EUROPEAN ACTIVITIES FOR FUTURE CIVIL UAV APPLICATIONS

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Abstract

This paper summarizes the activities of three European clustered projects, namely: UAVNET, CAPECON and USICO, which investigate and promote the utilization of Unmanned Air Vehicles (UAVs) for civil and commercial applications. These projects commenced in Oct. 2001 and terminated in 2005.

The paper describes the achievements of these projects, particularly in developing a public and professional awareness of the potential civil applications for UAVs. Considerable experience has been gained over the many years of UAV evolution, primarily for military applications, and the level of maturity and reliability now achieved offers a great potential for civil applications in the spheres of disaster management, forest fire detection, search & rescue, law enforcement, border surveillance, road traffic monitoring, environment monitoring, weather forecasting, mapping, agriculture and fisheries, oceanographic data collection, pipeline and power line monitoring, communications relays, etc. etc.

The paper describes how the 'UAVNET' network has succeeded in coordinating a number of European industries and research organizations, providing a forum for the promotion of the civil UAV concept.

Also described is the USICO project, which has contributed to improving the operational capability and safety of UAVs by recommending airworthiness certification procedures and standards for UAV operation. The importance of regulations is considered and the need for full integration of UAVs into civilian airspace is emphasized.

The paper also summarizes the CAPECON project. This project has made recommendations for a number of civil UAV configurations and has also studied the economic viability of UAVs with respect to alternative manned aircraft and their technological readiness. CAPECON addresses the two most important challenges facing civil operation of UAVs - Safety and Cost, and has prepared a basic cost model for civil operation.

UAVNET and CAPECON have published a roadmap that predicts the timescale for the availability of critical technologies and new concepts of operation, which form the basis for future development. The roadmap forecasts how civil UAV activity will develop in Europe based on technological advances in communications, navigation, collision avoidance and flight control systems, as well as aspects of reliability and safety.

The market potential of civil UAVs is addressed and some potential applications described. Design goals such as affordability, safety, mission reliability and all weather operation are mentioned. The paper presents examples of new aircraft currently in design such as the HA-50 HALE UAV, K-800 MALE UAV, K-80 surveillance UAV and the K-35 mini UAV.

1 Introduction

The schedule illustrated in fig. 1 gives a general impression of the civil UAV activities performed within the European Framework 5, and the anticipated developments during the next ten years.

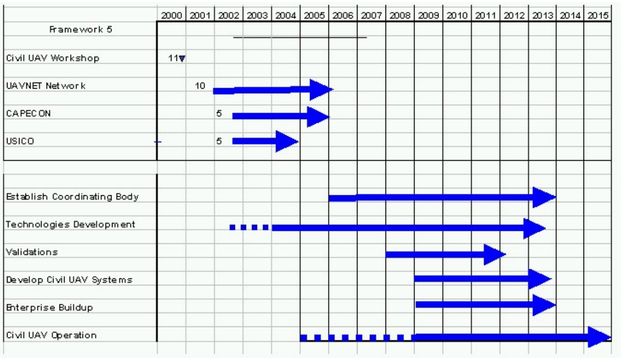

Fig. 1 Civil UAV Activity Roadmap

1.1 UAVNET

UAV-NET is a Thematic Network established under the European Framework 5 and coordinated by IAI Israel. Fourteen workshops with over 250 lectures have been convened for the exchange and dissemination of knowledge related to applications, technologies, configurations, cost reduction, operations, certification and ATC integration. Additionally nine Regional Workshops have been convened. UAVNET has succeeded in coordinating a "cluster" of projects funded at the European Community level, initiating new Civil UAV projects, and successfully networking a number of European industries and research organizations. It has also established an Internet website (WWW.UAVNET.COM), in which a wealth of material is made available to the general public.


