Exploring aerospace advancements and global collaborations: a comprehensive analysis of MCAST's aerospace program in Malta

Leonardo Barilaro[1,a*], Lorenzo Olivieri[2,b], Mark Wylie[3,c], Joseph Borg[4,d]

[1] The Malta College of Arts, Science & Technology, Aviation Department, Paola PLA 9032, Malta

[2] CISAS “G.Colombo”, University of Padova, Via Venezia 15, 35131 Padova (PD, Italy)

[3]South East Technological University (SETU), Aerospace, Mechanical and Electronic Engineering Department, Carlow campus, Kilkenny Rd, Moanacurragh, Co. Carlow, Ireland

[4] Department of Applied Biomedical Science, Faculty of Health Sciences, University of Malta, Msida MSD, 2080, Malta

[a]leonardo.barilaro@mcast.edu.mt, [b] lorenzo.olivieri@unipd.it, [c] mark.wylie@setu.ie, [d] joseph.j.borg@um.edu.mt

Keywords: Space Debris, Aerospace Structures, Satellites Shields, International Space Station

Abstract. This paper provides an overview of the Aerospace Program at the Malta College of Arts, Science and Technology (MCAST). The program comprises of four main projects that aim to address different challenges in the aerospace industry, in particular in the field of protection of aerospace structures and systems from space debris impacts. The first project focuses on the development of 3D printed Kevlar shields for aerospace applications. The outcome of this project is the development of repair strategies for inflatable manned modules in space and efficient small satellite shields. The second project describes the use of cold-welding phenomenon for spacecraft repair, in collaboration with South East Technological University (SETU), Ireland. The project aims to develop an experimental test rig to apply custom repair patches of different materials to pre-damaged metallic structures and monitor the performance of the adhered joint in low orbit and during re-entry. The third project presents a collaboration between MCAST and the University of Padova to develop a single stage Light-Gas Gun (LGG) impact facility in Malta. Finally, the paper discusses MCAST's participation in Malta's third space bioscience experiment launched to the International Space Station led by the University of Malta. The experiment aims to investigate how microgravity affects the behaviour of foot ulcer microbiomes in Type 2 Diabetes Mellitus patients. The project marks a significant milestone for both MCAST and the University of Malta. The projects presented in this paper reflect MCAST's commitment to contribute to the advancement of the aerospace industry and offer new opportunities for research, development, and commercialization.

Introduction

Over the past years, Malta has emerged as a promising player in the Space Sector, positioning itself as one of the up-and-coming nations in this field. This progress is underscored by Malta's Cooperation Agreement with the European Space Agency (ESA) on in 2012, aimed at establishing a framework for enhanced collaboration in ESA projects [1]. With its strategic location, access to the European Union (EU) market, administration and human capital, Malta presents a very good opportunity for the commercialization of space exploration. Guided by the central government, the Malta Council for Science and Technology (MCST) has taken on the crucial role of coordinating and governing space-related matters in the country since the signing of the Cooperation Agreement. MCST's Space Directorate actively fosters connections with foreign space agencies, the Maltese government, businesses, and educational institutions. Recognizing the potential for space exploration to become a pillar of Malta's economy, the government has outlined its commitment through the National Space Strategy 2022. Drawing inspiration from the success achieved in the aviation sector and incorporating best practices from other countries, this strategy encompasses a wide range of initiatives undertaken in the Maltese space sector. It focuses on upstream and downstream activities and examines the economic possibilities for Malta. Furthermore, it is noteworthy that Malta is set to join the ESA Plan for European Cooperating States (PECS) in 2024, further solidifying its commitment to and integration with the European space community. In light of these developments, this paper aims to present a comprehensive analysis of the aerospace activities carried out at the Malta College of Arts, Science and Technology (MCAST) in Malta, in particular in the field of protection of aerospace structures and systems from space debris impacts. Section 2 will present the development of 3D printed Continuous Aramid Fibers (Kevlar^R) based shields for aviation and aerospace applications, Section 3 the use of cold-welding adhesion for spacecraft repairing, Section 4 presents a collaboration to develop a single stage Light-Gas Gun (LGG) impact facility in Malta and Section 5 provides an overview of Maleth 3 mission that was onboard the International Space Station.

Smart ballistic optimization for repairing of aerospace structures using 3d printed Kevlar

