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Advanced technologies for bomb-proof cargo containers and blast containment units for the retrofitting of passenger airplanes

Reporting

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FLY-BAG2

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Final Report Summary - FLY-BAG2 (Advanced technologies for bomb-proof cargo containers and blast containment units for the retrofitting of passenger airplanes)

Executive Summary:

Aviation is constantly under threat. Terrorists have proven that they might be able to circumvent security scans both by carrying explosive devices on board themselves and by sending parcel bombs via mail or hidden in luggage. Currently available security scans are necessary, but cannot guarantee a 100% detection rate: complementary passive countermeasures are needed to protect aircraft, crew and passengers in case on board explosions.

Up to date, all efforts are focused on preventing an explosive device from getting on board, but no back-up protection exists in case pre-emptive security fails: the only way to overcome the circumvention of the active security measures by terrorists is by providing complementary passive protective measures, both for the cargo hold and passenger cabin, able to attenuate the effects of an explosion during flight in order to reduce the structural damage and maximise the chance of survival of the aircraft and of people on board.

The EU research project FLY BAG2 has developed a technology that could allow planes in the future to survive a Lockerbie-sized explosion. Made of highly resistant fabric, the simply looking FLY BAG2 comes in two variants – for cabin use and cargo holds. The FLY-BAG2 project was funded by the European Commission and ran by a consortium of institutes and specialist companies from Greece, Spain, Italy, Germany, Sweden and the Netherlands.

The idea is to protect the aircraft using a bag, a system made of textile that can be folded inside a headlocker under normal circumstances and if a suspicious device is found, it can be placed inside the FLY BAG and placed to the Least Risk Bomb Location (LRBL) – a reinforced part of the aircraft where an explosion would cause minimal damage.

While the cabin-version requires the crew to act before the explosion, the cargo hold type of the FLY BAG – coming in two versions for narrow-body and wide body aircraft, provides a ready passive countermeasure against a Lockerbie-inspired plot.

In the case of wide-body aircraft, FLY-BAG system made of multi-layered textile is fitted inside the standard aluminium containers that are used for loading luggage. The second type is suitable for narrow-body aircraft, where usually the aluminium containers are not used. So the idea is to create a bag that is installed inside the cargo hold of the narrow body aircraft and like an internal screen protects the fuselage against the blast.

Fundamental to the design of the bag is a combination of fabrics which have high strength and impact and heat resistance. The fabrics include aramid, which is used in ballistic body armour. Key to the concept is that the lining is flexible and this adds to its resilience when containing the explosive force and any fragments produced. This helps to ensure that the FLY-BAG acts as a membrane rather than as a rigid-walled container which might shatter on impact.
The FLY-BAG, which lines an aircraft's luggage hold with multiple layers of novel fabrics and composites, was tested under increasing explosive charges on disused planes at Cotswolds Airport, near Cirencester, on November 2014 and July 2015. The bomb-proof lining successfully contained blasts in a series of controlled explosions in the luggage hold of a Boeing 747 and an Airbus 321.
Using this technology, the tests have demonstrated that a plane's luggage hold may be able to contain the

force of an explosion should a device concealed within a passenger’s luggage be detonated during a flight. This would mitigate damage to the plane and help keep passengers safe. After the tests, explosives were placed in the aircraft without the lining to show the damage that could be caused.

The technology could either be something that becomes compulsory for all airlines to use if the law was changed or could be used by airlines responding to particular threats.

Project Context and Objectives:
PROJECT CONTEXT
Despite stringent security checks commercial airliners remain a favourite target of terrorists. Foiling these suicidal plots has always centred on intercepting suspicious packages and passengers within the airport before passengers board their plane. If a bomb evades security staff at this juncture then only a failure to detonate will avert disaster and mass casualties.

The dramatic event represented by the plane crash of the Russian airliner, brought down over the Sinai Peninsula on October 2015, is the latest terrorist atrocity involving commercial aircraft. At present, all efforts are focused on preventing an explosive device from getting on board, but no back-up protection exists in case pre-emptive security fails: the only way to overcome current limitations of active scanning methods is by providing complementary passive protective structures, both for the cargo hold and passenger cabin, able to attenuate the effects of an in-flight explosion and guaranteeing survival of aircraft and passengers.

The idea of reinforced air cargo containers is not entirely new: the research efforts performed in the 1990s in the USA and UK led to the development of several prototypes of reinforced containers, named Hardened Unit Load Devices (HULDs). Different HULD concepts were tested by the Federal Aviation Administration between 1997 and 1998. HULDs never gained market acceptance due to their common drawbacks, namely cost, weight, bulkiness and insufficient resistance to damage during everyday loading/unloading operations. Moreover, they were only designed for wide-body aircraft: narrow-bodies are in general not always compatible with ULDs; even when compatibility exists, airlines often prefer to load luggage in bulk due to cost and logistic problems.

Concerning the aircraft passenger compartment, aviation regulations mandates that a Least Risk Bomb Location (LRBL) be identified on each aircraft; this area represents a designated location where a bomb or other explosive device could be placed to best protect integrity of the structure and flight-critical systems from damage in the case of detonation. Some products have been proposed to provide a measure of attenuation of the explosive force in the event of detonation; these solutions, based on phase-changing materials or thick reinforced plates, are generally unacceptably bulky or are not suitable to be used in an aircraft passenger compartment.

The FLY-BAG2 research project - “Advanced technologies for bombproof cargo containers and blast containment units for the retrofitting of passenger airplanes” (Grant Agreement No. ACP7-GA-2008-213577 – Starting date: 2012-08-01 End date: 2015-09-30), co-founded by the European Commission, has developed solutions for mitigating the effects of a possible explosion of explosive devices concealed on board aircraft, an event that most of the times caused catastrophic results.

The FLY-BAG2 approach is based on the development of retrofitting solutions for the mitigation of on board explosions. Direct strengthening of the airplane structure would clearly result in thicker skins and a weight penalty; moreover, the related costs could not be justified in the majority of the commercial routes. Instead, the FLY-BAG2 blast mitigation solution has been developed to be easily implemented on existing aircraft without the need to modify their main structures.

As the name implies, FLY-BAG2 builds upon the success of a previous (2011) FP7 research project FLY-BAG, “Blastworthy textile-based luggage containers for aviation safety” ACP7-GA-2008-213577” which developed and demonstrated a blast-resistant textile-based luggage container for narrow-body passenger airplanes. The knowledge gathered in the previous project was exploited to develop new devices for both cabin and cargo environments, enlarging the experimental validation of the new concepts including full scale tests on dismissed aircraft, which were not performed in the previous FLY-BAG project.