Fig. 2 Flight over Kiruna Oct. 2002

Within the framework of UAVNET some demonstrations of civil UAV applications were performed in Kiruna Sweden and in Amsterdam Holland. Swedish air traffic control participated in a demonstration of a civil UAV (EADS/IAI Eagle) flying from Kiruna in Northern Sweden on a scientific mission, with a long flight over inhabited areas, - see fig. 2.

In Holland, a civil UAV was flown, monitoring rail tracks near the Amsterdam central train station, demonstrating automobile tracking, crowd control and observing waterways activities. By flying over the Amsterdam metropolitan area, the aircraft flew within airspace controlled by Schipol Airport ATC, - see fig. 3.


Fig. 3 UAV flown over Amsterdam June 2004

UAVNET is part of a broader integrated activity of two other projects within the European R&D framework, CAPECON and USICO. This integrated framework assists in creating an infrastructure and capability in the overall field of UAVs, and in particular in the area of UAVs for civil applications in Europe. This activity has created an awareness of the great mission potential and market for civilian applications, which was previously non-existent in Europe, and has created a momentum to promote further activity also in other parts of the world. The UAVNET network has also stimulated great interest and cooperation between research institutes, universities and industries in many countries. At the outset, the prime objective was to create a momentum within industry and potential customers, to develop enterprises in the areas of civil UAV applications, however this will require much more time than originally anticipated. The main obstacles to this objective are affordability and regulation.

1.2 USICO

The USICO Project was also established under the European Framework 5 and was coordinated by Airobotics GmbH of Germany. USICO focuses on the issues of Airworthiness Certification and inherent safety and reliability of UAV design in order to achieve Operational Certification and ensure that a UAV can be operated in airspace that is utilized by manned aircraft or other UAVs. USICO's scope of work includes recommendations for UAV system airworthiness certification, procedures standards and operational regulations. It also includes proposals for research into technologies relating to sense and avoid.

USICO also simulated a civil UAV flying safely in Frankfurt airspace using the concepts developed by the USICO project. With actual air traffic controllers from all over Europe playing an active part in the simulation, it was shown that by using the concepts developed by the USICO project, it was possible to fly a UAV safely within the Frankfurt airspace. The simulation was attended by representatives from industry, institutes and regulatory bodies, who were impressed by the possibility of smooth UAV operation – see fig. 4.

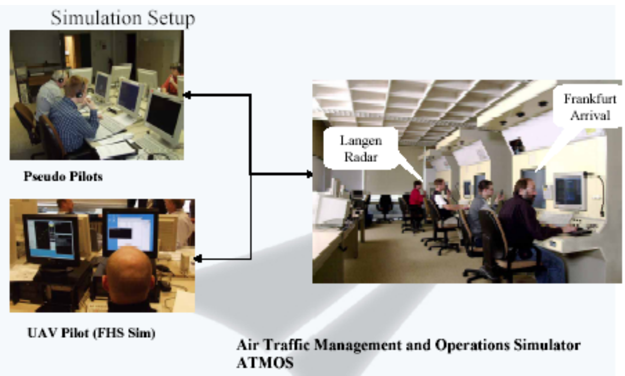

Fig. 4 USICO simulation of civil UAV in Frankfurt airspace

Representatives of USICO were key participants in the Joint JAA/EUROCONTROL Task Force on UAV Certification and ATC Integration. This task force produced a concept document approved by the JAA Executive Committee and Board in June 2004, which makes recommendations for future regulatory work.

1.3 CAPECON

The CAPECON project, also established under the European Framework 5 and coordinated by IAI Israel, identified and defined potential civil UAV applications - see fig. 5.

