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# Unmanned Aerial Vehicle Driven by Fuel Cell Technology, AVIZOR

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## 1 Introduction

The National Institute for Aerospace Technology (INTA), is a Public Research Body specialised in aeronautics and space technology R&D, and belongs to the Spanish Ministry of Defence.

Within INTA primary missions are to provide scientific support and technical assistance to the government services and to the industry. In this context, since the early seventies, renewable and alternative energies have been one of the R&D areas in which INTA has dedicated a continuous effort.

From a Spanish strategic point of view, INTA is promoting the use of hydrogen as an energy carrier long-term option, as well as the utilization of fuel cells as very efficient conversion devices for application in transportation and stationary electricity generation.

Apart from R&D activities, INTA is a national centre with testing capabilities accredited on aerodynamics, aerospace structures, automobiles, EMC (Electromagnetic Compatibility), environmental testing, solid rocket motors, space PV cells and turbojet engines. INTA owns and operate premises for unmanned air vehicle (UAV) systems testing.

Since 2003 a programme on the use of fuel cells for defence application was initiated. The first phase of the programme is devoted to develop diesel and ethanol reformers to be integrated with fuel cells and to build a power generation system demonstrator based on fuel cells. In order to test and monitor the technology developments, a test bench for fuel cells is being set up with a capability in electrical power up to 30 kW.

## 2 Fuel Cells for Aeronautic Applications

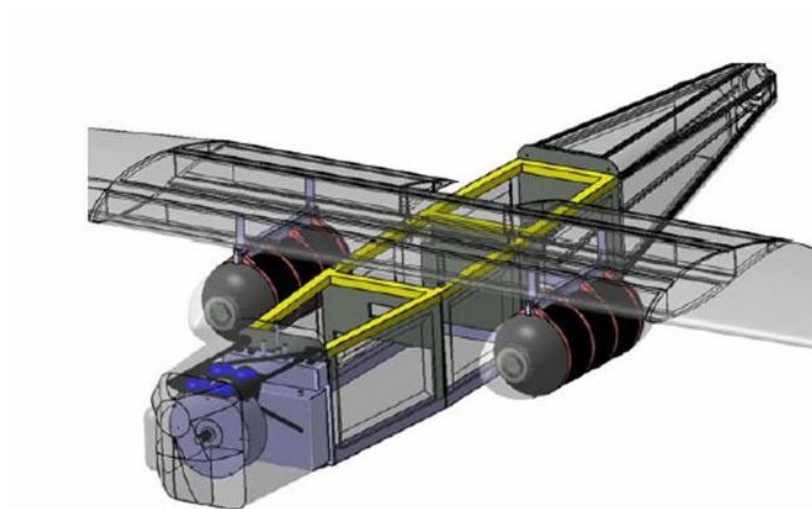
The National Institute for Aerospace Technology undertook in 1998 the development of vigilance and observation system based on unmanned aerial vehicle (UAV), designated with the name of SIVA. INTA has designed, developed and tested the system and the main subsystems, including the flight control.

SIVA is a sophisticated UAV surveillance system with multiple applications in civil and military fields, and can be used as an observation vehicle in real time. In the first step the vehicles from the SIVA project have been powered by a conventional internal combustion engine and at the moment, the Institute continues to develop new generation unmanned aircraft: mini UAV and micro UAV. After due consideration INTA decided to begin the study of a second phase of this project including fuel cells technologies, in order to evaluate the feasibility to include an electrical engine driven from the power supplied by a PEMFC or a similar system using fuel cells and H<sub>2</sub> technologies.



**Figure 1: SIVA UAV.**

Fuel cells are an attractive technology for implementation as power plants for aircraft because of their potential for rechargability and high energy density. The project is in the feasibility phase and the initial configuration envisages the use of compressed hydrogen and PEM fuel cells.



**Figure 2: Plane model.**

The main objective of this project is to prove with a theoretical study and practical tests, the feasibility to include a full UAV system with similar performances like the previous one, but driven by a fuel cell system.

The project base is the model designed and built to SIVA Project. For that reason, the Avizor provide an initials design data belonging to the project previous, and regarding fuel cell PEM, it is detailed below:

The system configuration has been chosen on the base of pre-dimensioning calculations considering several options: using air or pure oxygen as an oxidant, and using a small or big

battery pack. The final solution for this project uses pure oxygen at a working pressure of 2 bars.