OBJECTIVES

The improvement of the security in the aircraft was the primarily objective of FLY-BAG2, which addressed the threat of on board explosions in the cabin or in the cargo hold of passenger and cargo airplanes. FLY-BAG2 research work addressed the application of innovative and cost effective solutions, to reduce the possibility of an aircraft to suffer from an action of any kind which could compromise its security and improve survivability if the action takes place.

Direct strengthening of the airplane structure clearly result in thicker skins and a weight penalty; moreover, the related costs are not justified in the majority of the commercial routes. Instead, the FLY-BAG2 blast mitigation and retrofitting solutions were developed to be easily implemented on existing aircraft without the need to modify their main structures.

FLY-BAG2 was focused on developing two different devices for the protection of cabin and cargo compartment environments, the FLY-BAG2 cabin version and the FLY-BAG2 cargo version, both based on breakthrough high performance technical textiles and lightweight energy absorbing composite elements.

The FLY-BAG2 cabin solution was developed to address to a precise requirement set forth by aviation authorities: on October 2008, FAA in the USA issued FAR 25.795 (Design for security) for new airplane design, implemented by EASA in August 2010 with the 9th Amendment to CS 25, in particular the revised version of 25.795 stating that:

An aeroplane with a certificated passenger seating capacity of more than 60 persons or a maximum take-off weight of over 45 500 Kg (100,000 lbs) must comply with the following:
(1) Least risk bomb location (LRBL). Except for aeroplanes intended to be used solely for the transport of cargo, an aeroplane must be designed with a designated location where a bomb or other explosive device could be placed to best protect integrity of the structure and flight-critical systems from damage in the case of detonation. [...]

The FAA advisory circular 25.795-6 also foresees that:

“[...] When a suspect item is found in the cabin of an airplane in flight, measures to minimize its effect include the following: (...); minimizing the loss of integrity of the structure or systems; using explosive containment devices. [...]
“Traditionally, the LRBL was chosen where there was intrinsic structural reinforcement. However, the applicant may take other measures to meet the intent of the rule. An example would be a containment system [...]”

The LRBL regulation represents a challenge for aircraft manufacturers; a solution for containment systems specifically designed for addressing the above regulations would be extremely useful to further reduce the effects of on-board explosions. FLY-BAG developed a compact blast resistant flexible and foldable container based on a multi-layered high-performance textile structure. The opening is provided by a high-strength zip closure. The container is flexible and foldable, in order to be easily stored in a small volume (for instance in an overhead locker) when not in use.

The FLY-BAG2 cargo solution was conceived to tackle the menace posed by explosive devices concealed in cargo shipments. It was based on developing a ULD-like device, sharing all geometrical dimensions with currently used standard ULDs, in order to ensure maximum compatibility and reusability. A robust but lightweight composite floor is used to accommodate shipped goods, while a multi-layered textile cover hanging on a lightweight frame tubular structure is used for the external walls, instead of aluminium of the standard ULD, yielding blast protection. As for the cabin version, the closure of the bag is performed through a high resistant zip, which allows a quick and easy opening and closing of the ULD and, at the same time, blast resistant and gas tightness. An important objective was the development of blast resistant design, characterised by same dimensions and freight volume as a standard ULD, with also similar weight and price to the customer. In particular, LD3 AKE and PMC/P6P pallet were the reference standards for the FLY-BAG2 wide-body cargo solutions, as it is the most widely used for luggage. Thus, the containers developed within the project were “AKE compatible” and “PMC compatible” as far as dimensions and handling are concerned; AKE and PMC/P6P current products were used as a benchmark for the container’s cost and weight.

More in details, the following objectives were fully achieved at the end of the Project:
1. development of solutions for the effective protection of wide body aircraft: we already demonstrated in the previous FLY-BAG project that the textile-based technology, for the protection of narrow body aircraft, can be effectively applied also for solutions tailored for wide body aircraft. The approach followed in FLY-BAG2 was based on the development of blast-proof Unit Load Devices (ULDs), able to offer both the standard function of providing safe and airworthy transport of cargo and baggage on containerized aircraft and the fire and blast resistant function;
2. development of solutions addressing the Least Risk Bomb Location (LRBL), common to both narrow-body and wide body aircraft;
3. development of blast-resistant solutions characterized by low-weight, low-cost and ready to be installed on board of aircraft, without any long certification process;
4. validation of the FLY-BAG2 blast-mitigation capabilities, through full scale blast tests on dismissed aircraft: it was within the objective of FLY-BAG2 to perform blast tests on dismissed aircraft, with and without blast mitigation technologies, in order to proof their effective performance and the effects of the (mitigated) blast on the surrounding structures. The availability of such test results allowed the validation of

the numerical methods, developed in the Project, and brought a insight knowledge about materials performance in such extreme conditions.

Summarising, the main objective of FLY-BAG2 project is to provide passive security measures for the mitigation and containment of on board blast and for the cost effective retrofitting of aircraft travelling on critical routes. FLY-BAG2 solutions have been developed to achieve the highest degree of protection to aircraft and passengers by counteracting threats posed by both explosive devices smuggled inside the passenger cabin and by bombs concealed inside ULD, thanks to flexible and lightweight textile-based materials, lightweight composites and high resistant zip closures.

Project Results:
The Scientific & Technological (S&T) results achieved during the FLY-BAG Project are following summarized:

1. CABIN DEVICE: blast mitigation envelope for containment of suspected explosive devices found in a cabin of an aircraft during flight, addressing the Least Risk Bomb Location (LRBL) directive;
2. AKE VERSION (ULD) – FLY-BAG2 blast mitigation kit for standard air container ULD (type LD3 AKE and similar) to be installed inside an existing ULD container in order to make it blast resistant, without modification to the structural characteristics of the ULD itself;
3. PMC PALLET VERSION (ULD): blast mitigation unit for standard PMC/P6P pallet (ULD) used to load luggage, freight and mail on wide body aircraft, without modification to the structural characteristics of the PMC/P6P pallet (ULD). The unit can be tied down with a standard pallet net, just as any other standard palletized cargo;
4. CARGO HOLD LINER FOR NARROW BODY AIRCRAFT: development of a textile-based, lightweight, and blast resistant cargo hold liner, for the protection of narrow-body aircraft (A320 family);
5. COMPOSITE FRAME FOR AKE AND PMC PALLET KIT (ULDs): development of a composite lightweight frame for FLY-BAG2 AKE and PMC pallet kit, to support the textile blast resistant bag;
6. COMPOSITE FLOOR AND SIDE SANDWICH PANELS: development of composite lightweight panels for FLY-BAG2 cargo hold device (for AKE and cargo hold liner version), to enhance shrapnel mitigation of more vulnerable locations within the cargo hold;
7. BLAST RESISTANT ZIP CLOSURE: development of a high strength zip, to be used in the cargo and cabin blast containment unit, characterized by easiness of use, high strength and possibility to control venting through the zip teeth;
8. FIRE-RESISTANT ABRASION-RESISTANT, AND GAS-TIGHT COATED TEXTILES AND COATING APPLICATION METHOD; knowledge of suited coating formulations and their application on high strength materials as well as for the selection of commercially available additives;
9. AKE VERSION (ULD) - EXTRA-LIGHT ULD CONSTRUCTION: certified AKE version according to Aviation Authorities requirement made with new extra light materials for bottom, walls and profiles;
10. BLAST MITIGATION COMPOSITE HARDENED SIDE PANELS (AS REINFORCEMENT OF THE LRBL): a hardened composite panel to replace the conventional interior cabin liner. It is meant to provide protection to the airframe in case the cabin FLYBAG2 fails to contain the blast from an Improvised Explosive Device (IED). The panel concept could replace the whole cabin liner and provide blast and potentially fire protection to the whole structure;
11. MATERIAL NUMERICAL MODELS AND BLAST SIMULATION METHODS: textile and composite

