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Technical Capability of Self-Propelled Howitzers and Multiple Rocket Launchers for Remote Operation from Cover

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Abstract

Contemporary operational environments, particularly those characterized by the widespread use of unmanned aerial systems (UAS), expose artillery units to persistent surveillance and rapid targeting, significantly increasing the risk to crews operating at or near the weapon [1,2]. Despite growing automation, a systematic approach to assessing the capability to conduct fire without physical crew presence is lacking. This paper proposes a reproducible evaluation framework for the technical capability of artillery systems to conduct remote-controlled fire from a protected position. The approach combines necessary conditions - unmanned firing cycle, automatic gun aiming, and absence of crew at the weapon - with a multi-criteria assessment and explicit consideration of data uncertainty. The method is applied to selected self-propelled howitzers and multiple launch rocket systems. The evaluation indicates that modern howitzers generally meet the required conditions, while rocket systems exhibit emerging capability, often supported by expert assessment rather than documented evidence.
The results suggest that system architecture may represent a more decisive factor than the level of automation alone and highlight significant gaps in publicly available data.

KEY WORDS: *artillery systems, remote-controlled fire, unmanned firing cycle, crew survivability, system architecture, technical capability*

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1. Introduction

Contemporary armed conflicts demonstrate the continued and intensive use of artillery weapon systems, which remain a key means of fire support for ground forces. Self-propelled howitzers, as a dominant category of these systems, are traditionally employed using the shoot-and-scoot tactic, which minimizes exposure by rapidly relocating after firing. Within this operational concept, fire missions are typically conducted either from within the vehicle cabin in the case of systems that enable the conduct of fire without the physical presence of the crew at the weapon, or in close proximity to the weapon in systems that do not provide this capability.

However, recent developments, particularly in the context of the Russian invasion of Ukraine, indicate a shift in the employment of artillery systems [1,3]. In specific operational environments, artillery assets are increasingly used in static positions for extended periods of time [1,3]. Under such conditions, characterized by the widespread use of unmanned aerial systems and persistent surveillance, the survivability of the crew becomes a critical factor [2,4]. The increasing availability and operational use of UAVs has transformed the detection and targeting cycle of artillery units. Recent research has shown that UAV reconnaissance can significantly affect force protection activities, while autonomous or swarm-based surveillance models may increase the persistence and spatial coverage of observation in complex terrain [6–8]. At the same time, studies on multispectral UAV detection and electronic warfare methods against UAVs demonstrate that artillery units operate in an environment in which detection, counter-detection, electronic disruption, and rapid targeting are closely interconnected

[9,10]. These developments reinforce the need to reduce the exposure of crews at firing positions and to examine technical solutions that allow fire missions to be conducted from a protected location. Prolonged presence at a fixed firing position significantly increases the probability of detection and targeting [2,5]. In the event of a successful strike, the consequences for the crew located inside or in the immediate vicinity of the vehicle are often fatal.

While automation and remote control are both addressed in the context of artillery systems, their relationship is not always explicitly formalized. This paper therefore proposes a structured framework for their combined evaluation with respect to crew-independent fire operation, enabling consistent comparison of systems with different levels of automation and operational concepts. The aim of this paper is to propose and apply a reproducible evaluation framework for the technical capability of artillery weapon systems to conduct fire missions without the physical presence of the crew at the weapon, i.e. from a protected position. To achieve this, the paper first establishes a clear conceptual framework by defining key operational terms, including fire from the vehicle cabin, unmanned firing cycle, and remote control from a protected position. These concepts are then used as a basis for the development of a classification approach that enables systematic comparison of artillery systems with respect to their mode of operation and implications for crew survivability.

The contribution of the paper lies in linking these operational concepts with a structured evaluation framework, allowing for consistent and transparent assessment of existing systems and their suitability for remote-controlled conduct of fire.

2. Definition of terms

2.1. Basic Terms

For the purposes of this paper, the terms vehicle, weapon, weapon superstructure, platform, and weapon system are considered mutually distinct categories.

