Leonardo Aircraft

Leonardo Aircraft Division UAS flight testing experience capabilities and future developments

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Electronics

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Aerostructures

SUMMARY

- LAD vision on UAS flight testing
- Demonstrators development, deployment and testing experience
- Developing UAS Flight Test philosophy
- Testing manned and unmanned AS
- Future developments
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LAD vision on UAS flight testing

Distinctive approach

Leonardo started many years ago dealing with UAS, developing its proper vision on UAS development, testing and certification activities. Studies and research began in early ’90s with the participation in all major European research teamed with

Leonardo Aircraft Division (LAD) built its own technology and operational demonstrators with Sky-X (first flight in 2005) as UAV technologies demonstrator and Sky-Y (first flight 2007) as MALE & Surveillance technologies demonstrator achieving some significant results.

Since the first stage of activities LAD focuses on:

- Design, produce and operate medium to large sized drones
- Find out the best strategy to safely conduct test and qualification of these flying machines
- Demonstrate the capability to install and operate remotely state of the art or innovative technologies
- Integrate complex mission system capabilities.

Participation in major European and International research and operational program

- Dassault for Neuron advanced UCAV demonstrator
- Skydweller, medium-altitude pseudo satellite capable of carrying heavy payloads at long range and persisting overhead indefinitely
- Leonardo Electronic Division (LED) Falco XPlorer light MALE
- Piaggio AS for the P1HH RPAS.

Demonstrators development, deployment and testing experience

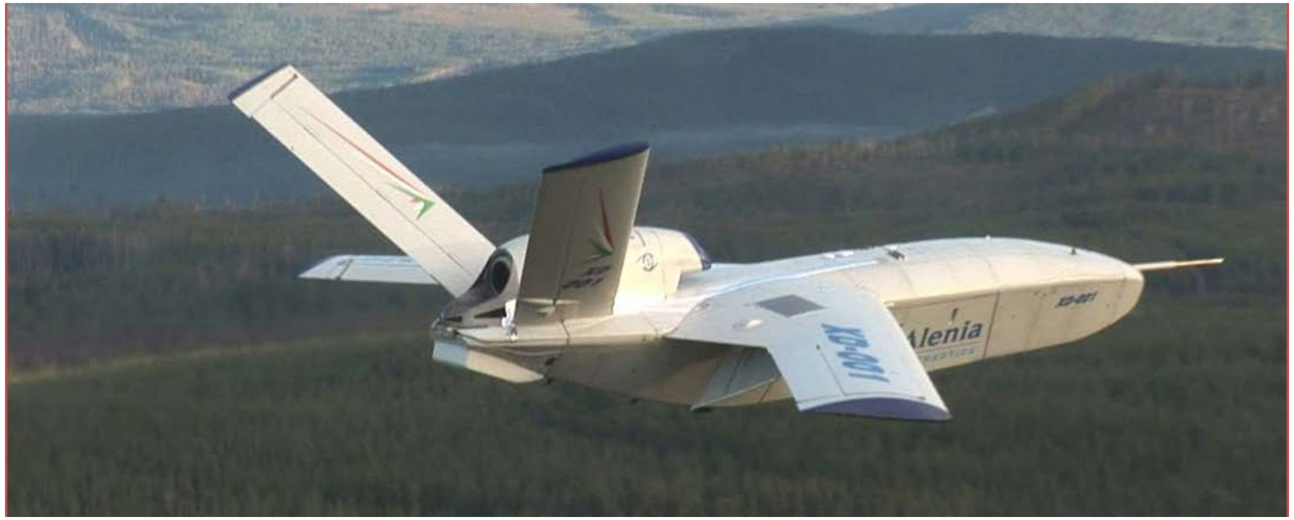
SKY-X

Sky-X, was built and operated to mature technology and competence in the unmanned vehicle flight autonomy. SKY-X, first flight in 2005, was the first UAV to fly in Europe in its weight category.

The aim of the Sky-X program was to acquire kwon-how in the unmanned vehicle, and in particular on the development of a platform dedicated to the testing of the so-called enabling technologies for unmanned systems. Another purpose of the project was to increase the degree of autonomy of the air vehicle and its ability to gather, process, synthetize and deliver information, make the uninhabited system a high added-value tool in the military and civil operational scenarios.

