DEAMAK
DEsign And Manufacturing of Krueger flaps

State of the art – Background

Krueger flaps are seen as the best candidates for laminar wing leading edge high-lift applications. Indeed, thanks to their position in front of the wing nose and orientation at a rearward incline, they are able to protect the wing leading edge and upper side front part from the accumulation and impact of insects or dirt and, to a substantial degree, also from surface erosion due to rain, hail or other particles during low-altitude flight. Such accumulations and erosions result in wing surface discontinuities that could significantly increase drag by causing loss of laminar flow in the affected areas.

Objectives

The DEAMAK project addresses the design and manufacture of Krueger flaps to be mounted on the A340-300 MSN1 BLADE Flight Test Demonstrator, an aircraft used within Clean Sky's SFWA-ITD to amongst others assess the leading edge insect-shielding efficiency of Krueger flaps during low-altitude flight phases (take-off and landing). The span of the DEAMAK Krueger flap is around 2m. No deployment actuation and linkage systems are required, since a Krueger panel will be mounted on each wing by means of fixed attachment structures for about 23 hours of Krueger flight testing.

Description of work

To comply with the objectives of the project, the work of DEAMAK is divided into four interdependent technical work packages. The proposed project work consists of the "Krueger Flap and Interface Struts Design" (WP1), the "Component Manufacturing" (WP2), the "Handling and Shipping" (WP3) and finally the "Validation & Verification and Flight Clearance" (WP4). Note that the definition of tasks in the Topic Description (listing design, manufacturing and logistics aspects) are dealt with by the three first WP's, while a fourth one was added to cope separately with the important V&V and flight clearance dossier preparation aspects (Permit to Fly inputs). The DEAMAK project coordination is assigned a separate work package (WP5) running all along the 73 months project duration.

Results

a) Timeline & main milestones

The KOM was on October 19th 2010 and the official end of the project towards Clean Sky SWFA was on November 18th 2016. Most of the DEAMAK milestones were reached later than initially scheduled because of planning shifts following the rearward shift of the corresponding milestones of the BLADE project. ASCO was one of the first partners within BLADE to pass the different design milestones (A/B/C-Maturity Reviews and DFM approval in 2011/2012/2013 and 2015 resp. for DEAMAK). Since the hardware only needs to be shipped to the Airbus test aircraft FAL mid-2017 and that the Krueger flight tests are postponed till the summer of 2018 (last batch of BLADE flight test campaign), the different component production and assembly tasks at ASCO were done at a lower pace than initially foreseen without adding risk to the BLADE project (sufficient time buffer remaining). The last operations on the DEAMAK Krueger flaps (drilling, painting, final assembly and FAI audit) are scheduled Q1 2017, leaving two full months of time buffer for unforeseen events before delivery.

b) Environmental benefits

Preliminary weight and cost comparison studies wrt metallic variants of the DEAMAK Krueger flaps look positive indicating several percent gains thanks to the use of the so-called 'one shot multi-cell' CFRP structure developed by ASCO in the frame of DEAMAK. However, it is impossible at this stage to quantify the effect on CO_2 and NO_x emissions and hence to assess how much the output of the DEAMAK project contributes to the ACARE 2020 objectives. It is however judged that the Krueger Flap is an indispensable mean to allow industrialisation of a laminar wing, offering a 4,6% fuel burn and hence CO_2 reduction compared to conventional wings on a 800 NM mission at Mach 0.75 (includes weight increase and laminarity only above FL220) according to the Airbus BLADE project manager in July 2015.

c) Dissemination / exploitation of results

All special processes needed for the production, assembly and control of the DEAMAK structure on ASCO site were qualified by Airbus in the frame of the BLADE project, proving the ASCO team had invested sufficiently and had acquired the required knowledge to be able to produce airworthy composite parts. The latter recognition is of paramount importance for ASCO who can now extend its commercial offer to clients from pure metallic to hybrid or even pure composite 'design and built' or 'built to print' projects. This is of major importance for the ASCO Group as this will support its continuous growth and improve its competitive position, required to maintain the workforce of around 1500 people on its different sites worldwide.