materials numerical models validated by means of the experimental tests carried out. Numerical methodology, implemented in simulation tools, to model the explosion phenomenon. The methodology was validated on the basis of the blast tests;
12. MANUFACTURING METHODS OF FABRIC ENVELOPE: development and set-up of methods for manufacturing in a suitable and cost effective way the blast resistant multi-layered envelopes for the FLY-BAG2 blast containment units;
13. BLAST TEST RESULTS: knowledge related to the blast resistance of the components of the construction (fabrics, zip) and the assembly;
14. IMPACT TEST METHODOLOGY AND TESTS RESULTS: an experimental methodology for the analysis of the impact behaviour of textile and composite materials was developed within the Project;
15. DYNAMIC TEST RESULTS ON FABRICS: availability of results of experimental tests during high-speed mechanical tests carried out for establishing the dynamic behaviour of fabrics used for developing the FLY-BAG2 blast resistance fabric envelope;
16. FIRE TEST RESULTS: experiences in different test procedures and evaluations referring also to automotive and aviation standardisation for selected and investigated high strength materials;
17. LEAST RISK BLAST LOCATION PROCEDURES: development of specific procedures for cabin and flight crew members adapted to use of the FLY-BAG2 container;
18. CERTIFICATION OF FLY-BAG2 CARGO HOLD LINER FOR NARROW BODY AIRCRAFT: approval of FLY-BAG2 cargo hold liner installation for A320 aircraft family.

CABIN DEVICE
One of the most important S&T project result has been the development of an innovative envelope for containment of suspected explosive devices found in a cabin of an aircraft during flight, addressing the LRBL directive.

In the milliseconds immediately following the explosion, a strong impulse load ("shock holing") of high intensity, highly localized and of short duration is generated and is transmitted to the structures in contact with the charge. In the milliseconds following the explosion, the expansion of gases generates a pressure wave that expands substantially uniformly distributed, as a sphere.
The passage of the pressure wave through the air, it causes the compression and imparts an acceleration to the particles of air in a radial direction, with respect to the point of detonation. The arrival of the shock wave corresponds to a peak value of pressure (overpressure), which decreases exponentially until it reaches again the value of the atmospheric pressure.

If the explosion occurs in a closed volume, as a container, a second effect is added to the first one: this is due by the multiple reflections of the pressure wave on the walls of the container. The queues of each peak are added together, giving an effect of accumulation of total pressure, higher than the ambient pressure and known as quasi-static (Quasi static pressure, QSP), which can last several seconds. The maximum pressure associated with this second phase is usually much less than that associated with the impulse, but given its long duration can also cause extensive damage.

FLY-BAG2 cabin device is intended to be used in a situation when an explosive object or device, for example found on board an aircraft, during the flight, has to be isolated as soon as possible. First of all, it is important to highlight that the device has been designed and manufactured such to be placed at an area called as “Least Risk Bomb Location” (LRBL) such to limit the effects generated by the explosion (if any) and such to contain the fragments of the device projected by the explosion, in the best possible manner.

Substantially the blast mitigation device is composed by the following components:
1. an inner bag suitable to contain the bomb threat, entirely made of textile;
2. an outer bag, entirely made of textile;
3. zips for closing the open ends of both the containers or bags;
4. longitudinal straps, similar to the safety belts currently used in the aeronautical field.

The two bags are two textile cylinders that in the assembled condition are placed concentrically, one inside the other one, with the open mouths facing the same side.
The two bags have been designed to have the smallest possible number of structural seams. The inner and the outer bag can be made in a similar manner, only having different dimensions or, preferably, the inner bag can have a different textile structure than the outer one.

From the blast tests conducted in FLY-BAG2 project, it has been found that the use of a gas permeable material is optimal. The gas permeability of the chamber inside the bag is able to discharge a part of the power and amplitude of the shock wave (initial pressure peak) before reaching the first breaking of the inner bag.
The outer bag, has a higher diameter and volume capacity, therefore is stressed (in case of an explosion) with a time delay to follow the peak of the explosive energy.

In an alternative configuration, in order to mitigate the “shock-holing” phenomenon (that can cause the device to be perforated in the point where the explosive is placed) a third component called ‘shield’ can be added, in addition to the two inner bag and outer bag. Such shield, as the inner and outer bag, has a flexible tubular shape and can be made of the same material used for the other components. The ‘shield’ is made in a manner similar to what described above, with the difference that it has no zipper or zip fastener.

Concerning the material, the inner bag is composed by a multi-layered fabric made of para-aramid fabric. It has still to be noted that the material is flame-resistant, both by its inherent characteristic and also by means of a flame-resistant coating that may be applied later. Concerning the outer bag, the material can be the same of the inner bag (para-aramid); however, an alternative can be the use of HM-PP (“High Modulus Polypropylene”).

From the blast tests conducted in the Project, it results that the overpressure peak is the one that risks to cause the most dangerous damages to the aircraft. Therefore, the technical characteristics of this blast containment system, even if allowing the exploded gas to escape from the device, slow down the escape, therefore limiting the intensity of the pressure wave deriving from explosion.

The blast mitigation device can be folded and stored in a storage compartment, inside the aircraft approved to be fire resistant according to aviation rules. To this end, deformability and the lightweight are important characteristics of the device.

The main characteristics of the cabin device are following summarized:
1. innovative product not available in the market up to now;

2. lightweight;
3. flexible;
4. relatively cheap;
5. when not used it is folded and kept in an overhead locker; this way it is not wasting space on-board and it does not scare passengers;
6. despite competitors exist, none of these products has up to now met market success from airlines.

Multiple reasons can be identified for the scarce diffusion of such anti-bomb protection devices: all of them share the same disadvantages, as they are in general heavy, bulky and moreover expensive. In addition, their potential impact on passengers must be considered: flying is more psychologically demanding then most other transportation means and the explicit presence of a blast disposal container on board can give rise to panic.

