Innovative Approach For Future Aircraft Development At IAI

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Abstract

A description of the innovative approach of airplane development at Israel Aerospace Industries (IAI) Engineering & Development Group is presented. The approach is a structured process including several steps and is the key to new product introduction. The first step is the generation of ideas, followed by a feasibility study and a product definition. These steps are preliminary for either a demonstration program or a full-scale development program. The paper defines the innovation and describes the main elements, including the market demand evaluation, technologies evolution and product characteristics definition. Typical examples of results of the innovation process at IAI are the Heron I Unmanned Air Vehicle (UAV) and the Mosquito micro UAV. Planned programs are the next generation of a very light jet (VLJ), more autonomous aircraft, autonomous personal air vehicle (APAV) and in parallel the evaluation of electrical propulsion, solar UAV and other directions.

1 Introduction

This paper discusses the innovative approach applied by IAI when developing new products. Two key elements of the approach are the market-study and the introduction of new technologies. The paper describes how new advanced technologies are being integrated with market requirements, for existing markets and for the creation of potential new markets.
New advanced technologies are the second essential element of innovation and are the main driver for the creation of new products.

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This paper provides an overview of the relevant advanced technologies, some of which are currently available, while others are emerging and require additional development effort in order to achieve maturity to the required technology readiness level.
This paper describes the innovation approach used in IAI Engineering Devision, introduces examples of typical market trends, presents advanced technologies directions, describes examples of prefered directions as the result of the innovation approach, and concludes with few examples for future trends.

2 Innovation Approach

The development of a new product is a continuous process stretching over years. Prior to program launch, three activities as shown in Fig. 1 have to be continuously performed.
Customer and market needs have to be studied and technologies have to be explored.
A feasibility study has to be conducted based on the former.
Then infrastructure and technology have to be updated; and a new program can be launched.

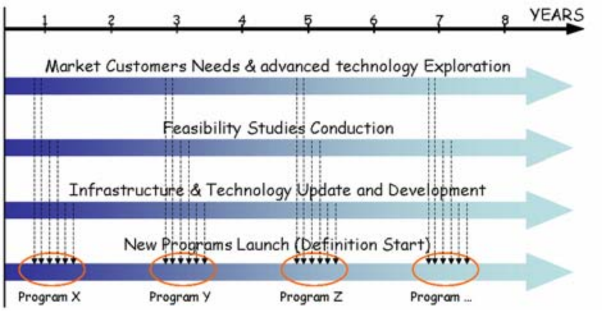

Fig. 1 New product development

To be successful, the development of the new product should underlay an innovative approach. Two definitions of innovation, as presented in two different conferences are given in Fig. 2. The U.S. National Science Foundation definition emphasizes knowledge, whereas Euro-Space emphasizes economics.

Fig. 2 Definition of innovation

The "Innovation" definition used by IAI is: The process which is used to develop a new product that can be sold to the market
Innovation spans from:
"Incremental Innovation" in order to sustain in established market to "Disruptive Innovation" in order to create a new market.
Fig. 3 presents an innovation pipeline which coincides with IAI experience in the development of new products.

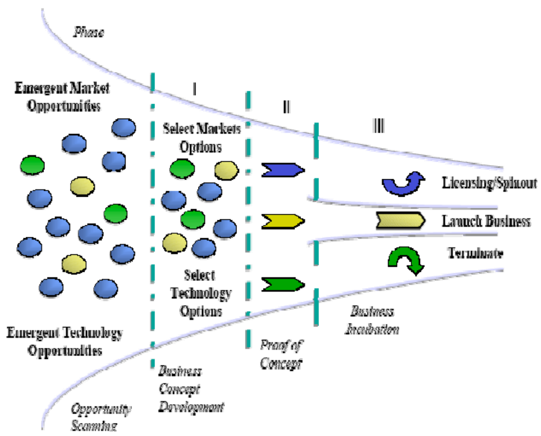

Fig. 3 Innovation pipeline

The process is based on the combination of emergent market opportunities with emergent technology opportunities.
C.M Christensen and M.E Raynor examine in their book [1] the nine business decisions integral to growth, including product development, organizational structure and financing. They address the important question of how to generate growth and sustain it over long periods.
The disruptive innovation model they address is shown in Fig. 4. The dotted lines represent the rate of improvement that customers can utilize or absorb. These lines are sloping gently upwards. The solid lines are steeper and represent growth of performance against time of innovative products. The pace of technological progress almost always outstrips the ability of customers to use it. The third dimension that extends toward us in the diagram represents new contexts of consumption and competition.