d) Communication

Thanks to its professionalism and excellent team spirit, the ASCO team active on DEAMAK acquired a broad recognition resulting in a.o. the nomination of the DEAMAK project for the Best Clean Sky Project award in 2015 [Figure 1] and the chance to present a roll-up banner during the first edition of the Clean Sky Forum in 2015 [Figure 2].
During the DEAMAK project duration, several articles were published in leading Belgian, European and global magazines [Figures 3 to 5]. On top of that, two displays of hardware at leading aeronautical fairs were made (DEAMAK prototype on ASCO booth at Le Bourget 15-18/06/2015 [Figure 6] and at Farnborough 18-21/07/2016 [Figure 7]). Finally, the details of the engineering work done during the design and production phase of the DEAMAK project were also presented by ASCO at SAMPE EUROPE 2016 in Liège, Belgium mid-September 2016 [Figure 8]. A DEAMAK Krueger flap prototype was on display on the ASCO booth as well during that conference [Figure 9]. All these initiatives enabled to officially position ASCO on the worldwide market as the partner of choice for hybrid or full composite aircraft safety-critical components, next to the metallic structures capability already present in the past.

Figure 1: Certificate DEAMAK nomination for Best Clean Sky Project 2015

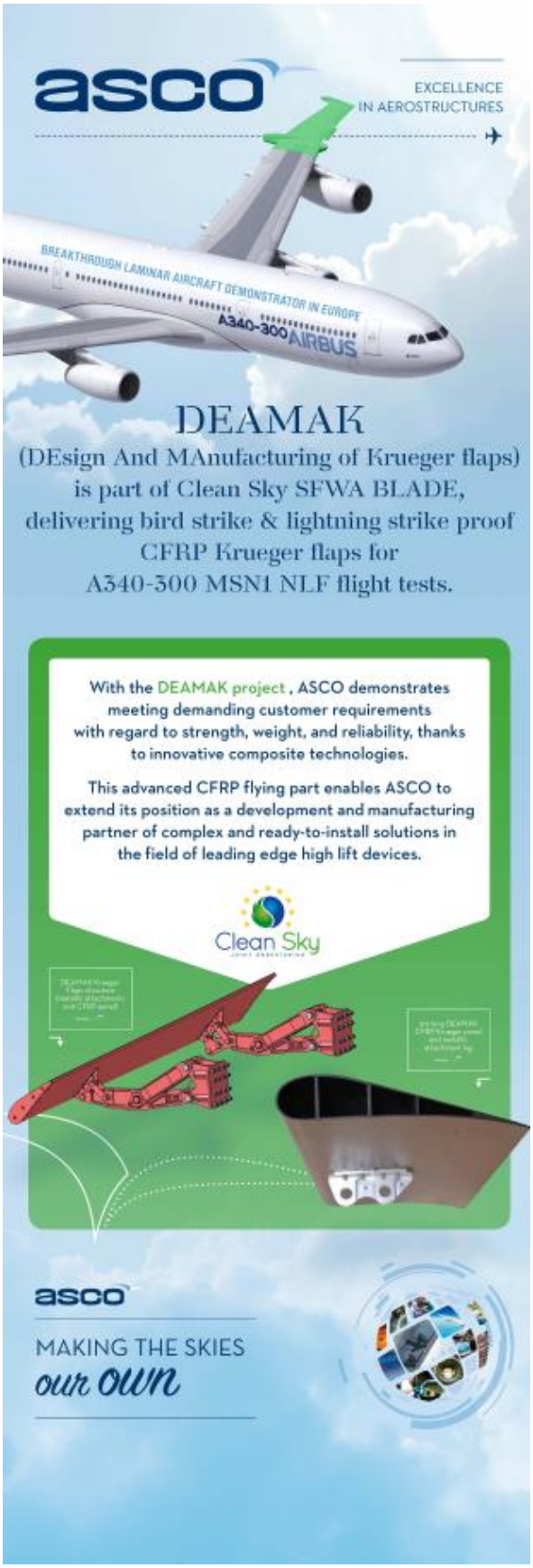


Figure 2: ASCO roll-up banner wrt DEAMAK on display during poster session of Clean Sky Forum 2015

SUCCESS STORIES

THE KRUEGER FLAP

ASCO, a privately owned Belgian aerospace company incorporated in 1954, is today the leading specialist in the design and manufacture of high lift devices for all aircraft platforms over 50 seats.

This position has been achieved through continuous evolution towards full supply chain integration from design to the final delivery of a product.

In recent years, ASCO has intensified its Research and Technology activities, in preparation for future challenges and is participating in several projects in the framework of Clean Sky.

