A VISION FOR THE FUTURE EVOLUTION OF AIRCRAFT

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Abstract

This paper envisages the future directions of aircraft evolution in IAI and forecasts how military and civilian aircraft will develop in the medium and long term. The paper expresses the authors' opinions of how commercial, military and unmanned aviation will evolve in the future.

A brief overview is given of those promising technologies, which will influence aviation worldwide, and a few examples of IAI's activities are described. Reference is made to the new G-150 business jet, which is at an advanced stage of development, the new IAI-AVOCET small jet "PROJET" which is in the definition stage, the next generation tactical UAV, a mini and micro UAV, a HALE UAV, a UAV propelled by fuel cells and the Autonomous Cargo Vehicle (ACV).

1. Aircraft Development Trends

New product development is a continuous process, which involves a number of simultaneous and parallel activities, which include – exploration of the market and available technologies, the conduction of a feasibility study, the development of certain additional technologies and the launching of the program. Of these, the feasibility phase is perhaps the most important since it tries to advance innovative directions in response to the requirements and available technologies and provides the direction in which we wish to move. The worldwide market and technologies are very important references for future plans.

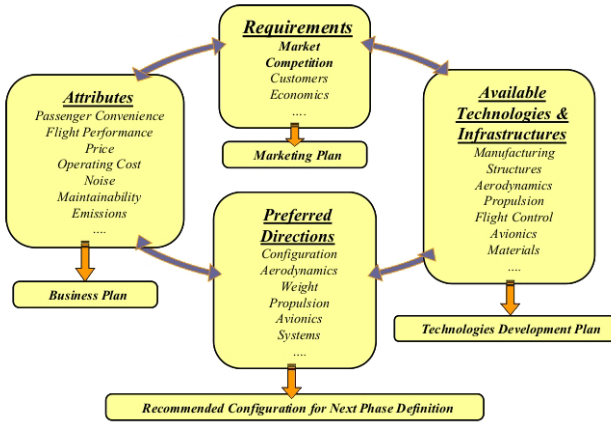

Fig. 1 Feasibility study

1.1 Commercial Aviation - Development Trends Overview

Solutions must be found to the chronic overcrowding of airspace by means of new ATC control systems and the overall travel time door to door must be reduced, all of this with a reduction in operating costs.
In summarizing the world trend in commercial aviation, market forecasts envisage a continuous expansion of passenger traffic at a rate of 5% from about 3 x 1012 RPK (Revenue Passenger Kms) today, to some 8.5 x 1012 RPK in the year 2020. Cargo traffic however is expected to increase at a rate of 8% from about 131 x 109 RTK (Revenue Ton Kms) today, to some 464 x 109 RTK in the year 2020.

The main airliner programs being implemented today are the Airbus A-380 in Europe and the Boeing 7E7 in the USA. Both programs are utilizing new advanced technologies to improve operating costs, safety, environmental friendliness etc.

Fig 2. Airbus A380 (model)

Fig 3. Boeing 7E7 (Impression)

1.2 Military Aviation - Development Trends Overview

The world economy is depressed and perceived threats are changing. The emphasis on new equipment and supply are changing with it, including the need for maintaining an economically efficient military force. The various development programs for military aircraft are becoming longer, and their extent is decreasing, however the development of unmanned aircraft is on the increase.

In the field of combat aircraft, the JSF is intended to be in service for the next 50 years and currently the F-22, F-16 E/F and the F-18 E/F are the major players in the USA, while in Europe the Eurofighter and Rafale occupy this role. Trainers continue to be the Hawk, MB-326, Mako-2000 and the AT-50.

In the field of large military aircraft the trend is to expand the lifetime of existing systems, however the new European A-400M offers a new alternative. Refueling aircraft are generally derivatives of transport aircraft while intelligence aircraft are simply modifications of other existing aircraft.

1.3 UNMANNED AVIATION - DEVELOPMENT TRENDS OVERVIEW

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. UAVs are fundamentally changing the tactical concepts of warfare. The development rate of military UAV systems and their utilization is accelerating and they have proven their efficiency in all recent wars:-

1982 - Lebanon, 1988 – Kosovo, 1991 – Iraq, 2001 – Afghanistan, 2003 – Iraq.