The cabin bag is being protected. An Italian patent was applied. The patent title is: "Dispositivo di attenuazione di uno scoppio e relativo metodo di fabbricazione" and was applied on September 29, 2014 (Ref. No. I0 50842, IT MI2014A001695 – International Patent Classification IPC: INV. F42D5/045 B65D90/32). The applicant is D'Appolonia S.p.A.

The patent was evaluated positively with regard to novelty, inventive step and industrial applicability. The partners decided to extend the Italian patent as a Patent Cooperation Treaty (PTC). The international patent "Blast mitigation device and manufacturing method thereof" was filed by D'Appolonia on September 28, 2015 (PTC/EP2015/001914).

AKE VERSION (ULD) – FLY-BAG2 BLAST MITIGATION KIT FOR ULD

Another important project result is the development of a mitigation system for different geometries of ULDs, able to contain the effects of explosion in the cargo area in case of charge concealed in the luggage.

The idea was to develop a blast mitigation kit for standard ULDs (LD3 AKE and similar). The FLY-BAG2 kit can be installed inside any existing ULD container. The installation of the FLY-BAG2 kit is done without any modification of the ULD, in order not to endanger the certification of the ULD. The kit does not have any physical connection to the ULD itself. The textile structure is sustained by an internal lightweight composite frame. A composite sandwich floor is added inside the structure. The FLY-BAG2 kit has basically the inner dimensions of the AKE and is provided by a zip, for loading and unloading luggage operations.

With exception of the zip closure, a seamless design was developed for the textile blast mitigation kit; based on the data measured during the project, this leads to maximum strength for the high tenacity fabrics chosen for the prototype. The teeth of the zip are directly mounted on the multilayer fabric. Such a seamless construction can be obtained by using a customized manufacturing process, developed for FLY-BAG2 production.

The kit makes blast resistant a standard ULD. The price/weight ratio is competitive against hardened ULD. Patent has been granted covering the main European countries.

PMC PALLET VERSION (ULD)

This project result consists in the development of a version of FLY-BAG suitable for PMC/P6P cargo ULD, to make the ULD blast resistant. The solution could be combined with a fire barrier concept which is currently being commercialized for the transportation of Lithium batteries.

The design of the FLY-BAG for PMC/P6P pallet started analysing the standard procedures used for loading the Euro-pallet on the PMC/P6P cargo pallet. In this case, the FLY-BAG device is composed by the following elements:
1. a FLY-BAG ‘base’ (called also ‘bottom assy’), similar to that used for thermal covers. The base can be fully opened and connected to the lateral sides of the FLY-BAG cover;
2. a FLY-BAG ‘cover’, similar to that used for thermal covers. The ‘cover’ can be fully opened thanks to the use of four vertical zips placed on the lateral sides;
3. Latitudinal straps at the bottom, all around the textile, to tighten the top to the base;
4. a ‘stabilizer rack’, to avoid collapse of the structure.

On the market, no solutions are available to make a PMC pallet blast proof. Patent has been granted covering the main European countries.

CARGO HOLD LINER FOR NARROW BODY AIRCRAFT
This project result is very similar to the precious one, with the difference that is a blast mitigation envelope tailored for the cargo holds of narrow body aircraft. The innovative potential of this concept stays in the possibility to protect against on board explosions the cargo area of narrow body aircraft, where no hardened ULD could be used.

FLY-BAG cargo hold liner device is based on full containment of the Quasi-Static Pressure (QSP), generated by the blast by deformation of the flexible composite layers making the container. Local reinforcement to withstand shock loading at floor and critical interfaces is achieved using rigid composite materials. The access is allowed by an innovative use of zip system which is designed to withstand the quasi-static pressure generated by the blast. The zip system also provides an easy opening and closing of the container during loading and unloading operations at the airport. In case non-hazardous goods bigger than the container itself have to be loaded inside the cargo hold of the plane, the container itself is designed to be foldable allowing to be easily removed and stored.

FLY-BAG2 blast containment unit has been developed to be installed inside a narrow body aircraft, namely the Airbus A320 family.

The FLY-BAG2 system foresees the same routine of operations as bulk loading, with the difference that luggage is loaded inside the container, which is already mounted in the hold. The only additional step required is opening the FLY-BAG2 container to load luggage in it. All equipment remains the same, with of course the addition of the FLY-BAG2.

Patent has been granted covering the main European countries.

COMPOSITE FRAME FOR AKE AND PMC PALLET KIT (ULD):
The composite frame for the AKE pallet is a lightweight structure to keep the FLY-BAG2 cargo unit used for wide body aircraft (both AKE container and PMC pallet) in its intended shape. The frame is one

component of the full AKE and PMC pallet unit containment unit.

COMPOSITE FLOOR AND SIDE SANDWICH PANELS

Composite panels designed for protection from explosion exist, but they are usually developed to offer protection from debris ejected by a distant detonation in free air: in that case, the shockwave can expand in a free volume far from the panels, and only a minimal fraction of it impacts directly on the panel.

Sandwich panels have stiff outer skins, coupled to a lightweight core which can be made crushable for energy absorption. Glass or aramid are the materials of choice for skins in high performance panels, while for the core various possibilities were investigated.

The composite panels are used for the floor of AKE and cargo hold liner units. Such panels are characterized by a structure which is designed to withstand the shock holing forces generated by the blast event and to distribute such impulse onto the internal surface of the textile container over a larger area. The composite panels cover entirely the floor of the internal surface of the textile container and the lateral walls, where required, to provide additional protection to rear critical structures. The composite lateral elements were designed to be foldable to allow the entire container to be quickly unfolded and removed.

The innovation is the composition of how many layers and how to space them together, alongside with what materials to use in the composite floor to make it resistant against the blast along with having it as lightweight as possible. The floor is a crucial part of the whole FLY-BAG2 cargo unit to protect the airframe from damage in case of a blast scenario.

The floor and the sloping side panels consists of only one piec,e avoiding weak point in the intersection among the panels. The floor is made by a foldable corner of the same materials as the rest of the floor. Special hinges were developed for this purpose.

BLAST RESISTANT ZIP CLOSURE

The connection between two fabrics forms a discontinuity in the textile surface; this is potentially a weak point in a blast resistant application: in order to avoid this, the connection must possess at least the same tensile strength as the weaker adjoining fabric. A zip is the most immediate and easiest way to connect two pieces of fabric: high strength zips exist having resistance to lateral pull high enough to be considered as a practical closure for FLYBAG2.

Zip closure was chosen, both for cargo and cabin applications. The choice was guided by three characteristics:

1. easiness of use;
2. existence of high-resistant zips;
3. possibility of controlled venting through the zip teeth.

Zips comprise two basic tapes each one carrying mutual engaging teeth and at least one slider that moves the teeth of the first and second zipper in a mutual engagement or disengagement condition; zippers then comprise also stops that join the zippers at their end portions and prevent the slider from coming off the zipper.