The Sky-X program has been characterized by a short developing time, relying to the greatest extent on the know-how and resources already available in the company. Moreover, a simplified Qualification Process was adopted in order to maintain the traceability of requirements and obtain a 'Permit to Fly' from two different Airworthiness Authorities (FMV in Sweden and ENAC in Italy).

In this research program the Flight Test Department played a new and important role. In fact, in addition to the traditional flight testing task, the Department had the responsibility of designing and developing the Ground Control Station and the Data Link System exploiting the experience in the field of telemetry and real time software.



- Length/wing span: about 7 m / 6 m   Max TO weight: 1200 kg
- Max speed: 350 KCAS Cruise speed: 260 KCAS
- Propulsion: Microturbo TRI60-268 jet engine
- Ceiling: 35000 ft Maximum load factor: 5 TO and landing run: about 900 m

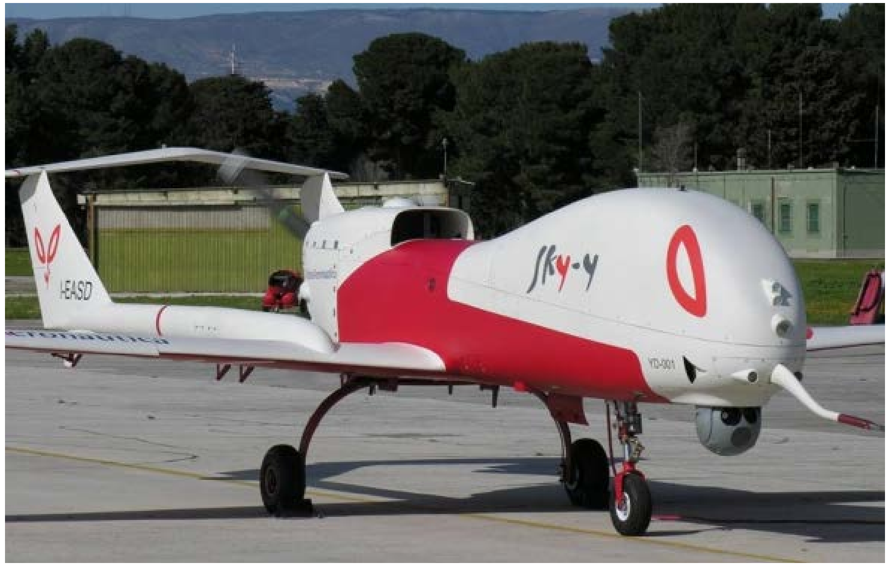
Demonstrators development, deployment and testing experience

SKY-Y

Sky-Y programme allowed developing technologies for a MALE such as surveillance technologies demonstration, autonomous take-off and landing, mission management system, sensor exploitation, full Mission system testing, data exploitation and dissemination, fully automatic night landing and extended range clearance. Sky-Y, first flight 2007, proved to be a surveillance asset capable of supporting monitoring and control of a wide range of events.

These technologies included: innovative carbon fiber composite construction, heavy fuel/JP-8 engine (automotive diesel derivative), advanced datalinks, surveillance sensor (EO/IR), and mission management system able to relevant data treatment, elaboration, fusion and distribution by means of an interoperable Tactical Control Station.

Dimensions	
Length	9.725 m
Span	9.937 m
Weights	
MTOW	1200 kg
OEW	850 kg
Fuel	200 kg
Payload (*)	150 kg
Performances	
LOS Radius	70+nm
Range	500 nm
Altitude	25.000 ft
Endurance	14 h
(* Typical)	



Demonstrators development, deployment and testing experience

PARTICIPATION IN OTHER TEST PROGRAMS

Leonardo Aircraft Division decides to participate to a number of international program to strengthen its capabilities or to share experience and vision with:

- Dassault for **Neuron** advanced UCAV demonstrator. The contribute of LAD was targeted to the achievement of important technological targets like Low Observables technologies, Weapon internal carriage and release from a bay, Combat capability with internal E/O sensor, Modular avionics, Autonomy and Automatic flight.

