Project: EDA B.PRJ.RT.796 Advanced Low Observable Coatings And Structures "ALOCAS"

ALOCAS Executive Summary

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1 Summary

The EDA project ALOCAS has performed successful research on developing low observable materials to reduce detectability of next generation platforms.

The Saab AB led project Advanced Low Observable Coatings And Structures is a joint material research project between Saab and FOI of Sweden as well AkzoNobel and NLR of the Netherlands. The project shows successful research performed in additive manufacturing (AM), design and measurement methodologies, tailored materials and novel low observable (LO) technologies. The developed LO materials have potential to significantly reduce the infrared and radar signature on next generation platforms.

LO technology is an essential part of future aeronautical and naval weapon systems. In general, LO technology is intended to reduce the detectability of military platforms against a variety of threat sensors, like radar, infrared, visual and acoustic detection systems. This project has focused on material development in the radar microwave- and infrared wavelengths with the goal of enabling the access to, and the survival within, hostile air and sea-space for combat, intelligence and reconnaissance assets to perform the designated missions.

The final meeting of the ALOCAS project, which recently took place at Saab Aeronautics in Linköping, Sweden, shows significant progress in the design and manufacturing of LO materials.

Figure 1. Additive manufactured honeycomb surface (left) and the tool to co-cure resin skin on to the core (right). AM absorbers on the rear base plate is not shown. Saab.

Figure 1 (left) shows the Saab optimized wing leading edge AM demonstrator. The core geometry is optimized as of a new methodology maximizing the transparency with consideration to paint and resin skins applied. The jointly developed LO coating (AkzoNobel, NLR and FOI) have successfully balanced high transmission and low emissivity, seen applied in grey colour. Finally, on to the base plate is the Saab AM optimized broad band radar absorption materials applied (not shown).

Figure 2. AM Radar absorbing honeycomb. NLR.

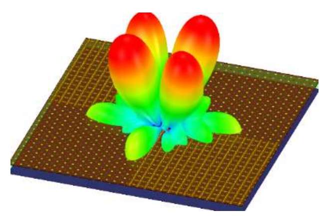

Figure 3. Scattering pattern of a scattering Cancellation Meta-surface. The incident radar wave (not shown) impinges the surface orthogonally and is redirected with lower intensity. NLR

Novel low observability concepts have been shown by FOI and NLR, exploring AM honeycomb structures (figure 2), Scattering Cancellation Meta-surfaces (figure 3) and maintainability of LO materials.

Possible applications for the materials developed indicated in Figure 5

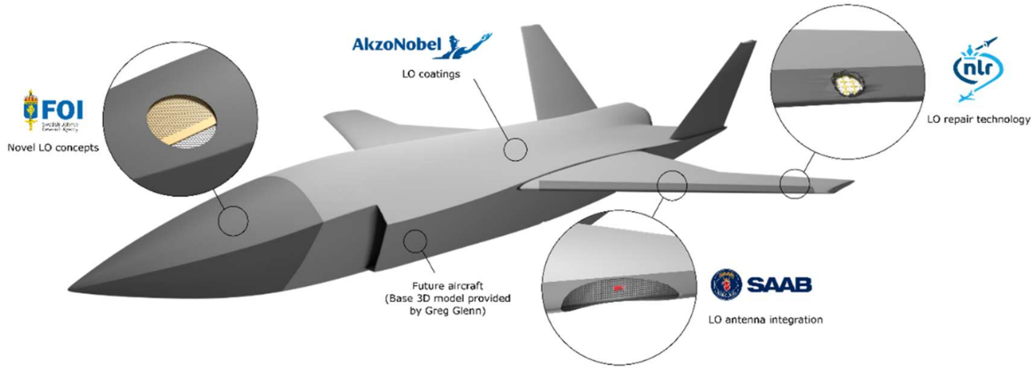

Figure 4. Application concepts of the materials developed in ALOCAS.

Follow-up activities are expected to build upon the outcomes of ALOCAS on the application on next generation aircraft and naval vessels. ALOCAS ties in with a successful long-standing line of research in advanced materials and structures of low radar observability, including the ALOA (ALOA-Web_v1 (europa.eu)) and ALOMAS (Dokument5 (europa.eu)) projects.

2 Introduction

Project EDA- B.PRJ.RT.796 “Advanced Low Observable Coatings And Structures (ALOCAS)” aim to improve future European defence capabilities in terms of survivability, with the goal of enabling the access to and the survival within hostile air and sea-space for combat, intelligence and reconnaissance assets to perform the designated missions. The same applies for effectors and UAV platforms to assure the capability to deliver the desired effects on targets.

An international consortium with the aim of carrying out the project was set up:

- Saab AB Aeronautics, Sweden – Lead Contractor
- AkzoNobel and NLR, the Netherlands – Co-contractors
- FOI and Saab Dynamics AB, Sweden – Co-contractors

The statement of work made in the Research Technical Proposal (RTP) proposes technical approaches and provides information necessary to evaluate the technical solutions. The ALOCAS project is based on the experience from the precursor programs EDA-B-003-GEM1-ERG “Advanced Low Observable Materials (ALOA)” and EDA-B-1192-GEM1-ERG “Advanced Low Observable Materials And Structures (ALOMAS)”.

