DEVELOPMENT APPROACH AND TESTING OF AN UNMANNED AERIAL VEHICLE

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Abstract

The development of the Unmanned Vehicle of the University of Naples Federico II is presented in the paper. With the financial support of the National Research Council (CNR), the Department of Aeronautical Engineering has developed an unmanned aircraft within a research project concerning the advanced composite materials aerospace application. The mature technology, in terms of reliability and availability of the miniaturized flight control systems, sensor and communication devices, has allowed to this UAV civil missions at low altitude in reserved airspace. The lack of standardized regulations regarding UAV civil applications doesn't permit to such an aircraft to operate as a manned aircraft in a non reserved airspace. Some consideration on safety and certification aspects will be outlined in the paper.

We are hardly engaged in many research groups relatively to this problems.

A general review of the development approach will be reported. The paper is particularly focused on the ground and flight tests performed. Wing and fuselage full scale static tests have been performed, and the comparison of experimental and numerical results (obtained from finite element models) will be discussed.

Some material tests have been carried out on specimens in order to substantiate numerical simulation developed during the design cycle.

First results of flight tests will be presented.

1 Introduction. UAV civilian use.

The authors of this paper and other who work with them, are forming a group for the development of some interesting items of the Aeronautical Robotic at DPA (Dipartimento di Progettazione Aeronautica-Naples University Federico II). The Aeronautical Robotic is a branch of the UAV field. The use of these vehicles become considerably more practicable when they are able to fly with an high degree of autonomy. It isn't mandatory to adopt always the full autonomy, but it can be cheaper to have non autonomous take off an landing.

The crucial point for the civilian UAVs use is: "How, where and when are they able to fly?"

This item is easier for military purposes. The use of civil UAVs is highly limited by the lack of regulations, standards and procedures. To address this lack some steps are made in this direction by the Australian Aviation Authority [1] concerning UAVs, rockets and airships, only within the Australian airspace. Also the Italian authorities, ENAC (known as RAI in the past), has published a draft, on line disposable, intended as a starting point for the future regulation definition.

At the today day it is impossible to operate with civil UAVs in a civil ATC/ATM environment. The main problem is the detection and the avoiding of collisions: the so called "See (Sense) and Avoid" item. The solution of this problem will permit the UAVs integration in the ATC/ATM environment [2].

Often the civil UAVs use was limited in the past also by the high cost and weight of the avionic systems needed for the autonomous fly.

The due weights were initially some hundred of kilos but they are being reduced to some kilos at the moment. The UAVs use has been originally restricted just to dangerous situation (e.g. Chernobyl). They still can't perform flight missions today also when manned flight is expensive and monotonous.

Many national and international organizations are interested to this matter. Our work group collaborates with them: it is involved in national and international research projects such as GRISAT, in Italy, and USICO and CAPECON in Europe. Both these last two projects are sponsored by EC.
USICO deals with all jurisdictional aspects regarding the civil UAVs use. This project will evaluate, trough a dialogue with the European Aviation Authorities, the existing certification procedures and recommendations needed to certify civilian UAV systems. Dialogues with the ATC bodies have also been started to discuss the due procedures for the UAVs integration into the common and civilian air space also evaluating the "see and avoid" technologies able to ensure to the ground pilot similar flight senses of an on board pilot.
CAPECON will study the configuration, the technologies and the potential market for UAVs civilian applications.
Many important aerospace industries, research centers and universities work in these programs. sample article is to show you how to prepare papers in a standard style for electronic publishing in the ICAS 2002 CD ROM proceedings. It illustrates the paper layout, and describes points you should notice before you submit your papers.

2 Federica

Our group has worked on the design and the realization of an advanced composite unmanned aircraft addressed to civil applications. The Italian National Research Council (CNR) offered his financial support; the full project involves others university departments. The name used for this aircraft is Federica. The main goal of the project has been to dispose of an aerial platform to support academic activities in the field of experimental aerodynamics, flight mechanics, stress analysis and testing [3], [4].
The DPA laboratory is furnished with many facilities as three wind tunnels, three tension and compression testing machines, static and dynamic testing equipments, etc.
Federica was designed by professors, researchers and students forming a team.
The dimensions of Federica are fixed by several different inputs:

