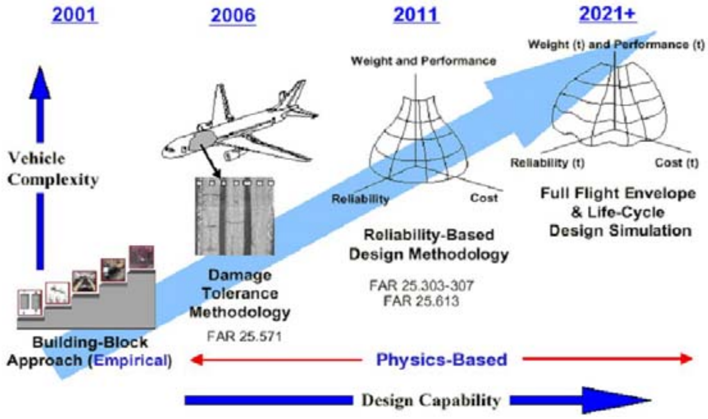


Fig. 25 Structural design & analysis - certification technology

Fig. 26 summarizes the general trends in the development of exotic air vehicles.

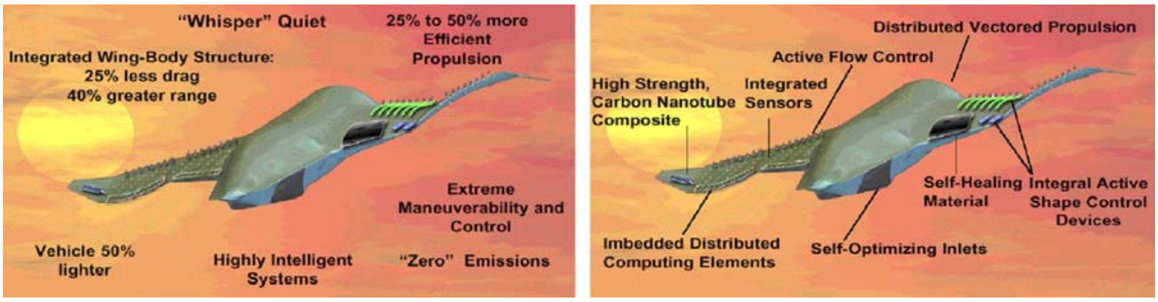


Fig. 26 Attributes of future flight vehicles

ARTE21 Plan

The aerospace R&D activity in Europe is co-coordinated by the aerospace industries with the additional participation of research institutes and universities. The research today is mainly directed at commercial aviation and is organized by the EEC in "Frameworks" which define the goals and fund much of the research activity.

The table in Fig. 27 lists the goals of the European ARTE21 (Aeronautical Research & Technology for Europe in the 21st Century). ARTE21 was presented in January 2001 and describes the position of the European aeronautics industry and wider community with respect to future research needs at a European level over the next 20 years.

GoP Challenge	*Target Concept*	*Target Concept Goals*
- Environment	- The Green Aircraft	Per passenger kilometre : 50% cut in CO_2 and 80% in NOX Noise nuisance = large city environment Reduce impact on global environment
- Safety	- The Safe Aircraft Operation	Five fold reduction in accident rate
- Capacity & Delay	- On Time Aircraft Operation - ATM of the Future * - Airport of the future **	99% of all flights < 15 min. delay, in all weather
- Passenger Comfort	- The Passenger Friendly Aircraft Operation	Wait at gate <15 min for short haul Wait at gate <30 min for long haul Stress free travel with home/work services Increase choice of flights/locations
- Affordability/Industry Competitiveness	- The Competitive Aircraft - The Competitive Enterprise	Steady and continuous fall in travel charge Capture 50% of market

Fig. 27 ARTE21 – Aeronautical Research & Technology for Europe in the 21st Century

The following I/V (Integration / Validation) projects are being promoted within the context of ARTE21.

1. Environmentally Friendly Aircraft
2. Environmentally Friendly Aero Engine
3. ATM of the future and FMS/CNS functionalities
4. Advanced Cabin, cabin systems and Multimedia services for improved Passenger comfort and better Aircraft efficiency
5. Low Cost Airframe Integration
6. Maintenance Free Airframe Structures
7. Aero Engine for Affordable Air Travel
8. Novel rotorcraft configuration for gate to gate passenger transport
9. More Electrical Aircraft
10. Next Generation Small Turbofan
11. Aero engine new concepts
12. The environmental friendly Helicopter including new turboshaft engines
13. Common core engine
14. Airborne Integrated Systems for Safety improvement, Flight Hazard Protection and All-weather Operation
15. Safe and Beneficial Approach/Landing and Ground Movement Procedures and Technologies
16. All Composite Aircraft
17. Supersonic Cruise Jets : SSBJ and ESCT
18. Next Generation Air Systems
19. New Aircraft Concepts
20. The Virtual Engine and Engine Enterprise
21. Virtual Product Within Virtual Enterprise
22. Technologies and Techniques for new Maintenance Concepts
23. Security of Aircraft operation

Fig. 28 diagrammatically depicts future activity in the field of CFD (Computational Flight Dynamics) in the European Framework 6 program “OPERA”.