Military missions include:- Intelligence (Radar, IR, EO), SIGINT (Comint, Elint), attack, communications (Relay, Satcom), and whereas about 60,000 flight hours were accumulated in 1990, some 300,000 flight hours were accumulated in 2003.

The USA will invest more than $B15 in military UAVs over the next six years, and the Europeans plan to invest a further $B6 in the next nine years.

Typical UAV configurations are shown in Figs. 4 and 5 : the General Atomics “Predator” and the IAI “Heron” respectively.

Fig 4. Predator

Fig 5. Heron

One of the major leading programs in the USA will be the Joint Unmanned Combat Aircraft System (J-UCAS), having twice the range of the JSF with a similar payload.

Future Civil UAV Applications

The accelerated development of UAVs for military missions which has now reached a high level of maturity, has produced a momentum for the use of UAVs for civilian applications. Currently the main obstacles to operating UAVs for civilian purposes are economic viability and safety of flight. However, experience gained and the maturity of technologies will act as a driving force for producing rules for operation and safety. In addition, technological developments in the field of aerospace will facilitate an improvement in reliability and lead to a lowering of acquisition and operating costs thus making civil UAVs affordable.

The integration of UAVs into civilian airspace is planned for the near future. This will be tailored to the UAV type, size, mission and operational concept.

The potential market for civil applications include disaster and emergency monitoring, border patrol, weather and atmospheric monitoring and scientific environmental missions etc.

IAI is involved with some 38 European organizations and industries in exploring new avenues for civil applications, in a study taking place in Europe within Framework 5, with projects such as CAPECON, USICO and UAVNET. The goal of these projects is to show that there is an economic viability (CAPECON), and a way of determining safety standards and flight rules (USICO). UAVNET is a thematic network which provides a forum for the exchange of ideas and information and is freely accessible to the general public on the internet at www.uavnet.com.

2. Advanced Technologies Overview

The evolution of flight and the future development of aircraft is strongly influenced by 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 technologies evolving from these roadmaps will determine future trends in the aerospace industries.

European plans

- A Vision For 2020 Jan. 2001
- Strategic Research Agenda Nov. 2002
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American plans

- NASA Aeronautics Blueprint Feb. 2002
- Aerospace Commission Final Report Oct. 2002
- US UAV Roadmap Mar. 2003

- JPO – Joint Planning & Development Office Nov. 2003
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2.1 Selected Promising Technologies

A few examples of the leading technology development plans have been selected for mention:

Fuel Cells

Fuel cell propulsion is advancing mainly due to environmental emission requirements in the automobile industry and we are now witness to attempts to employ this technology in aviation. Electrical propulsion based on fuel cells is being explored by Boeing and the University of Florida, and by IAI.

Nanotechnologies

Recent developments in "nano" technologies provide the potential for much stronger composite materials with a phenomenal potential for carbon nanotubes. According to NASA this will result in revolutionary aircraft concepts with 30% less mass, 20% less emission and 25% increased range. Flight control and avionics sensors will also benefit from nano-technology with a much higher degree of electromechanical microminiaturisation.

SATS

The “SATS”(Small Aircraft Transportation System) is another very important program which provides the basis for future autonomous small aircraft capability. It will vitalize the GA industry and airports, enabling 25% of communities to be served in 10 years and more than 90% in 25 years. Public travel times will be reduced by half in 10 years and by two thirds in 25 years.

2.2 IAI View Of Aerospace Technology Evolution

Future aerospace development is based on basic aerospace technologies, which are evolving but also on all the other technologies, which are from different areas like from automobile, entertainment, PC & Internet, Communication and etc..

Aerospace

Manufacturing capability (assembly, composite materials), Design capability, Aerodynamics(CFD), Avionics integration, Navigation, Flight Control, etc.

Automobile

Communication, MEMS (microelectronics), Fuel cell, computers, diesel engine, etc.

Entertainment

Computers (MEMS), Sensors (electronics) etc.

