A NEW UAV AFTER FEDERICA

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Abstract

"Federica" is a very small aircraft designed at DPA (Department of Aircraft Design) of University of Naples "Federico II". The composite parts were built by LMC, a local firm, specialized in the manufacture of composite materials. The CNR, Italian National Research Council, was the sponsor of this program. Others Departments of Federico II contributed as consulting for technological and control aspects. The principal aim of the project was the manufacture an aeronautical product completely realized in advanced composite materials. But today it's unmanned, it's a small UAV. His wingspan is 1.75 m and his weight is about 15 daN. After the first fly at September 2001, "Federica"(by Federico II university), was used as aerial platform for research objectives. The activities about the design, the construction, the use of Federica as aerial platform, are already described in many our papers presented at international congress. Two our paper was also presented at lasts ICAS congress (Harrogate and Toronto).

Our group also participated to many programs on the UAVs, as the European CAPECON and USICO (Unmanned aerial vehicle Safety Issues for Civil Operations). An important opportunity for the progress of the civilian use of UAVs in Italy will be connected to the possibilities that the UAVs Predator, purchased by Italian Air Army, will fly out the reserved sites. During last years many seminaries and meetings were promoted by Italian Air Army, our University and important industries to examine the problem of civilian use of UAVs. Some sentences often concluded the seminaries: it's very difficult to obtain airworthiness for UAVs, perhaps it's possible to obtain a policy for specific use. But it is an only certainty: it is necessary to make a classification of such typology of aircrafts. Last guidelines defined these groups: the UAVs that are heavier than 150 daN, the UAVs that are heavier than 20 daN and lighter than 120-150 daN and the UAVs lighter than 20 daN. The first group is composed primarily by HALE and MALE. The third group is composed by the mini/micro-UAV. The second group are not well defined at this moment. We propose to indicate their as trismall_UAV, because they have small endurance, "small" weight and can fly at "small" altitude.

It will be very difficult to obtain airworthiness for the mini-UAVs. The MALEs should to fly together the manned aircraft, but will not easy to resolve the problem about SENSE & AVOID. The trismall-UAVs can be used for the patrol, cost surveillance, fireman use, parks observation and other similar topics. For this typology of mission will be possible to reserve special areas. The problem for the trismall-UAVs is only to be sure that their left the reserved sites.

The skill obtained by the activities about Federica and our experiences about the above mentioned international activities has permitted to define the ideals specifications for a future design of a trismall-UAV.

The future of the trismall-UAV will be good, if their use will results cheaper than other technologies.

The small size not will be a real problem, because we think that the actual electronic trend

will permit to have high technology in small size and small weight.
Today the activities of our group is focuses to design and build a new trismall-UAV, bigger than Federica to fit up easily the payload and to improve general performance.
In compliance with airworthiness guidelines it need to have a weight bigger than 20 daN, but not is necessary to have a wingspan bigger than 3 m.
The same architecture of Federica can be saved.
It's also important to study cheaper processes in the use of the composite materials.
A very important matter will be to have a easy possibility to change the sensors of payload, because we can use the same vehicle for a large number of missions.
Officially this project, denominated "DIANA", will start before of the end of 2004, but today we are testing all future changes on a "transition" vehicle. All detail about our design choices will be explained in the paper.

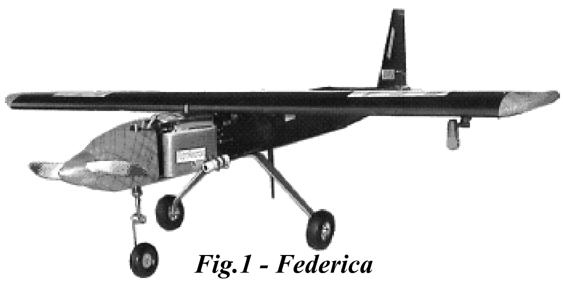


Fig.1 - Federica

Specifications	
Power plant: One 20 cc single cylinder two stroke engine (3,5 hp); two blade fixed pitch propeller	
Dimensions	
Length	1.66 m
Wing span	1.75 m
Aspect ratio	6
Weights	
MTOW	15 kg
Max payload	5 kg
Performances	
Max endurance	2.5 hr
Stalling speed	~60 km/h
T-O distance	25 m
Landing distance (no brake)	60 m
Max velocity (levelled)	~190 km/h