The SBORAEK project introduces an innovative concept by proposing the development of shields for aviation and aerospace applications using 3D printed Continuous Aramid Fibers (Kevlar^R). In the aviation industry, maintaining the structural integrity of aircraft is crucial for ensuring satisfactory performance [2]. The availability of repair materials and time often plays a significant role in deciding whether a part should be repaired or replaced. Repairable damage by patching refers to damage exceeding the limits that can be fixed by installing splice members to bridge the affected area of a structural component. Regarding aerospace applications and protection against impacts and hull damages, regulations and strategies for mitigation are currently under scrutiny. Active and passive debris removal technologies, as well as post-mission disposal techniques, are being developed. The current state and projected evolution of the debris environment necessitate the exploration and development of shields to protect active spacecraft. In crewed International Space Station (ISS) modules, mitigation techniques include reinforced hulls and shields to reduce the risk of hull perforation and subsequent depressurization [3]. Avoidance maneuvers are also performed for detected objects above a certain size threshold that may collide with the ISS. In contrast, unmanned systems utilize simpler and more cost-effective structures such as sandwich panels to mitigate the effects of space debris impacts. However, there is ongoing research to determine the best strategy for repairing damaged spacecraft hulls and shields while in orbit. In recent years, innovative processes like additive manufacturing have found applications in the satellite industry, enabling solutions that would have been challenging or expensive to implement using traditional manufacturing techniques. For instance, within the scope of the EU H2020 ReDSHIFT project [4], new 3D printed shields were developed for the protection of microsatellites. The SBORAEK will allow to go further, this will be the first time 3D printed Kevlar structures with optimized geometry will be applied to aviation and aerospace. There is currently no system targeting the same objectives of this project. SBORAEK, Figure 1, is however made from a number of subsystems, whose technology levels are mature enough so that they can be used and integrated together. The technology used for the SBORAEK project is divided into three segments: 3D printing, optimization algorithms and design techniques for high-energy impact conditions.

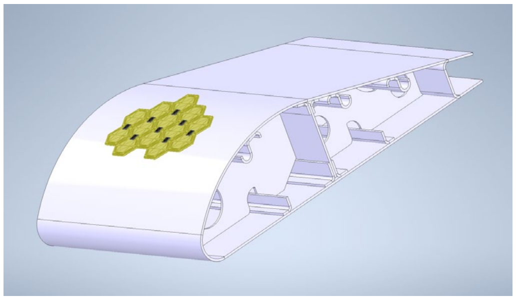
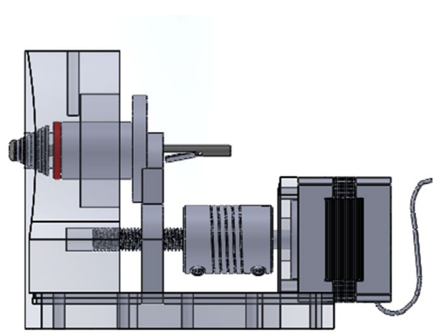


Fig 1: SBORAEK applications - Aviation structures (left), prototype spacecraft shields (right)

Cold welding adhesion for spacecraft repair

This research, in collaboration with South East Technological University (SETU), aims to explore the intentional cold-welding of metals as a method for spacecraft hull repair. This approach involves applying a repair patch to a perforated metal sample using an apparatus capable of applying combined axial and tangential forces [5]. Experimental evidence has shown that, in a near vacuum environment, cold-welding using this technique can be achieved with limited loads below 100 N. To validate this technique experimentally, it is necessary to recreate low orbit gravity and pressure conditions. The research plan consists of two phases: terrestrial experimentation and the subsequent development of an experimental payload to be tested in space. The terrestrial experimentation phase, Figure 2, establishes the primary system requirements, including perforation diameter and crater specifications, selection of material candidates for repair patches, mechanical interface design, actuation method (rotational, translational, or a combination), and applied forces. Secondary requirements encompass power needs and sensor specifications such as pressure transducers, load cells, and cameras. Currently, three non-ferrous materials are being considered as candidates: high ductility Indium foil (1-3 mm) shaped into a step tapered plug rivet, austenitic steels with a high Nickel content (Stainless Steel SS17-7PH plate), and a commonly used aerospace-grade Aluminum Alloy (AL AA-2024).



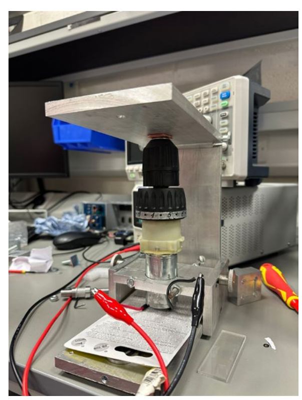


Fig 2: Test rig concept (left) and test rig prototype (right)

Single-stage Light-Gas Gun for high-velocity impacts

MCAST started a collaboration with the Center of Studies and Activities for Space (CISAS) at the University of Padova in Italy for the design of a hypervelocity research facility [6]. Considerable attention is directed towards essential components, such as the launch package and sabot-stopping system, in the construction of a hypervelocity impact facility. The launch package safeguards the projectile during acceleration, while the sabot-stopping system is responsible for terminating the sabot. Typically, Light Gas Guns (LGGs) employ an expandable sabot system to encase the

Materials Research Proceedings 37 (2023) 291-295 https://doi.org/10.21741/9781644902813-63

projectile. Subsequently, following the acceleration phase, the sabot separates from the projectile, fragmenting to prevent contamination of the target. However, this approach can inflict damage on the sabot-stopping system, necessitating either complete replacement or time-consuming maintenance. In order to establish a test facility capable of conducting high-velocity impact tests for the aviation and space sectors, a range of projectile velocities has been selected. This range is suitable for testing the impact of aircraft components as well as simulating low-speed impacts akin to those experienced in GEO orbit. The LGG is designed to primarily replicate impacts caused by metal impactors, particularly aluminum alloys. Its modular configuration can also be adapted to accommodate other types of projectiles, simulating space debris such as plastics and silica materials.