For ASCO, Clean Sky represents a unique and particularly interesting platform because the end targets of Clean Sky in terms of environmental footprint reduction are clearly defined, thereby allowing a specific and industrially relevant step change in making today's aviation greener.

Furthermore, the cooperation within Clean Sky is of strategic importance as it provides a platform to directly co-develop technologies together with Original Equipment Manufacturers (OEM's).

This is the case for the DEAMAK program, for which ASCO designs and manufactures two Krueger Flaps for Airbus that will be flight-tested on a modified A340-600.

A Krueger flap is a component situated on the leading edge of the wing in order to generate more lift, needed for take-off and landing of the aircraft, moments when the aircraft is flying at lower speed.

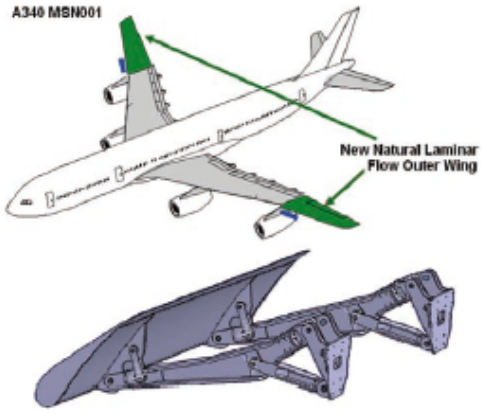
Most commonly, high lift devices are deployed in and out of the wing via a 'gliding' movement using actuation mechanisms, whereas a Krueger flap rotates around a fixed hinge point and has a circular motion during deployment.

Slats, flaps and Krueger flaps are so-called 'high-lift devices' and only used for landing and take-off flight phases. The rest of the time, slats and flaps are firmly retracted against the fixed wing and Krueger flaps even disappear completely in the wing.

The Krueger flap by itself is not new. It was invented by the German engineer Werner Krueger in 1943 and it is used on leading edges of big aircraft close to the fuselage.

However, the novelty of its use for the current project stems from its implementation on the green wings of the future that use a very specific airflow - called laminar airflow- that keeps the air gliding smoothly over the wing for as long as possible, the laminar wing.

As a Krueger moves entirely via the lower part of the wing and leaves the upper wing skin un-altered, it allows for a clean upper wing surface without steps or gaps that could disturb the laminar airflow.



Example of one of the two Krueger flaps (below), designed and manufactured by ASCO Industries for flight testing on a modified A340-600 by Airbus (above).

Classical slat system with actuation system visible:

Alternative Krueger system, entirely deployed via the bottom of the wing.

The laminar airflow diminishes turbulence, hence drag, thereby reducing the aircraft's fuel consumption. A 6% fuel saving per flight is envisaged through the use of such a laminar wing.

ASCO is proud to participate in the DEAMAK project, which contributes to the research for greener aviation. ASCO will continue its efforts to actively participate in initiatives that push technology and product development for a more environmentally sustainable future.

The advice ASCO

could give to potential partners of Clean Sky:

1) Budgets for Calls are provided in the respective Call information. However, do not try to consume all of it and set up a lean budget preferably under the target as proposals are selected– for comparable quality- on a competitive basis. This is often overlooked.
2) Do not be deterred by the size of Clean Sky and its administrative obligations. Although there is a certain level of administration required, you work with tax payer's money and you would probably request the same reporting if it was yours. Some people find it difficult to work with the required EC reporting tools. It takes some time to get familiar with them, but most things are difficult before they become easy.

ABOUT ASCO | www.asco.be

Asco, incorporated in 1954, is a proven technology specialist and supply chain integrator in design, development, precision machining, processing, and certified assembly of complex high strength metallic aircraft components (high-lift devices, landing gear components, and engine attachments).
Asco is headquartered in Zaventem, Belgium with operating subsidiaries in Germany and Canada combined with service offices in Brazil and the US. Today, the Asco Group employs 1,300 people. Its worldwide, 100% Aerospace, customer base includes most aircraft manufacturers as well as many related Tier-1 and Tier-2 suppliers.
> CONTACT PERSON: Ingrid De Keijser

Figure 3: Article on Clean Sky Website – Interview section – Skyline #7 – June 2012 – Krueger flaps applied to laminar wings (http://www.cleansky.eu/content/interview/krueger-flaps-applied-laminar-wings)

BLADE composite Krueger flaps produced at ASCO in the frame of DEAMAK

25/05/2016

*By **Michaël Raets**, DEAMAK Technical Project Manager, ASCO Engineering dept*

So-called 'one-shot multi-cell' Carbon Fibre Reinforced Plastic (CFRP) Krueger flaps, developed by ASCO Industries in the frame of the DEAMAK project (SFWA-ITD BLADE CfP Nr. JTI-CS-2010-2-SFWA-03-003 that kicked off in October 2010), were recently successfully produced by means of the Resin Transfer Moulding (RTM) technology at ASCO's headquarters in Zaventem, Belgium.

