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FASTWingCL

Foldable Adaptable Steerable Textile Wing for Delivery of Capital Loads

Specific Targeted Research Project

Aeronautics and Space

Publishable Final Activity Report

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1 Publishable Executive Summary

FASTWing CL started in December 2006.The present summary covers the full duration of the project (1st December 2006 to 30th June 2010).

Background

Paragliders, manoeuvrable parachute-like textile wing structures, are developed as personal parachutes for the sports and leisure market. They close the gap between manoeuvrable hang gliders or sailplanes and circular shaped parachutes. Being a controllable structure they offer the capability of steering to a pre-determined landing point. The controllability and the potential flight range resulting from the forward velocity capability and large glide ratio make such systems ideal means for the precise delivery of loads to be dropped.

Parafoil and paraglider performances that are available in the leisure market have improved during the past years and thus the technology has become more and more interesting for commercial use in emergency aircraft recovery as well as for delivering payloads. Other technologies such as the Global Positioning System (GPS) contributed to the vision of an autonomous and precise aerial payload delivery system. The European Space Agency (ESA) launched the Parafoil Technology Demonstration (PTD) project as a result of the previous Crew Transport Vehicle (CTV) studies which - beside other results - recommended the use of parafoil technology as the potential recovery system for a precise and soft land-based landing of re-entry payload systems. Furthermore, as predicted by wind tunnel tests, this high performance parafoil tested during flight tests a glide ratio of 5, being a world record for a parafoil of this size! Autoflug initiated and coordinated this project to increase the knowledge and confidence in parafoil technology as a potential land-based landing technology in Europe.

FASTWing CL focused on the development of a high performance parafoil for heavy loads up to 6000 kg with a high steering accuracy and soft landing capability. This approach was a clear step beyond the state-of-the-art. All functions of the developed system were tested and validated in real drop test. Such a heavy payload system was never dropped by a parafoil in Europe
FASTWingCL technology will allow a precise delivery of heavy loads, e.g. mobile medical aid units in disaster areas (earth quakes, flooding e.g. tsunamis) which are not accessible overland. In a second step exploitation of the technology is expected for aircraft and space vehicle rescue systems are targeted in accordance with European Space Agencies future planning scenario.

The FASTWingCL project showed good and successful results like high performance glide ratio, low opening and landing forces and an acceptable accuracy. These requirements will result in a modular (adaptable steering box and data acquisition system), light weight and small volume (minimized battery and packed parachute system), high accuracy (in-flight wind measurement, flight control software with landing strategy), high performance (high glide ratio, high forward velocity of parafoil), high flexibility (payload carrier for different payloads) and low-g-force flight system (parachute system with carefully designed opening stages as well as a damping system for landing).

2 Contractors involved

The consortium is representing members of five member states. Autoflug, the project co-ordinator, is a small and medium sized family owned independent enterprise (SME) with less than 250 employees. The most of the FASTWingCL (2006 – 2010) participants have worked together in the previous FASTWing project (2002 – 2005). This has ensured a smooth operation of the project.

The consortium was well balanced to perform the envisaged scientific work as well as for providing the technical hardware to validate the findings in hardware tests. Four research oriented organisations (Three research establishments and one university) have covered the research activities in FASTWingCL while the three industrial companies have tackled application oriented aspects of the RTD work including exploitation of results. The two participating parachute manufacturers will assure that FASTWingCL RTD work will be product and exploitation oriented.

The FASTWingCL consortium consists of the following partners:

No	Organisation Name	Nation	Business Activity	RTD Role
1	Autoflug	D	Safety Equipment Supplier	Co-ordinator Equipment technology
2	CESA	E	Equipment Manufacturer	Actuator specialist
3	CIMSA	E	Equipment Manufacturer	Parachute technology
4	NLR	NL	Research Establishment	Avionic and flight test technology
5	ComputIT	N	Research Establishment	Numeric analysis and fluid technology
6	DLR	D	Research Establishment	Data acquisition and parachute flight technology
7	Technion	IL	Research Establishment	Power supply specialist
8	DS	NL	Space System Supplier	Flight Control Unit

The FASTWingCL partners are the most professional European players in their field, assuring an added value not attainable on a national level.