- **Skydweller**, medium-altitude capable of carrying heavy payloads at long range and persisting overhead indefinitely thanks to an electric thruster powered by solar-powered accumulators . LAD is involved in Skydweller program with a team of design and test engineers located in Madrid.

- Leonardo Electronic Division (LED) **Falco XPlorer** light MALE. LAD is participating at Falco XPlorer program with a Flight Test Team in support of the development and certification Test Campaigns, basing on proper experience and skill on Test techniques and associated established procedures for manned aircraft. In addition, a collaboration in engineering task is also in place.

- Piaggio AS for the **P1HH** RPAS. The P.1HH is a remotely piloted aircraft developed starting from the fuselage of the Piaggio P180 characterized by thrusting propellers and its characteristics made it fall into the MALE category. An assignment in development, integration and qualification of an Armament System fit for the use on the Piaggio P1HH UAS was agreed between Piaggio and Leonardo. In particular, the development and qualification of the Armament System and Weapon Aiming, comprehensive of flight test support, was part of a complete “vertical” work package assigned to LAD.

Demonstrators development, deployment and testing experience

Contribute of Leonardo global approach to UAS enabling technologies

Leonardo Aircraft Division

The first Step in development of UAS technologies was done in the definition of an architecture for ATOL capabilities based on a data fusion of on board sensors (GPS, Inertial , Air data) and on field aids (video tracking system and differential GPS) extensively tested on both SKY-X and SKY-Y.

Some experience in Mission planning were developed and tested using SKY-Y as a platform such a testing new logic design for automatic definition of routes on the basis of EOST pre-planned capabilities. A new functionality of EO Intelligence Surveillance and Target Reconnaissance (ISTAR) were developed implementing an off track cruise mode capability, called “Direct Steering” (DS), that was the autonomous capability in driving SKY-Y towards a point of interest located outside of the programmed route for recognition purposes. Once the recognition was concluded the automatic definition of a trajectory that reconnects to the original trajectory was created and followed by the platform

In the field of autonomous replanning capabilities, a significant experience was made on Neuron program where Leonardo was in charge of the development of the SIWB (Smart Integrated Weapon Bay) that allow to demonstrate in flight important technologies like autonomous replan of detection and recognition mission with or without intervention of GCS operator

Another significant step in the field of autonomous flight plan capability was achieved on SKY-X platform during the Flight Test campaign named “Join Up” for a simulation of automatic IFR testing using C27J aircraft as cooperant. The data source was an integration of optical and GPS data for a fully automated 4D autonomous rendez-vous mission with real time re-planning, fully automated pre-contact in-flight refueling simulation & formation flight.

Demonstrators development, deployment and testing experience

Contribute of Leonardo global approach to UAS enabling technologies

Leonardo Aircraft Division

Within Neuron program, Leonardo was in charge of a new airdata system based on a number of low observable flush skin plates distributed among the aircraft surface linked to air data unit to acquire air data parameters and a non-linear algorithm to compute the aircraft information.

A significant activity for the identification of architectures and standards for the S&A (sense and avoidance) of unmanned aircraft has been conducted in the MIDCAS project aimed at demonstrating technological solutions that allow the use of UAS systems in non-segregated airspace.
MIDCAS system was installed on SKY-Y and a flight test campaign was carried out using different encounter scenarios and a company aircraft as intruder to validate high level requirements such as: provide situational awareness, provide separation maneuver, provide collision avoidance, abort collision avoidance maneuver, provide interface with data link, detect intruder, prioritize intruder.
After Clear of Conflict a Recovery manoeuvre started, bringing back the UAV to straight & Level flight with a commanded final heading. When S&L flight condition was reached, S&A asked pilot to revert back in command.
The S&A system provided the manoeuvre in terms of Nz/Bank/IAS commands then Mission Computer translated command (CA and Recovery) into Pitch/Bank/PLA/RPM for FCC compliancy.