PC & internet

Computers, Communications (Ethernet), Simulation (displays) etc.

Commercial communications

Narrow and wide band capability, Wireless etc.

TECHNOLOGY EXAMPLES IN IAI

In order to facilitate the development of advanced state-of-the-art aircraft which will be competitive, IAI performs extensive aeronautical research and development. Some examples are illustrated below.

Computational Flight Dynamics

In the field of aerodynamics the development of the "NES" CFD (Computational Flight Dynamics) program was recently upgraded by considerably increasing its parallel processing capability. The IAI "NES" CFD Program now employs 144 processors performing parallel processing. Fig. 6 shows a drag polar example computed by the IAI "NES" program in the framework of the 2nd AIAA drag prediction workshop. A close correlation can be seen between wind tunnel tests and the calculated values.

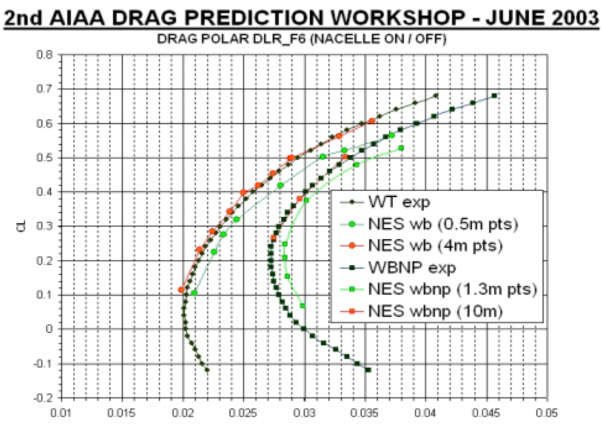

Fig. 6. Drag polar diagram

Composite Materials

Another example of manufacturing technology is in the use of composite materials to considerably reduce weight and production costs. IAI has integrated the RTM (Resin Transfer Molding) and LRI (Liquid Resin Infusion) technologies into several projects. Example of the application of these technologies in a future IAI program is illustrated in Fig. 7.

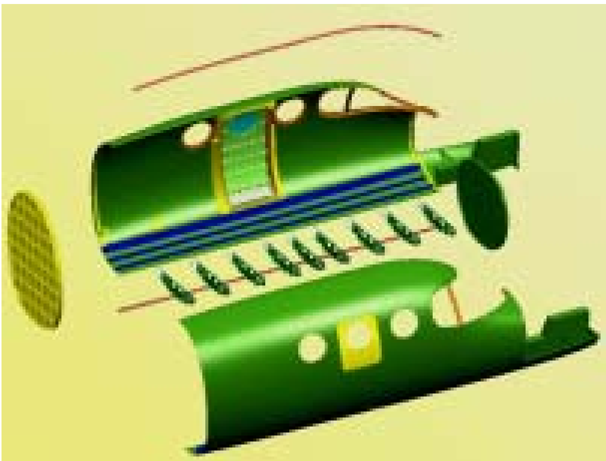

Fig 7. PROJET LRI application

Flight Control

A program sponsored by the European community "ADFCS" (Affordable Digital Fly By Wire Flight Control System) is an investigation to discover an affordable means to bring Fly-By-Wire to small commercial aircraft.

Figure 8 shows an ADFCS simulator facility. It is anticipated that this can be achieved by the introduction of new design methodologies, more automated design, rapid prototyping (fast lab to simulator), reduced hardware replication, new technology of fault detection, virtual sensors and the use of shared sensors. Simple hardware which involves recurring engineering costs could be replaced by complex software with no recurring engineering costs, which would be modularly reusable.

Fig 8. ADFCS simulator facility

Affordability

The new technologies evolving today in production, materials, electronics and propulsion are the foundation stones of the future development of aviation. The leading goal – Affordability, is being achieved in two directions:

Acquisition cost reduction – reductions at manufacturing, avionics, propulsion and subsystems costs.

Operation cost reduction – by using fuel-efficient engines, new concepts of operation/exploitation, advanced efficient training, commercial practices and advanced maintenance concepts (health monitoring, LRU concept not only for avionics, and higher reliability).