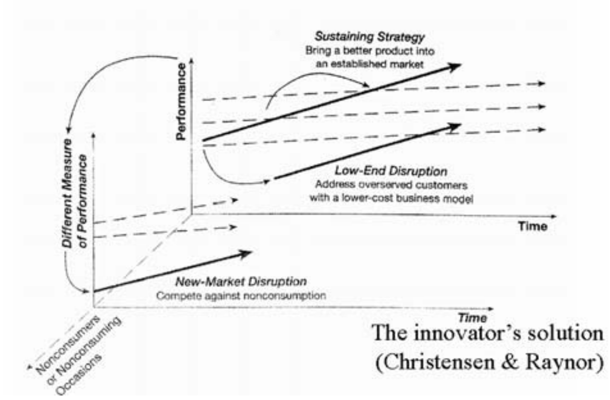

Fig. 4 Disruptive innovation model

G.H Gaynor [2] explains the different types of innovation resources and the different approaches to innovation. He provides a detailed plan on how to create an innovative company.
According to the author the innovation process is based on:

- Resources (team)
- Processes (infrastructure)
- Values (culture)

The innovation classification includes: incremental innovation, new to the market innovation and break through innovation.

The IAI innovation process is presented in Fig. 5. The key elements underlying the process are:

- Generation of ideas
- Feasibility studies
- Definition process as a result of a recommended new direction

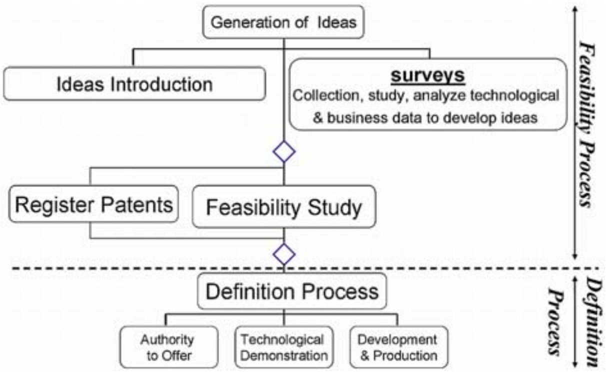

Fig. 5 IAI Innovation process

The first step of innovation is the generation of ideas and is based on two parallel processes, a systematic survey of technologies, markets and competitions; and brain-storming meetings to present and generate new ideas.

The feasibility study (Fig. 6) addresses:

- Demands
- Performances
- Technologies
- Preferred directions

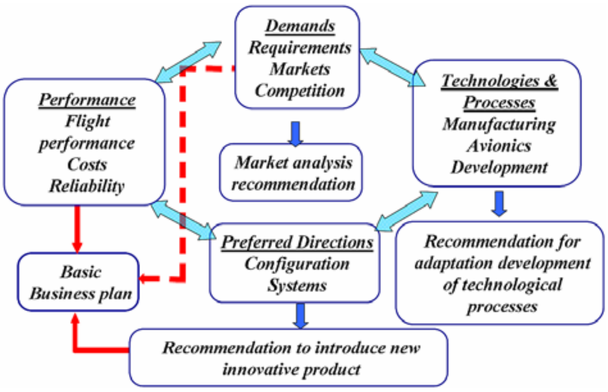

Fig. 6 Feasibility study

In the feasibility study, in an iterative process the preferred direction for a new product is introduced as a result of the evaluation of market demand, advanced technologies and the target performance of the new product.
Additional products of the feasibility study are:

- Market analysis recommendation
- A basic business plan
- Recommendation for adaptation and development of technological processes.