1 General Introduction

During last years the University of Naples Federico II, and in particular the Structures Group of DPA directed by Prof. A.F. Accardo, has focused a lot of activities on UAVs systems. This know-how derive also from the experience matured on this type of aircraft, intended also as remote controlled aircraft or in general pilot-less onboard. In particular our activities are focused on vehicles of small size.
First two objectives of last project "Federica" (name derived by Federico II University), were to design an aeronautical product completely realized in advanced composite materials and to build a technological demonstrator of new aircraft category "mini UAV".
The phases followed from our group during the design and the construction have been the same of those normally followed for a standard aircraft of the general aviation.
The singles composite parts were built by LMC, a local firm, specialized in the manufacture of composite materials. The CNR, Italian National Research Council, was the sponsor of this program. Others Departments of Federico II contributed as consulting for technological and control aspects: DIMP (directed from Prof. Nicolais) and DISIS (directed from Prof. Vetrella).
The staff involved in this project was constituted from professors, researchers, Ph.D and students. All skills worked together constituting a standard technical staff with all necessary specializations, from theoretical analysis to experimental phases.
As we said in others paper, the main phases followed for the design and the construction of this vehicle have been: mission configuration options, wind tunnel tests (performed in two different tunnels), choice of material, structural loads, preliminary sizing, performance determination, structural design and test (CAD, FEM), constructive plans of single parts, systems definition, single parts construction, static tests, acquisition and installation of the propulsion system, assemblage, systems installation and setup, test flight organization

and realization, post processing of data acquired during flight and theoretical model validation.
Parallel to the study of technical problems we have been trying to define the guidelines that consent to civilian UAV operations in non reserved space areas.
This research, created through the absence of a international univocal regulation, has lead our research group both to an international cognitive investigation on the aeronautical regulation adopted by the various countries, and to the participation in a European group for the definition of the new regulation and new airworthiness standards.
In particular our group also participated to many programs on the UAVs, as the European projects CAPECON and USICO (Unmanned aerial vehicle Safety Issues for Civil Operations).
Besides, during last years, many workshops, seminaries and meetings were promoted by our University, Italian Air Army and important industries, to investigate the problem of civilian use of UAVs.
Some sentences often concluded these meetings: it's very difficult to obtain airworthiness for UAVs, it's possible to obtain a policy for specific use; but an only certainty: it is necessary to make a classification of such typology of aircrafts.
From these considerations and technical know-how acquired, following the international airworthiness guidelines, our research group decided to begin a new project: DIANA.

2 Ties for the development of a new UAV

Last guidelines defined from JAA Taskforce, EASA and national/international meeting propose three class of UAVs: the UAVs that are heavier than 150 daN, the UAVs that are heavier than 20 daN and lighter than 120-150 daN (only for national missions) and the UAVs lighter than 20 daN (with the same rules and limits of the models RC). The first group is composed primarily by HALE and MALE. The third group is composed by the mini/micro-UAV. The second group are not well defined at this moment. We propose to indicate their as "trismall_UAV", because they have small endurance, "small" weight and can fly at "small" altitude.
It will be very difficult to obtain airworthiness for the mini-UAVs. The MALEs should to fly together the manned aircraft, but will not easy to resolve the problem about SENSE & AVOID.
The trismall-UAVs can be used for the patrol, cost surveillance, fireman use, parks observation and other similar topics. For this typology of mission will be possible to reserve special areas. The problem for the trismall-UAVs is only to be sure that their won't go out the reserved sites.
The future of the trismall-UAV will be good, if their use will results cheaper than other technologies.
Today the activities of our group is focuses to design and build a new trismall-UAV, bigger than Federica to fit up easily the payload and to improve general performance.
In the respect of airworthiness guidelines it need to have a weight bigger than 20 daN, but not is necessary to have a wingspan bigger than 3 m.
The architecture of Federica can be saved.
It's also important to study cheaper processes in the use of the composite materials.
A new UAV need a fuselage larger than Federica to fit more complex systems.
We think that new payload for DIANA will be about 10-12 daN .
It isn't convenient for economic aspect to realize a new full aerodynamic theoretical and experimental study. We can use the aerodynamic study of Federica whit same small additions to check same new solutions.
The requirements of the new contractor for DIANA (a Government Military Organization) are very similar to those already followed in the design of FEDERICA, but the new one and surely important difficulty is the possibility of certification, at least on the National territory.