Preferably the teeth of the zipper are produced by pressure die casting of high-modulus thermoplastic resin. An example of a particularly useful thermoplastic resin is POM (Polyoxymethylene); POM is a plastic material high a high stability, stiffness and temperature resistant.
The tensile strength of each individual tooth of the zipper or zip fastener is further optimized by a self-tapping screw that passes through it at the center engaging also, contemporaneously, the tape.
Such screw clamps the tooth body around the tape such to avoid breaking it when a strong tensile force is applied. Preferably glass fiber reinforced nylon is used for the sliders. Preferably, for the tape, a fabric made of aramid for the weft and polyester for the warp is used. Preferably for the stops at both the ends aluminium alloys are used.

FIRE-RESISTANT ABRASION-RESISTANT, AND GAS-TIGHT COATED TEXTILES AND COATING APPLICATION METHOD
Special coating compounds were developed within FLY-BAG2 Project increasing fire-resistant, abrasion-resistant, and gas-tight effects without losing the high-strength properties of the material.

The multilayer textile structure can be coated by a coating layer with a thickness of 0.05 to 0.5 millimetres of polyurethane or silicone or natural rubber mixtures or polytetrafluorethylen, or ethylen-tetrafluorethylen, which transforms the internal textile layer into a flexible composite system with absolutely gastight properties of the textile multilayer so that the tensile strength in this system is provided by the flexible interaction of high strength fibres and the gas tight coating.

AKE VERSION (ULD) - EXTRA-LIGHT ULD CONSTRUCTION
Lightweight ULD construction using plastic sheets instead than aluminium were developed within the Project, as lateral closing element of the ULD box, with substantial weight saving compared to standard aluminium ULDs.

Similar products are already on the market, but the possibility to combine it with the FLY-BAG kit could result difficult to be proposed by competitors.
BLAST MITIGATION COMPOSITE HARDENED SIDE PANELS (AS REINFORCEMENT OF THE LRBL)
Additional strengthening elements were developed for protecting the Least Risk Bomb Location inside the airplane. A local strengthening of the airplane structure is somewhat feasible since it would be very localized. This reinforcement could be used in combination with the FLY-BAG2 cabin device.

The cabin bag device has to be hanged from four attaching points inside the generic galley area. When the blast event is foreseen, the area has to be closed by the reinforced sandwich panels.

The panels are proof tested and optimized in terms of weight and performance. The cost could be the same of the competitor products.

MATERIAL NUMERICAL MODELS AND BLAST SIMULATION METHODS
A reliable numerical methodology, implemented in simulation tools, was developed to model the explosion phenomenon. The methodology was fully validated on the basis of the wide testing campaign conducted during the Project. Numerical simulations of the blast mitigation and shock propagation phenomena, as well as the assessment of the expected damage to the surrounding aircraft structure were developed. The

computations involved the use of codes specific for highly dynamic simulations based on explicit time integration able to model the large deformation dynamic response of the system in the milliseconds of duration of the blast event.

Numerical models of the main materials (fabrics, composites, zip,…) were developed, to be used for the full scale numerical simulations of the explosion event inside the aircraft fuselage. The numerical models were calibrated on the basis of the wide testing campaign conducted during the Project (e.g. dynamic tensile test, impact drop test, high velocity impact air-gun test).

Two simulation tools were used for setting up the FLY-BAG2 numerical methodology: LS-DYNA and ABAQUS. The first was used to develop the numerical models of the textiles and the composite materials of the mitigation devices (mainly the FLY-BAG2 cargo and cabin versions). The latter was used to model the explosion event inside the Least Risk Bomb Location (LRBL) area, with the final aim to refurbish the surrounding structures (composite panels) of that area, to better resist to the blast event. All the main material models implemented in the simulation tools were developed and validated.

The numerical simulations have been fundamental to explore all possible mitigation devices, saving time and increasing the competitiveness. The experimental tests have played a key role in the project for the verification and the reliability of the numerical results.

The material numerical models and blast simulation methods developed in FLY-BAG2 have supported correctly the final design of the mitigation systems and can support any other future improvement and analyse the effects of the different parameters of configurations, such as the pressurization inside the aircraft.

MANUFACTURING METHODS OF FABRIC ENVELOPE

The manufacturing methods of confectioning the fabric envelope for both the cabin and cargo units are another important result of the Project. The approach was based in developing manufacturing methods able to limit as much as possible the weakest points of the blast resistant envelope, represented by the seams.

As far as the FLY-BAG2 cabin device is concerned, both the inner and outer bags are composed of a single piece of fabric made of a para-aramid textile which is wound, starting from a fixed edge, on itself for a given number of times till obtaining the desired number of layers. The two free edges of the piece of fabric, are then connected by means of a series of seams. The tearing strength provided by the seams is considerably lower than that of the material of the several layers. The main function of seams is to keep the several layers in place, making all of them working together, thus maximizing the performances and avoiding creating folds or flaps that can be an obstacle during the operation using the device or that can limit its efficacy. The inner and outer bags have both one openable mouth and a blind bottom; during the manufacturing process, this latter is flattened and extensively kept fastened by a series of seams which are transversal to the body and parallel with each other, with a zig-zag and crossed pattern.

The manufacturing process for the FLY-BAG2 cargo hold liner (narrow body aircraft) comprises the following steps:

1. cutting at least three single layers of the multilayer textile structure for the three parts (front, back and middle part);
2. cutting the opening for the zip into the front part into at least three single layers;
3. placing and pre-fixing the number of textile layers in the predetermined sequence whereof at least one layer is placed as an intermediate layer;
4. sewing and/or gluing the zip covering pads for the zip onto the front part of the container covering the full length of the zip;
5. sewing the zip into the front part;
6. sewing the textile belt holders onto the front part, back part, and the middle part;
7. sewing at least four hanging loops onto the outside of the front part and/or the back part whereby the hanging loops are equipped with hooks and/or single studs for later installation of the container into the aircraft;
8. sewing the back part and the middle part together and/or glue the seam;
9. sewing the front part onto the other side of the middle part together and/or glue the seam;
10. spray the whole textile container by using a coating in this way that the sprayed coating is inside the container;
11. attach the loose horizontal air cargo straps and/or air cargo tie down net which are equipped with air cargo karabiner hooks at the outside of the container by using the belt holders.

The manufacturing method for the FLY-BAG2 AKE-device is similar to that above described.

BLAST TEST RESULTS

A wide full scale blast testing was performed for the validation of FLY--BAG2 systems. The demonstration showed that the structure can withstand the blast effects from a bomb of a certain size and configuration, chosen to represent a realistic and potentially lethal threat to the aircraft and passengers survival. Tests included verification that: (1) the textile structures can withstand the explosive blast with no major rupture of the external layer; (2) that no fragments penetrate the textile structure with a sufficient speed as to cause structural damage to the aircraft structure and injury passengers; (3) that no fire had erupted after the blast; (4) no critical damages and no serious injuries are suffered by aircraft and passengers.