Developing an UAS flight test philosohy

THE FLIGHT TEST PROCESS

Facing for the first time the in-flight experimentation of unmanned aircraft, Leonardo relied on the consolidated experience in flight tests of piloted aircraft, trying to transpose the test techniques on this new kind of machines. The test and evaluation was initially platformcentric, that means it was aimed at developing the air vehicle and proving its airworthiness as a platform. But since from the first experiences the need for an operational test and evaluation approach to validate the effectiveness and suitability of the UAV system was highlighted.

At the beginning the driver in the development process was to keep the development risk at minimum, by using at the greatest extent as possible resources, experience and equipment already available or used on different programs and to limit the development of new system/equipment.

The process followed for UAV flight test activities is in Leonardo the same adopted for manned aircraft, with the necessary tailoring due to the ground-flight parts of the system.

Importance of the EME testing, the loss-of-communication backup strategy has been duly taken into consideration.

Training of the crews, risk mitigation actions and approach, hazard assessment in each phase must be considered at higher level for UAS testing: consider that for size, speed and dimensions the LAD managed drones could be considered in the medium to large categories.

Developing an UAS flight test philosohy

THE GROUND TEST PHASE: what’s different for UAS

Ground test phase on UAV has to be considered as a System Integration Test because it should include the Ground Control Station, Air Vehicle, Data Links, Recovery Systems, and any other subsystems required to execute the mission.

Quality ground testing is essential not only to reduce the risk of mishap, but also to ensure that the system is technically ready for the flight testing to follow in all its components.

The ability to force the system into a simulated flight mode with a high fidelity model residing in the GCS, facilitates quality ground testing and improves risk reduction. It also reduces the time and effort required to find and fix problems by allowing isolation to the message containing the error.

The key words that characterized the testing approach during the development phase was ‘synergy and integration’. A strict and highly integrated collaboration among the Flight Test Department, the Simulation Department and Avionic RIG., possibly co-located, is fundamental.

During System Integration Testing a thorough test of the data link, both primary and back up is necessary. A “range” check has to be conducted in the intended flight test environment. It is also extremely important to verify the procedures by which the backup data link assumes control in the event of a primary failure. In many cases this operation is completely automatic and requires no operator intervention or action.

A more difficult phase of the control transfer may be required when the control of the air vehicle is transferred not from the primary to backup data link, but from one ground control station to another.

Electro-Magnetic Interference and Compatibility testing are very important in UAV systems due to the fact that UAV rely on Radio Frequency (RF) transmissions for all operator control inputs, and all operator displays. There are no mechanical backup systems when the air vehicle is in flight.

Developing an UAS flight test philosohy

THE FLIGHT TEST PHASE: what's different for UAS

In general, many aspects of UAV or UCAV test planning and execution are not significantly different from manned aircraft testing. Attention to the same risk factors is required, and much of the data to be collected is very similar. There are however, unique requirements and differences that need to be understood in order to develop effective and successful test programs

If the UAV can be kept within approved boundaries with fail-safe or flight termination systems, loss of the air vehicle may become an acceptable risk. This is diametrically opposed to the entire philosophy of manned aircraft Risk Management.

The major difference between manned and unmanned testing is a necessary requirement to have a fail-safe ability to terminate the flight. So, in addition to the failure mode analysis of engine, avionics, flight control system, servos, and generators a new aspect to consider is the communications signal uplink and downlink.

Flight termination philosophy may vary on UAS type, test conditions and usage rules, but must be stated, approved and tested, Autonomous return, parachute release or drone destruction are examples used.

Human factors with respect to the ground station man-machine interface should also be considered early in the design process. A fundamental and unique aspect of UAV operation is the complete lack of the multitude of feedback provided to the pilot of a manned aircraft. Wind noise, engine vibration, peripheral cues, and feel of acceleration on the human body are all missing for the UAV pilot. The safe operation of a UAV requires intense concentration on exclusively visual feedback.

So training of the entire team is essential to reduce risk. Hardware in-the-loop simulations were used to provide crew with realistic training and practice opportunities as well as to simulate anomalies and failures.