Scientific Missions		
	Atmospheric research	Oceanographic Observations
	Geological Surveys	Volcanoes Study and Eruption Alert
	Hurricane Evolution and research	Weather Forecasting
Emergency Missions		
	Disaster operations Management	Catastrophe Situation Assessment
	Firefighting	Search and Rescue
	Oil Slick Observation	Hurricane Watch
	Flood Watch	Earthquake Monitoring
	Volcano Monitoring	Nuclear Radiation Monitoring
Surveillance Missions		
	International Border Patrol	Road Traffic Monitoring and Control
	Forest Fire detection	Coastline monitoring
	High Voltage Power line	Pipeline Monitoring
	Environment Monitoring	Maritime Patrol
	Law Enforcement	Drug Traffic Monitoring
	High Accuracy Terrain Mapping	Crop and Harvest Monitoring
Communications Missions		
	Broadband Communications	Telecommunication Relay Services
	GPS/Galileo Augmentation System - Pseudo satellite	

Fig. 5 Major civil UAV applications identified by CAPECON

CAPECON also defined ten different configurations for these applications (4 HALE, 2 MALE, 2 Rotary and 2 Small/Mini configurations). The main UAV domains are depicted in fig. 6.

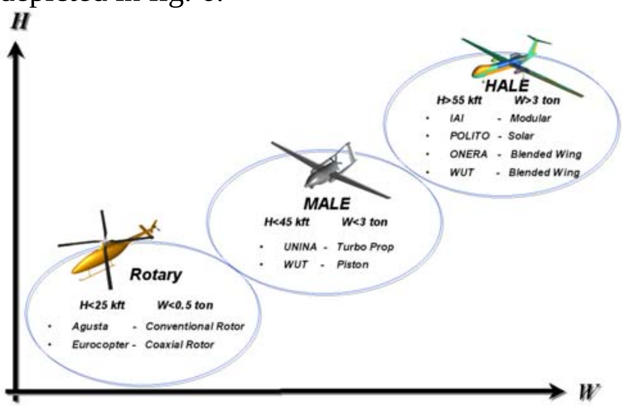

Fig. 6 CAPECON UAV Domains

Suitable payloads were evaluated for these civil UAV applications and various technologies researched. A major concern of the project was meeting safety criteria in the ATC / ATM environment, while demonstrating economic effectiveness compared to other airborne (manned), space borne (satellites) and ground based systems. In order to evaluate costs, a special cost model was developed – see fig. 7.

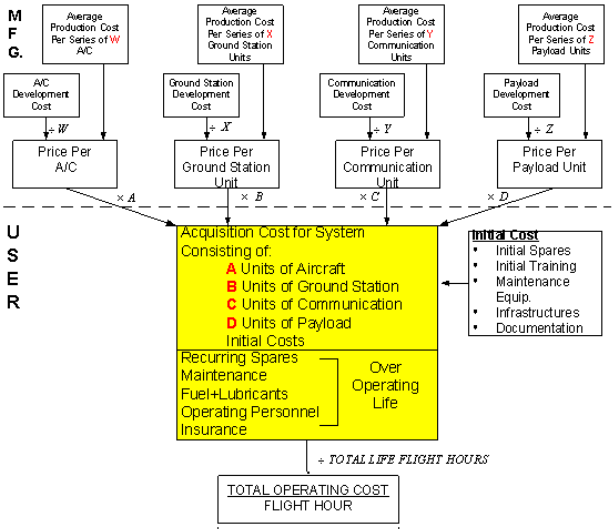

Fig. 7 UAV Cost Model

The CAPECON UAV configurations were defined in a multitask activity that was carried out in two iterations by separate teams for each configuration.

- Task 1 - Ground rules and assumptions
- Task 2 - Preliminary design
- Task 3 - Flight performance analysis
- Task 4 - Reliability and Safety
- Task 5 - Maintainability
- Task 6 - Structure analysis
- Task 7 - Aerodynamic analysis (CFD)
- Task 8 - Control and stability.

The most promising configurations were selected, based on mission requirements, the characteristic technologies and cost aspects.