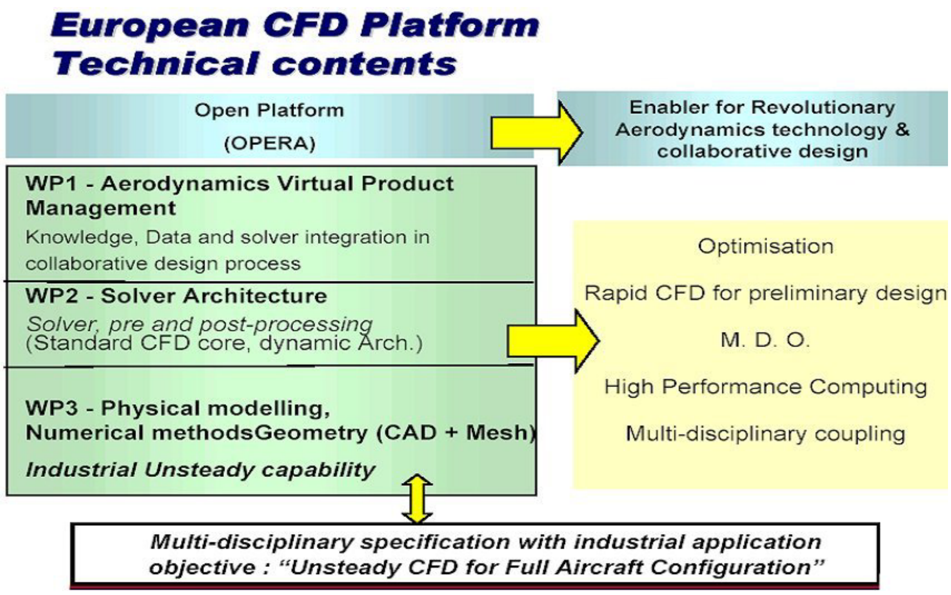


Fig. 28 European CFD platform **“**OPERA”

UNMANNED AIR VEHICLES (UAVs)

One of the revolutions in the aerospace industry which is rapidly gaining momentum is the increasing use of unmanned aircraft for military missions. This trend is fuelled by the positive experience gained from the application of UAVs for intelligence gathering, and also more recently in accurate combat. Fig. 20 shows the Predator UAV armed with Hellfire missiles. UAVs proved their value and efficiency in the following important landmark events :–

- 1982 – The Lebanese war
- 1991 – The Gulf war
- 1995 – 2000 – The wars in Bosnia and Kosovo
- 2002 – The war in Afghanistan

Military UAV activity in the USA is in a process of acceleration, with the main programs exceeding one billion dollars per year. The budget for all DoD UAV programs :-

- doubled between 2001 and 2002
- will double again between 2002 and 2005
- will triple between 2002 and 2007

US Army programs include :-

RQ-9A TUAV Shadow-200 employment, Hunter improvements, FCS – new generation SUAV, OAV, TUAV, HALE, A-160 helicopter, Dragon Eye, Dragon Warrior and UCAR attack helicopter.

US Navy / Coast Guard programs include :-

Pioneer life extension, VTUAV, Tilt rotor and UCAV-N (X-46, X-47).

US Air Force programs include :-

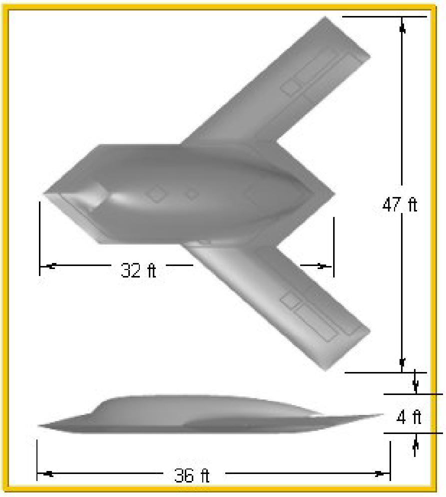
Predator A, Predator B, Global Hawk and UCAV X-45A, X-45B.

Fig. 29 Predator

A new UAV American Road Map Document will be published at the beginning of 2003. The rapid growth within DOD is underscored by the fact that the roadmap document became outdated so quickly (first issue April 2001).

Unmanned Combat Vehicles (UCAV)

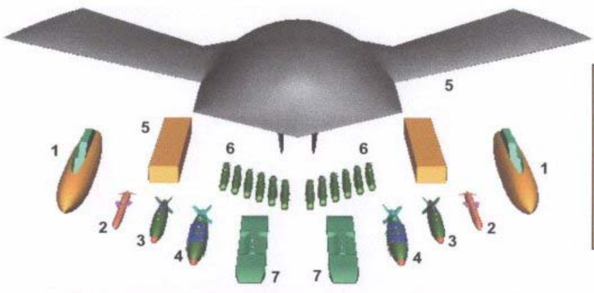
Fig. 30 shows the Boeing A-45 UCAV test demonstrator. The first demonstration flight took place in May 2002, and it is planned to be combat operational in 2008. Fig. 31 illustrates the payloads which it can carry.



Operational UCAV (A – 45)

- **Sensors:** SAR
- **Radius:** 900 nm
- **Endurance:** 3 hr
- **Max Altitude:** 45,000 ft
- **Max Weight:** 25,000 lb
- **Payload:** 3600 lb

Fig. 30 Operational UCAV



	Aircraft Quantity
1 - External Pylon with 300 Gallon Fuel Tank	2
2 - Miniature Air-Launched Decoy	2
3 - JDAM 500 Guided Bomb	2
4 - JDAM 1000 Guided Bomb	2
5 - Internal Auxiliary Fuel Tank	2
6 - Small Diameter Bombs	12
7 - SDB Multiple Ejector Rack	2

Fig. 31 UCAV Payload

Fig. 32 illustrates the UCAV-N, a somewhat larger aircraft with considerably greater range and endurance. The first flight of this demonstrator is expected towards the end of 2002 and is planned to be combat operational by 2015. The contractors are Northrop-Grumman (X-47) and Boeing (X-46).

