A New Munitions Taxonomy: Categorizing Advanced Weapons for Robust Analysis and Artificial Intelligence Assisted Applications

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ABSTRACT

Determining weapon-target pairings and munitions inventory requirements is an enduring challenge for warfighters, campaign planners, and defence analysts. These tasks are increasingly difficult as munitions become more complex and adopt advanced technologies such as delivery from multi-domain platforms, collaborative capabilities, enhanced autonomy, and modular sensors and payloads. Previously disparate classes of weapons and platforms are becoming more challenging to categorize and distinguish for analytical purposes. New types of innovative weapon systems feature onboard sensors with multiple phenomenologies and loitering capabilities, which blur the line between munitions and unmanned aircraft. Munitions with non-kinetic payloads cross existing boundaries between munitions and platforms with capabilities for communications, electronic warfare, and intelligence, surveillance, and reconnaissance. A new method of categorizing and grouping modern munitions is necessary to fully leverage sophisticated weapon systems and determine the most effective or efficient munitions inventory requirements. This paper begins to develop a new munitions taxonomy for classifying current and future munitions as an analytical foundation for mission planning, campaign analysis, operations research, and defence policymaking. The comprehensive categorization of munitions and their characteristics can enhance NATO cognitive superiority and cross-domain command at all echelons—from mission and campaign planners at the tactical and operational levels to policy and procurement analysts at the strategic level. Moreover, this taxonomy is an essential building block for the application of machine learning techniques and artificial intelligence-assisted planning approaches to weaponeering, campaign analysis, and military decision-making.

1.0 INTRODUCTION

Munitions are an essential aspect of contemporary and future warfare and play a central role in determining force design, doctrine, strategy, and procurement. Recognizing this importance, four of 18 of the North Atlantic Treaty Organization's (NATO) High Visibility Projects focus on the development, acquisition, and storage of munitions in the air, land, and maritime domains [1]. Beyond munitions development, determining munitions requirements at the engagement, theatre, and strategic level is an enduring challenge for warfighters, campaign planners, and defence analysts. Because of the varying technical characteristics of munitions, these tasks require analysts to classify and categorize munitions based on their differing attributes. Terms such as *long-range*, *hypersonic*, and *loitering* are used to feed analytical models and frame discussions about munitions. However, due to advanced technologies and the growing complexity of modern weapon systems, existing taxonomies are increasingly insufficient. Previously disparate classes of munitions and platforms are becoming more challenging to categorize and distinguish for analytical purposes. A comprehensive method of categorizing and grouping current and future munitions is necessary to fully leverage sophisticated weapon systems and frame future munitions discussion and analysis. This paper offers initial ideas on the potential to develop a new taxonomy for classifying munitions as a foundation for future mission planning, campaign analysis, operations research, and defence policymaking.

1.1 Key Stakeholders

Munitions taxonomies are important to several groups of stakeholders in NATO and across the world's defence community. At the tactical level, weaponeers and targeteers must have a comprehensive database of munitions characteristics in order to compare weapons against one another and determine munition options and priorities for a specific engagement. Beyond single engagements, mission planners rely on weapon attributes to determine platform loadouts and unit sustainment requirements. Today, these on-the-ground users must consider more than simply which warhead is most effective for a given target. Guidance method, sensor type, survivability, and launch platform all play key roles in effectively pairing modern munitions to their targets. At the operational level, campaign planners use munitions classes to plan theatre inventory requirements and model the portfolio of weapons required to flexibly prosecute a given target set. Finally, at the strategic level, strategists, acquisition personnel, and policymakers must classify munitions to manage and pursue force structure and doctrine. Policymakers use broad categories to drive the discussion around munitions procurement and employment. An incomplete or obsolete munitions taxonomy furthers the risk of these stakeholders relying on outdated weapons and failing to fully leverage the advanced capabilities of next-generation munitions. A comprehensive taxonomy is a vital building block for robust analysis and applying artificial intelligence (AI) to the automation of these processes.