CAPECON's key findings state that there is a need to research and develop methods to lower the costs involved in present UAV technologies, in order to bring them into the commercial and civil UAV sphere. There is also a need to increase the present safety and reliability levels through technological research and development into structures that are more efficient, enhanced fail-safe systems and improved collision avoidance systems tailored to civil UAVs with autonomous system recovery. More research is needed to formulate the final civil UAV configurations that will provide the highest affordability rating to be competitive in the commercial market.

1.4 Civil UAV Roadmap

A guiding document entitled "European civil UAV Roadmap Objectives" was distributed in Feb. 2006 to more than 500 key decision makers in all 25 European states. This document should act as a catalyst to encourage pan-European activity and establish relevant research, development and manufacturing infrastructures in the aerospace sector across Europe. Figs. 8, 9, 10 and 11 illustrate schematically some of the important Civil UAV applications referred to in the Roadmap.

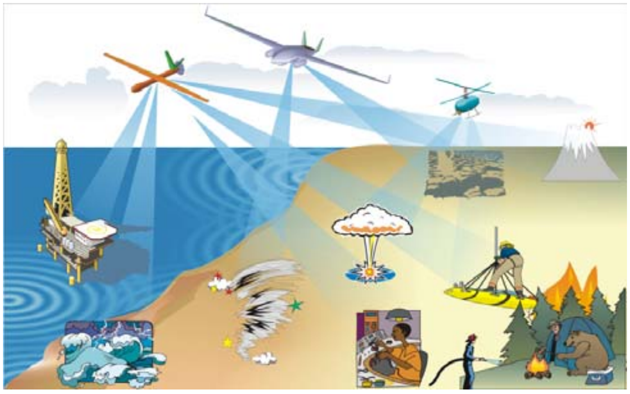

Fig. 8 Emergency applications

Fig. 9 Monitoring operations

Fig. 10 Environmental applications

Fig. 11 Communications operations

2 Market Potential

Civil UAVs are expected to produce over €1 billion for Europe alone over the next decade. In the long-term, UAVs are likely to become a true 'disruptive technology', eventually taking on many of the roles currently performed by manned aircraft and also opening up some new markets. A market survey conducted by Frost and Sullivan estimates that the civil and commercial UAV market in Europe will grow particularly fast once certification and ATM regulations are established, and will be worth €1.1bn between 2006 and 2015. They maintain that the market for earth observation is likely to be the largest market (37%) largely because it is in fact several markets in one. Telecommunications (13%), border patrol (11%), coastal patrol (13%) and forest fire management (12%) will comprise between 11% and 14% each, with power line (5%) and pipeline (6%) monitoring taking a smaller share.

This estimate is a total one and includes UAVs operating at all altitudes – see fig. 12.

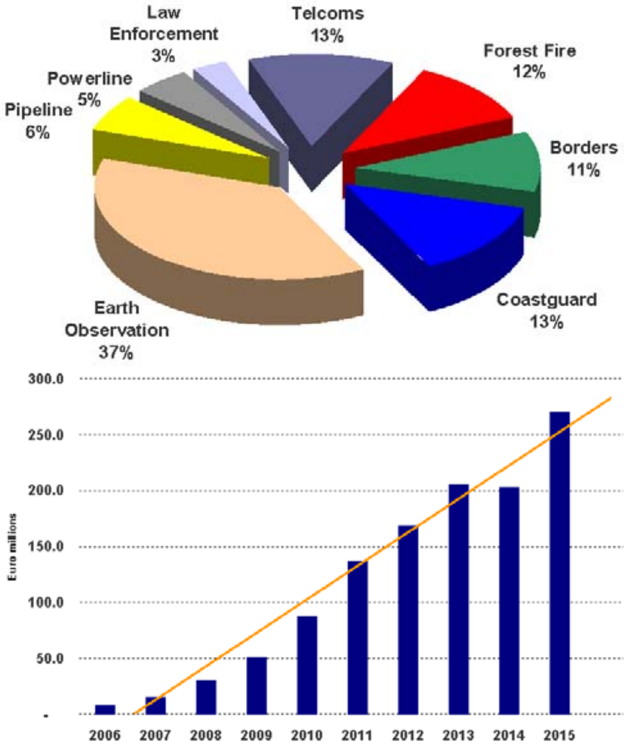

Fig. 12 European civil UAV market (F&S)

3 Civil UAV Applications

In the light of experience over the last few years and on the basis of our contacts with many people active in this sphere, we have chosen the following applications as appearing to have the most promising potential for civil UAV applications.