UCAV-N

Sensors: SAR, EO/IR

Radius: 1500 nm

Endurance: 12 hr

Max Altitude: 40,000 ft

Max Weight: 29,000 lb

Payload: 5,500 lb

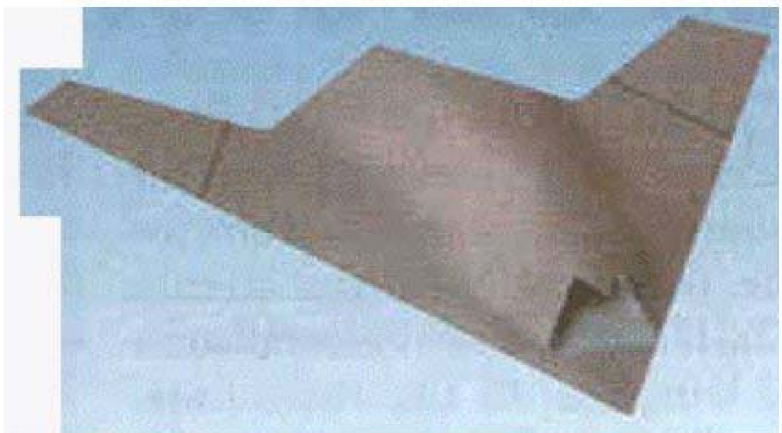


Fig. 32 UCAV - N

Fig. 33 UCAV–N X47A – PEGASUS (NORTHROP) demonstrator

Revolutionary and Unconvential Trends

LEWK

Technologies from the Joint Navy/Army FASM-Quicklook program are incorporated in LEWK which is illustrated in Fig. 34. This includes inflatable wings, a heavy fuel engine and G hard compact design to enable tube launching. The open architecture permits plug-in modular payloads – 4 stations in payload bay. Low speed cruise and loiter facilitate "man in the loop" targeting

- SAIC RAID software and image processing
- COTS technologies – CCD EO and LWIR cameras, actuators, avionics
- Demonstrated affordable military technologies – jam resistant, GPS, com links, radar jammer, submunitions.

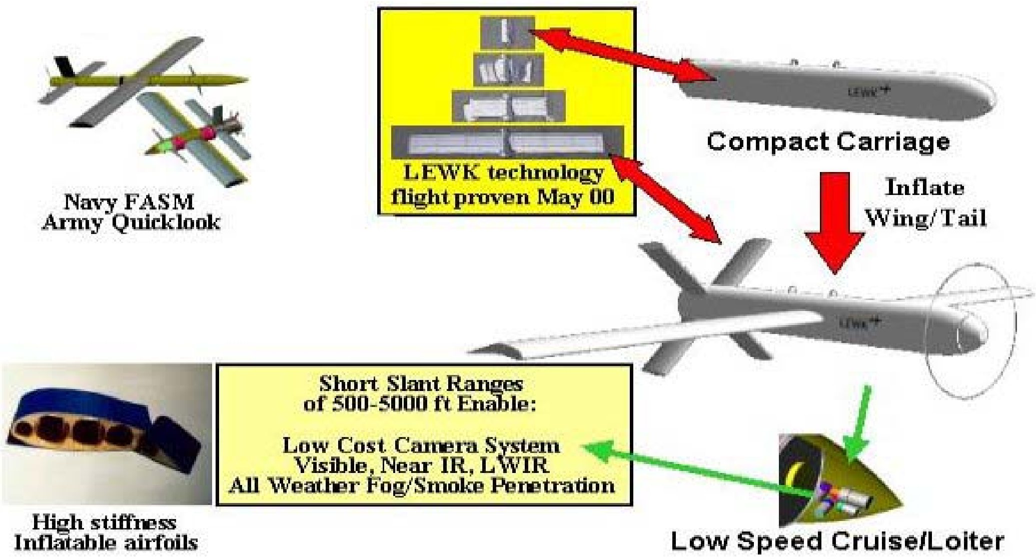


Fig. 34 LEWK technologies

The pursuit of an intelligence capability for the ground forces resulted in numerous programs. We have chosen to make mention of the OAV (Organic Air Vehicle) which exemplifies an innovative air vehicle concept. The OAV which has a ducted fan propulsion system, has vertical takeoff and landing as well as hovering and forward flight capabilities. This type of vehicle is intended for the US Army FCS (Future Combat System), for platoon and company level self intelligence. Fig.35 shows OAV prototypes built by the Microcraft Company.

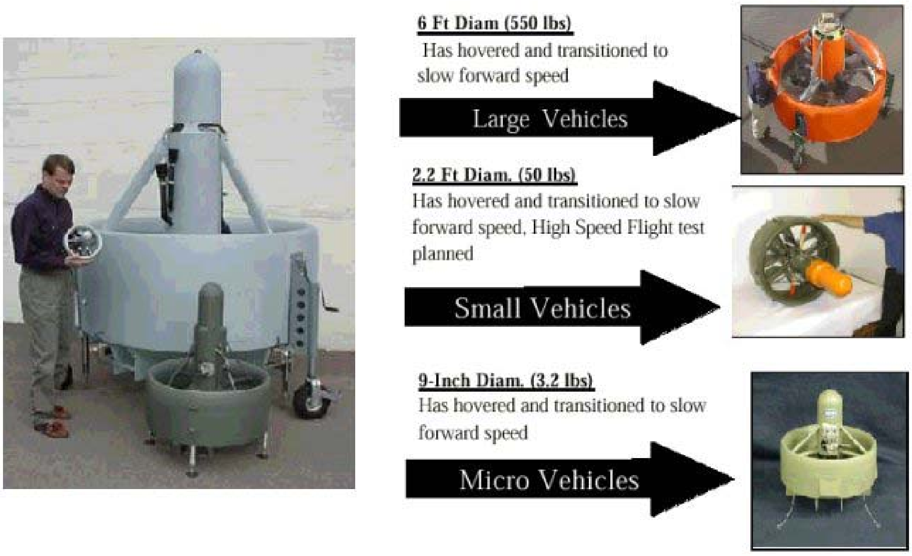


Fig. 35 Microcraft: Lift Augmented Ducted Fan (OAV)