3 New data acquisition systems and R/C control capabilities

As we said in the summary today we are trying some of new features of DIANA on a transition vehicle: FEDERICA rev. B.
For this reason in this paragraph we report synthetically a description of the last configuration that today is installed onboard; this will be the start point for the develop of DIANA.

Two data acquisition sub-system were installed, in particular:

- Data acquisition system for flight mechanics
- Data acquisition system for structural stress (installation/setup are currently in progress)

Data acquisition system for flight mechanics include:

- 1 GPS Receiver
- 1 Flight Recorder
- 1 Anemometer
- 3 Barometers
- 1 Thermometer
- 1 Digital compass
- 1 Vario-meter

Using this system, it is possible to monitor various flight parameters and elaborate data with appropriate software installed on the ground station (after the flight).

The systems has the following specifications:

- Integrated electronic compass (res. 1°)
- Automatic direction finder ADF
- GPS link
- Glide computer GPS
- McCready function
- Next waypoint height
- Wind direction indicator
- Wind speed indicator
- Efficiency
- Automatic Speed To Fly
- Barograph FAI
- Peak values recorder (last 100 flights)
- Multi Flight Recorder in 2 or 3 dimensions (2D 3D) with continous recording of: altimeter, air speed, vario, Gps fix, marker, ground speed, flight time, time and date take off / landing
- Memory size up to 100 flights (max 130 hours)
- Polar recorder
- 3 settable polars
- 3 altimeters 9000 mt (29527 ft) with adjustable QNH
- Vario with dynamic filter ' IntelliVario '
- Vario analog +/- 12 m/s (2400 ft/min)
- Vario digital +/- 25 m/s (5000 ft/min)
- Vario acoustic with presettable thresholds
- Vario average (integrator) adjustable 1 to 60 sec
- Vario netto
- Total energy compensation presettable
- Air speed
- Stall alarm adjustable
- Barometer (range 1200 300 mB) calibration ±200mB
- Thermometer (range -30 °C +70 °C -22 °F +158 °F)
- Continuous battery voltage check
- Timer, clock calendar

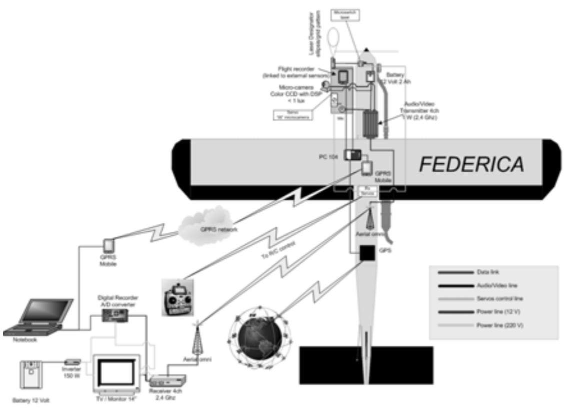


Fig. 2 – Federica (rev. B) systems

The stored data are processed and allow the complete virtual flight re/construction of one or more flight (path 2D or 3D, map overlap, etc.)

The data acquisition system for structural tests, instead, is currently in progress. This system was planned with the same logic applied in static tests (strain gauges bounded directly to the structure). The only difference being the strain gauges are located inside the aircraft.
To apply this solution was necessary to built an other structure (in particular a second wing) with cables and strain gauges already inserted on the internal last ply to avoid aerodynamical interferences.
Complete the acquisition data systems a video/audio datalink:
Audio/Video TX/RX to monitor/control in real-time (4 channels, 2,4 Ghz analog with A/D converter on GCS).
The CCD camera onboard has a 90° TILT control (pilot view to earth view).
In the next flights we will add a laser telemeter linked to a PC to improve the control during the final approach.

Fig. 3 – Pilot views

Today, all onboard systems have a weight of about 3,5 Kg (power system included).
The configuration of this system is also sufficient for the standard mission of a trismall UAV, and even if we want to suppose to add other sensors, the weight should not increase a lot.