1.2 Previous Munitions Taxonomies and their Inadequacy

Analysts have long relied on several common methods of classifying munitions which, until recently, have been sufficient for previous generations of weapons. The most basic taxonomy categorizes munitions by range. For example, range is typically used to divide classes of ballistic missiles between short, medium, intermediate, and intercontinental range (SRBM, MRBM, IRBM, and ICBM, respectively) [2]. Weapon engagement zone (WEZ) or effective engagement range as it relates to the range of adversary weapons is another common categorization [3], [4]. Other familiar categorizations include by launch platform [5], target type [6], and guided versus unguided munitions [7]. Many agencies and defence organizations use several of these categories simultaneously to describe various weapons, although many do not use uniform taxonomies across all categories of munitions and instead use specific terminology for cruise missiles, ballistic missiles, bombs, and other types of weapons [8], [9].

While conducting research on next-generation munitions, however, the authors found these existing taxonomies inadequate to effectively classify growing numbers and types of modern munitions. Advanced technologies and characteristics such as enhanced autonomy, miniaturized sensors, non-kinetic payloads, enhanced manoeuvrability, networked and collaborative capabilities, swarming, modular components, multi-domain launch capability, and complex flight paths can cause these weapons to blur the lines between many existing munitions classifications, both in characteristics as well as dynamic changes to features based on mission need. Furthermore, weapons with these attributes are increasingly difficult to classify and muddle the traditional boundaries between munitions and other platforms, particularly in the air domain. These features are key to future munitions employment techniques and operational concept development and should be addressed in analytical taxonomies.

1.3 Previous Attempts to Create a New Munitions Taxonomy

A new munitions taxonomy for classifying future and current munitions is necessary to enhance the foundation for mission planning, campaign analysis, operations research, and defence policymaking. Initially, the authors referenced recent work on categorizing modern ballistic missiles from the Aerospace Corporation [10] and on non-kinetic weapons from the RAND Corporation [11]. These taxonomies are useful steps but are limited to ballistic missiles and non-kinetic effects. A broader and more comprehensive system of classification is necessary for future analysis and the introduction of AI-assisted decision-making.

2.0 ANALYTICAL METHODS

The development and refinement of such a munitions taxonomy involves two principal tasks. First, the taxonomy and its various classifications must be scoped. Second, a comprehensive survey of modern and developmental munitions must be conducted to identify relevant categories and subcategories.

2.1 Scoping the New Taxonomy

Creating a munitions taxonomy that is comprehensive, inclusive of systems on the cutting edge of weapon development, and useful to a broad set of stakeholders is daunting and may be unfeasible due to the continued advancement of technology. No current taxonomy will be able to account for the features and capabilities of all future weapons. Instead, a new taxonomy is better imagined as a framework to organize current munitions that remains flexible and open to adaptation to include further advancements. This framework must be able to shift and grow to accommodate new models and analytical efforts. Although the taxonomy should be general enough to include the full range of weapon systems, analysts must be able to fit more detailed models within this broad framework. The taxonomy should expand policymakers' awareness of munitions capabilities but should contain several levels of detail to avoid over-complicating non-technical discussion and prioritization.

With these requirements in mind, this paper begins developing a comprehensive munitions taxonomy for surface strike munitions of all types and within all domains, as an illustration. Surface strike munitions are the focus of several studies by the authors and include a wide range of weapons with varying features and characteristics. Furthermore, many of the systems that are now exceeding the capabilities of existing taxonomies are surface strike weapons. Currently, this initial taxonomy effort intentionally excludes surface-to-air missiles and waterborne weapons such as torpedoes and sea mines. The authors also excluded nuclear payloads and effects. These systems represent opportunities for future expansion of the framework presented in this paper.

2.2 Developing the New Taxonomy

With the taxonomy's scope bounded, the authors conducted a comprehensive survey of current and developmental munitions to identify the range of characteristics and features of surface strike munitions. The survey includes strike weapons from all domains in U.S., NATO, Russia, China, and other nation's inventories. In addition to currently fielded weapons, the database includes the known or anticipated characteristics of developmental weapons and previously developed but never-fielded weapon systems. In total, the authors collected detailed information on the attributes of more than 125 past, current, and developmental surface strike munitions. Data collected includes details such as weapon speed, flight profile, launch weight, guidance system (initial, mid-course, and terminal), circular area probable (CEP), payload type and weight, cost, launch platform, and manufacturer.