Developing an UAS flight test philosohy

THE FLIGHT TEST PHASE: what’s different for UAS

Another important difference between manned and unmanned process is relative to the Permit To Fly. The Remotely Piloted Aircraft (RPA) are certificated by the issuance of a Type Certificate, which includes all the associated components required for controlled flight. Operation of an RPA requires that the remote pilot have the ability to manage the flight on a real-time basis through use of a C2 (Command and Control) link. Therefore, the C2 link is necessarily part of this safe flight principle, and must be addressed in the certification process. The C2 link is not a “product”, therefore it will not be independently type certificated. There are two forms of operation related to the C2 link: within RLOS and beyond BRLOS. In either case, the link forms part of the overall type design and as such it will need to be defined and fully addressed within the certification process.

Even in the flight manual some differences have to be underlined. The RPA flight manual should contain all necessary information for operation of the RPAS. In addition to those required for manned aviation, the following procedures should be included:

- RPA handover procedures from one Remote Pilot Station to another;
- C2 link specifications and procedures to respond to interruption or loss of the C2 link;
- flight termination procedures;
- security procedures unique to RPAS (e.g. Remote Pilot Station security, C2 link).

Testing manned or unmanned Air Systems

CONSIDERATIONS

When dealing with testing of a new category of flying machines, different approaches can be adopted: a brand new, revolutionary one, with relevant risks and advantages, or a modified, improved, evolutionary one, based on lessons learned, achievements and experienced gained by the organization or consortiums.

The **evolutionary** approach bases on some solid arguments: the flying machine often is a derivative of an existing one or has “classic” design, Mission system integration is felt as a process very similar on manned and unmanned AS and Basic airworthiness testing, envelope expansion and H&P quite similar to the one for manned aircraft

On the other hand, you have to encompass some aspects that **make new** the business:

- The interaction between the human being and the machine is remote, either if the pilot is on ground or some degree of autonomy (little to full) is reached on the AS. This impact in the design of the system, ground and flight for the UAS, and in the design of the associated testing
- Rules and regulations vary according to type, size, destination (military, civil), country and aviation authority involved, but in general are brand new
- Scope and logistics of the activities may require a change in the standard test set up
- New technologies deployed all together in a new AS require a revision in the safety approach of the test.

Testing manned or unmanned Air Systems

CONSIDERATIONS

To mitigate most of these challenges, some practices are already in place:

- Anticipate most of the activities at an early stage of the design: analysis tools, simulation, system and integrated rigs, test benches, iron bird, global benches and so on. The continuous feedback to the previous stage allow for validate and improve the prediction capabilities
- Use of innovative technologies, like digital twin or rapid prototyping, can make more efficient the development process
- Train every part of the system, human or machines, since the beginning
- Integrated planning of multi-asset, multi-tasking, multi-resources programs with some degree of automatics and some degree of freedom of adjustment.

Some parts of the activities require more attention: Safety of operations, risk assessment/mitigation, Activities authorizations and limitations.

One may argue if, for testing an UAS, is necessary an **established organization** or a **new one**: it largely depends on the nature of the machine and on the history/experience/culture of the organization: normally large companies test dept. rely on well-established and staffed team, with procedures, regulations and approval gained in long years of test campaigns. New organizations are nevertheless more agile and result-oriented: a blend of the two approach could be considered, but requires solid technical and program knowledge. At the end the only consideration must be: Safety first.