Flight Safety

I.A.I is developing collision avoidance system. The system provides an onboard sense & avoid capability. It is based upon an appropriate combination of "cooperative" and "non cooperative" technologies. The "Cooperate" concept is based on mutual detecting by both aircrafts on collision course – it requires sense & avoid sensors on both aircrafts and on ATC ground systems. The communication networks use TDMA flexible smart data link system. This system runs on next generation data link communication with an auto relay capability. It provides efficient fleet integration with situation awareness display and it is independent from ground station or master stations. The "non cooperative" concept is a self capability of collision avoidance based on electro-optic passive technology (Integrates Day-Light TV, IR camera).

3. IAI Vision For Future Aircraft Development

The section which follows gives a brief insight into what is envisioned for the future development of new aircraft in IAI. The new aircraft programs are based on a combination of two major factors:- (a) the market demands and (b) the availability of new technologies. At the commencement of 2004, IAI is involved with the following 4 types of aircraft :

Commercial aircraft, military aircraft, uninhabited aircraft and a new class defined as "autonomous" aircraft.

3.1 Commercial Aircraft

G-150

One of the projects which IAI is currently developing, is a new version of the G-100 business jet, known as the G-150. The G-150 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 balancing and blending. The rear section of the G100 including the engines and the tail section, has been retained unchanged but has been raised in order to improve the geometrical transition. The cockpit has been modernized and brought into line with the G-200. Extensive use of CFD in this program provided solutions for keeping the existing drag level of original configuration despite the enlarged fuselage volume. An impression of the G-150 is shown below in Fig. 9.

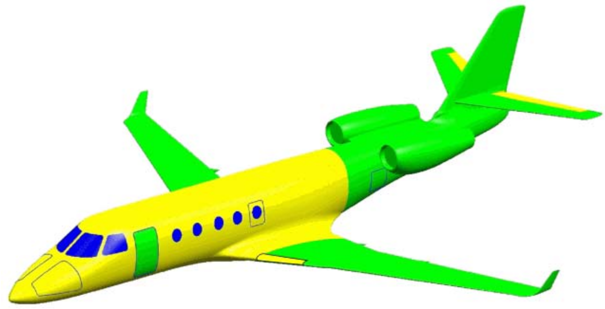

Fig 9. G-150

IAI / Avocet PROJET

Combining new technologies enables the development of new trends in civil aviation, with emphasis on affordability. Aircraft prices are expected to decrease to half of their predecessors, and operational costs to a third of the price today. An example of this trend is a new generation of small business jets, and the IAI / AVOCET "PROJET" aircraft which is currently in the definition phase. The project employs new communications and navigation systems which will reduce air traffic overcrowding and considerably reduce door to door travel time by utilizing airfields that are little used today. An impression of the "PROJET", is shown below in Fig. 10. 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 ground transportation.

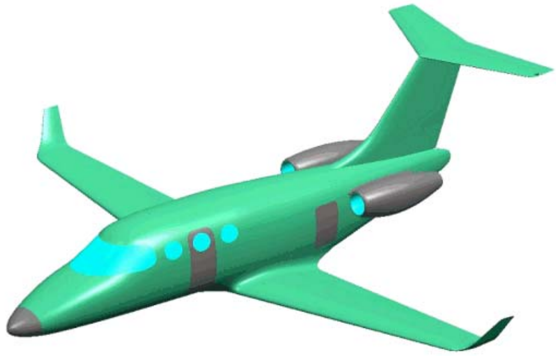

Fig. 10. IAI / AVOCET- “PROJET”

The PROJET which is expected to have a price tag of around $M2, will be powered by 2 engines each having a thrust of 1,350 lb (either Williams FJ33 or P&W 615 series). With a maximum take off weight of 7,160 lb and a maximum payload of 1,400 lb, it will have a maximum speed of 365 kts and a range of 1,300 nm with 3 passengers.