ALOCAS started 18 December 2020 and finalized November 16 2023.

3 Work Breakdown Structure

The work breakdown structure (WBS) of the ALOCAS project as shown in Figure 5

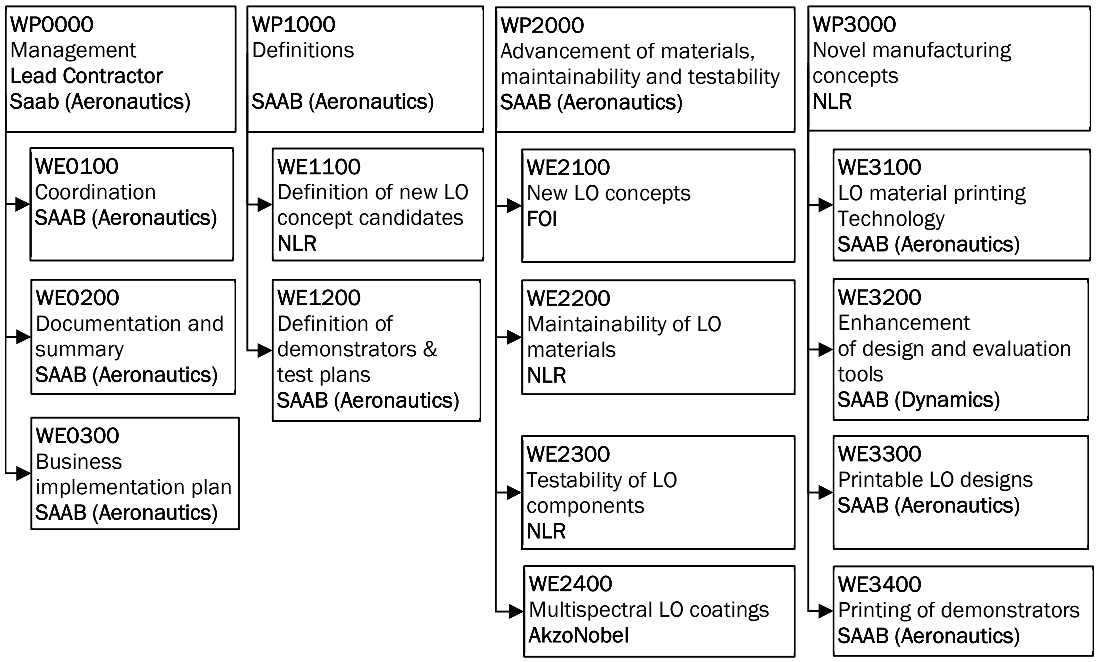

Figure 5 ALOCAS work breakdown structure

4 Result

WE1100 Definitions

The objective of this WE was to identify materials used in the ALOMAS project for further investigation in the ALOCAS project. In addition, new concepts were identified for stealth materials, their manufacturing and required improvements of simulation tools and requirements are defined for maintainability and testability of RAM/RAS. In this WE, lists of relevant LO techniques, concepts and materials were prepared, based on previous projects (ALOA, ALOMAS) and on the open literature. After discussions within the consortium the results were summarized in the report DE1100-1. The document reflects the view of the ALOCAS consortium at the start of the project.

WE1200

Demonstrators and the overall purpose and size are defined in DE1200-1 issue 1, date 29.03.2022

Test plans with general descriptions of the setup and measurements are defined in DE1200-2 issue 1, date 29.03.2022

WE2100 research on “New LO concepts” covers several different material types and has led to increased knowledge about novel radar signature materials, new and improved simulation tools, and increased knowledge about material measurement and manufacturing techniques. Several new concepts presented have potential to reduce or re-direct local RCS in order to improve a platforms overall RCS.

WE2200 research on “Maintainability of LO materials” regarding the repair and maintenance of LO structures. Scattering Cancellation Metasurfaces (SCM) were applied to flat panels and also on curved structures, which were EM-characterized, then damaged, repaired and re-characterized. The standard impact test (steel ball impacting the structure exterior surface) damages a small area only. The subsequent EM-measurements shows insignificant change of the LO functionality. The small damage gives a very small impact on the SCMs reflection performance. The required repair impacts a much large area when milled layer by layer and rebuilding the structure with patches matching the SCM. However, the repair was successful and the re-characterization shows limited impact on the LO functionality.

WE2300A research on the non-destructive testing of structure beneath RAM, with the goal to investigate the detectability of the different types of defects in the aluminium reference plate using eddy current. An Eddy current array can detect metallic substructure overlaid with composite and low observable coating layers, when applying a horse shoe large axial field probe working at reflection mode. Thicker RAM makes detection problematic. More research required.

WE2300B research on surface waves and usage of compressive sensing to identify surface waves on objects. Instead of using the usual ISAR technique, compressive sensing is applied since it allows using different scattering dictionaries, the deterministic and the Bayesian solution method. Study of the scattering mechanism involved is essential. This preliminary study shows a robust methodology and further research should focus on improving the dictionaries to cover a complete set of scattering mechanisms.