CRW

Fig. 36 shows Boeing's CRW (Canard Rotor Wing) which is based on existing engine technology, has a drive system which eliminates the need for both an anti-torque system and a heavy transmission, and thus reduces maintenance. The rotor /wing has a low disk loading and an oblique wing for high speed cruising. The configuration has no inherent speed limitation and greatly increased survivability. This concept is at an advanced stage of development and is another example of the search for a solution to combine VTOL with fast forward cruising. The concept is very complicated and high risk.

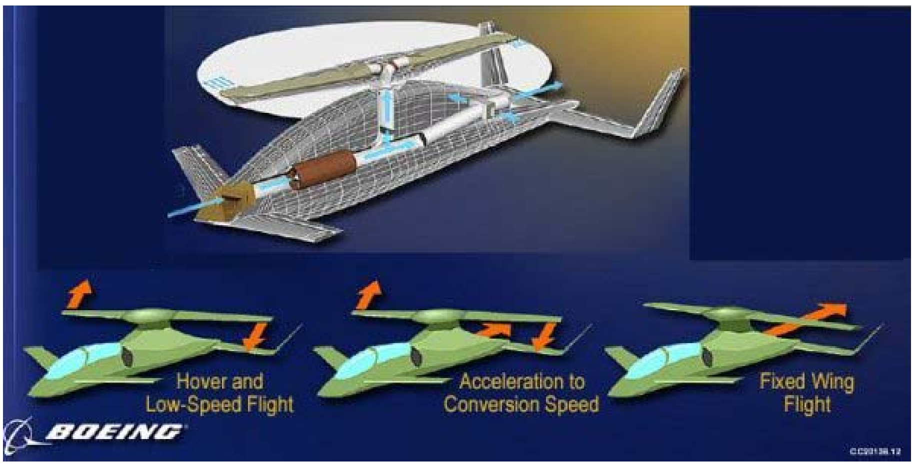


Fig. 36 Boeing CRW – Canard Rotor Wing

Solar HALE

A new direction for High Altitude Long Endurance (HALE) flight is demonstrated by NASA's activities in solar HALE air vehicles being developed by an American company - Aeroenvironment. This unique configuration shown in Fig. 3 is powered by electric motors which derive their energy from solar panels and fuel cells. One of the main potential applications for this air vehicle is for communications relay. Fig. 37 illustrates this concept using the Helios UAV.

Fig. 37 Sky tower concept

Micro-UAVs

An additional new trend has been emerging in recent years, that of the micro-UAV. This concept can be realized by the microminiaturization of subsystems using MEMS (Micro Electronics Mechanisms) which was developed for the automobile, electronic entertainments and hobby airplanes industries. US DARPA initiated this activity a few years ago, and today it is advancing in a number of different spheres. The goal is autonomously operated air vehicles in the weight class of 100 grams, with an endurance of thirty to sixty minutes. Fig. 38 shows the Black-Widow (Aeroenvironment), and the Microstar (Lockheed) micro-UAVs.

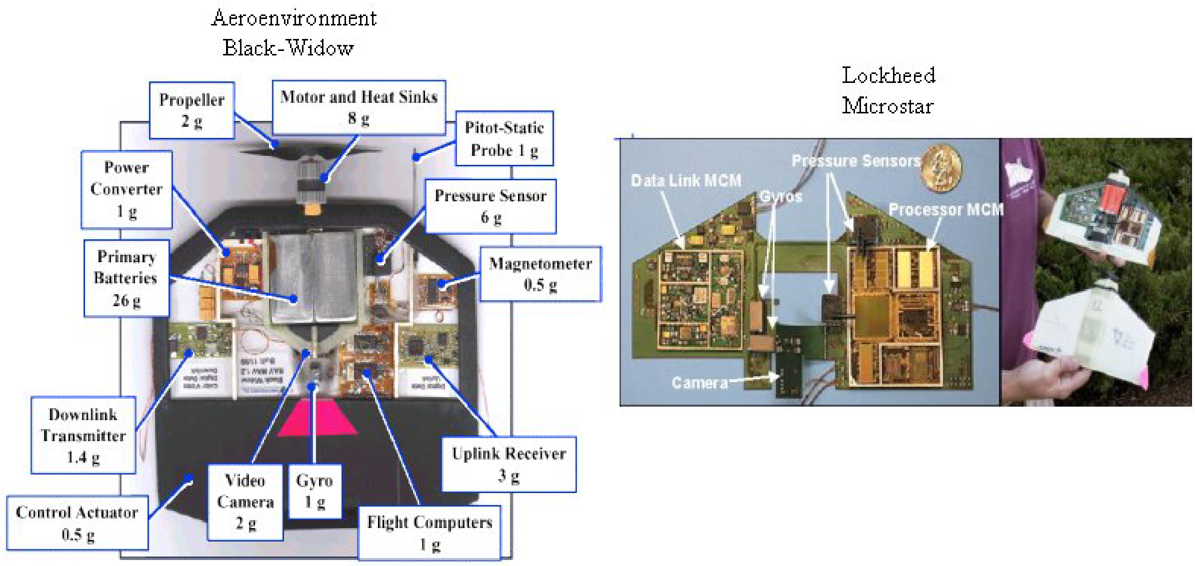


Fig. 38 Micro-UAVs

Sensor Craft

Sensor Craft describes future long term projects for the US Air Force in development by AFRL (the US Air Force laboratories). Figs. 40, 41 and 42 list the challenges and technologies with respect to sensors, air vehicles and propulsion systems. The potential of the new advanced technologies creates the basis for new challenges for the next generation intelligent UAV systems. Fig. 39 illustrates the general concept of operation.