The definition phase of the recommended product is a result of the feasibility study and an important stage for validating the technical characteristics of the product, verifying the market including launch customers interest and proof of the business case.
The definition phase (Fig. 7) comprises of several iterations, at the end of which an aircraft definition documents are established.

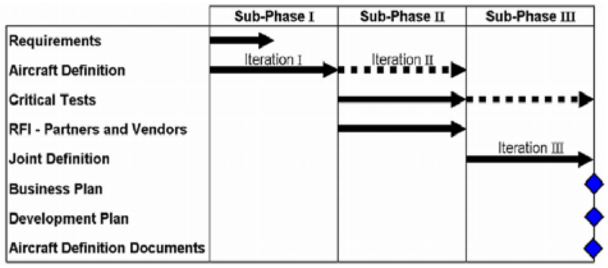

Fig. 7 The definition phase

Following a successful definition phase, the program development is launched.

The phases and a typical timetable of an aircraft development process are presented in Fig. 8. Both the feasibility study and definition phase would last about two years, before launch of a program can be announced.

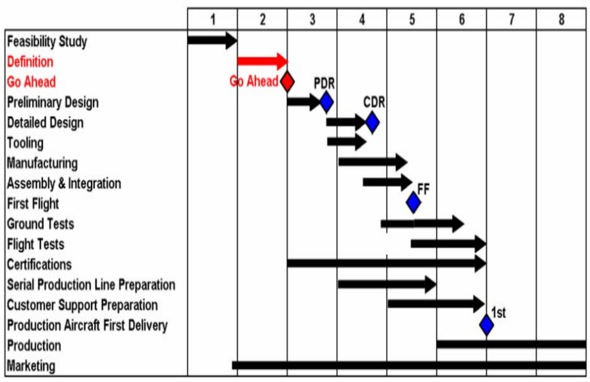

Fig. 8 Typical aircraft development timetable

3 Market Trends

The first main element for an innovative new product is understanding of the market. Example of typical market data which is used when looking for new direction is presented here. Despite high oil prices, aviation is currently strong. In the past three years, the recovery of air travel is the strongest in history. Fig. 9, 10, presented by Roger H. Bezdek [3], show past and forecast world air travel numbers and U.S. airlines fuel costs.

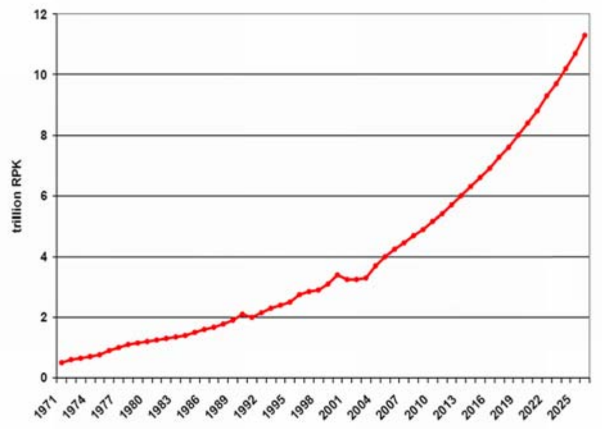

Fig. 9 World air travel: historical and forecast (Revenues in trillion revenue passenger km)

Fig. 10 Aviation fuel cost

It can be stated that commercial aviation will keep growing as long as economic growth will continue, especially in developing countries (Fig.11 [3]). That is why it is important to find the golden path between the rising prices of oil and the growing demand for aerial transportation.