Mid-term achievements were previously reported on the Clean Sky website in mid-2012. Since then, a lot of activities have taken place at ASCO for DEAMAK as well as in the rest of Europe for BLADE (nearly 20 partners and hundreds of people involved). Hard engineering work and a sound collaboration with Airbus enabled the design freeze of the ASCO Krueger flap structure in mid-2013. ASCO was the first to achieve this important milestone in the frame of BLADE. Subsequently, part, assembly and installation drawings were compiled by ASCO and successfully reviewed by Airbus in 2014 and 2015. The production of the metallic wing attachments was launched in parallel with the design and subsequent production of state-of-the-art RTM moulds for the CFRP Krueger panels. Last year, no fewer than four composite panel prototypes were produced by ASCO: two for mould validation (symmetric moulds for both left and right-hand side panels), one for US-NDT inspection strategy development and referencing, and one for First Part Qualification (FPQ) purposes. Thanks to these achievements, the DEAMAK project was nominated for the Best Clean Sky Project Award in 2015.

A DEAMAK panel was on display at the ASCO booth of the Le Bourget fair in mid-2015 (see *Figure 1*).

Figure 1: DEAMAK composite panel prototype exhibited at ASCO's Le Bourget booth in June 2015

Finally, in May 2016, after an efficient collaboration of the several ASCO departments involved, the US-NDT special process audit was passed with great success and the production of the flying shipset panel was completed at ASCO, at least for what concerns the RTM process itself. In particular the latter forms a key milestone for ASCO as it corresponds to the first-ever production of flyable composite ASCO parts as the company, founded in 1954, had only been working on commercial projects concerning (hard) metallic structures! In the last couple of weeks, the following operations were carried out in the ASCO RTM production facilities (only operative since June 2013 and already successfully qualified in the frame of BLADE in May 2015): fibre cutting, preforming, compacting, mould closure, resin degassing & injection, curing and demoulding. Both the BLADE port and starboard wing Krueger flap panels are depicted in *Figure 2* below.

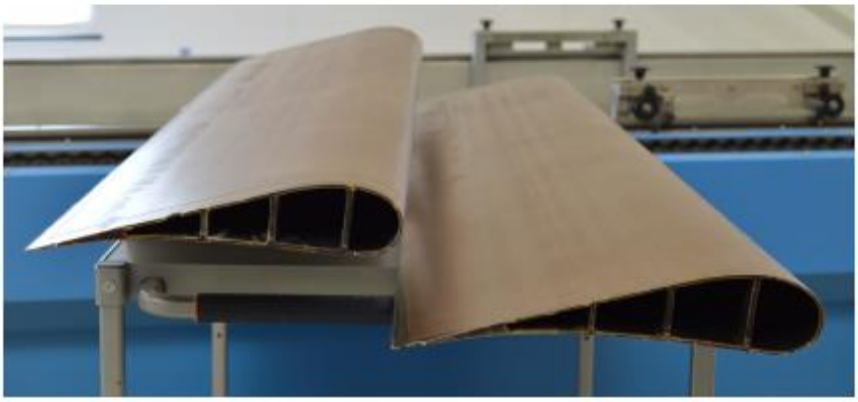


Figure 2: DEAMAK left- and right-hand wing Krueger panels for BLADE aircraft after demoulding at ASCO in May 2016

Finally, it should be stressed that the DEAMAK project does not end with the above production. Indeed, several operations are still scheduled in the coming weeks and months on the two parts, namely dimensional control, visual & US-NDT inspections, machining of side & trailing edges, drilling of holes, testing of coupons cut from flap edges for material health validation, painting (2 primers + topcoat), assembly (limited thanks to the chosen 'one-shot multi-cell' concept), FAI activities for Airbus and final reporting towards Clean Sky. The common goal is to achieve all of this before the end of the year.