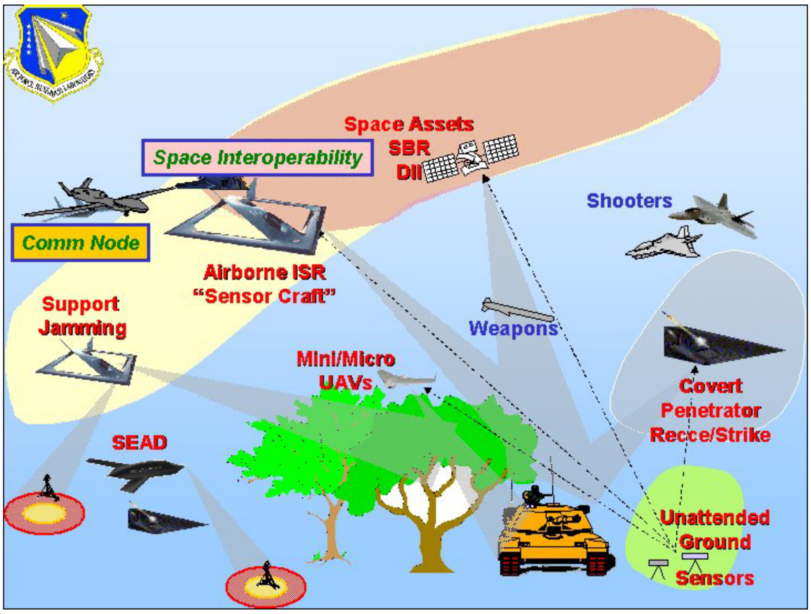


Fig. 39 Sensor Craft - UAV as Element of Global Awareness/Global Engagement Vision

Challenges	Technologies
Greatest challenge – Affordability, reduce a $50-100 million RF sensor suite to $5-10 million	Production MMIC Transmit Receive (T/R) Modules
Beamforming over doubly curved surfaces	Conformal Active Electronic Scan Arrays
100X reduction in size and weight of today's receivers	Conformal Wideband Receive Apertures
Weight reduction of at least 1000X of all sensors systems from current aircraft configurations	Compact, Wideband Digital Receivers
Performance improvement of at least 30 dB for AMTI and at least 12 dB improvement in GMTI from existing systems	Direct Digital Synthesis
Conformally integrated Low Frequency and High Frequency apertures. Laboratory samples demonstrated	Multi-beam Space Time Adaptive Processing
Light Weight, compact & tunable lasers	Passive Detection and Location of RF Emitters
	Multiple/Simultaneous Radar Modes (GMTI, AMTI, SAR)
	Infrared Search and Track Systems
	LADAR Imaging Systems
	HSI
	Precise Reference Systems/Geolocation
	Ownship Sensor Fusion and Identification

Fig. 40 Sensor Craft - Sensor Challenges & Technologies

Challenges	Technologies
360° aperture integration for resonance detection never done	Revolutionary Integrated Air Vehicle / Sensor Design
Integrated high aspect ratio wing, sensor, passive cooling, power generation & distribution has never been done	Low Cost Smart Structures
Integrated structural sensor integrity, durability, damage tolerance increased 4X	Capillary Pump Heat Rejection
High altitude heat rejection, cooling system weight, volume improved 2-3X	Reconfigurable Damage / Fault Tolerant Control
High aspect ratio joined wing has never been done	Prognostics and Health Management
Reliable and affordable sensor, propulsion, vehicle integrated design for overall unit flyaway cost 10X less than AWACS, JSTARS	Reliable And Affordable Control Systems
	Intelligent UAV Autonomous / Cooperative Control
	Collision Avoidance / Aerial Resupply
	Simulation Based R&D

Fig. 41 Sensor Craft - Air Vehicle Challenges & Technologies

Challenges	Technologies
Need to improve power generation capacity by 2-fold and reduced logistic footprint Need to extend mission duration (goal – 80 hrs; threshold – 60 hrs) Increase fuel efficiency Light weight, high efficiency regenerative power Reduce Cost of Engine / Power system Reduce Maintenance Cost	Integral Starter Generator (ISG) Magnetic bearings / ISG eliminates oil system Technologies for high altitude, long endurance fuel burn reduction by up to 50% Photovoltaic, fuel cell for regenerative power Technologies for up to 50% cost reduction for an integrated engine/power system Technologies for a "Full Life" hot section and maintenance free engine core

Fig. 42 Sensor Craft - Propulsion/Power Challenges & Technologies

DEVELOPMENT ACTIVITY AT IAI

IAI (Israel Aircraft Industries Ltd.) has been involved in the production, development and support of both military and commercial air vehicles since 1966. The principal projects over the years have included :–

- The Kfir and Lavi fighter aircraft together with the overhaul and refurbish of numerous other combat aircraft.
- The Arava, The Westwind, Astra (G100) and Galaxy (G200) business jets.
- Since 1973, numerous UAVs (Unmanned Air Vehicles).
- Adaptation and refurbish of large aircraft for cargo and AEW (Electronic Warfare)

In order to facilitate the development of advanced state-of-the-art aircraft which will be competitive, IAI performs extensive aeronautical research and development.
For example in the field of aerodynamics the development of the "NES" CFD (Computational Flight Dynamics) program which was upgraded recently by considerably increasing its parallel processing capability.