- vehicle – a vehicle is understood as a mobile means forming the carrier of the weapon system, crew, and associated equipment, ensuring its mobility, protection, and energy supply
- weapon – a weapon is understood as a functional unit intended for the conduct of fire, including mechanisms for aiming, loading, and initiation of the shot
- weapon superstructure – the weapon superstructure is a structural unit mounted on the platform that integrates the weapon and associated subsystems, particularly mechanisms for loading, aiming, and fire control
- platform – a platform represents the load-bearing and structural base on which the weapon system is integrated. It includes the vehicle and its structural modifications enabling the installation and operation of the weapon
- weapon system – a weapon system is a complex unit consisting of the weapon, weapon superstructure, platform, and other subsystems necessary for its operation, including fire control systems, communication, and supporting technologies

Hierarchy
weapon ⊂ weapon superstructure ⊂ platform ⊂ weapon system

Additionally
vehicle ⊂ platform

2.1 Fire from the Vehicle Cabin

Fire from the vehicle cabin is understood as a mode of operation of the weapon system in which, after completing the necessary preparation of the vehicle and the weapon prior to occupying the firing position, the crew provides all activities related to the conduct of fire exclusively from within the vehicle cabin. The cabin thereby serves as a protective element.

A characteristic feature of this mode is that from the moment of occupying the firing position until leaving it, the control, operation, and conduct of fire are fully ensured from within the cabin.

2.2 Unmanned Firing Cycle

An unmanned firing cycle is defined as a sequence of operations leading to the conduct of firing that proceeds without the need for physical assistance of the crew at the weapon during its course.

The firing cycle includes activities directly related to loading and initiation of the shot, as well as automatic reloading between successive rounds.

The decisive criterion is the necessity of physical assistance of the crew at the weapon as a condition for the continuation of fire. A firing mode shall not be considered an unmanned firing cycle if its continuation is dependent on physical intervention of the crew at the weapon, even if such intervention is performed only periodically, for example when replacing an initiator magazine after firing a specified number of rounds.

2.3 Automatic gun aiming

Automatic gun aiming is defined as the capability of a weapon to determine and set the required firing direction and elevation without the need for physical intervention of the crew at the weapon.

This capability includes the processes of orientation, laying of the weapon in azimuth and elevation, and the application of firing data provided by the fire control system.

Automatic gun aiming does not include target acquisition or fire control decision-making, but only the execution of aiming commands at the level of the weapon system.

The decisive criterion is whether the aiming process can be completed and repeated without any physical interaction of the crew at the weapon. If manual intervention at the weapon is required to perform or correct the aiming process, the system shall not be considered as capable of automatic gun aiming.

2.4 Remote Control from a Protected Position

Remote control of a fire mission from a protected position is understood as a mode of operation of the weapon system in which, after completing the necessary preparation of the vehicle and the weapon, the crew conducts all activities related to the conduct of fire remotely from a protected position.

The protected position represents a location which, by its structural design, placement, and distance from the weapon system, reduces the risk to the crew from the effects of hostile activity or operational hazards associated with the system.

The method of transmission of control and data signals between the crew and the weapon system is not restricted for the purposes of this paper and may be implemented using various technical means.

2.5 Technical Capability

Technical capability expresses the extent to which the architecture of the weapon system enables the conduct of a fire mission by means of remote control.

2.6 Documented Capability

Documented capability means that there exists a verifiable and credible source confirming that the weapon system actually possesses the given capability.

3. Data and Method

3.1 Selection of Systems and Data Sources

The analysis focuses on selected self-propelled artillery systems representing different levels of automation and operational concepts. Systems were selected to cover a representative spectrum of current solutions with respect to the conduct of fire and potential for remote-controlled operation. The selection is limited by the availability of publicly accessible technical information.

The evaluation is based on open-source data, including manufacturer documentation, technical specifications, professional publications, and other publicly available materials [2,5]. Given the nature of military systems, the availability and reliability of data vary significantly. For this reason, the level of documented capability is assessed separately (see Section 3.5). To distinguish between empirical observations and analytical inference, the paper differentiates between (i) documented system characteristics derived from available sources, (ii) classifications resulting from the application of the evaluation framework, and (iii) interpretative statements. Interpretative conclusions are explicitly formulated to reflect the limitations of available data.

3.2 Evaluation Framework

The capability of a weapon system to conduct fire missions by means of remote control from a protected position is not assessed directly. Instead, it is derived from the evaluation of individual system characteristics. The evaluation framework is based on a two-step approach:

- assessment of necessary conditions (gate),
- detailed evaluation using multi-criteria scoring.