AUTOFLUG (Germany) as the co-ordinator is an experienced aeronautic safety equipment manufacturer. AUTOFLUG designed and produced the parachute system and emergency system. AFG was responsible for the composition of the design requirements and the overall system design as well as for the hardware integration. The planning and realisation of the parachute verification tests were managed. AFG has adapted an existing deployment analysis tool for the FASTWingCL system up to 6tons.

CESA (Spain) is an experienced equipment manufacturer who contributed with his expertise in actuator systems. CESA developed and manufactured suitable actuators and platform subsystems.

CIMSA (Spain) is an experienced equipment manufacturer who contributed with his sophisticated knowledge of parachute technology.

NLR (Netherlands) as the Netherlands' aerospace research centre brought their knowledge in two special fields into the consortium:
- developing flight test instrumentation and avionics, integrating this equipment into airborne platforms and supporting flight test operations
- development and analysis of flight control software for small parafoil

ComputIT (former CFDn) (Norway) is an expert in numerical analysis of fluid flow problems. Computational Fluid Dynamics were used to compute the environmental flow field of textile wing structures based on Navier-Stokes equations and various turbulence models. Further CFD has developed tools for prediction of flow field - structure interactions.

DLR (Germany): DLR is the largest scientific/engineering establishment in the area of aerospace research in Germany. The DLR Institute of Flight Research contributed to the project with its expertise in system identification and the know-how from the Small Autonomous Parafoil Landing Experiment (ALEX).

Technion (Israel) is one of the top Technical Universities in the world. They provided expertise in small lightweight power supplies and payload carrier system.

Dutch Space (Netherlands) Dutch Space is the main supplier of (sub) systems for the European space industry in the Netherlands and has ample experience with recovery- and parafoil systems. Dutch Space designed the control unit structural system and provided specifications for flight tests and evaluated the test results.

None of these partners is able to develop the FASTWing CL technology alone. The European approach is required to deliver competitive results.

3 Project objectives

This approach is a clear step beyond the state-of-the-art. Such a system doesn't yet exist in Europe. All functions of the developed FASTWingCL system were tested and validated in real drop test with a demonstrator at the end of the project.
FASTWingCL technology will allow a precise delivery of heavy loads, e.g. mobile medical aid units in disaster areas (earth quakes, flooding e.g. tsunamis) which are not accessible overland. In a second step exploitation of the technology is expected for aircraft and space vehicle rescue systems are targeted in accordance with European Space Agencies future planning scenario. The objectives were in detail the following:

- Development and manufacturing of a high performance parafoil with a high glide ratio of >5 and a forward speed of more than 18m/s. This enables the system to be delivered with higher stand-off distances as well as wind independent flights directions.

- Development and manufacturing of an effective parachute system for low g-forces during deployment of <4g, to be optimized by deployment flight tests (parachute verification tests with a payload dummy) and verified in steerable flight tests. Low g-forces allow delivering of shock sensitive equipment and protect manned missions from injury.
- Development and/or adaptation of a deployment analysis tool for parafoil material selection and reefing layout for payloads up to 6tons. Such software is not available on the market!
- Reusable system layout for budgetary, safety and training reasons by means of short, cheap and easy refurbishment after a drop dropping, e.g. by easy change of batteries, easy handling prior to flight (automated pre-flight procedures like pre-flight functional test and target input)
- Selection of an advanced flight termination system to be tested in-flight. To drop such payloads the test range authorities requires implementation of a backup system to be initialized in case of malfunction of the system, in order to reduce hazardous situations or damage on the ground. (Note: This will require a new design complying with the requirements of the test range in order to qualify for flight testing).
- Adaptable low cost-, volume- and weight steering box for autonomous, remote controlled flight and flight to a beacon (control modes), to be verified in steerable flight tests with all control modes
- Development of advanced flight control software for all control modes, to be validated in steerable flight tests with all control modes
- Development of a portable ground station for monitoring of all control modes and measurements, to be validated in steerable flight tests. The ground station will enable remote control of the system, especially required during the first drop test, but also during later flights to monitor in real time the flight parameters.
- Adaptable flight data acquisition system for monitoring and transmitting the in-flight measurement data, to be tested during deployment and steerable flights. Being independent from the operational system, the design of hard- and software for avionics and GNC (Guidance, Navigation and Control) can focus on the requirements for the end product without considering the specific needs for the evaluation phase.
- Development and/or adaptation of software tools for aerodynamic design (incl. flow field analysis), deployment analysis and flare manoeuvre analysis, to be validated with results from steerable flight tests.
- New concept for power distribution of all components (low energy, single voltage) for avionics, actuation and flight termination system in order to minimize number, weight and volume of batteries.
- New concept for actuation, steering manoeuvres and in particular the flare manoeuvre. Usually the actuator system will be used to perform the flare manoeuvre. This manoeuvre consumes a lot of energy, requiring a larger actuator system than required for normal control. New flare technologies might reduce the weight of both the actuator system and the batteries.
- Design and manufacturing of a new advanced light weight payload carrier for different payloads up to 6tons (i.e. for medical equipment, rice bags, vehicles).

