

Qualification and Full-Scale Test of the Airbus A400M Barrier Net

2011-01-2519

Published
10/18/2011

Mark Trafford
AmSafe - Defense Cargo

Sebastian Klein
IABG mbH

Dirk Meiranke
Airbus

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doi:10.4271/2011-01-2519

ABSTRACT

AmSafe®, Airbus and IABG were the first in decades to undertake an ultimate forward load Full-Scale Test (FST) of a 9g¹ Barrier Net. Barrier Nets are safety critical products used during an emergency landing (FAR25.561/CS25.561) to protect passengers and crew. When Airbus Military required an A400M Barrier Net they identified requirements well beyond the “normal” and demanded that payloads from a rigid structure to a frangible be restrained.

AmSafe uses non-linear Finite Element Analysis (FEA) technology to analyse their nets and proposed an innovative solution for a new Barrier Net to satisfy these very demanding requirements. Given these new requirements, it was decided to also carry out a Full-Scale Test (FST). This test required the expertise of IABG, a testing facility based in Germany. The rig requirements - the capability of asymmetric loading, with a rigid and frangible payload and the unusual behaviour of a textile test object - made predicting the resultant load performance on the test set-up and the rig design very challenging. IABG developed a unique test set-up to perform the FST up to a maximum design load of 4.2MN.

The Barrier Net was able to achieve the demanding requirements and better due to the innovative use of “Tear Webbing” (AmSafe patent pending). The Tear Webbing

technology was able to share the load evenly with the aircraft attachment points. Seven tests were performed with the test-rig performing perfectly each time. The associated monitoring system provided load data for all Barrier Net attachment fittings to the aircraft, as well as total load application and distension data for the Barrier Net.

The testing confirmed that the Barrier Net could achieve all the attributes that the FEA predicted. It also confirmed that the limitations stipulated by Airbus for the airframe were met. This first-of-a-kind test - undoubtedly a step forward for safety - is a testament to all three partners that this technically challenging project was a success.

INTRODUCTION

The A400M aircraft as designed by Airbus Military is a transport aircraft with a varied role, but in the main it is a cargo and troop carrying transport aircraft. The cargo role is equally varied, capable of carrying both military and civil aviation pallets/containers, as well as ISO Containers.

While the military devices can be restrained by a 463L floor based cargo handling system with aerial delivery function (CHS/ADS), the civil unit load devices have to be restraint by an optional civil roller restraint system and for the ISO Air/Surface container separate ISO locks are needed. Only the cargo handling system is designed for FAR25.561/CS25.561