3.3 Necessary Conditions (Gate)

A weapon system is classified as technically capable of remote control from a protected position only if all of the following conditions are met:

- the weapon system enables an unmanned firing cycle as defined in Section 2.3
  - 0 = NO, 1 = YES
- the system is capable of automatic gun aiming as defined in Section 2.4
  - 0 = not capable, 1 = capable
- no physical presence of the crew at the weapon is required during the conduct of fire
  - 0 = crew presence at the weapon required, 1 = no crew presence at the weapon required

Failure to meet any of these conditions results in a negative classification (NO).

- **Technical Capability**
  YES = system meets all necessary conditions for remote control from a protected position
  NO = system does not meet one or more necessary conditions

The gate-based approach represents a deliberate and conservative operationalization of the concept of remote-controlled fire from a protected position. It does not aim to capture all possible modes of operation, but rather to define a strict threshold corresponding to complete elimination of the need for physical interaction of the crew with the weapon system during the firing cycle.

Each condition addresses a specific aspect of this requirement: the unmanned firing cycle ensures continuity of fire without interruption by crew intervention, automatic gun aiming enables repeatable execution of fire missions without physical input, and the absence of crew at the weapon establishes full spatial separation.

The gate is therefore normative rather than descriptive. While systems with partial or intermittent crew interaction may still provide operational advantages, they are intentionally excluded in order to preserve conceptual clarity and ensure reproducibility of the classification.

3.4 Multi-Criteria Evaluation

For systems that meet the necessary conditions, a detailed evaluation is performed using selected technical criteria. These criteria reflect the level of system autonomy, robustness, and practical applicability. Each system is evaluated according to the following criteria:

1. **Loading automation**
   0 = manual, 1 = semi-automatic, 2 = fully automatic
2. **Energy autonomy of the weapon superstructure**
   0 = dependent on main engine,
   1 = partially autonomous,
   2 = autonomous (e.g. APU/APHU)
3. **Stabilization energy autonomy**
   0 = dependent on main engine,
   1 = independent (APU/APHU),
   2 = not required
4. **Autonomy of safety and auxiliary functions**
   assessment of functions such as fuze setting, safety mechanisms, emergency interruption and diagnostics
5. **Remote controlled weapon system**
   This criterion does not assess the actual capability of the system, but reflects how the system is presented in available sources. It is used to compare declared capabilities with the results derived from the evaluation framework.
   0 = the system is not presented as remote controlled in available sources
   1 = the system is explicitly presented as remote controlled

The multi-criteria evaluation does not determine whether the system is capable, but provides additional differentiation between systems that meet the necessary conditions.

3.5 Documented Capability and Data Uncertainty

Due to the limited availability and varying reliability of data, the level of documented capability is assessed separately. Each evaluated capability is classified as:

- A (Confirmed) = supported by manufacturer documentation or official technical manuals
- B (Partially confirmed) = supported by multiple independent sources

- C (Estimated) = in cases where publicly available data are insufficient, expert knowledge may be used to assess system characteristics.

This approach allows explicit consideration of uncertainty and prevents overinterpretation of incomplete data. The use of structured scoring and documented uncertainty is consistent with broader defence-oriented research in which utility-based decision-making, fuzzy expert systems, multi-criteria analysis, optimization methods, path-based testing, and statistical modelling have been applied to support the assessment of complex military systems and operational problems [13, 17–21]. These approaches show that transparent criteria, explicit assumptions, and reproducible evaluation logic are essential when direct empirical verification is limited or when the available evidence is incomplete.

4. Comparative Analysis of Systems

155 mm self-propelled howitzers – first block

Weapon System	**Unmanned firing cycle**	**Automatic gun aiming**	**No physical presence at weapon**	**Technical Capability (Gate)**	**Loading automation**	**Energy autonomy of weapon**	**Stabilization energy autonomy**	**Remote controlled weapon system**
AGM	1	1	1	**YES**	2	NC	NC	1
Archer	1	1	1	**YES**	2	NC	NC	0
DITA	1	1	1	**YES**	2	NC	NC	1
MORANA	1	1	1	**YES**	2	NC	NC	0
RCH 155	1	1	1	**YES**	2	NC	PC	1