3.2 Potential New Aircraft Directions

Beside the “Projet” aircraft, other innovative directions are considered, so as to benefit from the opportunities that the new technologies pose. These directions include a personal aircraft, a next generation air-taxi/on demand aircraft, a commuter aircraft, and an autonomous cargo aircraft. All these configurations will integrate some of the technology breakthrough building blocks, to introduce next generation air-transportation solutions.

The potential directions will be based on the technologies presented in figure 11:

Composite Materials	• *Affordability* • *Performance (weight)*
Advanced Fly By Wire Flight Control	• *Affordability* • *Automation* • *Safety* • *Airspace integration*
STOL Advanced Aerodynamics	•*Short Take-off fields*
Fuel Cell Propulsion System	• *Environmental friendly* • *Alternative fuel*
Autonomous Aircraft	• *Safety* • *Operating cost* • *Airspace integration*
Safety Enhancement	• *Pilot competence* • *Airspace integration* • *Communication*

FIG 11. Advanced technologies for future small transportation system

Personal Aircraft

The personal aircraft would be a small aircraft for 2-4 passengers that would achieve range greater than 300nm at 150Ktas. It would be capable of short TakeOff and Landing (STOL, <1000ft). The airplane will incorporate advanced propulsion system (diesel / fuel cells / turboprop / turbofan) and will be constructed out of composite materials. New aerodynamic and high lift technologies would be employed in order to attain the STOL objectives. A sketch of the future personal aircraft is shown in Fig. 12

Fig. 12 – Future Personal Aircraft

Next generation Air-taxi aircraft

The next generation Air-Taxi aircraft would be a small aircraft for 6-8 passengers that would achieve range greater than 1200nm at 300Ktas. It would be operated by a single pilot, and be capable of short TakeOff and Landing (STOL, <1000ft). The airplane will incorporate advanced turbofan propulsion system, will be constructed out of composite materials and will employ new aerodynamic technologies to attain the STOL objectives. A sketch of the aircraft is shown in Fig. 13

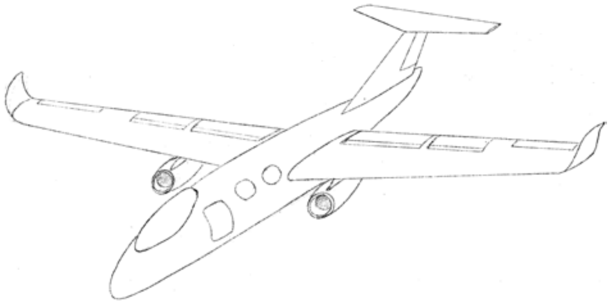

Fig. 13 – Future Air-Taxi Aircraft

Commuter Aircraft

The future commuter would be a single pilot operated aircraft and could carry 19 passengers. It would be designed to achieve range greater than 1200nm at 300Ktas, and would be able to operate from short airfields (runway<2000ft). The plane would have a low price tag due to integration of advanced technologies like composite materials, and it would also be cheap to operate comprising single pilot, efficient turbofan engine and high dispatch reliability. A sketch of the aircraft is shown in Fig. 14

Fig. 14 – Future commuter aircraft

Autonomous Cargo Aircraft

Using advanced technologies of avionics and flight control, a new generation of aircraft will emerge: "Autonomous aircraft" – inhabited aircraft which will fly autonomously. These autonomous aircraft with proven safety and high mission reliability will have lower operating costs and improved safety due to the virtual absence of human errors. IAI envisages that these will first appear as cargo aircraft as illustrated in Fig. 15

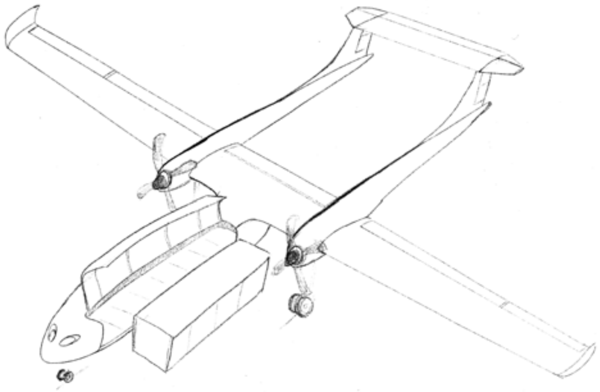

Fig. 15. ACV-B

3.3 Uninhabited Aircraft

A few typical examples are described which include a next generation tactical UAV, mini and micro UAVs and high altitude and long endurance UAVs.