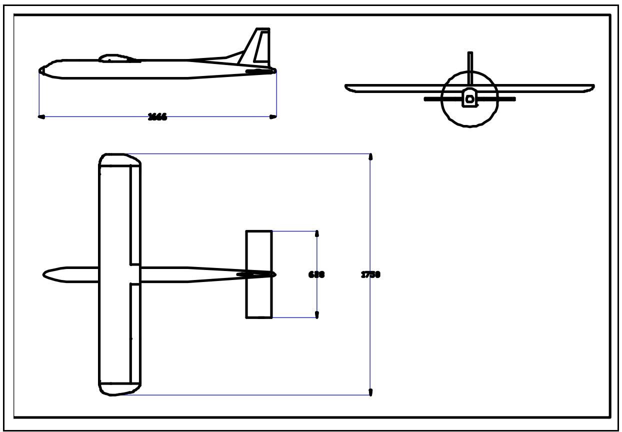
1. the budget (the size of financial support).
2. the width of the disposable wind tunnel test (2m for the main facility of the DPA)
3. the wing span (Federica wing is of 1.75m) able to let its transportability also by traditional road vehicles such as cars
4. the payload (the actual payload is of about 6-7 kg that considering the present disposable technology means a lot of useful electronic devices).

The present disposable avionic is much cheaper and lighter then in the past.
Federica is a starting research program. UAVs bigger then Federica are going to be built, as decrypted in the following sections of this memory.
The study and the realization of Federica started 3 years ago. Federica has performed its first flight in the September 2001 taking off from the Salerno (Pontecagnano – Italy) airport.
It has performed other flights mainly to check its aerodynamic performances. Some tests are scheduled also to validate the structural rigidity and strength.
The whole structural program was scheduled with numerical analysis for the design and validation, for the static tests (also to be conducted in the wind tunnels) and for the structural flight tests. After the first flight tests, according the Italian aviation authorities, no other tests could be performed taking off from airports used also by manned airplanes.
From that time, we are performing all the flight tests from a model aircraft strip, not well cured. This problem slows down the flights. Therefore the absence of some regulation is also bounding our research activities: it is very difficult to schedule any test.
The characteristics of Federica are:

1. Overall length: 1.66 m
2. Wing span: 1.75 m
3. Wing chord: .29 m
4. Aspect ratio: 6
5. OEW: 6.5 kg

6. Fuel: 3 kg
7. Payload: ~6 kg
8. MTOW 16 kg
9. Weight of power plant: 0.83 kg
10. Max power @9000 RPM: 3.5 bhp

In the fig 1 are shown three views of Federica.

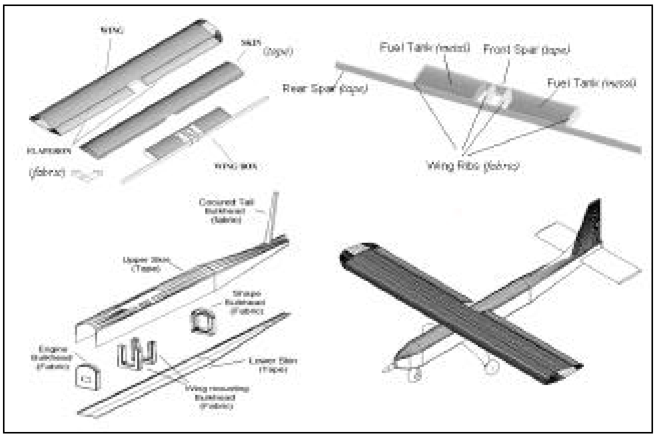


-fig1- Federica's tree views

In the fig.2 is shown Federica during a flight.

-fig2- Federica's first flight

As written in [3], many models of Federica and its parts have been tested in the two tunnels of DPA. The smaller wind tunnel, also used in selecting the tests to be conducted in the bigger one, has a chamber test section of 0.80x0.60m while the bigger one is 2x1.2m.
We have performed initial tests on 5 scale (1:2.5) wing models each one having different airfoil. The best two airfoils, by means of their aerodynamic coefficients and derivatives, were selected to build up two full scale wings to be investigated by the use of the main wind tunnel (the bigger one).
We also built a 1:2.5 model of Federica, who was tested in the smaller tunnel using a three-component symmetric balance obtaining also the non symmetric derivatives.
In the main tunnel, where full scale models have been tested at the real Reynolds number, a classical test program was conducted.
The structural design project limited strongly the configuration design.
The number of the aircraft parts was reduced at the minimum in order to decrease the manufacturing tools cost. The wing is high and have flap-ailerons. The horizontal tail is a stabilator. The fuselage is co cured with the spar of the vertical tail. In the fig 3 are shown the aircraft components.