155 mm self-propelled howitzers – second block

System	**Unmanned firing cycle**	**Automatic gun aiming**	**No physical presence at weapon**	**Technical Capability (Gate)**	**Loading automation**	**Energy autonomy of weapon**	**Stabilization energy autonomy**	**Remote controlled weapon system**
SIGMA	1 (B)	1	1 (B)	**YES**	2	NC	NC	1 (B)
ZUZANA 2	1	1	1	**YES**	2	NC	NC	0
EVA M2	1 (B)	1	1 (B)	**YES**	2	NC	NC	0
AHS Kryl	0	1	0	**NO**	1	NC	NC	0
ATMOS 2000	0	1	0	**NO**	1	NC	NC	0

155 mm self-propelled howitzers – third block

System	**Unmanned firing cycle**	**Automatic gun aiming**	**No physical presence at weapon**	**Technical Capability (Gate)**	**Loading automation**	**Energy autonomy of weapon**	**Stabilization energy autonomy**	**Remote controlled weapon system**
CAESAR	0	1	0	**NO**	1	NC	NC	0
G6-52	0	1	0	**NO**	1	NC	NC	0
Nora B-52	0	1	0	**NO**	2 (B)	NC	NC	0
PCL-181	0	1	0	**NO**	1	NC	NC	0
Type 19	0	1	0	**NO**	1	NC	NC	0
Yavuz	0	1	0	**NO**	1	NC	NC	0
EVO-155	1 (C)	1 (B)	1 (C)	**YES***	2 (C)	NC	NC	1 (C)

122 mm multiple rocket launchers

System	Unmanned firing cycle	Automatic gun aiming	No physical presence at weapon	Technical Capability (Gate)	Loading automation	Energy autonomy of weapon	Stabilization energy autonomy	Remote controlled weapon system
BM-21 (original)	0	1	0	**NO**	0	0	NC	0
BM-21 MT	1 (C)	1	1 (B)	**YES**	0	NC	NC	0
RM-70	0	1	0	**NO**	1	0	NC	0
RM-70/85M	0	1	1 (B)	**NO**	1	0	NC	0
RM-70 VAMPIRE	1 (C)	1	1 (B)	**YES**	2 (C)	0	NC	0
WR-40 Langusta	0	1	0	**NO**	0	NC	NC	0
SR-5 (122)	1 (C)	1	1 (B)	**YES**	1	NC	NC	0
Tamnava (122)	1 (C)	1	1 (B)	**YES**	1	NC	NC	0
Jobaria TCL (122)	1 (C)	1	1 (B)	**YES**	1	NC	NC	0

5. Classification Results

5.1 Tables and Overview of Results

The results of the evaluation of individual weapon systems are summarized in Tables for self-propelled howitzers and Tables for multiple launch rocket systems. The assessment is based on the defined method combining necessary conditions (gate) and multi-criteria evaluation.

For self-propelled howitzers, the evaluation indicates that modern systems with a high level of automation generally meet all necessary conditions for technical capability for remote control from a protected position. In contrast, older or less advanced systems, particularly those requiring crew presence at the weapon, do not meet these conditions.

For multiple launch rocket systems, the situation differs. Although modernized systems enable fire execution from within the vehicle cabin and incorporate advanced fire control systems, the necessary conditions are often only partially documented or inferred based on expert assessment.

5.2 Brief Interpretation of Results

The results indicate that:

- the ability to conduct fire without physical presence of the crew at the weapon system is the key determinant of technical capability,
- modern self-propelled howitzers achieve this capability through integration of automated loading, aiming, and fire control,
- multiple launch rocket systems show a clear architectural trend towards enabling this capability; however, their implementation remains inconsistent and insufficiently documented.

At the same time, a discrepancy between declared and verifiable capabilities is observed across multiple systems.

6. Discussion

6.1 Tactical Implications

The ability to conduct fire without physical presence of the crew at the weapon system has a significant impact on crew survivability in the current operational environment [2,4]. In conditions characterized by:

- persistent surveillance,
- widespread use of unmanned systems,
- and high-precision counter-battery fire,
- separation of the crew from the weapon system can be expected to contribute to reduced operational risk [2,5].

Remote control from a protected position should not be understood as a replacement for mobility-based tactics such as shoot-and-scoot. Rather, it represents a complementary mode of operation applicable in specific tactical situations, particularly in scenarios requiring prolonged presence at a firing position under increased threat conditions.