Next Generation Tactical UAV

UAVs are fundamentally changing the tactical concepts of warfare and plans are being laid for the next generation advanced tactical UAV to replace the existing Hunter, Searcher, Ranger UAVs, etc. The future tactical UAV illustrated in Fig. 16 will have a multiple payload carriage with a payload and endurance of two to three times that of existing UAVs at twice the altitude and a 50% maximum speed increase capability. Reliability and safety will be improved, as well as availability and maintainability. Acquisition costs will be reduced by a third to a half and total operating costs by an eighth to a quarter.

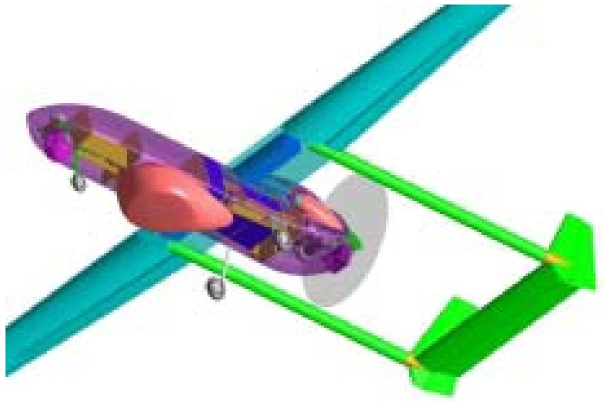

Fig 16. Next generation tactical UAV

Mini / Micro UAVs

Technological developments in the fields of computers, sensors, navigation, communications, photography, MEMS etc. has facilitated the production of mini UAVs (less than 15 kg.) and micro UAVs (less than 0.5 kg.).

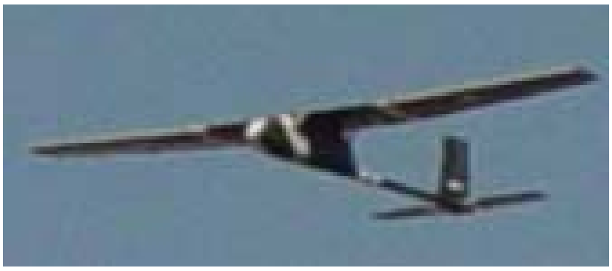

Fig 17. Mini UAV

The Mini UAV weighs 5kg and has a wingspan of 1.8m (shown in Fig.17).

Mosquito 1.0

The Mosquito shown in Figure 18 is a micro UAV with a span of 300 millimeters and weighing only 250 grams. It was flown in January 2003 and achieved an endurance of about 35 minutes using zinc/air batteries and provided on-line video information.

Fig. 18 – Mosquito 1.0

Mosquito 1.5

Mosquito 1.5 is another AV from the micro-UAV class. It weights 500gr and is completely autonomous with waypoint control. Principle characteristics are semi gimbaled high quality daylight video camera, and high-level survivability. Major performance objectives are: Range-1mile, Endurance-1hour. The first flights took place in March and April 2004. Figure 19 shows an installation sketch of Mosquito 1.5

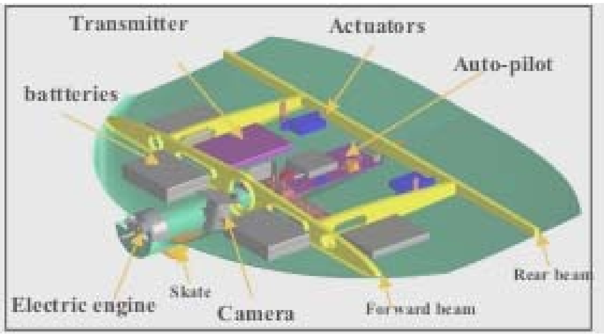

Fig. 19 – Mosquito1.5

Both UAVs employ electrical propulsion.