Maleth 3

The first-time collaboration for a space project between MCAST and the University of Malta, took place for the launch of the space bioscience experiment 'Maleth 3' on March 15th, 2023. The experiment was part of a commercial re-supply mission (CRS27) by SpaceX to the International Space Station (ISS). The objective of the experiment, titled "Microgravity effects on microbiome studies of Diabetic Patients", was to explore how microgravity influences the behavior of foot ulcer microbiomes, a major complication prevalent among patients with Type 2 Diabetes Mellitus, often requiring amputation surgeries [7]. The project entails a collaborative effort between also other institutions facilitated by Spaceomix in conjunction with Space Applications Services from Brussels, Belgium; Weill Cornell Medicine, New York, USA; King Faisal Specialist Hospital & Research Centre, Jeddah, Saudi Arabia; Metavisionaries based in Oxford, UK; and the Mohammed Bin Rashid Space Centre (MBRSC), whose astronaut is part of NASA's Crew-6 and handled Maleth 3 in space, Figure 3. The outcomes of this experiment have the potential to yield breakthroughs in life science research and treatment methods.

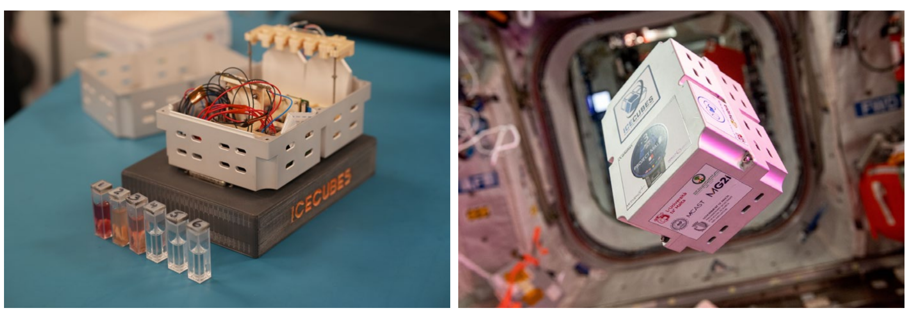


Fig 3: Maleth 3 experiment

Conclusions

This paper presented the Aerospace Program at MCAST, focusing on the protection of aerospace structures and systems from space debris impacts. The program consists of four main projects: 3D printed Kevlar shields, cold-welding for spacecraft repair, a single-stage Light-Gas Gun impact facility, and MCAST's participation in the Maleth 3 space bioscience experiment. The development of 3D printed Kevlar shields enables repair strategies for inflatable manned modules and efficient small satellite shields. Cold-welding adhesion shows promise as a method for spacecraft hull repair, with experiments conducted under near vacuum conditions. Collaboration with the University of Padova is designing a single-stage Light-Gas Gun facility for high-velocity impact testing in the aviation and space sectors. MCAST's collaboration with the University of Malta resulted in the successful launch of the Maleth 3 experiment, investigating the effects of microgravity on foot ulcer microbiomes in Type 2 Diabetes Mellitus patients. These projects reflect MCAST's commitment to advancing the aerospace industry, contributing to research, development, and commercialization.

Acknowledgments
The work described in this paper was partially carried out as part of the SBORAEK (R&I-2022-002L) project which was financed by the Malta Council for Science & Technology, for and on behalf of the Foundation for Science and Technology, through the FUSION – Technology Development Programme LITE.

References

[1] Malta Space strategy: https://maltaspace.com, last visited: 18th May 2023

[2] Roach D., Rackow K. "Development and Validation of Bonded Composite Doubler Repairs for Commercial Aircraft". Aircraft Sustainment and Repair (2018) pp.545-743. https://doi.org/10.1016/B978-0-08-100540-8.00011-X

[3] Barilaro L., Francesconi A. et al. "Impact damage and ballistic limit equations for flexible multilayer meteoroid and debris protection shields. ARA Congress (2010)

[4] Rossi A. et al. "The H2020 ReDSHIFT project: a successful European effort towards space debris mitigation". 70th International Astronautical Congress (2019)

[5] L. Barilaro, M. Wylie, L. Olivieri, Cold welding adhesion for spacecraft repair: Experiment design and roadmap, Acta Astronautica, Vol. 210 (2023), pag 511-517. https://doi.org/10.1016/j.actaastro.2023.04.011

[6] L. Barilaro, L. Olivieri, R. Tiscio, A. Francesconi, Evaluation of a single-stage Light-Gas Gun facility in Malta: Business analysis and preliminary design, Aerotecnica Missili & Spazio 101(3) (2022). https://doi.org/10.1007/s42496-022-00113-w

[7] C. Gatt et al., The Maleth Program: Malta's first space mission discoveries on the microbiome of diabetic foot ulcers, Heliyon 8(639396) (2022). https://doi.org/10.1016/j.heliyon.2022.e12075