**Table: System configuration.**

AERIAL PLATFORM	REQUIRED POWER, during different flight steps:
Maximum weight: 300 kg (takeoff)	Takeoff: 26 kW during 90 s.
Wingspan: 5,81 m	Rising: 20 kW during 30 min
Load Factor: 3,5 g (Landing) & 4,4 g	Cruising speed: 16 kW
Range: around 1 hour	Auxiliary systems: about 1 kW
Maximum altitude: 1000 m	
Max. pitch: 21° & Max. roll: 60°	

### 3 AVIZOR System

The AVIZOR system is made up of three main parts:

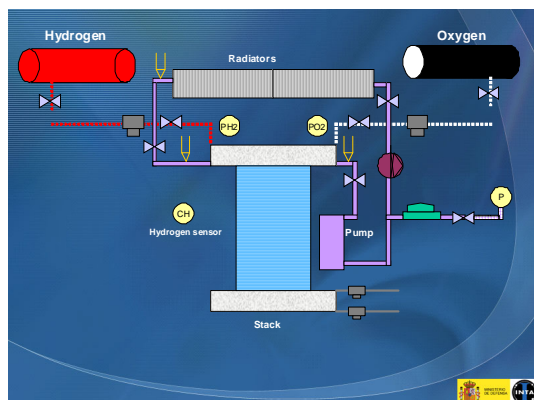
- Power system (Fuel Cell and batteries)
- Engine and controller
- Fuel Storage

The AVIZOR system details are the following:

#### 3.1 Power system (fuel cell)

Among the different types of fuel cells, proton-exchange membrane fuel cells (PEMFCs) are considered the best solution for the propulsion system of this application at the moment.

The functional role of the PEMFC System (extracted from the functional analysis) is to provide electrical energy to an electrical converter (high voltage) which will provide a voltage compatible with the high and low voltage electrical networks of the plane. System is supplied from fuel and combustive from requirements of the UAV communication network. This system must be cooled to insure optimal operating conditions.



**Figure 3: Stack configuration.**

- Stack (One stack between 20 and 30 kW).
- Max. Volume: 46 X 24 x 115 cm [W x H x L], (127 l).
- Cooling system (coolant pump).
- Cathode humidification system.
- Water management system.
- Voltage output 60 – 96 V.

In order to achieve a fuel cell system appropriate for the UAV project, the components concerning about the preliminary specifications are detailed next:

### 3.2 Power system (auxiliary batteries)

Aim of doing to make a light vehicle and a system more efficiency our first studies recommend to use an auxiliary battery that can supply the additional power for the takeoff and during a few minutes just to the final flight level. We propose to use a modular and rechargeable ion-lithium high power battery.

The batteries of AVIZOR are of nanophosphate lithium-ion. These batteries provide low weight and very fast discharge with high power (as others lithium ion technology) but also very fast charge at high power with a high level of safety.

### 3.3 Engine and controller

The electrical engine that works together with the fuel cell will run in a continuous mode, so it shall be a high efficiency and a long useful life device. For this application we have considered “brushless” engines like appropriate equipment working in a high speed. The electrical engine is according to the industry standard for reliability, functionality and performance in fuel cell test equipment, in the same way it should be compatible as much as possible with INTA techniques and actual laboratory systems. The location into the platform should achieve the best configuration to avoid aerodynamics problems.

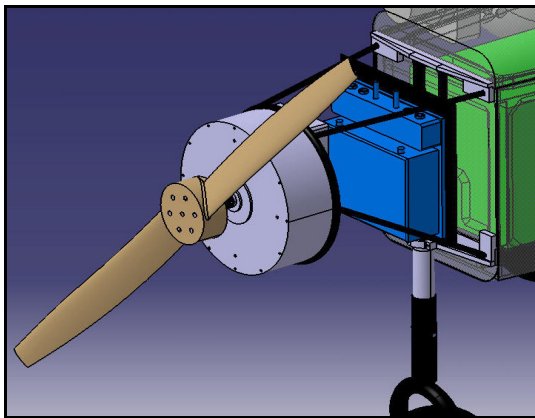


Figure 4: Engine and controller.

Brushless PM Motor:

- Peak power: 47 hp; 35 kW
- Continuous power: 31,5 hp; 23,5 kW
- Maximum speed: 4500 RPM

Controller/Inverter:

- Nominal input range: 270 to 336 VDC
- Input current limitation: 300 A
- Inverter type: PWM & phase advance

### 3.4 Gas storage (hydrogen and oxygen)

After considering different possibilities, (liquid hydrogen, high pressure gaseous hydrogen, metal hydride storage,...etc), we have decided to use in a first step two 25 L wing spot ( $P_n = 350 \sim 750$  bar and 1200 ~ 1600 gr of Hydrogen), with a total weight of around 30 kg. The oxidant is high pressure gaseous oxygen and the storage system is a tank to 200 bar.

- Two tanks around 25 l each.
- Pressure: 350 bar
- Tank Weight: 15 kg each

The use of oxygen instead of air makes it possible to be freed from the humidification of gasses supplying the fuel cell stack. Indeed, in the case of an air supply, oxygen accounts for only 21% of cathodic gas put in contact with the stack. Its flow must thus be almost 5 times higher than in the case of a pure oxygen supply, with for consequence a drying of the stack, moisture being evacuated with nitrogen of the air.

The absence of nitrogen among the combustive gas also allows to an operating process in dead-end mode without recirculation, without risk of smothering of the stack. It consumes the whole anodic and cathodic gas progressively of its need, controlling the gas inputs, and thus frees us from a management of the input of gases and from a recirculation loop on the anodic line, rather complex control.

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