¹g = the unit of the acceleration of gravity; 1g = 9,80665 m/s²

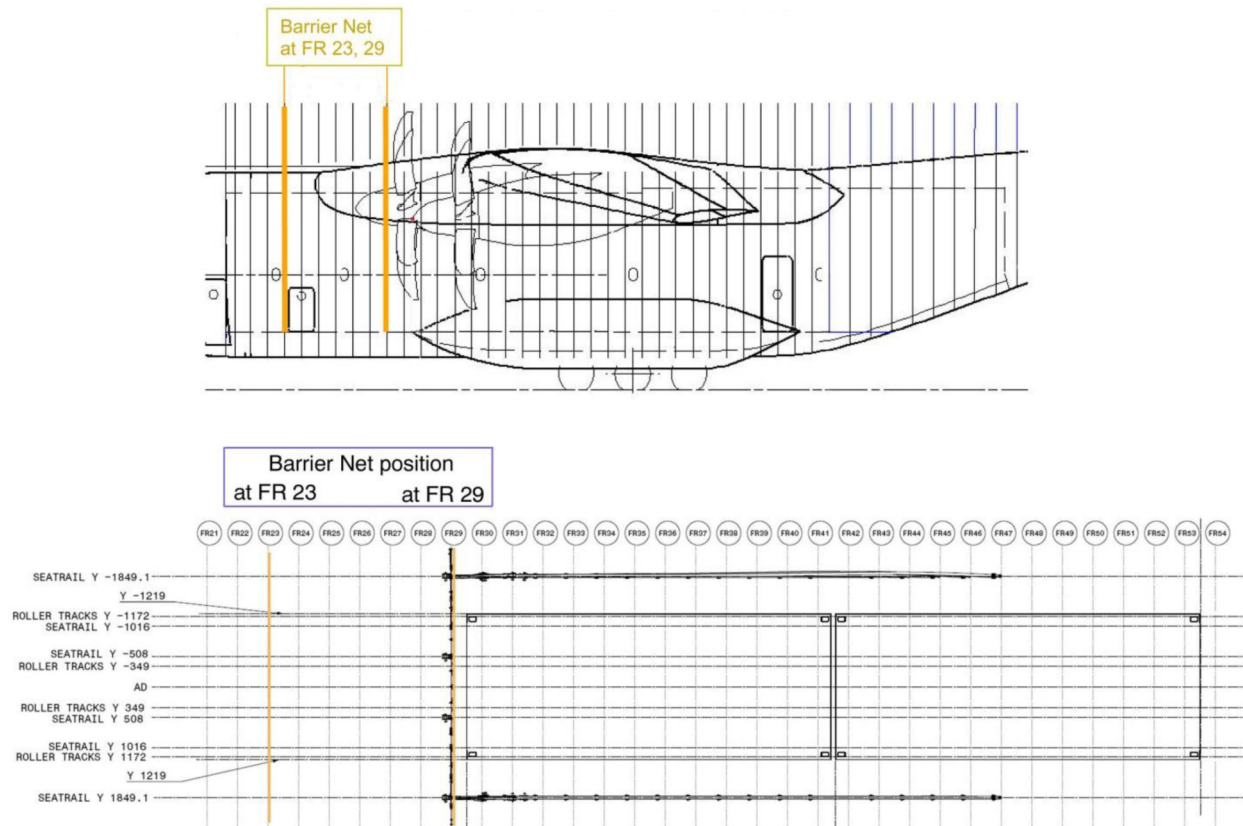


Figure 1. Installation position of the Barrier Net at frame 23 or 29; the two installation positions for the Barrier Net are specified to give the customer more flexibility in load configurations

crash conditions based on the strength of the transport devices. All other load restraint devices do not have this load capability and are typically designed for 1.5g forward and sideward load. Therefore a Barrier Net has to be installed in front of the civil payload to fulfil the requirements of the FAR25.561/CS25.561.

Following table shows all load cases, the Barrier Net has to withstand:

Table 1. Load configurations for the Barrier Net

ULD	ULD max. dimensions (L x W x H)	Qty. Cargo Hold	Max. gross weight per single ULD	Max. Total Weight
A-Size Civil Pallets (NAS3610/AS36100)	88 in x 125 in x 96 in	7	mGross = 5682 kg	32000 kg
M-Size Civil Pallets (NAS3610/AS36100)	96 in x 125 in x 96 in	6	mGross = 5682 kg	32000 kg
10 ft ISO AIR/Surface Containers (ISO 8323-1985(E))	(10ft x 8ft x 8ft), (10ft x 8ft x 8,5ft)	2	mGross = 5670 kg	11340 kg
20 ft ISO AIR/Surface Containers (ISO 8323-1985(E))	(20ft x 8ft x 8ft), (20ft x 8ft x 8,5ft)	2	mGross = 11340 kg	22680 kg
30 ft ISO AIR/Surface Containers (ISO 8323-1985(E))	(30ft x 8ft x 8ft), (30ft x 8ft x 8,5ft)	1	mGross = 15876 kg	15876 kg
40 ft ISO AIR/Surface Containers (ISO 8323-1985(E))	(40ft x 8ft x 8ft), (40ft x 8ft x 8,5ft)	1	mGross = 20412 kg	20412 kg
20 ft ISO Freight Containers (DIN ISO 668: 1999-10-1985(E))	(20ft x 8ft x 8ft 3in)	2	mGross = 13608 kg	27216 kg
Pallet base: PGF				

This meant that Airbus required a Barrier Net for both frangible and rigid payloads - a different need from the normal frangible only payload requirement for civil freighters.

For AmSafe - the world leader in safety and securement equipment for the aerospace, defence, and ground transportation industry - this meant that the design, analysis and qualification of the A400M Barrier Net were far more challenging than normal and that the design of such a Barrier Net would be very different to the traditional design.