Several blast test series were conducted on full FLY-BAG cabin and cargo variants. These included open-air tests at the BLASTECH blast laboratory, and two series of tests on decommissioned aircraft.

Six preliminary explosive detonation tests conducted on prototypes of the FLY-BAG cabin variant. Four preliminary tests were conducted at the BLASTECH blast research laboratory, Buxton, UK. Two tests were conducted inside a decommissioned Boeing 747 aircraft at the premises of Air Salvage International, Cotswold Airport, Gloucestershire, UK. In the first test series in November 2014, results show that the FLY-BAG cabin variant prototypes are capable of containing the effects of the detonation of an explosive charge of mass [CONFIDENTIAL], without the failure of the outer envelopes of the protection system, or significant egress of blast pressure. Tests conducted inside the aircraft indicate that the detonation of an explosive charge of mass up to at least [CONFIDENTIAL], can be contained by the FLY-BAG cabin variant prototypes placed over passenger seats, with only localised and non-structural damage to seat-back tray tables and arm rests.

Further tests were conducted on a standard cabin variant and a compact cabin variant. A secondary aim of the testing was to assess the performance of some ‘hardening’ composite panels within the confines of a mock-up galley.

Three explosive detonation full-scale blast tests conducted on prototypes of the FLY-BAG2 cabin variant in the July 2015 test series. All three tests were conducted inside a decommissioned Boeing 747 aircraft at the premises of Air Salvage International, Cotswold Airport, Gloucestershire, UK. Results show that the FLY-BAG cabin variant was able to contain the effects of the detonation of an explosive charge of mass [CONFIDENTIAL].

Following successful initial open-air blast tests on FLY-BAG AKE prototypes at the BLASTECH blast laboratory, three tests were conducted on FLY-BAG prototypes within aluminium AKE containers in the first test series on aircraft in November 2014. The tests were conducted in the forward luggage hold of a decommissioned Boeing 747 aircraft. Results show that the FLY-BAG prototypes are capable of containing the effects of the detonation of an explosive charge of mass [CONFIDENTIAL], with nothing more than minor, non-structural damage to the aircraft, no significant, measurable egress of blast pressure in the hold and no significant impact loading transmitted into the passenger compartment immediately above the location of the detonation.

Five further tests conducted on FLY-BAG cargo hold prototypes in the second series of aircraft tests at ASI, Cotswold Airport in July 2015. Two of these were designed to be used in the cargo hold of a wide bodied aircraft and so were tested within a typical AKE container, and three of which were designed to be used in the cargo hold of a narrow bodied aircraft and so were tested as a free standing bag. The wide bodied tests were performed in the forward luggage hold of a decommissioned Boeing 747 aircraft, and the narrow bodied tests were performed in the luggage hold of a decommissioned Airbus A321.

The wide bodied prototype/AKE system is capable of surviving a charge of magnitude [CONFIDENTIAL] with negligible damage to the AKE, no damage to the structural airframe and minor damage to the cabin and hold floor structure.

A final series of open-air tests was conducted at the BLASTECH blast laboratory on wide bodied cargo variants (AKE), a narrow bodied cargo variant (A320) and a palletised cargo variant (PMC). The testing has shown that the FLY-BAG within an AKE can potentially withstand the largest threat at [CONFIDENTIAL]. Despite some failure of the AKE panels, no fragments were thrown from the structure, with the FLY-BAG itself remaining essentially intact. The PMC pallet variant passed a blast test at a charge of mass [CONFIDENTIAL].

The results of the full-scale blast tests were used to support the certification of the FLY-BAG2 solutions and open the way to extend the application of this technology to civil aviation.

IMPACT TEST METHODOLOGY AND TESTS RESULTS

An experimental methodology was developed for the analysis of the impact behaviour of textile and composite materials.

An important characteristic of the textile structure is the capability, for trapping accelerated luggage fragments during a blast event. “Fractovis” impact tester was used to investigate the FLY-BAG2 multi-layered textile structure. Moreover, a custom clamping system was realized to reduce the sliding of the textiles during the dart impact. The comparison of all the tests results on different fabrics allowed selecting the best performing configuration: Innegra and Twaron woven fabric. The calibration of the numerical models was focused on these experimental data (curves force - time of the impact).

Impact drop tests were carried out on composite panels, to investigate the impact response of different sandwich panel configurations. An airgun equipment was set up for performing the ballistic tests on composites. The results obtained were in agreement with drop tower tests. The airgun set-up was suitable for the study of damage development and the classification of different materials only for samples of lower thickness (composite skin without core).

DYNAMIC TEST RESULTS ON FABRICS

The dynamic testing campaign on fabrics was focused on analysing the tensile behaviour of FLY-BAG2 materials (fabrics, zip) when subject to strain rates in the region of those expected during an explosive event, including an investigation into the performance of seams, with the intention of providing stress strain relationships to be used during numerical modelling of FLY-BAG2 materials.
A new dynamic tensile test rig was designed and commissioned for testing fabrics and fabric/zip samples.

Measurement of the stress transmitted by samples of FLY-BAG2 materials were carried out for a given strain, when subject to varied strain rates, eventually increasing to those expected during an explosive event. Samples were also be subject to varying severities of shock loading achieved by adjusting the amount of initial slack in the system during each shot. Performance of seams was also investigated.

FIRE TEST RESULTS

Fire test and burning behaviour protocols were defined for all investigated FLY-BAG2 materials, according to the test standard “Burning behaviour – DIN 4102, B2” and “Burning behaviour – DIN 75200”. Flame tests were carried out in order to investigate the behaviour of the materials with respect to the fire, with the evaluation of the rate of burning and/or extent and time of burning, and the surface flammability of the materials. The test gave information on the fire spread and its speed (burn-length and after flame time). Burning or hot drippings can cause new fire sources and must therefore be avoided. The after-glow time is an indicator for the thermal insulation of the layer, e.g. how the heat is transmitted to a nearby layer.

LEAST RISK BLAST LOCATION PROCEDURES

Generally, a bomb placed near the outer skin of the aircraft will, most probably, blow a hole in the skin and cause explosive decompression: although damaged, an aircraft may be able to make an emergency landing under these conditions, provided that the fuselage structure still holds together.
However, in cases where the bomb is placed in a position not adjacent to the outer skin (or when a larger explosive amount is employed) severe, often fatal, damage can be caused if overpressure is allowed to build up in the cabin volume, leading to extensive disruption of the fuselage. For these reasons, emergency procedures identified by aviation authorities are devised in order to minimise overpressure build-up and allow venting towards the outside.
In particular, the “Least Risk Bomb Location” (LRBL) regulation mandated by EASA and FAA foresees the

deployment of the suspicious object in direct contact with a fuselage wall in a least-risk position, usually one of the aft doors to facilitate venting. This treatment is designed to attenuate the explosive shock wave inwardly and to direct the major explosive force outwardly, letting it rip the door open and thus allow venting.
This procedure suffers some clear drawbacks: in particular, cabin crew is exposed to unnecessary risks while performing the long and complex procedure. Moreover, passengers, crew and the aircraft itself are exposed to an unacceptably high threat from detonation in case of explosion.