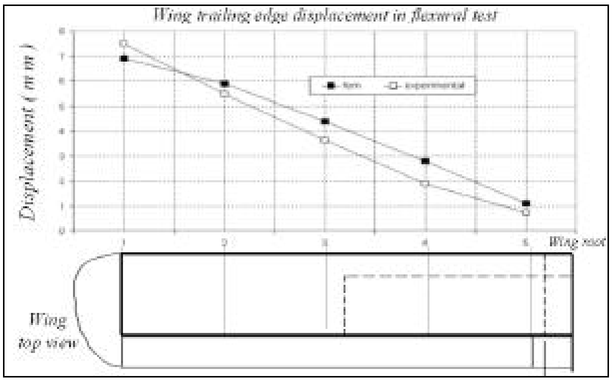


-fig3- Federica's parts

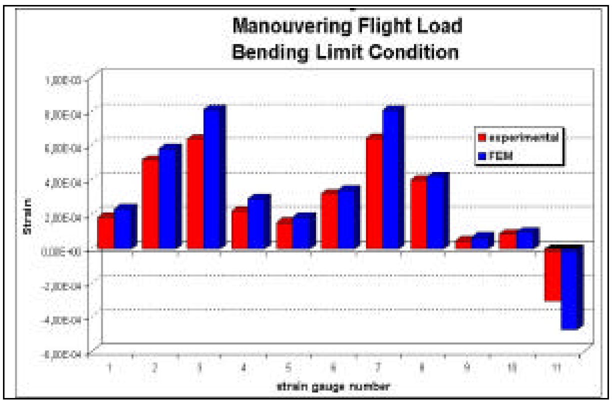
The material used to build all the parts is an advanced composite material particularly the graphite-epoxy. To obtain balanced laminates also for small components, the number of plies used is often plentiful. At any rate the structure of Federica is much lighter then an equivalent metallic one, as a consequence of the materials and the manufacturing processes used [4].
The structural strength was validate by static tests both on fuselage and wing.
The absence of any regulation didn't obstruct to follow a precise test procedure. We used the JAR-VLA regulation as the main outline with some changes. The load factor was increased, because the aircraft hasn't a man on board, the factor of safety was reduced (at 1.2) and so on.

In the figures 4, 5 and 6 are presented the photos of the tested components and some results.

-fig4- Federica's static tests setup



-fig5- Federica's wing static test - displ.



-fig6- Federica's fuselage static test – strain

3 Towards programs

Federica has got dimensions suite to perform classical small unmanned vehicles missions. Therefore it's not possible at the present moment to put on it recovery devices such as a parachute and an airbag, sometimes scheduled for similar UAVs.

Our group is furthermore studying, in collaboration with other companies, the design and the realization of one bigger unmanned aircraft, with a wing span up to 4 m, able to be recovered by the use of a parachute and an airbag. The bigger size will also allow a bigger payload anyway increasing the operating range.

References

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4 Conclusion

The results of our research are based on many items:

1. the project of a suitable UAVs
2. the use of advanced composites for the development of aeronautical structures
3. the approach for the UAVs regulation
4. The use of Federica as an aerial platform

The future UAV programs of our group are strongly linked to the possibility of the certification of such vehicles for civil use. It must be clear that the most difficulty for the diffusion of civil UAVs is related to the meaning of the expression "civil use". For manned vehicles "civil" could figure two different categories: the civil air transport and general aviation aircrafts. Civil use of UAVs are very different form that for manned aircraft. In the civil use of UAV it's very probable a paramilitary utilization: by the police for runway patrolling, by navy corps for the coastguard surveillance, by fireman for the fire detection and in general for the surveillance of natural parks and unmanned zone like forest, desert, volcanic and so on. All this missions will be performed by paramilitary personnel well trained to make the UAV flight in safety. The certification authorities and ATC/ATM controllers must be considered as natural partners in achieving the needed civil UAVs regulation.

If all the country will develop own regulations, are strongly recommended efforts for the uniformity of such certification rules. This is the primary USICO goal and a milestone for future research works on the UAV field.

The conclusion of this paper must point out that the commercial growth of UAVs is fully dependent by the mission typology and the flight areas. Therefore it's again recommended the development of regulation derived by the existing one for the manned vehicle, with the due modifications. The new regulation must have consideration of the exiguity of the disposable fly zones. Above in this paper, the Australian experience has been mentioned, intending it as a good starting point.

After the missions and the relative problems definition, all the technologies needed for the aeronautical robotic, like the platform development and the choice of the launch and recovery systems have also to be developed. Once these items addressed, it will be possible civil UAV future missions; our research group participation in projects as USICO and CAPECON but also in many other researches supported by CNR for military and paramilitary purposes, is so intended.

At the end, one of the main requirement for an UAV system must be the low cost; at the present day, the "see and avoid" technologies are almost expensive, but we hope that a large diffusion of these technologies will run them down, and with an increased level of security it will be almost probable the use of UAVs also over populated areas and in the civil transport air space.