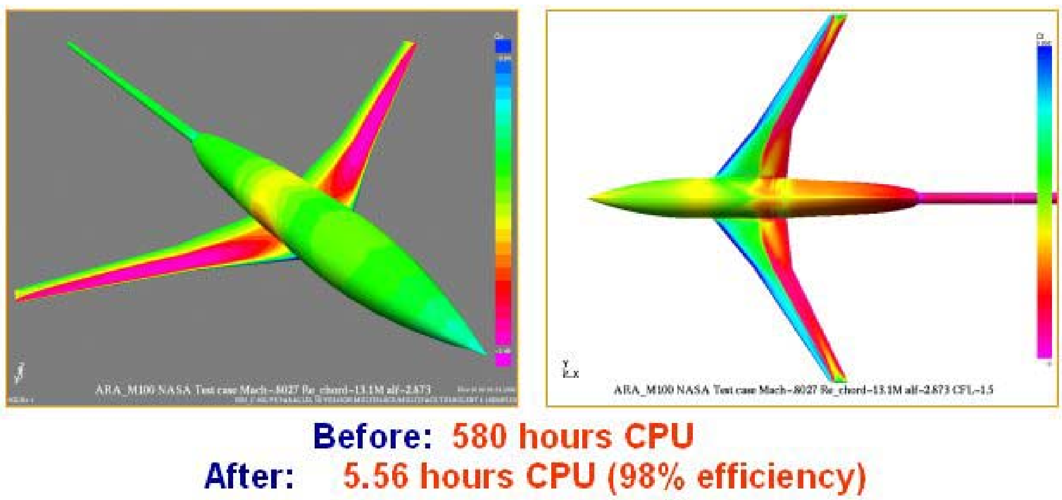


Fig. 43 IAI "NES" CFD Program

The IAI "NES" CFD Program employs 106 processors performing parallel processing. A process that previously took 580 hours of CPU time now takes only 5.56 hours (overnight). Fig. 43 illustrates the time saving.

Composite Materials
Another good example of manufacturing technology is in the use of composite materials to considerably reduce weight and production costs. Figs. 44 and 45 illustrate examples of parts produced in IAI using DTM (Design Transfer Molding) and LRI (Liquid Resin Infusion) – this technology is being transferred to the next generation of IAI air vehicles.

Fig. 44 Wing rib – resin transfer molding

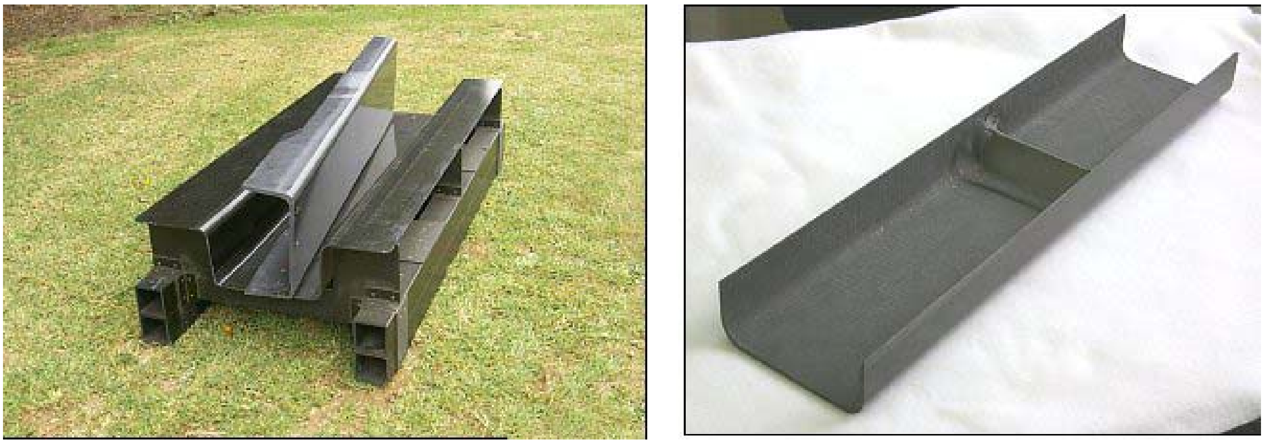


Fig. 45 Wing spar – liquid resin infusion

G150
IAI is currently working on a new version of the Astra business jet, known as the G150. The G150 is based on the G100 with the following new features. The body has been widened to improve passenger comfort and a plug has been inserted aft of the fuel tank for balance. The rear section of the G100 including the engines and the tail section, has been retained unchanged but has been raised by in order to improve the geometrical transition. The cockpit has been modernized and brought into line with the Galaxy 200. An impression of the G150 is shown in Fig. 47. Fig. 18 illustrates the aerodynamic airflow around the fuselage.