3.1 International Border Patrol

A UAV flying at about 200 km/h at an altitude of about 5 km could monitor a swathe of border 12 km wide using a 36 kg MOSP EO/IR payload. Thus, three UAVs operating day and night in relays could cover a border length of about 500 km – see fig. 13.

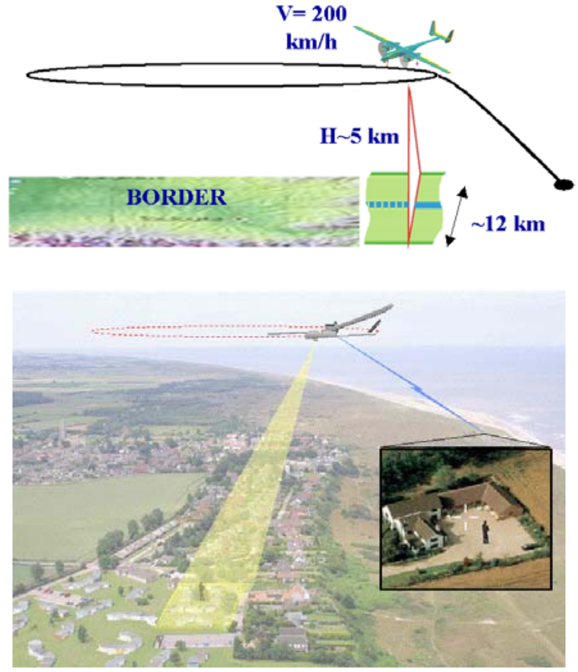

Fig. 13. Border patrol

3.2 Pipeline and Power line Monitoring

Fifty percent of all North American pipelines have exceeded their design life and are over 40 years old and twenty percent of Russian pipelines are nearing the end of their design life. US legislation is making it mandatory to have an integrity management methodology for pipeline maintenance and replacement and EU legislation is about to issue a similar draft. UAVs are particularly suitable for the task of monitoring gas and oil pipelines and also high voltage power lines – see fig. 14.

Fig. 14. Pipeline monitoring

3.3 Fire Monitoring

As early as 1995 the Firebird UAV was developed by IAI for the monitoring of forest wildfires. In 1996 it demonstrated fire detection in Montana USA – see fig. 15.

Fig. 15. Fire monitoring

3.4 Environment Monitoring

UAVs can be applied to monitoring environmental pollution such as oil spillage from tankers or oilrigs. They could also be applied to predicting and managing flood control.

4. Future UAV Design Goals

The leading measures of effectiveness that are becoming the main drivers for future development of UAVs are: -

- Affordability - Reduction of system acquisition and operational costs.
- Safety - Airworthiness of the UAV systems and their integration into commercial air traffic.

- Mission reliability - The ability to perform the mission when required without interruption.
- All weather operation - Adaptation to rain, ice, winds etc.

4.1 UAV Affordability

A major issue that will influence the UAV industry in the future is the capability to provide affordable solutions to the diverse missions, compared to other competing solutions. Acquisition costs of the air vehicle can be reduced by efficient and innovative use of composite materials manufacturing LRI (Liquid Resin Infusion) and RTM (Resin Transfer Molding) and "Lean" concepts for manufacturing, as employed in the aircraft industry. Lower subsystems costs are anticipated due to production quantity increase, and competition. Operating costs will be reduced by new concepts of operation and training requiring less operational personnel, and automatic health monitoring and Built In Test (BIT) will result in reduced maintenance.