WE2400 research to design balanced LO multifunctional coatings comprising a combination of conductive IR emissive aluminium flakes and non-conductive mica effects enable to achieve the contradictive properties of low IR emissivity in the thermal infrared wavelengths and high Radar transmission in the microwave wavelengths. This makes the coating suitable for application on a low emissive yet radar transparent radome. However, an insufficient low temperature flexibility is observed, most likely caused by the high pigment loading. Further research is recommended on the resin system vs. effects of the high loading.

The paint developed was successfully applied on the WE3400 demonstrator. Good application properties were observed, all sheets show a kind of cloudy appearance, dried paint is shiny, more colour pigments required to achieve a military grey appearance.

WE3100 investigates LO material printing technology.

Filament Melting Deposition (FDM) also called Fused Filament Fabrication (FFF) is selected to print multimaterial lossy absorbers since the method allows custom-made filaments with lossy additives and allows to print two or more materials side by side in each layer. This enables to print lossy gradient custom-made structures. However, FDM is a slow print method and in case of unexpected shut down (filament failure) the printing must restart from scratch.

Selective Laser Melting (SLM) is selected to print commercial powder of undoped polymer to create the radome structure with varying core thickness in order to enhance transparency or increase the antenna gain. SLM is a fast print method but utilizes a single type of powder, making multimaterial printing difficult.

The market of available FDM filaments with EM-transparent or EM-lossy properties have been surveyed. A down selection was procured and tested. Several FDM base material have been investigated, and doped with functional additives to achieve electrical or magnetic losses. See further work in WE3300.

WE3200 investigates the methods required for optimization of radomes and absorbers, respectively. The considered radomes have so called gradient cores, i.e. additively manufactured honeycomb cores. The radome results show that the directivity of the antenna enclosed by the radome is significantly increased. Regarding the absorbers, the results are in agreement with independent FEKO simulations, which confirms that the optimisation software works as intended.

Target objectives of the radome design are: Beam shaping radome and Increased antenna gain. The optimization variables (degree of freedom) are: permittivity variation in normal direction (for bandwidth) and permittivity variation laterally (for beam shaping).
The research shows that the developed optimisation routine is able to steer beams in a desired direction and was applied in the development of the radome of the WE3400 demonstrator.

Further work is recommended to include scanning antennas and double curved radomes, including gracing angles, wider frequency range and to handle larger objects/problems.

WE3300 manufacture and characterize custom-made filaments to AM RAM. In the beginning of the project, the high temperature material PEKK was tested but was found very difficult to extrude into doped lossy filaments, which in turn were found very complicated to print. To not stall the project were the ambition lowered regarding temperature resistance and mechanical strength and instead focus to extrude doped lossy filaments based on other polymers. After extensive testing, the absorber was designed, optimized and printed from doped filaments of the base materials PLA and ABS.

The developed RAM shows high and fairly broadband performance at an intermediate tile thickness, which is applied on the WE3400 Demonstrator backplane to reduce RCS.

However, the PLA and ABS withstand temperatures up to 120°C, which limits the absorber to be applied in conditioned compartments. Future research should study base material with higher temperature robustness, preferably > 150°C as could be expected in a standard autoclave process.

WE3400 design, optimize and manufacture a broadband transmissive 3D printed focus beamed leading-edge radome.

The electromagnetic designs and optimizations are performed using the methods developed in WE3200 Enhancement of design and evaluation tools.

The radome is mounted on a backplane with a broad band antenna. The free space at the back plane is covered with the RAM tiles developed in WE3300.

The radome was 3D printed as a gradient core by SLM where each layer was Polyamide Powder (PA12) melted by a laser beam. Quartz fibre prepregs were applied on the radome core, which was cured in an autoclave process.
The manufacturing of the radome is fairly straight forward and of low cost since commercially available PA12 powder was applied. At the moment the printer volume is limiting the size of the articles to print. SLM printers with larger print volumes are expected in the coming years.

The radar absorbing materials (RAM) tiles were printed by FDM from custom-made doped filaments which is melted in a heated nozzle and applied layer by layer over the printer bed. The base materials are of low-cost type. However, the associated work to dope the base material with lossy additives and extrude to printable lossy filaments increases the procurement cost to intermediate level. The FDM print process is time consuming and the printing chamber volume is limited. This often reduces the size of the articles to print.

The assembled demonstrator was measured with respect to radar cross section (RCS) and antenna performance. The measured RCS is slightly lower than the predicted (simulated) RCS with and without radome and RAM tiles respectively. The antenna performance measurement results show that the gradient radome focuses the beam of the antenna as intended. The measured antenna gain increase is slightly lower than the predicted, however considered well in-line with the expectations.

In summary, the ALOCAS Demonstrator is considered successful primarily because it demonstrates the ability to design, manufacture and verify a 3D printed advanced RAM- and Radome components. The demonstrator is an example of how the AM technique can be utilized for design and manufacturing high-performance LO materials at an affordable cost.