Based on Finite Element Model (FEM) analysis results, interface requirements and engineering judgment two critical load cases were selected by Airbus for the design and qualification of the Barrier Net - a frangible load case based on a LD7 container and a rigid load case based on a 20ft ISO container. These two load cases place very different requirements on the Barrier Net and also have the potential to place very different requirements on the aircraft structure. Yet Airbus wanted to maintain the same requirements on the aircraft structure.

Therefore AmSafe came up with a new innovative design that utilized Tear Webbing in a novel and ultimately ingenious

and successful way. This design ensured that the Barrier Net could cope with both frangible and rigid payloads and it fulfilled the limitations stipulated by Airbus. AmSafe utilized a non-linear FEA to help in the design of the Barrier Net. The rigid and frangible payloads place very different loadings on to the Barrier Net and the FEA showed how that loading would be distributed, thus helping AmSafe to refine the design.

At the start of the project, Full-Scale Testing (FST) was not intended. Part way through Airbus decided that FST for both a rigid and frangible payload had to be undertaken for the qualification of the Barrier Net. Furthermore the FST should be taken above the FAR/CS 9g requirement.

This is when the services of IABG, a renowned European test house who had a lot of FST experience in the civil and military aerospace market, as well in the automotive field joined the team. IABG's full expertise was called upon for the test-rig design since the nature of a textile material based test object and additionally the unknown behaviour of a frangible payload made predicting the loads in to the test-rig a very challenging project.

The 3 teams from AmSafe, Airbus and IABG worked together to ensure that the projects needs were fulfilled, but also that a test-rig that was effective, safe and could be produced on time and to budget. The process of test-rig design followed the normal aerospace design philosophy of PDR and CDR, as well as other design and project milestones, and was, like in all other aerospace projects, governed by the high-level EN 9100 quality rules.

THE BARRIER NET DESIGN AND FINITE ELEMENT ANALYSIS

The A400M has a very strong cargo floor, based on the high payload amount of up to 32 tons and its 9g resistant cargo handling system. This aircraft also offers individual restraint by lashing devices, attached to tie down points with up to 111kN load capability. This was taken into account for the interface definition of the Barrier Net. Instead of attaching it only at one frame all around the compartment shape - typical installation for civil freighters - it was decided to transfer the major loads to the cargo floor by Drag Straps. For the remaining loads at the ceiling a connection to the stronger frames close to the wing (frame FR34) via so-called Installation Kit Cables avoids a reinforced frame at both net installation positions. With this solution significant weight was saved in the structural design of the aircraft.

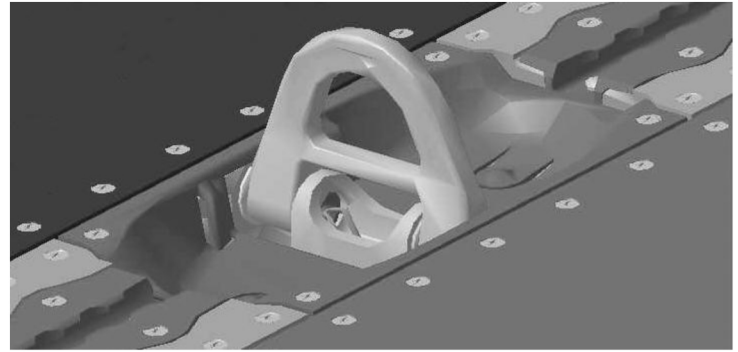


Figure 2. Typical Tie Down Point at the cargo floor

The Barrier Net (shown in [Figure 3](#)) consists of a number of elements:

- The main large area central body net, the so-called Primary Net.
- 2 Secondary Nets, positioned on each side of the Primary Net.
- Drag Straps that attach to 16 aircraft floor Cargo Deck Fittings on each side of the aircraft. Some of the Drag Straps attach to 2 aircraft floor Cargo Deck Fittings.
- Installation Kit. A kit of 8 textile cables that attach the top portion of the Barrier Net (ceiling region) to the strong hard points of the aircraft AFT of the Barrier Net location in the wing box region.