Acquisition costs can be lowered by the use of COTS, MEMS Miniaturization and Automotive Electronics in avionic systems; composites and welding in manufacturing; more efficient sensors, production tolerances and electronic control in propulsion systems.

4.1 UAV Safety

The UAV system must be viewed in its entirety, that is the air vehicle, ground control station and the MMI and communications data link. The safety approach in all probability will be based on existing airworthiness and safety design criteria for manned aircraft, modified and tailored to UAV specific features and types of operation. The prime objective is to minimize the risk of uncontrolled UAV flight and uncontrolled landings.

Ground structural tests are already being performed by IAI in anticipation of this requirement for any future certification process as shown in fig. 16.

Fig. 16 Comprehensive structural tests of Heron-1 UAV in IAI

Currently the following features are incorporated into UAVs to enable them to be integrated into common airspace: - an IFF transponder capable of mode S communications; some means of avoidance relying on ATC and/or TCAS of other aircraft; switching logic to given transponder codes in emergency situations; navigation and anti-collision strobe lights; a forward vision camera and/or EO/IR sensor. Also a 2-way communications voice relay VHF/UHF radio from the ground control station via the UAV is provided using its communication data link, so that it would appear that ATC is talking directly to the Air Vehicle. Additionally direct GCS-ATC communications is provided.

4.2 UAV Reliability

The reliability design objectives are to minimize the risk of air-vehicle loss by introducing rigorous design principles for the flight critical systems and to avoid single point failures. The UAV loss rate due to random failures of critical items must be equal or lower than the maximum rate applicable to manned commercial aircraft of a similar class. The HALE UAV loss rate must be considerably below the current state-of-the-art and will be comparable to the loss rate of manned commercial aircraft equipped with multiple turbine engines.

4.3 Mission Reliability

It is not sufficient that the UAV system is inherently safe and reliable, but also that it is available and ready to fulfill its mission. Operation of UAVs employing EO/IR and radar payloads is potentially possible both day and night. The Mean Time Between Critical Failures (MTBCF) of a UAV improves with operational time following maturity. The Hunter UAV is approaching about 400 hours, which translates to about 98% mission reliability for a designed 12-hour endurance.

4.4 All Weather Operation

All weather operation capability is constrained mainly due to rain and icing conditions. In order to improve the capability of UAVs to operate under all weather conditions, a glycol anti-icing system may be employed, as seen in fig. 17.

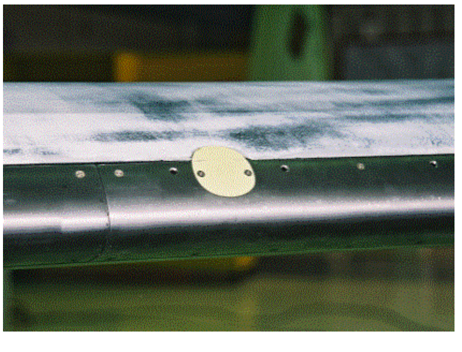

Fig. 17 - Glycol anti-icing system on leading edge of Heron-1 wing

This system is simple, partially removable and has a minimal impact on performance. It can be activated either manually or automatically and provides about 3 hours of protection in moderate icing conditions.

5. Civil UAV - New Directions

UAVs may be classified according to their size and their operational altitude. Fig. 18 illustrates this classification for a broad selection of military and civil fixed wing and rotary UAVs.