Weapon systems lacking this capability remain vulnerable, especially when operating from static positions for extended periods.

6.2 Difference Between Automation and True Remote Mode

The results demonstrate that automation and remote-controlled capability represent fundamentally different concepts, and should not be treated as interchangeable. In this context, remote-controlled fire should be understood as a system-level capability rather than as a single automated function. It depends not only on loading and aiming automation, but also on the reliability of communication links, fire-control data exchange, positioning, command-and-control procedures, and resilience to degraded operational conditions [12–16]. Previous research on artillery fire-support control systems, military communication, AI-supported command and fire-control processes, manual fire-correction procedures, and GNSS-denied positioning indicates that automation must be complemented by robust fallback procedures and resilient information flows [12–16]. It is necessary to distinguish between:

- internal system automation, which enables the crew to remain inside the vehicle cabin,
- and true remote mode, in which no physical interaction with the weapon system is required during the firing cycle.

Many systems achieve a high level of automation, yet still require:

- crew intervention during loading,
- or physical presence at the system in certain phases of operation.

This distinction is also relevant in the wider context of robotic and digitally supported artillery capabilities. Research on unmanned ground vehicles for artillery survey, swarm maneuver on the digital battlefield, GNSS-denied positioning, and AI-supported command and fire-control systems indicates that future artillery architectures will increasingly combine automated subsystems, remote operation, resilient navigation, and digital command links [14, 16, 22, 23]. In such an environment, remote-controlled fire should be assessed not as an isolated feature of the weapon, but as part of an integrated system architecture. This distinction represents a critical factor in assessing technical capability.

6.3 Limitations of the Study

The primary limitation of this study is the availability and quality of open-source data.
While core system functions are often well documented, key areas such as:

- energy autonomy,
- stabilization,
- and safety and auxiliary functions,

are only partially described or not described at all in publicly available sources.

For this reason, expert judgement was applied in selected cases, and such assessments are explicitly indicated in the evaluation. An additional limitation is that some systems are still in development or are primarily presented in exhibition or promotional contexts, which increases the uncertainty of their evaluation.

7. Conclusions

The study demonstrates that the technical capability of a weapon system for remote control from a protected position is primarily determined by its ability to conduct fire without physical presence of the crew at the weapon. Modern self-propelled howitzers generally meet this requirement. Multiple launch rocket systems demonstrate emerging capability for remote-controlled fire; however, in most cases this capability is supported primarily by expert assessment rather than consistently documented evidence. Within the evaluated framework, system architecture appears to be a key factor, as it determines whether physical crew interaction is required during the firing cycle.

7.1 Practical Contribution

The proposed method enables:

- systematic and reproducible evaluation of weapon systems,
- comparison of systems with different levels of automation,
- identification of systems suitable for remote-controlled operation from a protected position.

At the same time, it provides a useful tool for supporting decision-making in:

- procurement,
- modernization,
- and operational assessment.

This practical orientation is consistent with defence research emphasizing that capability development depends not only on technical innovation, but also on procurement decisions, modernization priorities, interoperability requirements, education, and the ability to evaluate operational and economic utility before new systems are introduced into service [17, 24, 25, 29].

7.2 Future Research

Future research should focus on: detailed analysis of energy autonomy of weapon systems, verification of system capabilities under real operational conditions, assessment of resilience to communication disruption and electronic warfare, and integration of tactical factors into the evaluation of technical capability, development of integrated architectures combining automation, remote control, and resilient energy and communication systems.

Future assessments could also consider wider operational and support factors, including terrain mobility after artillery effects, transport infrastructure resilience, and non-standard employment of artillery capabilities in crisis-response scenarios [30–32]. These factors do not determine remote-control capability directly, but they may influence the practical suitability, deployment conditions, and broader operational value of artillery systems.

Future development of the framework should therefore include simulation-based validation of remote-controlled fire under realistic tactical conditions. Previous research using constructive simulation, live simulation, UAV reconnaissance models, and war-gaming methods has shown that simulation environments can support the assessment of force protection, commander training, operational planning, and combat effectiveness before procedures are tested in live conditions [7, 11, 26–29]. Such an approach would make it possible to evaluate not only whether a weapon system is technically capable of remote operation, but also how this capability affects survivability, firing-position defence, and mission accomplishment.

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