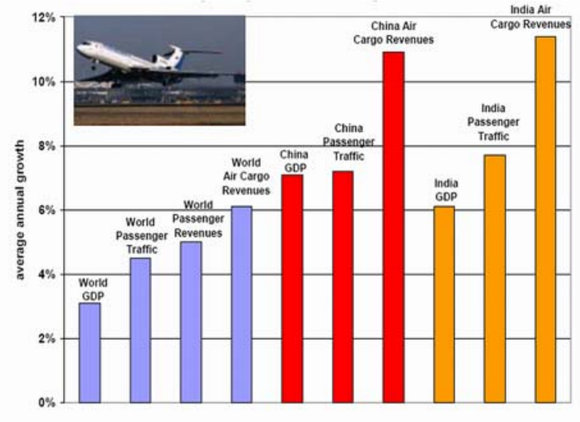

Fig. 11 Aviation and gross domestic product annual growth forecast

Example of forecast of the commercial aviation market for the years up to 2026 as estimated by Rolls Royce in March 2008 is given in Fig.12.

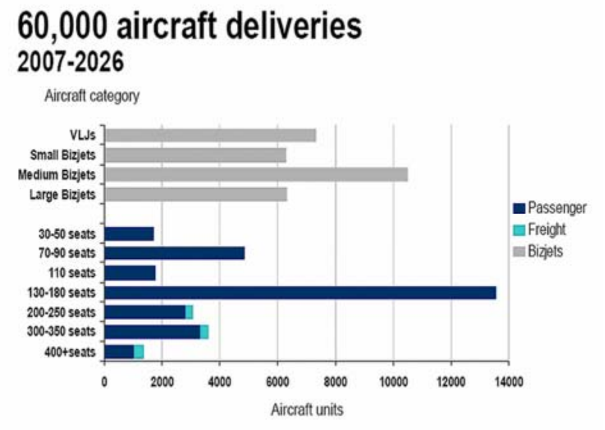

Fig. 12 World aircraft deliveries forecast as estimated by Rolls Royce

Updated predictions of jet fuel costs in 2008 show high steep soaring from January of 60-70 $ per barrel to June 135-160 $ per barrel. The impact of this trend on air transportation growth will be very significant.

4 Advanced Technologies Directions

The second main element of innovation is new advanced technologies.

IAI's view is to search and evaluate in addition to the search of aerospace technologies, every potential new technology created in different disciplines:

- Manufacturing & design
- Automotive, fuel cells
- PC, internet, communications, microelectronics
- Micro and nano technology etc.

Aerospace main technologies that are drivers for future products include:

- Design for affordability
- Composite materials design and manufacturing
- Advanced avionics
- Miniaturization
- More electric systems
- Fly by wire control systems (FBW)
- Computerization
- Propulsion
- Communication etc.

Design for affordability

Main driver in development of most innovative products is design for affordability, including acquisition costs and operating costs. Processes using advanced technologies and concepts of operation are presented in Fig13.

Fig. 13 Acquisition and operating cost reduction

Composite materials and manufacturing capability:

In recent years, technology maturity drives an increased use of composite materials in aircraft versus reduction in the use of aluminum. Fig. 14 shows the percentage use of composites in transport airplanes beginning with the B737, first certified in 1967 up to airplanes not certified yet.

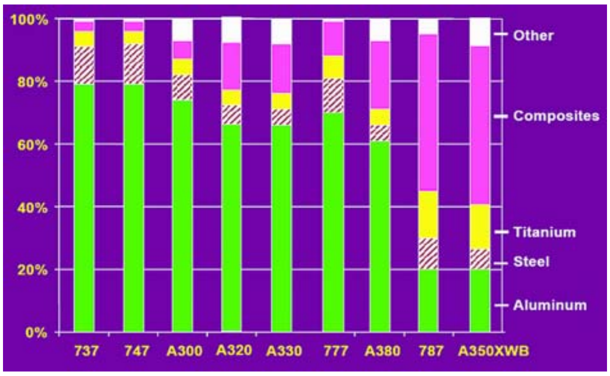

Fig. 14 The material composition of aircraft

Fig. 15 shows the percentage use of composites (IAI estimation) versus aircraft max. takeoff weight. Small airplanes are already constructed to 100 % of composites, whereas big transport aircraft reach the level of 50% of composites.