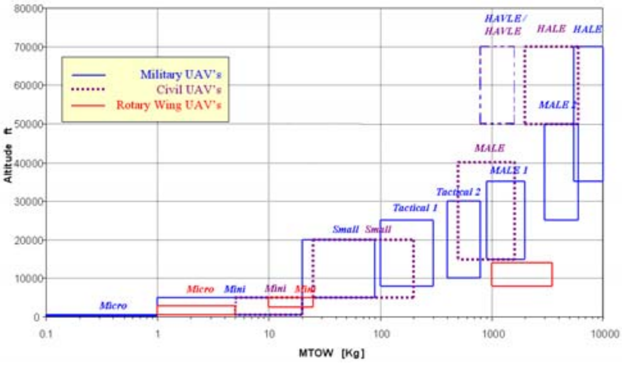

Fig. 18 Military, civil & rotary wing UAV classification

Civil UAVs are classified as follows: -

Mini UAV	-	10 - 30 kg
Small UAV	-	30 - 120 kg
MALE UAV	-	500 - 2000 kg
HALE UAV	-	> 4000 kg

In order to meet the design goals referred to in the previous section we believe that a new generation of UAVs specifically for civil missions will be conceived. Activities towards this end will have commenced by the year 2010. Potential UAV configuration design goals are described in the following paragraphs.

5.1 HA-50 Civil HALE UAV Design Goals

The proposed twin engined HA-50 UAV with a take-off weight of about 6,000 kg, an endurance of 26 - 30 hours and a payload capability of 500 - 1000 kg, will operate at an altitude of 60 - 70 kft and will be based on new technologies and design approaches. Compared to the current state of the art, the air vehicle acquisition cost is potentially about one third and the total operating cost about one fifth, and it will have a higher reliability of 10^3 –10^4. A goal of Mean Time Between Losses (MTBL) is put at > 10^6 hours.

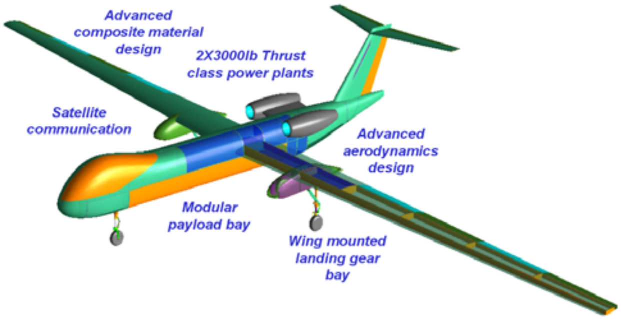

Fig. 19 HA-50 civil HALE UAV

5.2 K-800 Civil UAV Design Goals

The twin engined K-800 UAV with an Endurance > 30 hours and a flight ceiling > 25 Kft, is designed for a low Life Cycle Cost (LCC) and very high reliability. For greater reliability it has two engines and the MTBL of the UAV is > 10^5 hours and the MTBL of its crucial sub-systems > 10^6 hours. Its useful load is 50% of its gross weight, and its maximum payload is 250 kg.

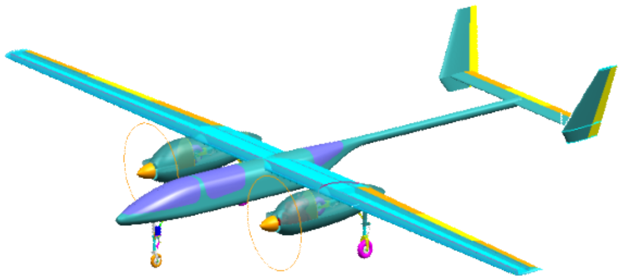

Fig. 20 K-800 civil UAV

5.3 Civil K-35 Electric UAV Design Goals

The rapidly emerging fuel cells powered technologies (based also on the automotive industries) may be used to launch a new revolution of electric propulsion systems for aircraft. The K-35 being designed in IAI, has a maximum takeoff weight of 43 kg. With a range 150 km and an endurance of 6 hours by 2007 and 12 hours by 2010, it will carry a payload of 6 - 8 kg. It has a span of 4.0m and a length of 2.3m and its twin electric motors each of 2 kilowatts can achieve a speed range of 40 - 80 knot (74-148 km/h). The K-35 which is illustrated in fig. 21, is currently powered electrically, but can be upgraded to fuel cells when this technology becomes sufficiently mature.