Collecting detailed and accurate information on world munitions presented some challenges related to classification and information availability. For many U.S. and NATO munitions, the most accurate information on range, sensor type, and survivability features are classified. The authors utilized only open sources in the creation of this database to ensure the resulting framework is publishable and open to critique, refinement, and expansion. Future users could, however, use the taxonomy to organize munitions based on classified data. To ensure the information's accuracy and open-source nature, at least two publicly available sources were used for each munition. The authors also confronted difficulties finding complete and detailed open-source information on developmental weapons and Russian and Chinese munitions. In many of these cases, the authors collected as much data as could be verified by two publicly available sources. In the case of developmental weapons, the authors often relied on estimates or anticipated features from weapon developers and program requirements.

With the survey complete, the authors compiled the list of categories, attributes, and feature options from across the span of surface strike munitions. Within these categories, subcategories and major groups of features were identified. These categories were then compared with the range of common munitions classifications currently in use across defence literature. For example, the authors collected munition speed in Mach number. Munition speed, however, is commonly further subcategorized into subsonic, supersonic, and hypersonic. Accordingly, the taxonomy includes speed as a major category and the Mach regimes as subcategories. The authors evaluated categories and subcategories according to several criteria: Do the classifications accurately account for each munition and its unique attributes? Are there features or characteristics that fall outside the categories and subcategories? Most importantly, to what degree do the categories and subcategories assist in the comparison of one weapon to another? Which categories and subcategories are most analytically useful to the previously identified stakeholders?

3.0 RESULTS

Figure 1 displays the resulting taxonomy developed for surface strike munitions. The major categories are bolded, with subcategories bulleted below. In total, the taxonomy identifies 10 major categories for consideration. Some subcategories are intentionally left broad and open-ended. This section will demonstrate the taxonomy's classification method using a category that is challenging to uniformly classify across weapon types—munition range. Range labels vary widely based upon the type of munition and its intended use. Rather than attempting to broadly classify weapons as *short* or *long* range, the taxonomy divides range classifications into three major subcategories: absolute, relative, and loitering. First, range classifications can be absolute measures of distance, such as differentiating between *short* and *medium-range* missiles at the 1,000 kilometre mark.

Second, range classifications can be defined in relation to adversary weapon systems. A munition could be considered a *standoff* weapon if it can be launched from outside the threat range of an opponent's defences. Of course, this measure is relative, and changes based on the choice of adversary and the evolving capabilities of their defences. The U.S. AGM-154 Joint Standoff Weapon, first fielded in the late 1990s, has a vastly different range than the current AGM-158 Joint Air-to-Surface Standoff Missile. Their shared nomenclature illustrates the evolution of what can be considered a true *standoff* munition.

Third, the range category includes a subcategory to denote loitering capabilities. Although munitions capable of maintaining a presence over the battlespace for a limited amount of time are not new themselves, this taxonomy identifies loitering as a function related to, but separate from, the munition's total range. In future iterations, this loitering subcategory can be further divided by loiter duration, profile, and function—which are a result of combinations of range, speed, and trajectory.

Importantly, this taxonomy identifies and annotates several munitions features not currently well-described and labelled. Characteristics such as survivability features, autonomous functions, loitering capabilities, and non-lethal payloads are of increasing importance to munitions employment and analysis. For example, the ability to internally carry a munition inside an aircraft's weapons bay is not uniformly considered by previous taxonomies but is key to maintaining a stealth aircraft's radar cross-section and executing strike missions in increasingly contested environments. By identifying and classifying these attributes, the taxonomy serves as a basis to increase the relevance of analysis and inform future discussion.