The webbing for the Net is made from Dyneema® in order to achieve the high strength and low weight requirements. The Barrier Net contains specific reinforcing primarily in the main body area to cope with high stress concentration areas that the FEM predicted (the FST showed this to be true). These reinforcing also help to cope with higher areas of wear and tear.

As mentioned before Drag Straps are used to transfer the major net loads to the cargo floor. In total 32 Drag Straps (16 on each side) are part of the Barrier Net to evenly distribute the load over the cargo floor tie down points. To assure that the allowable load at any Barrier Net to aircraft attachment will not be exceeded, AmSafe developed a Tear Webbing mechanism which is a key element of all net attachment straps (see [Figure 4](#)).

The nature of Tear Webbing is that at a certain load the webbing tears (hence the name tear webbing). This is the maximum load the Tear Webbing will achieve. The Tear Webbing can't exceed the max. load, but as it tears the load will be maintained, until such point (distance) the tear has finished, i.e. the 2 leafs in the Tear Webbing have been pulled fully apart. Therefore the maximum load into any aircraft attachment point was known not to exceed a maximum value of 111kN.

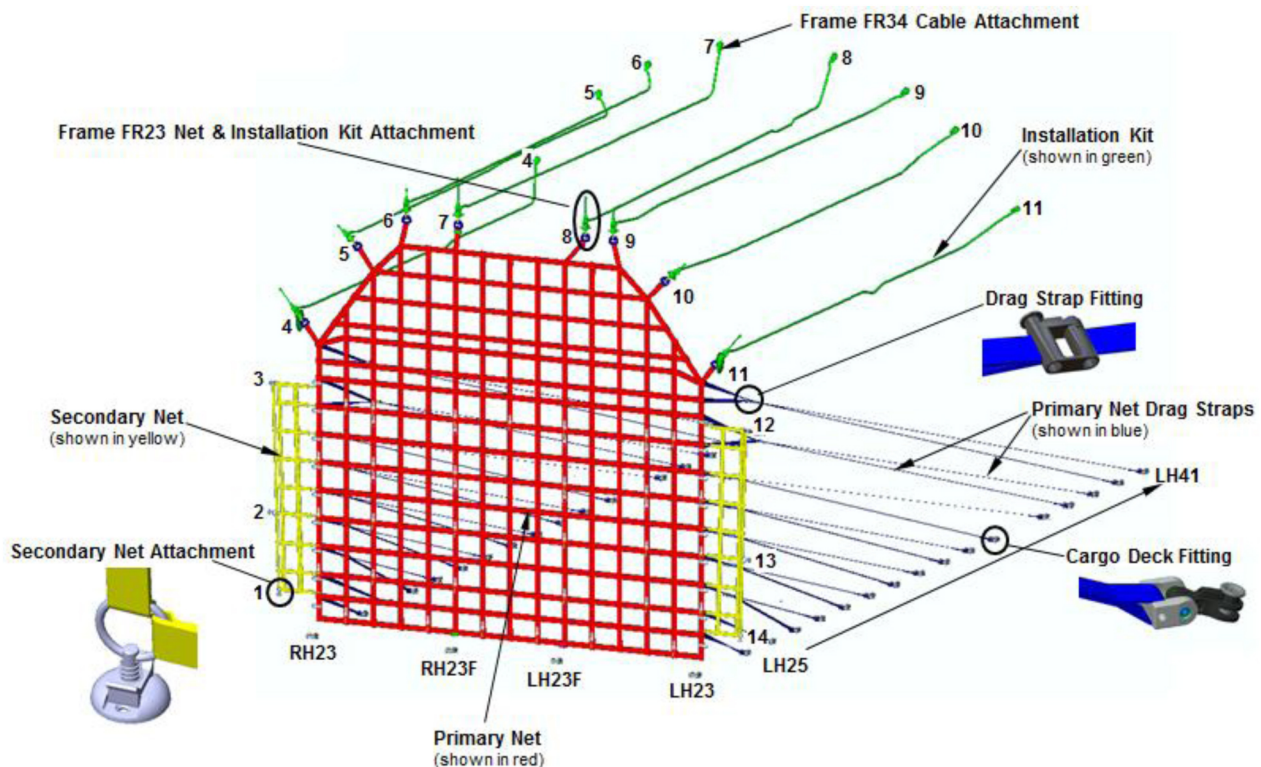


Figure 3. Barrier Net looking FWD (Forward), with elements identified

Due to the design of the Barrier Net and the use of the FEA Model that AmSafe had produced, AmSafe were able to predict what the maximum load the Barrier Net design could achieve for the rigid and frangible load cases. AmSafe's Finite Element Model (FEM) predicted 12g for the rigid load case and 10g for the frangible load case.