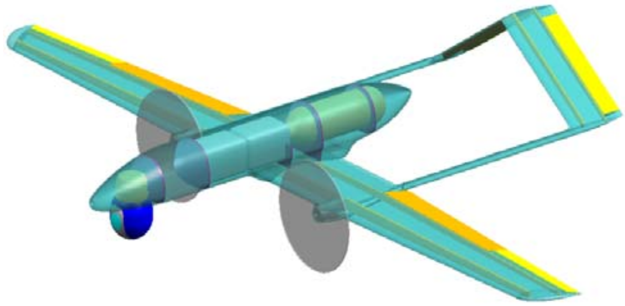

Fig. 21 K-35 civil electric UAV

6. Civil UAV - Future Potential

Subsequent to the development of the relevant technologies, it will be necessary to establish new regulations for operating civil UAVs. It will then be possible to produce civil HALE UAVs such as the HA-315 that will be powered by fuel cell technology. The HA-315 configuration that is illustrated in fig. 22 has a span of 40m and a takeoff weight of 1000 kg. With an endurance of 7 days it will be able to carry a payload of 200kg at an operating altitude of 50 kft.

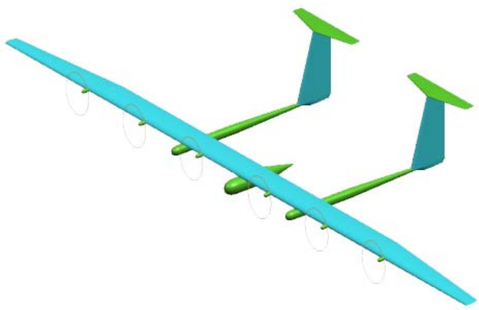

Fig. 22 HA-315 civil HALE UAV powered by fuel cells

Another example with great future potential is an autonomous commercial cargo aircraft. This will be an uninhabited cargo aircraft flying autonomously which will lower operating costs, improve safety by excluding the possibility of human errors. There are however certain regulatory and psychological barriers to overcome. A possible configuration is illustrated in fig. 23.

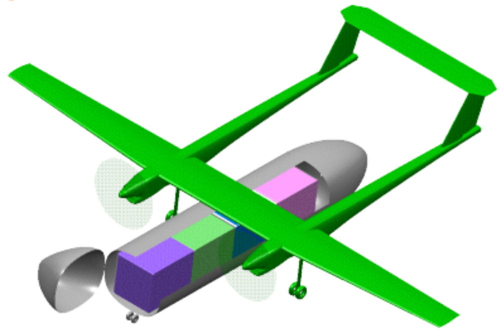

Fig. 23 Autonomous cargo aircraft

A small step technologically from the autonomous commercial cargo aircraft is the autonomous commercial personal aircraft. This STOL aircraft would carry 2 passengers with full autonomous operation including navigation (terrain, weather, airspace integration, air traffic control) and automatic takeoff and landing. A possible configuration is illustrated in fig. 24.

Fig. 24 Autonomous personal aircraft

7. Summary

This paper has reviewed the activities relating to civil UAVs within the R&D frameworks of the European Union. The projects UAVNET, USICO and CAPECON have increased public awareness of the benefits that could be achieved by developing a new generation of UAVs specifically for civil applications that could be operational by the beginning of the next decade. Several examples of potential applications were mentioned such as border patrol, fire monitoring and pipeline monitoring etc., which could be utilized throughout the world.

Civil UAVs are characterized by very high safety requirements with a MTBL of 40,000 hours, and a much reduced operating cost of about one fifth of that currently obtainable.

The emerging technologies act as a driver for the development of UAVs for civil missions, which in turn will produce the necessary safety regulations and achieve the desired level of affordability.

7. Acknowledgements

The authors wish to thank the many people who participated in the UAVNET, CAPECON and USICO projects for their contributions and success of these projects.