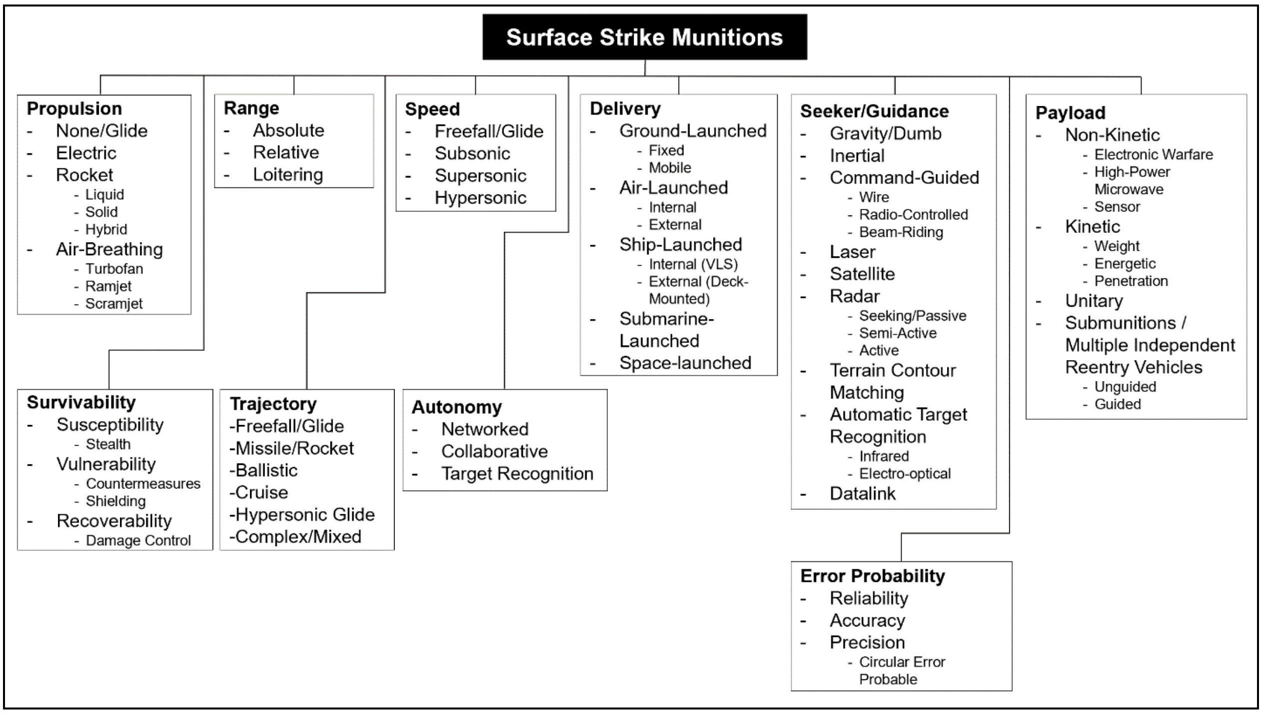

Figure 1: A new munitions taxonomy: example for surface strike weapons.

4.0 CONCLUSION

Although this paper develops a taxonomy limited in scope and detail, it serves as an illustrative example to outline the inadequacy of current munitions taxonomies and highlights the value of considering new methods of comprehensively categorizing and comparing munitions. The taxonomy is not intended as a final product but as a developmental framework for evaluation, refinement, and expansion. This framework represents an initial attempt to address a challenge of growing importance and is a foundation for future study. The comprehensive categorization of munitions and their characteristics will enhance NATO cognitive superiority and cross-domain command at all echelons—from mission and campaign planners at the tactical and operational levels to policy and procurement analysts at the strategic level.

4.1 Future Applications

Future taxonomies can be applied by each of the previously identified stakeholders. Weaponeers can use the additional detail offered by this taxonomy's categories to better match munitions to a given target, platform, and mission. More detailed and uniform classifications will assist campaign planners and operations researchers to better model munitions employment and theatre requirements. Lastly, the various categories help to illuminate the full range of important munitions attributes to policymakers and strategists. The taxonomy provides a standardized framework through which to compare, prioritize, and identify relationships between various weapons.

Such a taxonomy is also vital to applying AI to munitions analysis. AI applications can include using semantic reasoning engines [12], [13] to automate some of the processes used to generate and recommend options, whether to the weaponeers/targeteers, the campaign planners, or to policymakers and strategists. Taxonomies like the one proposed, along with conditional rule sets, can be used to build ontologies [14] for semantic reasoning engines. Techniques for unsupervised semantic mapping with natural language processing [15], may also be used to further extend and evolve the various taxonomies as new munition types and applications are introduced.

4.2 Further Research

Further research can expand the taxonomy's scope and further evaluate its utility through case studies. A truly comprehensive taxonomy must be expanded to include all types of munitions, including surface-to-air missiles, waterborne munitions (such as mines and torpedoes), additional directed energy weapons, and various nuclear payloads. The categories and classifiers will need to be expanded as additional munitions and technologies are developed and fielded. The taxonomy should be evaluated through specific case studies to further refine the various categories and subcategories. Valuable cases for further examination are those at the forefront of technological advancements and include non-kinetic munitions, modular munitions, networked and collaborative weapons, and munitions with enhanced autonomy.

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