The Problems of Standardization of Ground-to-Air Missiles

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ABSTRACT

The article presents the issue of determining tactical and technical premises for proposed standards of calibres of ground-to-air missiles. The possession of the missile-to-air missile systems by the state is not an end in itself, or a way of mutual allied settlements, and is a requirement of the modern battlefield. In connection with the decisions made in the Wista program, only the Narew program implemented by Polish enterprises can improve the air defense capabilities of the country and operational forces. The proposal for the standardization of ground-to-air missiles is aimed at defining the requirements for these missiles to such an extent as to increase the sense of security of citizens in peacetime, while, in wartime, the loss of human life and infrastructure will be reduced. During military operations, the state of air defense is no longer of such importance for the state authorities, because the authorities are evacuated in the face of threats, because they are the greatest asset of the nation. In the case of combat operations, the standardization of arms systems is the basis for logistical security. The purchase of rocket equipment for half an hour of combat is pointless, because, during this time, there will be no direct contact with the opponent, while the potential opponent probably has supplies for many hours of combat activities. If it is planned to start combat operations on its own, it makes sense, because, after the firing of the first volley, there will be no more. Therefore, the authors draw attention to the benefits for Polish society resulting from the development of an anti-aircraft system for the Narew programme by Polish companies and serving primarily to secure the air

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defense of the country. Corporate lobbyists should not write requirements for weapon systems, because the only weapon system compliant with their requirements will be those that are offered by the corporations that hired the lobbyists.

Keywords: missile, classification of battle missiles, missile destruction zone, warhead, weapon system, Polish enterprises

PRELIMINARY

Missile weapons are now one of the most important and promising combat weapons of modern armies. Missiles of various classes and destinations are used to equip subdivisions of land forces, navies, aviation, anti-aircraft, and territorial defense. The missile arsenal extends from miniature rockets, for a single soldier with a range of several kilometres, to strategic multi-tone giants, capable of flying many hundreds of kilometres in one minute. Development is taking place both in terms of qualitative and quantitative improvement, particularly in air forces and air defense forces. The use of rockets as a combat weapon has been known since ancient times, but the most intensive development began only in the twentieth century. This is mainly due to the changes that have occurred in the very nature of military operations, i.e. a significant increase in the dynamics of military operations, an increase in their manoeuvrability, the speed of reaction, and an increase in the depth of operations of troops. In turn, these factors require rocket weapons to increase their range of action, their mobility, precision, and effectiveness. The initial response of weapon designers in the new war conditions was missiles with engines for various types of fuels. In terms of their ease of use, the designs came close to small arms, and, in terms of fire efficiency, they came close to artillery. Then, especially in the last decade, many technical improvements in the process of rocket production and control were introduced, a number of specialized machines and equipment were built, the application of which significantly improved the development of mechanization, automation, and innovation in the modern production of rocket weapons. Missiles have a complex construction. For them, various requirements have been developed, resulting from the nature of the modern battlefield. According to these requirements, missiles differ in specific combat, operational, and technical characteristics, details of structural solutions, technological execution, and the specificity of operation and combat purpose.

One of the major shortcomings in the production of modern missiles is the heterogeneity of their production. Hence, it became important to standardize the production of rocket munitions, and to achieve a complete identity in the geometry and quality of the manufactured parts, the chemical composition of the rocket charge, its density, configuration, and many other parameters. With the development of missiles, there have been significant changes in rocket launchers that were
previously not sufficiently stable after firing, which had a significant impact on the ballistics of missiles and their accuracy, for example, for unguided missiles.

As can be seen from many strategic documents, NATO’s alliance on standardization knowledge assimilates the collective capabilities and potentials of air, land, naval, and special operations forces, and others. It is standardization that creates the ability to coordinate, control, and use the resources of the Member States in pursuit of the objectives of the whole alliance.