The Barrier Net contained a number of different “Fittings” for installing the Net in the aircraft, as well as providing other features as required by the Airbus specification.

- Drag Strap Cargo Deck Floor Fitting: Used to attach the Net to the D Ring Floor Fitting of the aircraft. This has a quick-release feature in order to aid quick installation and removal.
- Drag Strap Fitting: Used to attach the Drag Straps to the Main Body of the Barrier Net. Some of the Drag Straps are integral to the Main Body of the Barrier Net, but many are separate to aid installation and removal. The separate ones are attached to the Main Body of the Barrier Net with the Drag Strap Fittings. These also have a quick-release to aid installation and removal.
- Front Cargo Deck Floor Fitting. Used to attach the front lower part of the Barrier Net to the aircraft floor at 4 locations. Similar to the Drag Strap Cargo Deck Floor Fitting, but thinner due to limited space. They also have a quick-release feature and maintain the same strength requirement.
- Quick Release Fitting (QRF) assembly: A male and female fitting that links the 8 upper Barrier Net Straps to the

Installation Kit and thus the aircraft structure in the ceiling region.

All these fittings were designed for the A400M project to achieve the specific requirements, each fitting was analysed and tested to qualify that they meet the requirements.

The design of the Barrier Net was constructed in the FEA tools (HyperWorks® and Pam-Crash®) and these tools were used to change and refine the design in order to meet the requirements stipulated by Airbus.

Properties for all the textile and metal fittings materials (linear and non-linear load-elongation curves, tensile strength and other properties) were entered in the FEM. AmSafe designed and manufactured new Dyneema® webbing and Dyneema® based Tear Webbing and tested these webbing materials to ascertain the material properties for inclusion in the FEA. The FEM predicted loading for ALL areas of the Barrier Net that is for all straps, straps to fitting interfaces, stitching interfaces, webbing intersection and so on. All features of the Barrier Net, including all fittings, all textile materials and their intersection/stitching features, as well as their interface with any fittings were tested and qualified in advance of any FST (see Figure 5).

The FEM provided the output data and this was reviewed to ensure compliance with the requirements.