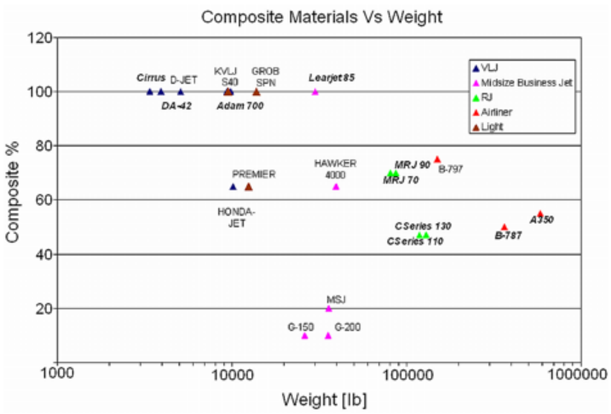

Fig. 15 Composite material usage versus aircraft weight

The advantage of composite materials is lower weight compared to aluminum, a smoother aircraft skin and lower manufacturing cost. Although airplane structures become lighter, airframes still retain appropriate durability and damage tolerance properties.

In parallel, a major development in manufacturing technology are processes which once were based on manual labor and now becoming fully automated: "Network Enabled

Manufacturing", smart tools, indoor GPS, laser projection etc.
Fig. 16 gives an image of a modern automatic fiber placement machine. Combined with new methodologies it also provides the possibility to help to reduce the number of parts needed for constructing the airframe of an aircraft.

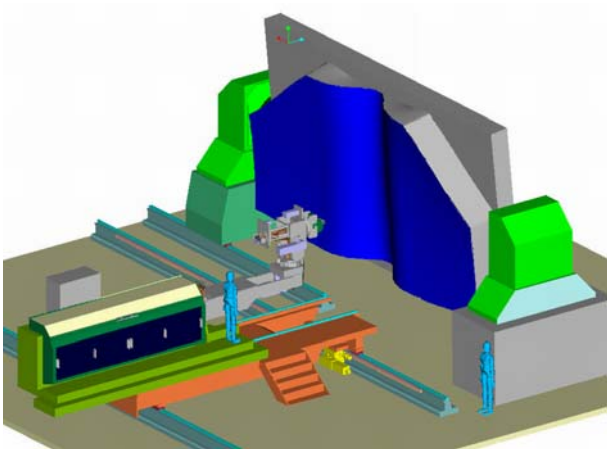

Fig. 16 Automatic fiber placement machine

Fig. 17 shows an example of a next generation very light jet (VLJ) designed and manufactured from composite materials, using automatic fiber placement machines, with the design goal to design and manufacture the aircraft from 200 structural parts.

Fig. 17 VLJ reduced number of parts

Advanced avionics:

The accelerated development in electronics provides the basis for new generations of avionic systems for the new generation of flight vehicles. Example of this trend can be seen in advanced integrated avionics suite which is leaping advanced flight management including "Free Flight" implementation.

Fig. 18 describes the relationship between the different contributing disciplines which include: precision navigation, precision surveillance, digital information services, digital surface data bases, high bandwidth digital communication and a glass cockpit

Fig. 18 Advanced integrated avionics suite

Miniaturization

Miniaturization is an important advanced technology, by using advanced micro design technologies in the field of materials, optics, electronics, and entering nano-technology, new potential capabilities are created. Fig. 19 shows as an example the development of the inertial navigation system over the 50 years between 1953 and 2003 [4]. The weight of the gyro was reduced by 10^6 in 50 years.

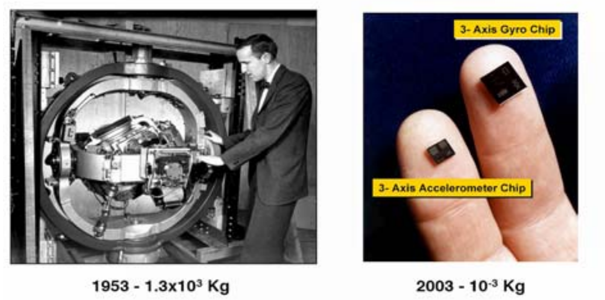

Fig. 19 Fifty years of miniaturization

An example of today's development of micro unmanned air vehicles (UAV) is the IAI Mosquito (Fig. 20) – very small, 500 gr, electric propelled micro UAV with close range visual intelligence, real time video transmission and completely autonomous.

