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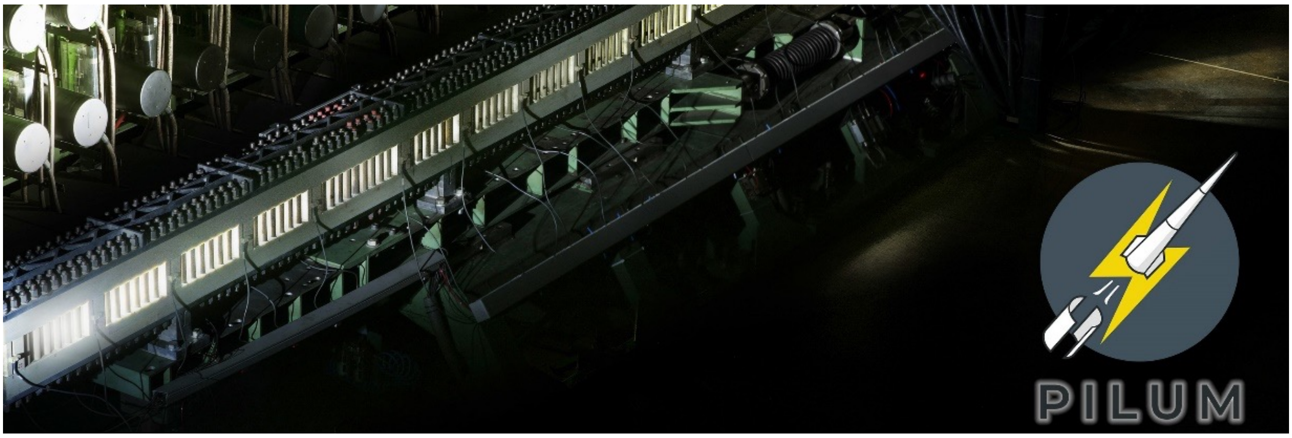

PROJECTILES FOR INCREASED LONG-RANGE EFFECTS USING ELECTROMAGNETIC RAILGUN – PILUM

In March 2021, EDA commissioned an in-depth feasibility study to investigate and assess the use of the electromagnetic railgun (EMRG) as a long-range artillery system with a budget of 1.5 M€ under the European Commission's Preparatory Action for Defence Research (PADR). Due to the significantly higher projectile velocities that can be achieved with an EMRG compared to conventional artillery, strike distances of 200 km and above are possible. The combination of the EMRG with novel hypervelocity projectiles results in the disruptive concept of a future complementary artillery system. Besides research on EMRG and its projectile, the project examined the integrability in terrestrial and naval platforms.

Objectives

PILUM's overall objective was to theoretically and experimentally investigate the feasibility of the EMRG and its hypervelocity projectiles as a game-changing concept for the future to achieve the required long-range effects through an insightful and instructive study.

Methodology

The study includes a comprehensive definition of scenarios for an EMRG system, which was worked out in close cooperation with end-users in the initial stage of the project. Based on these scenarios, high-level operational and technical requirements were identified for the EMRG system and its subsystems. Taking into account these requirements, PILUM considered the EMRG system in detail by investigating and designing its three main subsystems, namely the electromagnetic rail launcher, the energy conversion system and the hypervelocity projectile. Investigations were performed by analytical and numerical simulation and further complemented by laboratory tests and free-flight open range experiments. For each subsystem, the upscale potential was evaluated and complemented by the theoretical and experimental assessment of the electromagnetic compatibility (EMC). In the later stages of the project, systems engineering aspects were treated, and integration concepts were elaborated for both naval and terrestrial military platforms, to result in a proof of concept. Finally, a roadmap considering the technological challenges which had been identified in PILUM was developed, thus indicating a realistic way to mitigate the technical risks on the way towards an operational EMRG.

The implementation of PILUM was guided by four key challenges:

- the design of a hypervelocity projectile that can be launched by an EMRG,
- the identification and design of the most suitable energy conversion system for the EMRG,
- the inclusion of electromagnetic compatibility requirements in all development steps of the EMRG, the energy supply system and the projectile, and
- feasibility to embark the EMRG system on a European class ship or land platform.

The consortium

The PILUM consortium, highly complementary in terms of activities, expertise, experience, and practical and theoretical knowledge, was composed of seven partners from four different European countries. It benefited from the expertise of the French-German Research Institute of Saint-Louis (ISL) as the leading EMRG expert in Europe. The project could rely on partners with a firm military background and track record in developing guns, projectiles and the corresponding subsystems (Nexter Systems & Munitions, Diehl-Defence, Naval Group). The consortium also included partners with very specific knowledge for achieving technological advances and breakthroughs, in particular when it came to improving the physical properties of structures (Explomet) and when cutting-edge expertise in the aerothermodynamics of projectiles was required (Von Karman Institute).

Key findings

A first-design study provided the principal parameters for a long-range electromagnetic artillery system regarding energy needs, gun dimensions and the design of a hypervelocity projectile. Furthermore, essential parameters were specified for dimensioning an EMRG system and presented by means of a feasible parametric area, defined by launch package mass, gun calibre, maximum acceleration, and barrel length.

Efficiency considerations were carried out by examining the impact of the essential subsystems on the overall system efficiency. These considerations allowed to corroborate the feasibility of the EMRG system.

For the **EMRG,**

- The **lifetime** of the launcher rails can be significantly increased by using mixed-material pairings combining excellent electric conductivity with **high resistance to wear** on the sliding surfaces that are in contact with the moving launch package.
- Several **barrel concepts** were presented, and a favourite design was selected for further investigation.
- Concepts for **ammunition feed** and aiming adapted to the specific needs of an EMRG have been worked out.

For the **hypervelocity projectile,**

- **A projectile concept** could be designed. Wind tunnel tests and numerical simulation accompanied the work. Interior, exterior and transitional ballistics aspects were taken into account: **high acceleration forces** are acting on the projectile structure and the **GNC components** during the launch. Subsequent free-flight at velocities close to Mach 6 generates aero-thermal heating, particularly critical along the leading edges of the control devices. **Heat loads were quantified**, and preliminary investigations were undertaken to make the projectile structure heat resistant.
- Down-scaled **free-flight tests** at Mach 5 were successfully carried out in an **open-range environment** on the ISL proving ground.

For **the energy storage and conversion system,**

- Dedicated **pulsed-power capacitor tests** were carried out and analysed for lifetime determination. They showed that the energy density of this type of storage can be increased by about 25% compared to the nominal values, when used under EMRG- specific operational conditions.
- Concerning inductive energy conversion solutions, a high energy-density XRAM storage was investigated. A conceptual proposal is given for integrating an **XRAM generator onboard a ship.**
- Alternative pulsed-power conversion concepts were investigated as well. Kinetic energy concepts proved to be interesting candidates for more detailed studies in upcoming projects.

Platform integration concepts were presented for both naval and land platforms. Suitable solutions could be proposed depending on the available space in the platform.

Outlook

Based on the results of the PILUM project, future steps of EMRG research and development until 2035 are detailed in a roadmap. The EMRG technology maturation phase is planned from 2024 to 2028 and will be covered by the follow-on project THEMA (TecHnology for Electromagnetic Artillery). THEMA is awarded under the European Defence Fund (EDF) call 2022 and expected to start in Q4/2023. It will focus on solving the current technical challenges on the EMRG subsystem level and aim to increase the maturity of the critical components identified in PILUM.

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