Thanks to the DEAMAK success story, ASCO is broadening its offerings and remaining at the forefront of technology. This proves again the ASCO dedication to meet its customers' present and future needs.

More interviews

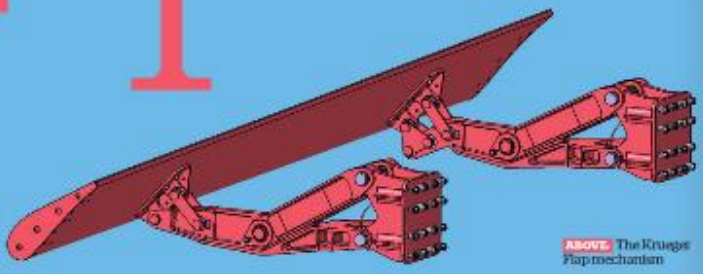
Tags

ASCO | blade | Clean Sky 2 | DEAMAK

Figure 4: Article on Clean Sky Website – Success Story section – May 25th 2016 – E-NEWS June 2016 – BLADE composite Krueger flaps produced at ASCO in the frame of DEAMAK (http://cleansky.eu/content/interview/blade-composite-krueger-flaps-produced-asco-frame-deamak)

LIGHTENING THE LIFT

Ed Hill discovers how high-lift assembly specialist, Asco has developed a new Krueger flap from composite materials.



ABOVE: The Krueger Flap mechanism

Civil aircraft designers are continually improving wing designs with natural laminar flow (NLF) sections. With such developments fuel savings of around 6% per flight are claimed to be possible. However, there is an inevitable trade-off between the smoothness of wing surfaces for cruising speeds and movable high-lift devices such as flaps and slats needed to generate lift at take-off and landing. These moving elements of modern wings unavoidably create turbulence and drag, reducing efficiency.

One high-lift device employed on the leading edge of aircraft wings is the Krueger Flap. This aerodynamic profile and its corresponding mechanism, is named after the German engineer Werner Krueger who invented it in 1943. The flap hinges down from the underside of the wing when needed to increase the critical angle of attack of the wing. When deployed it increases lift and delays the onset of a stall. The flap is then retracted during cruising flight.

One of the advantages of the Krueger flap is that that it leaves the upper wing surface smooth when retracted, and while fully deployed it can protect the wing from insect and dirt accumulation and surface erosions.

Making this assembly as light as possible has obvious advantages in terms of reduced fuel burn, but materials that can lead to more integrated designs also have huge potential.

Belgium headquartered Asco is a technology specialist supplying design, development, precision machining, processing and certified assembly of high-lift devices for the aircraft industry. Its customers include most of the major OEMs in the aircraft business alongside tier 1 and tier 2 suppliers.

In recent years the company has been working on its Deamak Project, a programme to design and build a Krueger Flap using composite materials. The aim of the project was to produce a flap from Carbon Fibre Reinforced Plastic (CFRP) that could be manufactured

RIGHT: Krueger flaps mounted close to the fuselage on a Boeing 737

Figure 5: Article 'Lightening the Lift' about ASCO in Aerospace manufacturing – author Ed Hill – published on July 03rd 2015 (https://www.aero-mag.com/digital-editions/july-2015/view)