FLY-BAG cabin version offers the chance to modify the LRBL procedure and to reduce the impact to an airline in case of the occurrence of a critical situation: in fact, the cabin device can be considered as loose equipment to be stowed for example in overhead bins and no certification is needed for this item. No impact on Certification Specification CS 25.795 “Security Considerations” has to be considered due to the fact that LRBL is a design aspect already defined by aircraft manufacturer (Type Certificate Holder), combining parameters from different panels (structures, cabin safety, ECS Environmental Control Systems (ECS)), that can be eventually improved, but not modified by this loose equipment. Furthermore AFM Aircraft Flight Manual (AFM) Emergency Procedures provisions for flight crew in case of bomb on board can be considered not influenced by FLY-BAG installation, even if is able to drastically reduce the impact of an on board explosion.

CERTIFICATION OF FLY-BAG2 CARGO HOLD LINER FOR NARROW BODY AIRCRAFT
Meridiana Maintenance Design Organization finalized the installation approval of FLY-BAG2 inside FWD and/or AFT Cargo compartment of Airbus A320 Series Family Aircraft on which Cargo Loading System and Auxiliary Fuel Tanks are not installed.
To guarantee the installation, a dedicated assessment on the materials used for the FLY-BAG2 construction, as per JAR25.603 requirements, together with flammability tests, to verify flammability compliance, was performed.
Approval of FLY-BAG2 Installation Service Bulletin package has been granted through Chance approval Certificate nr. MM_CAC15F25S-0051 R00 issued by Meridiana Maintenance on September 30, 2015.

Potential Impact:
POTENTIAL IMPACT
On October 2015, a “terrorist act” brought down a Russian Metrojet airliner in Egypt’s Sinai Peninsula, killing all 224 passengers on board the flight to St. Petersburg. The Airbus A321 was downed by a homemade bomb carrying the explosive equivalent of up to one kilogram of TNT. This dramatic event is the latest terrorist atrocity involving commercial aircraft. Several plane crashes have been caused by terrorist attacks since the period between the early 1980s and the mid-1990s, when at least seven jetliners were brought down world-wide by explosive devices and a handful of others suffered damage and some passenger fatalities.

Within this framework, FLY-BAG2 has a key role to improve the security of flights from terroristic attacks, having developed advanced blast containment units to be used on board of the aircraft. The FLY-BAG2 containment units do not aim at substituting security checks, but rather to act as a complementary further step for passengers and cabin crew security.

The FLY-BAG2 paradigm is based on acting as a (currently lacking) complementary passive measure with respect to active security scans: in this way, it is possible to ensure a double layer of protection, effectively contributing to minimising the hazard of hostile on board actions against aircraft. Moreover, in case an attack is carried out, the proposed blast-resistant elements will effectively protect the aircraft and contribute to improve survivability in case of hostile actions.

FLY-BAG2 has a crucial impact not only in preventing catastrophic in-flight failure in a critical blast scenario likely to result in hull loss, but also in attenuating the consequences of smaller blasts, which may not cause the airframe to collapse but would almost certainly injure and possibly kill passengers and crew members with hurled explosion fragments.

The FLY-BAG2 cabin and cargo solutions, thanks of the use of advanced textile, composites and zip technology, have been designed to be lightweight, foldable, compact and compatible with aeronautic procedures and constraints: FLY-BAG2 cargo hold liner, tailored for narrow-body aircraft, was certified for installation on A320 family aircraft; the other FLY-BAG2 devices have been designed to be installed without any structural aircraft modifications, in other words, without the need of new certification. This is mandatory to facilitate prompt implementation by airline end-users, as demonstrated by the failure of technically valid but hardly implementable products as Hardened Unit Load Devices (HULDs) in the past. This will enable implementation of the FLY-BAG2 range of products in the immediate future after the end of the research project, allowing the establishment of more secure European aviation.

In order to maximise the benefit for the European aviation safety, the FLY-BAG2 team developed cost-effective products. This will allow a capillary penetration of the market, which, in turn, will enable the achievement of effective blast protection for the greatest number of passengers: a great benefit at the price of a small investment. On the basis of a detailed market analysis carried out during the project, it is expected that the initial potential market volume for the FLY-BAG2 cabin version products is of about 9 MEuro; for the other FLY-BAG2 cargo products, such as the cargo hold liner, AKE version and PMC pallet version, the potential market size could be of 50 MEuro, 45 MEuro and 17 MEuro respectively. It is important to highlight that these possible market values could notably increase if there will be a change in actual normative related to Homeland Security that forces the airline companies to adopt for each aircraft specific anti-blasting devices.

The project is likely to result also in a contribution to the setting of new standards and norms: the availability of an effective device as FLY-BAG2 on the market could in the future lead to a tighter definition of LRBL, making it mandatory for airlines to carry a blast containment device on board, resulting in higher security standards. This possibility has been actively pursued by the project, by contacting European regulatory bodies.

FLY-BAG2 has been tailored to satisfy the needs of the aviation sectors, nevertheless, with some modifications, the FLY-BAG2 concept is easily adaptable to any scenario were a relatively small amount of explosive can cause an extensive damage. The first and most important field of application could be in fast moving means of transport as trains, underground metros or ships. These means all share with airplanes the same crucial characteristic of being crowded by people and vulnerable to localised blasts, as victims are killed either directly by the blast or – more frequently – indirectly by the vehicle crashing. The

applicability of the FLY-BAG2 concept to railway applications would be straightforward.
A large secondary market service is represented by all security-sensitive places as government buildings, tribunals or airports: every time a suspicious-looking box or suitcase is found the building has to be evacuated while waiting for the bomb disposal squad to secure the area. A FLY-BAG2 device would in these cases help minimising the risk of an explosion in the lapse of time between bomb discovery and bomb disposal squad arrival.
Similarly, other possible huge secondary markets include all scenarios in which a great crowd of people is gathered in a relatively small space: these include stations, airports, concert venues, meeting places, shopping malls and public squares. A common way in which terrorist organisations act is by hiding their explosive devices in garbage bins in crowded areas: a bin with a FLY-BAG2 reinforced liner could mitigate the risk of attacks in public places.
Lastly, a natural extension of the anti-blast device designed within FLY-BAG2 is related to the equipment of law enforcement agents: the all-textile, bag-like structure will be easy to carry and store for instance in police cars or fire brigade trucks, in order to be readily available in case of emergency and to enable the agents setting up a first level of protection while waiting for the bomb disposal squad.