Future Developments

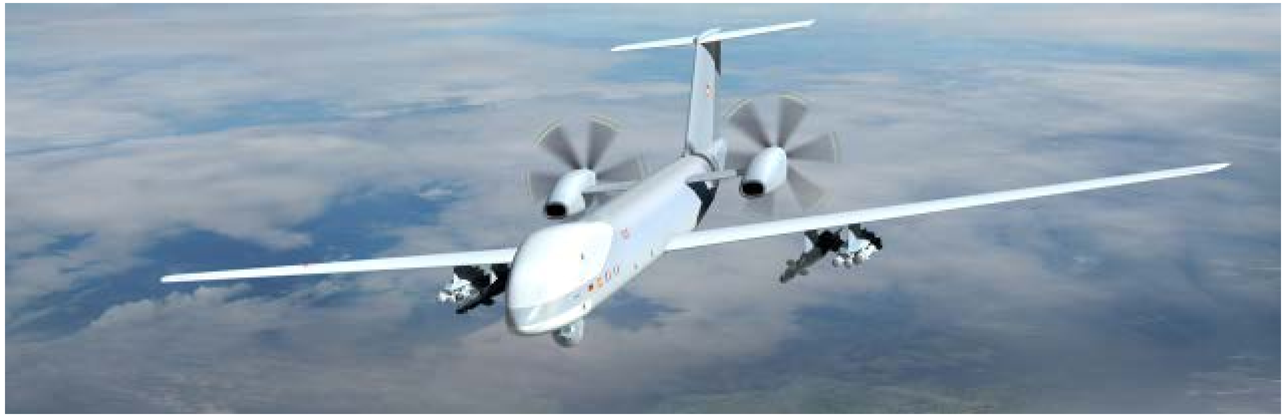
EURO MALE RPAS

LAD is engaged in the Euro MALE RPAS Joint Development Program for the Next Generation European MALE. The aim is to establish an independent European UAS capability by developing an advanced MALE RPAS able to fulfil future European requirements through a joint high level European Governments and Industrial initiative launched by Airbus D&S, Leonardo Aeronautics Sector and Dassault Aviation. The new system will give to Europe a full sovereignty and independence, in terms of ownership of technology, ability to enhance the system through the life-cycle, management of operations and information. Moreover, the certification basis will be agreed among the airworthiness authorities, to allow the system to insert in the European non-segregated airspace.

As far as the flight test is concerned, one of the 3 prototypes will be managed by LAD.

LAD is acting to manage with the National Military Authorities the way to implement the euro MALE Italian test activities, both for regulatory, logistic and operational aspects.

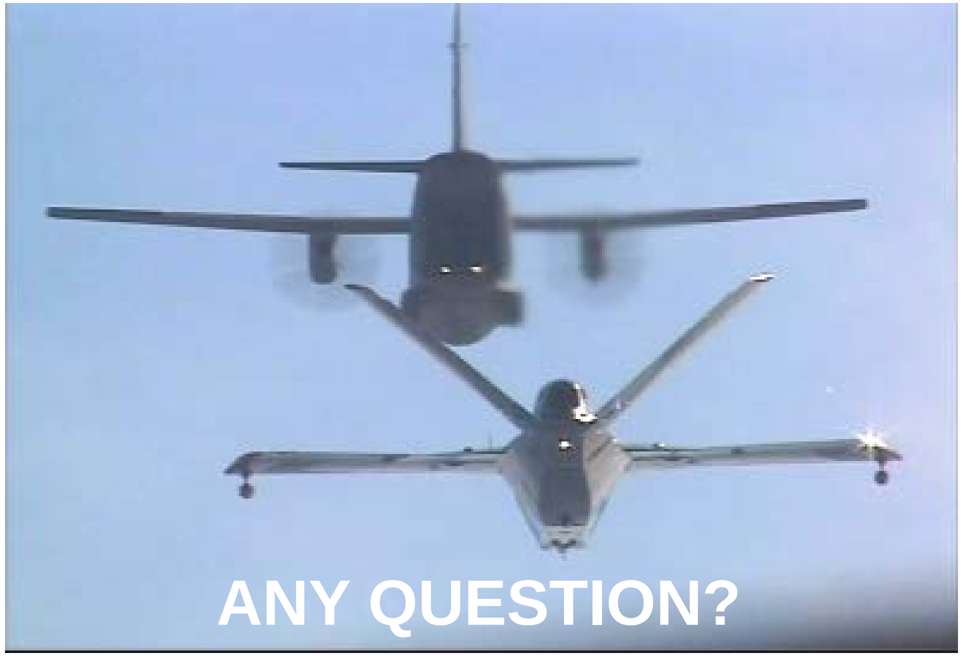
The “Italian” Euro MALE prototype will be mainly dedicated to mission systems and armament development and qualification.



Conclusions

Unmanned systems with current intelligence, surveillance and reconnaissance technologies, combined with high level of endurance, no risk of loss of on-board life could increase their potential use to become independent also in an unknown environment and in operational situation where complex judgements are needed.

In order to enlarge their application UAS should increase safe operation to overcome the restrictions on flying over people.



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