**BENEFITS OF APPLYING STANDARDIZATION IN DEFENSIVE INDUSTRIES**

Standardization is one of the basic principles of Lean Manufacturing. It makes it easier to observe processes, measure them, notice discrepancies, and reveal problems. At the same time, there is no shortage of work associating standardization with stiffening work methods, freezing changes, or bureaucracy. It seems that such opinions may be a direct result of some experiences resulting from the examples of treating standardization as an end in itself without understanding that it makes sense only in balance with continuous improvement and as a tool for building the stability needed to improve. The issues of the standardization and normalization of rocket weapons are also discussed at the design level in the works [3, 4, 5].

Publication [3] presents a controlled missile as a defense product for the needs of the Polish Armed Forces, subject to a specific model of acquisition. The principles of the functioning of suppliers (enterprises) of defense products were expressed by describing the binding legal acts and standardization documents. The general technical requirements for the product, the principles of developing tactical and technical assumptions, and the specificity of research insuring that the product meets the adopted assumptions are presented.

In Publication [4], it was stated that within the project implementation, e.g. missile control block assemblies were classified to the group R.5- O-I-C (according to NO-06-A103), which means that they were classified to the group R.5- O-I-C (according to NO-06-A103): R - deck rocket device, 5 - group of rocket devices, O - general climate, state of combat readiness (capable or incapable), and C - single use.

This classification corresponds to the group of devices to which the 122 mm projectile belongs in the production version in progress. The classification of control block assemblies according to NO-06-A103 allows the determination of the environmental requirements to be fulfilled by the designed assemblies. The complexity of the project and the number of consortium members and involved participants required the team implementing the project to define information about the product (product definition, product performance information, requirements, and specifications), and first of all, to adopt an unambiguous numbering rule for configuration objects. In Publication [5], the author described the application of the European Directive 2009/81/EC on the market of equipment suppliers for military
use. The means of preparing technical specification with the use of standardization documents was presented. The main standards concerning the system and quality are presented. The method of the application of standardization documents in development works is discussed.

Standardization applied as a technique from the theory of work organization enabling the introduction of changes for the better is undoubtedly a dynamic process. Figure 1 shows important relationships between standardization and change resulting from continuous improvement of the organization.

Standardization includes the standardization of defense products, the planning of document development, the development of these documents, their distribution, the implementation into production, and exploitation. Standardization is understood as the processes of selections in several EU countries as uniform technical solutions in the field of armaments. Standardization is based on three pillars: mutual compatibility, interchangeability, and suitability for common use in combat. Standardization of armaments is certainly connected with the restructuring of military and economic relations in the NATO system, the improvement of armament systems and military equipment, as well as their joint production. It means not simply combining efforts, but overcoming economic and political problems, and consolidating potential command capabilities and technical interdependencies.

![Figure 1. The relationship between continuous improvement and standardization [19].](image)

**STANDARDIZATION IN PRACTICE—AN AMERICAN EXAMPLE OF THE BENEFITS OF STANDARDIZATION**

In the case of rocket weapons, which are exploited in Poland, we have to deal with post-Soviet [1, 2] and modern rocket weapons obtained through purchases mainly from various manufacturers. Currently, the anti-aircraft missile set is expected to be effective in combating threats in the fire zone of a given set. Multilayer defense allows effective counteraction of threats coming to the defended
object from different levels. However, it is expected that the system itself is capable of protecting the object and also of self-defense [6].

It is not economically or tactically justified to create an anti-aircraft defense system requiring the creation of a chain, e.g., Set A protects the object, Set B protects set A, and Set C protects the weapon access to Set B. If one link in a chain is lost, the entire system becomes ineffective. It is important that the anti-aircraft systems introduced in Poland at a huge cost have the capabilities essential for the Polish anti-aircraft defense, and that they are universal and enable the configuration of launchers with different missiles from different manufacturers.