DISSEMINATION ACTIVITIES
Great care was taken since the beginning of the Project in ensuring effective communication of project concept and results to the public opinion and concerned stakeholders.

The official Project website was created at the very beginning of the Project (www.fly-bag2.eu) and was used for the daily communication among partners, as generator of public awareness for the approach followed, and the (publishable) results achieved, and as a repository for the knowledge generated.

Project partners participated to several regional, national and international workshops, conferences and events in Europe, US and Asia: AIRET Workshop (Rimini, Italy, September 2013), ULD Care Meeting (Vancouver, Canada, May 2013), Techtextil 2013 (Frankfurt, Germany, 2013), EASN Workshop (Milan, Italy, October 2013), Interairport (Munich, Germany, October 2013), Transport Security Expo TRANSEC 2014 (London, UK, December 2014), Berlin Air Show, ILA (berlin, Germany, 2014), ULD Care Meeting (Mainz, Germany, September 2014), Business Opportunities in the Convergence Regions at BIAT (Naples, Italy, December 2014), Advanced Materials International Forum – SmartPuglia (Bari, Italy, February 2015), Compotec 2015 (Carrara, Italy, 2015), Europoltech Warsaw (Warsaw, Poland, April 2015), Techtextil 2015 (Frankfurt, Germany, May 2015), 61st Air Safety Forum (Washington DC, USA, July 2015), Tegel Sky Conference Berlin-Tegel Airport (Berlin, Germany, September 2015), ULD Care Meeting (Bangkok, Thailand, September 2015), XXII Conference - The Italian Association of Theoretical and Applied Mechanics – AIMETA 2015 (Genoa, Italy, September 2015), MRO Europe 2015 (London, UK, October 2015), Aerodays 2015 (London, UK, October 2015)

More than 60 articles about FLY-BAG2 Project were found on the web. Some web-links are following reported:
• Engineering and Technology Magazine;
• The Independent;
• The Times;
• BBC News;

• TechInsider;
• ReasearchItaly;
• University of Sheffield;
• DailyMail;
• Huffington Post;
• American Association for the Advancement of Science.;
• The Engineer;
• The Register;
• IFSEC Global;
• NBC News;
• Agenzia Giornalistica Italiana - AGI;
• Punto Agro;
• Lainformacion.com;
• Primocanale;
• ANSA;
• L'InfoExpoProtection;
• Futurity;
• Италия по-русски;
• Aero Telegraph;
• CNBETA,
• Ingenieur.de;
• Scintille;
• ANSALatina.com;
• ViaggiNews.com;

Awareness was also raised by attracting the interest of general press and television. Several project documentaries were produced by the following TV channels:
• BBC: the news article is available at the following address: http://www.bbc.com/news/science-environment-33650713. The documentary was broadcasted in UK on Friday, 24 July 2015 (20:00 h);
• MDR "Middel German Television", in the show "Einfach genial – simply clever". The FLY-BAG documentary was broadcasted in Germany on September 8, 2015 at 19:50 with a length of 15:10 min by the public TV channel MDR. They have also included a documentary on material parameters to be fulfilled which sequences were taken in the textile institute STFI;
• Pro7 TV in the show "Galileo". The documentary was broadcasted in Germany on September 16, 2015 at 19:05 with a length of 12:46 min by the private channel ProSieben.
• SkyTG24: FLY-BAG documentary/interview, broadcasted on November 17, 2015 in Italy (http://video.sky.it/news/mondo/fly_bag_il_sistema_per_contenere_le_esplosioni_sugli_aerei/v261234.vid);

Several published scientific articles were produced during the Project: Compositi Magazine (Advanced technologies for bombproof cargo containers and blast containment units for the retrofitting of passenger airplanes), 2014 ATRS Special Issues (Advanced technologies for bombproof cargo containers and blast containment units for the retrofitting of passenger airplanes), Proceedings of International CAE Conference 2014 (fabric impact drop tests: numerical simulations using the ls-dyna micromechanical approach and experimental characterization), TEX Innovation (FLY-BAG - New safety system for airplanes against bombing attacks), Proceedings of TRANSEC 2014 (Blast-proof textile solutions for aviation security: FLY-BAG & FLY-BAG2), International Journal of Aviation Systems, Operations and Training (IJASOT) (Advanced technologies for bombproof cargo containers and blast containment units for the retrofitting of passenger airplanes), Proceedings of EASN Workshop on Aerostructures (Advanced technologies for bombproof cargo containers and blast containment units for the retrofitting of passenger airplanes).

EXPLOITATION ACTIVITIES
The FLY-BAG2 Consortium has identified eighteen (18) project results, grouped into four (4) main groups:
• blast mitigation units;
• sub-components;
• other-components;
• tools and methods.

The main results are those clustered in the first group; these are represented by the FLY-BAG blast mitigation units, in particular: the (a) cabin device, the (b, c) FLY-BAG kit for ULD (LD3 AKE container and PMC/P6P pallet), and the (d) cargo hold liner for narrow-body aircraft (A320 family). Another relevant result is represented by the (e) blast mitigation composite side panels (as reinforcement of the LRBL) (in the category of 'Other components'). A secondary project result grouped in the first category ('blast mitigation units') is represented by the AKE version (ULD) - extra-light ULD construction.

The project results clustered in the second group ('sub-components') are: (f) composite frame for AKE pallet kit, (g) composite floor and side sandwich panel, (h) blast resistant zip closure and (i) fire-resistant abrasion-resistant, and gas-tight coated textiles and coating application method.

Material numerical models and blast simulation methods are another important result achieved during the Project ('Tools and methods') group.

A detailed risk assessment for each project result has been performed by each responsible partner, supported by the other partners of the Consortium involved in the results.

The partners involved in the first exploitation result (cabin bag) decided to apply for an Italian patent. The patent title is: "Dispositivo di attenuazione di uno scoppio e relativo metodo di fabbricazione" and was applied on September 29, 2014 (Ref. No. I0 50842, IT MI2014A001695 – International Patent Classification IPC: INV. F42D5/045 B65D90/32). The applicant is D'Appolonia S.p.A. Furthermore, after the positive evaluation of the national patent, it was decided to proceed with the application of an International patent (under the Patent Cooperation Treaty). The international patent "Blast mitigation device and manufacturing method thereof" was filed by D'Appolonia on September 28, 2015 (PTC/EP2015/001914).

Exploitation agreements were set up to define the rules for exploiting commercially the main project results and for managing the relative IPR.
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Last update: 4 April 2016

Permalink: https://cordis.europa.eu/project/id/314560/reporting