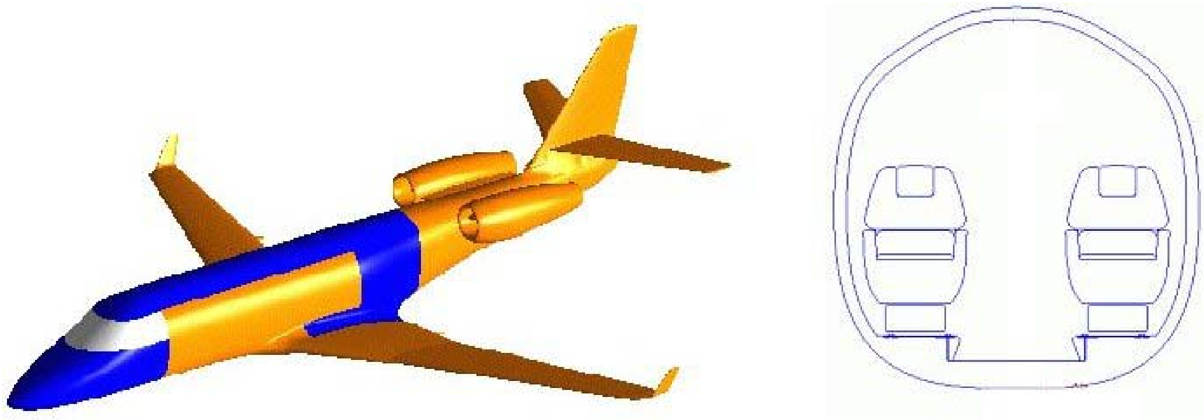


Fig. 46 Gulfstream G150

The G-150 was developed by means of "NES" CFD (Computational Flight Dynamics) program, and a good correlation can be seen between the wind tunnel test results shown in Fig. 48.

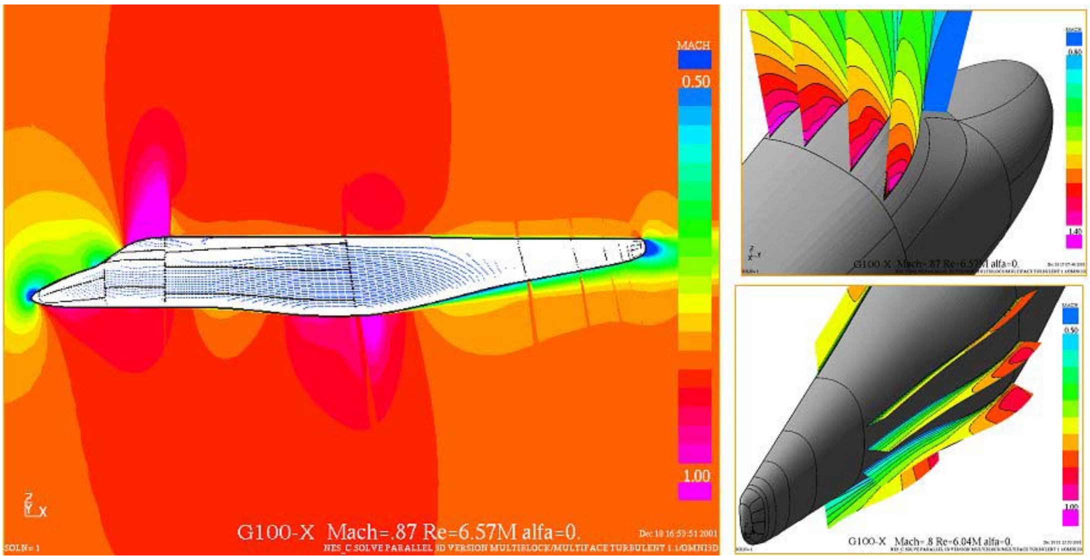


Fig. 47 G150 aerodynamics – NES CFD calculation of flow around the fuselage

G150. Full Model – Scale 1:12 **CFD vs. WindTunnel Tests**

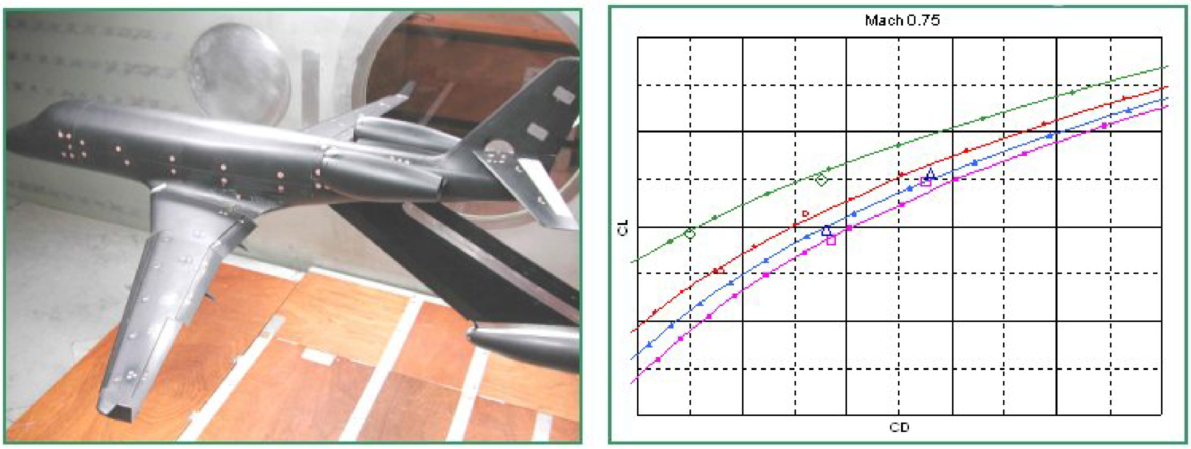


Fig. 48 Astra G150 Wind tunnel tests

AirTruck 225/250
A new potential direction for a new cargo aircraft is being evaluated with an emphasis on low cost design and manufacturing, in order to provide competitive solutions in this market.