Fig. 20 IAI Mosquito

Computerization

The computer capability which evolved in the last years has tremendous impact on development of new products. Computer as the brain of the product and computer as the development tool of the product.
H. Moravec describes in his paper [5] the evolution of computer power. Fig. 21 show the cost of computer power in millions instructions per second (MIPS) per $1000 and the equivalent brain power.

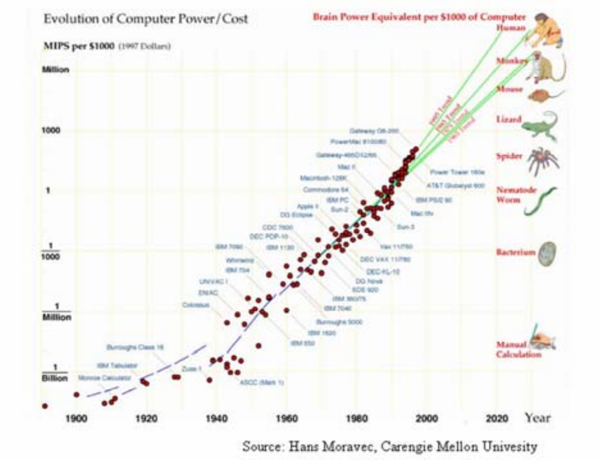

Fig. 21 Evolution of computer power/cost (Moore's law)

Dennis Bushnell describes in his paper [6] that computing on silicon has improved by some factor of ten-to-the-nine since 1959. As we leave silicon and go to Bio, optical, Quantum, Nano and molecular computing there are projections of some ten-to-the-eight to ten-to-the-twelve to go in the next 30 years. Only ten-to-the-second of this additional power will already provide "human speed", the additional power will be "beyond human".

More electric

One additional area of innovation is the tendency towards "more electric" aircraft - increased use of electrical systems in lieu of mechanical systems. Jet engines are developed, where the starter generator is part of the engine, thus eliminating the gear box. Ice protection using electrical power in lieu of engine bleed air is presented as an example from Airbus (Fig. 22). Electrical landing gear accessories, electro-mechanical retraction and deployment, electrical brakes, electrical nose wheel steering and brake by Wire system are used.

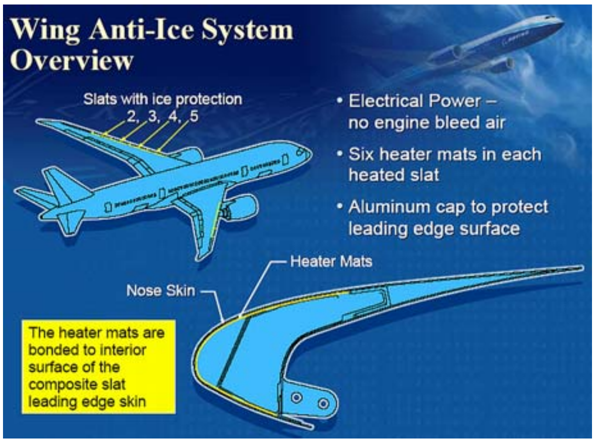

Fig. 22 Airbus ice protection system

FBW

Fly By Wire (FBW) flight control provides improved and safer control of air vehicles' (military, unmanned, commercial). Fly by wire was introduced in the eighties serving in military and big transport airplanes. Today the goal is to make it affordable for small commercial aircrafts.
Fig. 23 shows MTOW against planned certification dates of business jets equipped with FBW technology