High altitude and long endurance (HALE) UAV

The HA-50 HALE UAV is designed for modularity, and provides a large capacity for payload installation. With a take-off weight of about 6,000 kg and an endurance of 36 hours at 60 kft, it can carry a payload of 500 – 1,000 kg.

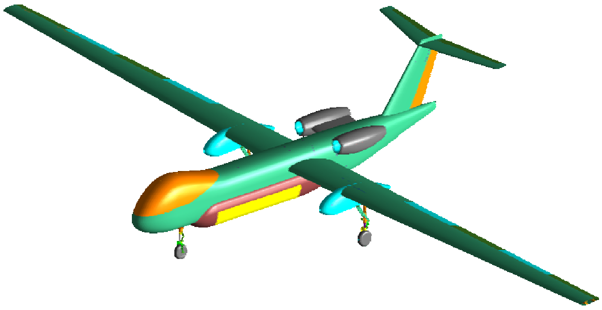

Fig. 20. HA-50 HALE UAV

Fuel cell propelled UAV

Rapidly emerging fuel cell propulsion technologies (derived from the automobile industry) may be used to launch a new revolution of electric propulsion systems for aircraft. An all electric tactical UAV powered by fuel cells illustrated in Fig. 21, will demonstrate the benefits of the fuel cell technology. Its first flight is planned for 2006. The expected benefits of this technology are low noise, no pollution, high reliability, low maintenance, easy start up of engine and moderate performance decrease with increase in altitude.

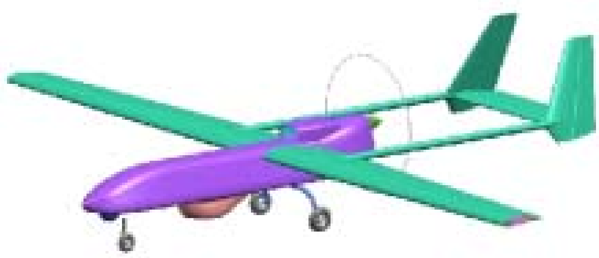

Fig. 21. Tactical UAV powered by fuel cell

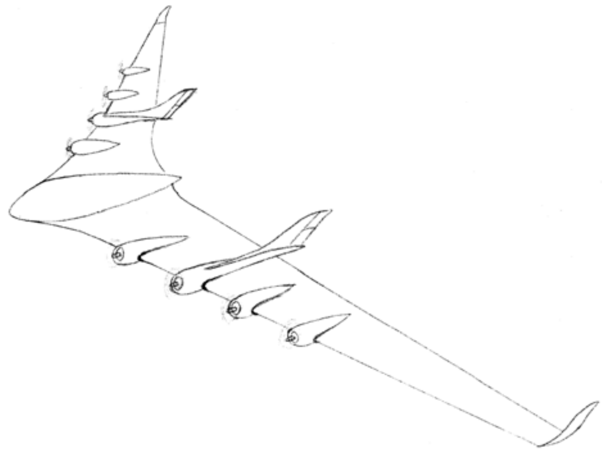

Fig 22. HALE UAV HA-310

The HA-310 high altitude and long endurance UAV is illustrated in Fig. 22. It has a take off weight of 1000 kg and a payload capability of 200 kg. The goal for its endurance is 7 days, at altitude of 50 Kft.

Summary

The needs of tomorrows' passengers and cargo aviation demand innovative solutions and new operational concepts based on emerging technologies, combined with more efficient, safer, more reliable and environmentally friendly aircraft. We anticipate the future expansion of small aircraft, which will decrease air traffic and ground traffic densities and reduce the door-to-door travel time.

Military aviation as we know it today will decrease due to the evolution of uninhabited aircraft which will gradually takeover more of the activities of manned military aircraft. Uninhabited aviation is expanding at an accelerated rate in the military field, and in the near future is expected to be also utilized for civil applications.

The new technologies evolving today in production, materials, electronics and propulsion are the foundation stones of the future development of aviation. These emerging technologies will facilitate the transition to autonomous aircraft whose operation will commence with cargo and small aircraft in the foreseeable future.