But this weight not include the remote control system (actually a very light standard model R/C system, about 300 g) and then, if we want to add new features, like autonomous or semiautonomous flight, this is a critical tie to establish a new maximum payload for DIANA.
In fact, also if we suppose to improve onboard only a semiautonomous flight system (manual take-off and landing, autonomous flight over prefixed way-points and 2/3 axis stabilization) we need of about 10 kg for total payload.
This payload will must include an integrated system both data acquisition both semiautonomous flight and real-time telemetry.
This last point will be very important point to realize a "real" unmanned aerial vehicle and not only a high technology R/C plane.

Certification and qualification

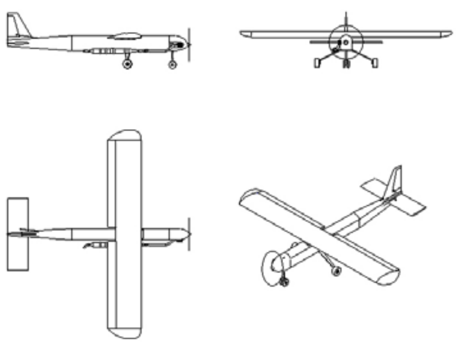
About the civil use of the UAVs is fundamental know the state of international regulations.
Synthetically the key factors about these topic are: safety and security.
These factors have a smaller impact in military context, but are the start point in civil field.
It is also necessary to permit the daily civil operations, if we want that the costs of this technology decrease and become a real competitors of the manned technologies.
As said before in some considerations, the aspects which will be encountered by the introduction of Civil UAVs in an ATC/ATM environment, are on the table of a lot of working groups (USICO, CAPECON, Task Force JAA, etc)
Only if this technology can be used in all the countries of the world (also in limited areas), every potential manufacturer can think about the realization of a product that has a great market.
Today, a lot of documents are drafted about the problems of certification of UAVs, but we can say that we are still in the year "zero".
The art. 8 of Chicago Convection would give the possibility to every country to issue special permissions for every special case; this will be surely only the start point to allow the first flights of new UAVs.
Even if synthetically, we want to remember the main points from which to depart for resolving such problems:

- actual interpretation of Chicago Convection (art. 8)
- Concept of Sense & Avoid and requirement for the safety
- Harmonization of the local regulation (where are already existing)
- Integration with manned ATM/ATC environment

All these topics, by us detailed in other documents, have been introduced in the preliminary study of DIANA.
In fact, the dimension and the weight of DIANA have been select to follow the international guidelines about airworthiness.
Then it won't be a mini UAV, but it will have surely a weight less then a manned standard aircrafts.
We hope that such choice will allow to have a more affordable system.

Structure configuration

As said before, after a lot of years spent to search an optimal configuration for FEDERICA, we think that DIANA has to start from this point.
For this reason DIANA will be surely (at least in the geometry shape) very similar to FEDERICA. The most important difference will be the size and weight: about 3m of wingspan vs 1,75 m and 28 daN vs 15daN of FEDERICA.
Also the fuselage will be increased, both for structural and aerodynamical reasons, both to fit inside the new payload.



Conclusions

In the planning of DIANA some aspects will have to be considered to permit a real operation of this vehicle:

- Structure JAR (VLA adapted) or new EASA compliance
- Safety systems (both as sense & avoid, both as termination flight system)

Surely the small size permits a lot of cheaper missions, especially in limited areas.
The small size not will be a real problem, because we think that the actual electronic trend will permit to have high technology in small size and small weight.
A lot of checks, about the our design-choices to improve in DIANA project, are currently in progress. For these test we are using as “flying laboratory” the version B of FEDERICA.

It is important underline that also initially the project DIANA will be developed in a military context, the next step will be surely the civil use.
We have in our mind the objective of to realize a aerial platform, classified as UAV, certificated for civil use, that has the maximum range of potential missions in limited areas, but with maximum priority on such topics: safety and cheaper.
We think that the only solution for this equation is an optimization of actual configurations and not only the research of new high technology.

We can conclude remember an important market law: the customer is always right.

Today the our customer wants an UAV not real different from FEDERICA (like performances or payload), but he want a vehicle that can really use in the airworthiness and safety compliance.

The proposed new class of UAV (trismall) surely not could be directly accepted from EASA, but, in compliance with art.8 of Chicago Convention, surely could be accepted from a national regulation to permit missions in limited areas in national land.

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