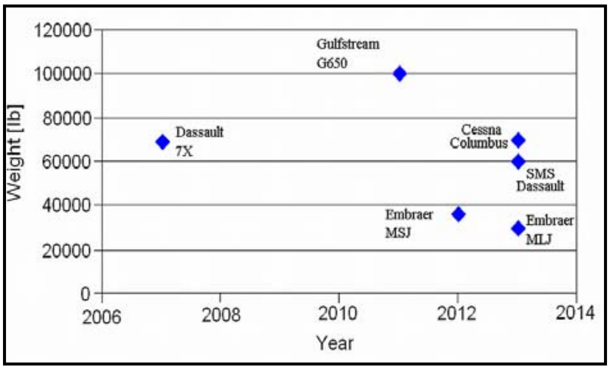

Fig. 23 MTOW (Lb) and planned certification dates of FBW equipped business jets

Affordable fly by wire can be achieved by using

- New design methodologies: more automated design technologies, rapid prototyping – fast lab to simulator.
- Reduced hardware replication: new technology Failure Detection and Identification (FDI), virtual sensors.
- Shared use of sensors/reusable software.
- New generation computers.

5 Preferred Directions

As the result of the innovation approach, combining new advanced technologies with new or existing markets, preferred directions of innovative products are developed.
Examples of new products that were introduced are presented here:
The **"HERON 1" UAV** shown in Fig. 24 was at launch time an innovative product, with: An advanced aerodynamic wing profile with a high lift coefficient, containing a large internal volume of fuel, low cost production composite materials and a new generation "Rotax" 4 stroke piston engine with low noise (First flight October 1994). The **HERON 1** sets an example for disruptive innovation which created a new market.

Fig. 24 HERON 1

The new generation **UAV "HERON TP"** (Fig. 25) using advanced technologies, has high mission endurance, operates above commercial traffic, has all-weather capability, satellite communication and an automatic takeoff and landing system. It uses a reliable high power turbo-prop engine (first flight, July 2006). It is another example for disruptive innovation which creates a new market.

Fig. 25 HERON TP

Example of incremental innovation in order to sustain the market can be found in **G-150** business jet which IAI developed by improving the existing **G-100** business aircraft.
The main improvements are in internal volume, enlarged cross section for improved comfort (Fig. 26) and flight performance using advanced propulsion and advanced aerodynamic design.

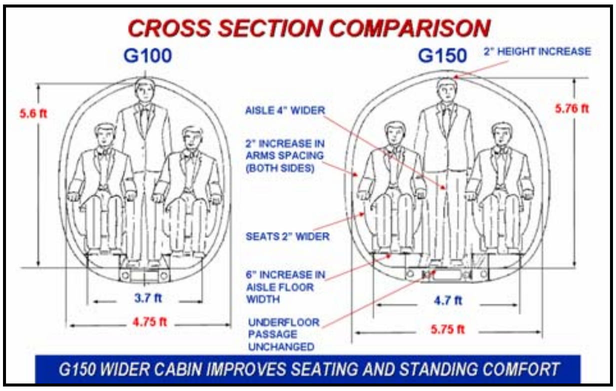

Fig. 26 Cross section comparison between G150 and G100

Example for future preferred direction is the new generation of VLJ airplanes (Fig. 27), based on advanced technologies of propulsion, structure and avionics. Its goal is to provide a solution for the growth of air transportation, using small airfields. It is an example for low end disruptive innovation entering into existing market.

Fig. 27 very light jet (VLJ)

6 Future Trends

Future trends in development of aerospace products include:

- Environmental adaptability requirements.
- More autonomous aircrafts.
- Alternative propulsion: electric, fuel cells, solar cells, etc.

Based on new technologies and the demand for low cost and high performance, examples of future trends are described in the following:

Environmental adaptability (Clean sky programs)

In order to reduce environmental hazards such as noise, CO_2 emissions etc, new technologies for green operation are developed.
In Europe a 1.7B Euro "Clean sky" program was launched 2007, with the goal to reduce:

CO_2 emissions by 20-40%
NO_x emissions by 60%
Perceived noise by 50%

By 2020. The program includes different platforms:

- Green regional aircraft
- Smart fixed wing aircraft
- Green rotorcraft
- Sustainable green engines
- Systems for green operation
- ECO design

A similar program, "Cleen aircraft", was introduced recently in U.S.