Fig. 49. shows two versions of the AirTruck cargo aircraft currently under consideration. The smaller AirTruck 225 has a cabin cargo volume of $60M^3$, whilst the larger AirTruck 250 has a cabin cargo volume of $80M^3$. The 225 has a range of 500 km. with a payload of 12,500 lbs. whilst the 250 has a much greater range of 1,110 km. with a greater payload of 20,000 lbs.

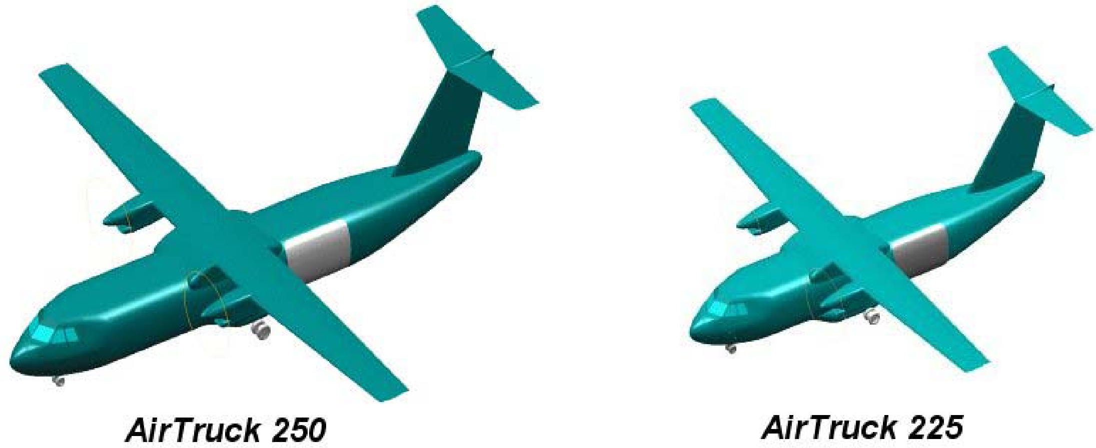


Fig. 49 AirTruck 225/250

UAVs
IAI has been involved in the development of air vehicles since 1973 and is today one of the leaders in the field of tactical UAVs. About 600 UAVs for some 20 customers have been produced by IAI, and these have accumulated over 135,000 flight hours. These include Zahavan, Ranger, Searcher, Heron-1, Pioneer, Hunter and others. Fig. 50 shows the new generation of IAI UAVs. Heron1 is today in production for customers while the Heron TP is at an advanced stage of development.

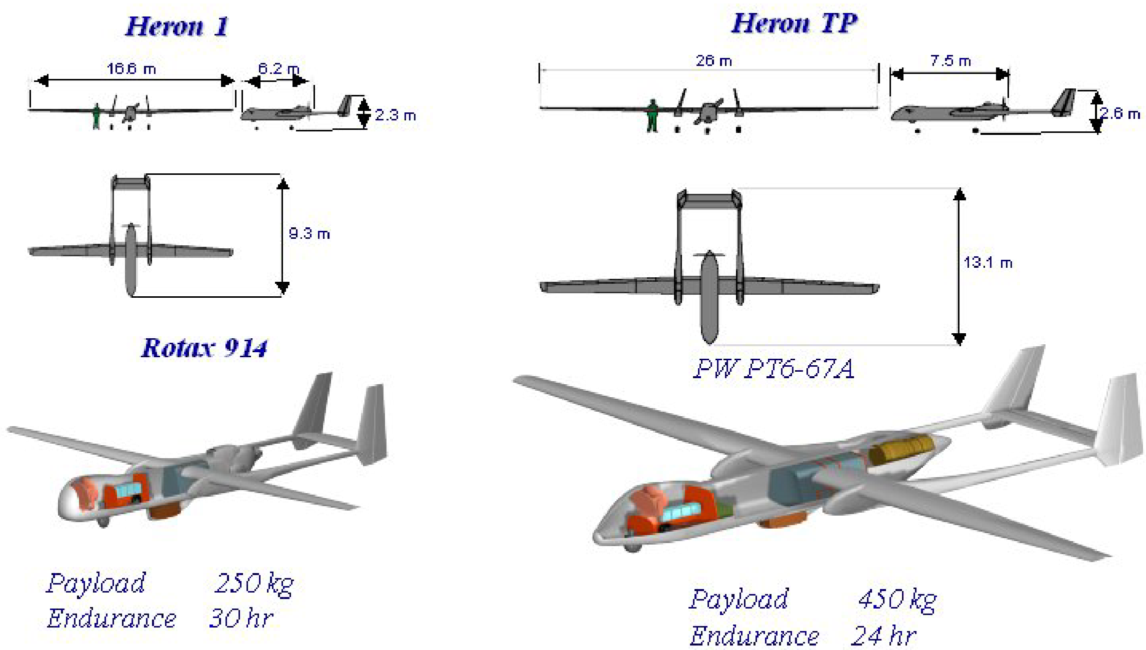


Fig. 50 Heron UAV

SUMMARY

Much is happening in the world of aviation. Market demands and technology lead to new means of improving the capabilities of commercial and military aviation by – shortening times, reducing operational costs, improving safety and becoming more environmentally friendly. A whole new set of technologies in the fields of computerization, communications, miniaturization and materials directly influence this evolution. The new technologies are accelerating mainly thanks to the development of information technology (computerization) and by integrating optimal design together with many disciplines, - this facilitates innovative designs which were not previously possible.

ACKNOWLEDGEMENTS

The review presented here is based on many open and unclassified sources which were published in the press and the internet. This includes NASA AFRL, US DOD, Airbus, Boeing, DARPA, European Commission reports,, Aeroenvironment, Microcraft, Lockheed and IAI publications and presentations.