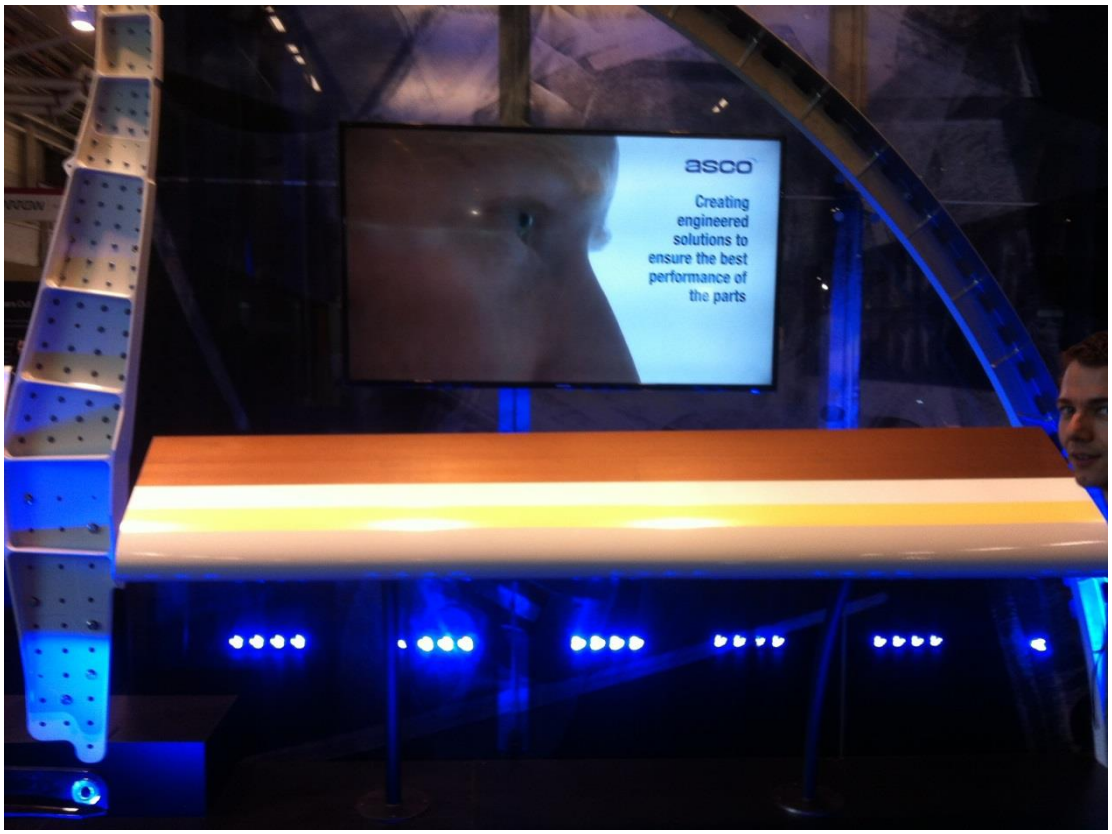


Figure 6: DEAMAK prototype on display at Le Bourget's ASCO booth 15-18/06/2015

Figure 7: DEAMAK prototype on display at Farnborough's ASCO booth 18-21/07/2016

Design and manufacturing of a safety-critical aircraft Krueger flap

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SUMMARY

The Clean Sky BLADE research project provides a flight test demonstrator displaying industrially mature Natural Laminar Flow (NLF) wing sections. For max 10 flights at the end of the test campaign, fixed Krueger flaps designed and manufactured at ASCO Industries in the frame of the DEAMAK project will be mounted on the inboard portion of the new A340-300 NLF outer wing sections. These Krueger flaps will be flight tested at low altitude to examine their insect-shielding effect, which is crucial to a successful NLF wing application. The ASCO components were engineered using a multi-cell approach for damage tolerance and manufacturability improvement, in close collaboration with the production site which is of uttermost importance to come up with an industrially viable design.

After a general introduction during which the ASCO group, the general trend to increase the use of composite materials on civil aircraft and the DEAMAK project are presented, five aspects of the engineering work done at ASCO in the frame of DEAMAK are outlined. First of all, the four main material selection criteria and the final material choice (CFRP consisting of 5H satin weave and RTM6 resin) are presented. Subsequently, the reasons for using an RTM process are presented, next to the five most important design drivers of the DEAMAK Krueger flaps. The various composite flap sizing activities which were carried out are listed and the testing done for three specific purposes is presented. Finally, general conclusions are drawn and an outlook of the future is given.

KEY WORDS

DEAMAK, BLADE, Krueger, flap, multi-cell, composite, RTM, NLF, laminar, insect-shielding

Figure 8: Front page of ASCO's paper submitted for & presented during SAMPE EUROPE 2016 13-15/09/2016

Figure 9: DEAMAK prototype on ASCO booth during SAMPE EUROPE 2016 in Liège 13-15/09/2016

Project Summary

Acronym:	DEAMAK
Name of proposal:	DEsign And MAnufacturing of Krueger flaps
Involved ITD	Smart Fixed Wing Aircraft ITD
Grant Agreement:	CS-GA-2010-271496
Instrument:	Clean Sky
Total Cost:	759.840,00€
Clean Sky contribution:	379.920,00€ (50%)
Call:	JTI-CS-2010-2-SFWA-03-003
Starting date:	October 19th 2010
Ending date:	November 18th 2016
Duration:	73 months
Coordinator contact details:	Stein Janssens Group Leader Research & Innovation and Test & Development ASCO Industries NV - Engineering department stein.janssens@asco.be
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