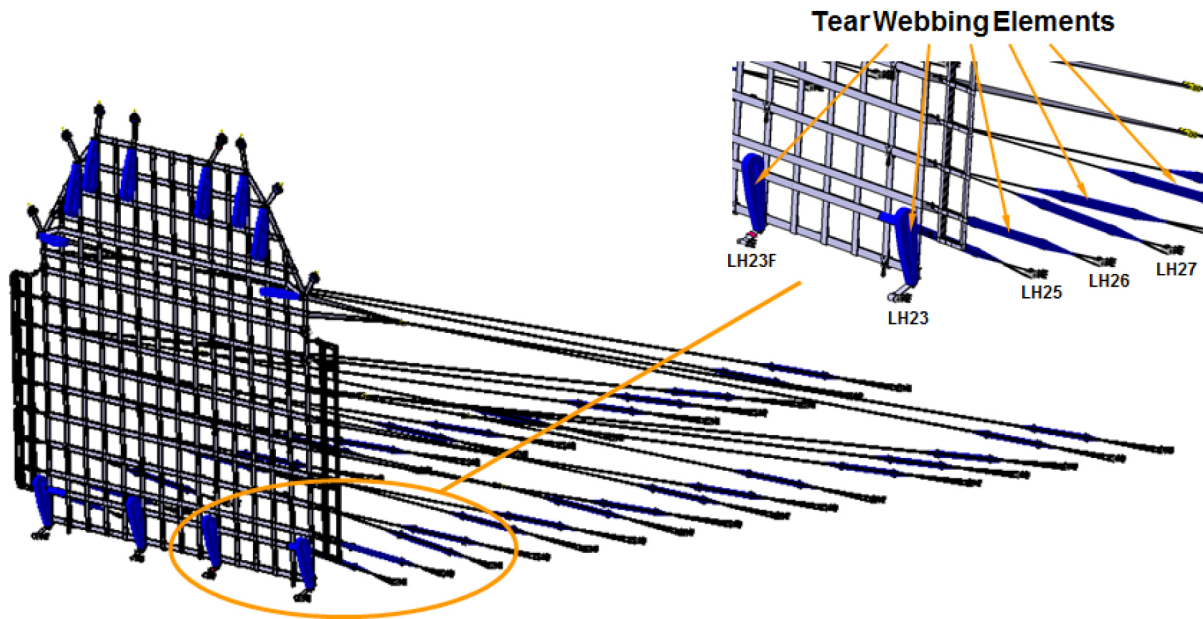


Figure 4. Barrier Net looking FWD (Forward), with Tear Webbing Elements

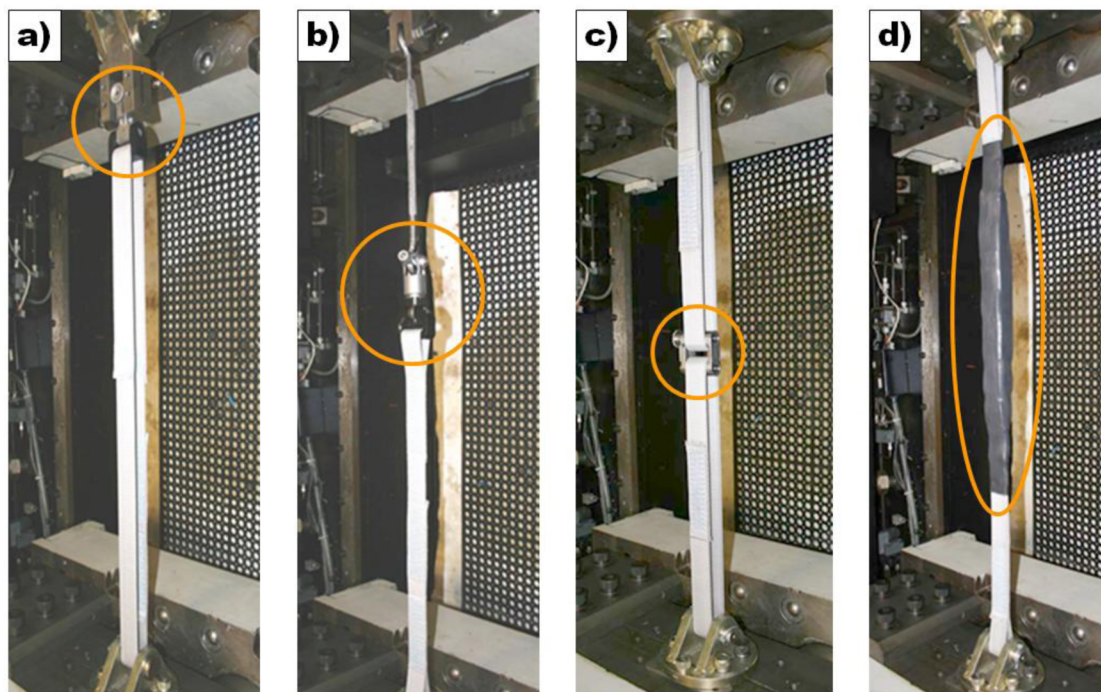


Figure 5. Qualification test (tensile strength test) on coupon level of a) Cargo Deck Fitting, b) Quick Release Fitting, c) Drag Strap Fitting and d) Tear Webbing

TEST SET-UP DESIGN

The requirements on the test set-up design were for several reasons unique and challenging. Firstly the behaviour of a textile test object and of the frangible container (including frangible cargo) made the rig design and prediction of the

resultant performance of the test set-up a very demanding task.

Secondly the high design load of up to 4.2MN, the performance of symmetric and asymmetric load cases with two different container designs and the geometric restrictions