More autonomous aircraft

Two examples for autonomous aircrafts can be seen in Fig. 28 and 29.
The Commercial Autonomous Personal Air Vehicle (APAV) will be a two passenger seats aircraft designed with autonomous take off & landing capability (STOL), Autonomous navigation with real time information about Terrain, Weather, airspace integration and air traffic control.

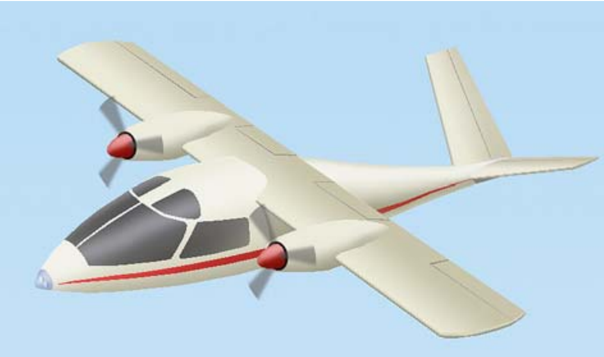

Fig. 28 Autonomous Personal Air Vehicle (APAV)

The Commercial Autonomous Air Cargo Vehicle (CAACV) designed to carry up to 20,000 lbs cargo weight, using autonomous systems which will ensure avoidance of human errors and improved operating costs. Regulatory and psychological barriers has to overcome. The goal of the European strategic agenda is to reach this capability by 2020-2025.

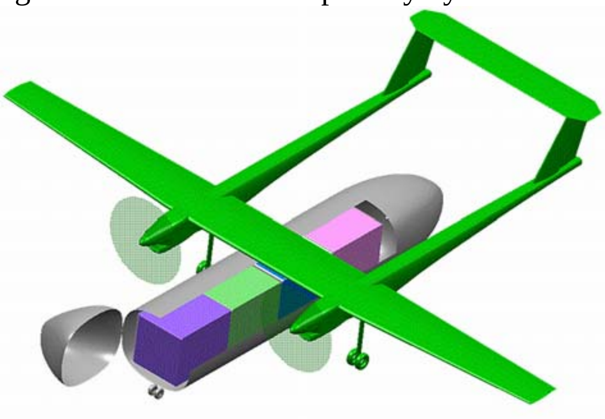

Fig. 29 Commercial Autonomous Air Cargo Vehicle (CAACV)

Alternative propulsion

The area of Alternative propulsion is being studied to demonstrate the possibility of obtaining a more/all electric aircraft through the integration of fuel/solar-cells technology as main power supply system. Recently due to the sharp rise in jet fuel cost, alternative fuel sources for jet propulsion are explored including bio-fuel, ethanol etc.
An example is the HA-315 aircraft (Fig. 29). 40 m wing span, solar & fuel cells High Altitude Long Endurance (HALE) UAV, with 7 days endurance, a payload of 200 Kg and a ceiling of 50,000 feet which will operate with 700 watt systems power.

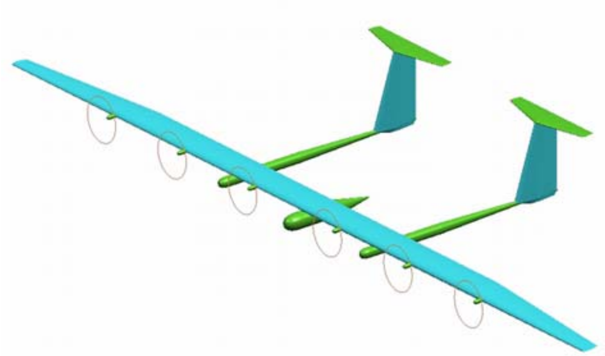

Fig. 30 HA-315

Another example is the fuel cells propelled aircraft (FCA) which will have 4 seats and a range of 700 km flight (Fig. 30) for intercity STOL transportation.

Fig. 31 Fuel Cells Aircraft (FCA)

7 Conclusions

The innovative approach is a continuous process of market and technology exploration, feasibility studies and definition phases.

The innovation is a process which prepares new products that can be sold to the market.
The next generation of aircraft will be the result of evolving new technologies adapted to existing market and creating new markets.

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