4 Main Achievements

Within the duration of FASTWingCL project the main achievements have been:

- An non-steered technology model for parachute verification tests allowing analysis of opening and in-flight behaviour of the parachute system (by on-board cameras and flight data acquisition system)
- A technology model capable of performing remotely controlled and autonomous flights to a pre-defined target with a payload between 3000kg and 6000kg
- A reliable parachute system showing soft opening shocks below 4g and with a glide ratio higher than 4, mostly independent from wind influence due to a high horizontal flight velocity
- A steering system capable of guiding the parafoil to a pre-defined target with an accuracy of better than 200m if released from a distance of 5km (to be realised with the autonomous flight tests)
- A modular light weight & low volume steering system to reach max. payload mass for different payload carriers, max weight of steering system less than 2% of payload mass
- Low energy consuming actuation system for steering and flare in order to reach a maximum flight time with a minimum sized power supply
- Flight control software capable to fly to pre-defined targets including wind influence and failure considering parameters (i.e. malfunction of an actuator, the failure tolerant system will be simulated but not tested during flight tests)
- Software capable of directing a number of flight systems to one single or to different targets and capable of controlling multiple cooperative systems (multiple systems will not be tested with flight tests, but simulated)
- A light weight structure payload carrier capable to carry different payloads up to 6tons like medical equipment, vehicles and food bags by standard transport aircraft like C-160 and C-130 and the new A400M.
- A landing shock below 3g to be realised by a new flare strategy and damping system in order to be able to transport fragile payloads like medical equipment
- An autonomous emergency system able to terminate flight in order to reduce the horizontal flight distance to ensure safety of flight, if the flight system shows an unexpected potentially dangerous behaviour
- An adaptable flight data acquisition system capable to measure location, attitude, accelerations etc. for flight analysis during and after flight of different payload carriers (for parachute verification tests and steerable flight tests)
- Design software tools for the aerodynamic design and analysis of parafoil of up to 6tons payload w.r.t. stable flight performance as well as glide ratio and forward velocity
- Design software capable of analysing material textile selection and opening staging of the parachute system in order to reach a minimised opening shock

- Software capable of analysing the interaction between parafoil and payload prior to landing in order to find the optimal activation of the flare manoeuvre

The innovative character of the aircraft industry and the high technological standard of equipment made in Europe have made Europe competitive. In this respect FASTWing CL is continuing this approach by actively developing new theories and ways to model aerodynamics of thin textile structures. This will have a positive influence on the reputation of European research effort as well as a positive spin-off for other applications demanding low weight and high efficiency lifting surfaces.

5 Publishable Results

At the end of the project the full-scaled parachute system verification tests were planned and performed in three test campaigns. The first test campaign was carried out with a payload dummy (step by step from 3000kg to 6000kg) in order to validate the functionality of the deployment process and to identify opening loads over time of the parachute/parafoil system. In the second test campaign remote controlled flight tests were performed to verify the behaviour of the overall system during pre-defined manoeuvres. In the third campaign fully autonomous controlled flight tests were conducted. The results / analysis served as basis for validation of the design tools and flight control software developed within the project.
After the completion of the project the developed and validated software tools is now available for the development and design of e.g. aircraft emergency recovery, space vehicles and load delivery systems. The availability of intelligent GPS or remote controlled cheap delivery platforms may make future humanitarian relief actions more flexible and more efficient in short times.