In the United States and Russia [7, 9], the use of Multi-Mission Launcher (MML) multi-task launchers has been under development for a long time [8]. Manufactured exclusively for the U.S. Army, the multi-purpose launcher successfully hit a rocket target and an unmanned aerial vehicle using the AIM-9X rocket during a rocket test in New Mexico. The action test against manoeuvring rockets was conducted on April 1, and the UAS combat test was conducted on March 29, 2016 [10]. On April 4, the army also fired a Mini-Hit-to-Kill (MHTK) rocket from MML. MHTK does not have a traditional warhead, but it destroys rockets, artillery, and mortar missiles with kinetic energy through a direct hit [11].

MML is developed and produced by the U.S. Army and represents the first step in more than 30 years in the development of an important rocket program by the government's industrial base. The basic capabilities of MMLs are summarized in Table I.

![Figure 2. Multi-Mission Launcher (MML) [8].](image)

| TABLE I. THE BASIC CAPABILITIES OF THE MML SYSTEM. |
|------------------|------------------|
| **Mobility** | Mounted on a medium tactical truck |
| **Targets** | Unmanned aircraft systems (UAS), cruise missiles, rockets, artillery, and mortars |
| **Role** | Short- and medium-range multi-mission air defense system |
| **Interceptors** | AIM-9X Sidewinder; Miniature Hit-to-Kill (MHTK); Lockheed Martin’s Longbow Hellfire; Raytheon’s Stinger; Rafael’s Tamir |
| **Status** | Prototype and testing phase; two MML prototypes at White Sands Missile Range; Plans to develop eight additional MMLs |
| **Producer** | Army Cruise Missile Defense Systems (CMDS) and the Army Aviation and Missile Research Development, and Engineering Center (AMRDEC) |
Interceptors Fired by MML:

- AIM-9X Sidewinder: Originally designed as an air-to-air missile and has recently been adopted as a ground-to-air interceptor because of its unique capabilities;
- Longbow Hellfire: Originally designed as an air-to-ground tank-killing missile and has recently shown success in destroying UAS targets [11];
- Miniature Hit-to-Kill (MHTK): Has no warhead and is designed to intercept and defeat rocket, artillery, and mortar threats with kinetic energy during a direct hit [12];
- Stinger: Originally developed as a man-portable air defense infrared homing surface-to-air missile and has been adapted to fire from a wide variety of ground vehicles [13]; and,
- Tamir: Used by Israel’s Iron Dome to counter rockets, artillery, and mortars [14].

The receptors used in the MMLs were probably chosen so that each missile has a different dominant feature. The set of features is shown in Figure 3. The set of interceptors allowed them to be configured to meet the needs for the required fire zone coverage of a particular rocket launcher.

![Figure 3. Selected features of Multi-Mission Launcher missiles (MML).](image-url)
SELECTED PROBLEMS OF COOPERATION IN THE MISSILE PRODUCTION SECTOR

In today's world, the ability of any country to defend its interests in an armed manner depends to a large extent on external cooperative relations. The position and vigour of the economy and the armed forces of the state influence the forms, directions, and depth of industrial-military cooperation. Therefore, this type of cooperation of states, due to its role, mechanisms and effects, occupies a special place in the international economic relations of states. The cooperation of armaments industries has a long history and many successful constructions. Programs in this area were launched in 1960, and their number increased significantly in the following decades. Projects such as Transall, Tornado, HOT, Milan and Eurofighter—to name but a few—have demonstrated both the political will and the technological capacity to jointly develop advanced weapon systems. However, military cooperation did not cover all areas. So far, it has been limited mainly to aviation and electronic automation, while armaments, control algorithms, and shipbuilding industries still remain largely focused on their own country. Defense cooperation has traditionally been organized on an intergovernmental and ad hoc basis, with complex institutional and industrial arrangements leading to delays and cost overruns. These well-known weaknesses in the sector have not altered many of the shortcomings of the European armaments sector, in particular, the fragmentation of the market, which results in costly and unnecessary duplication of solutions. Recent conflicts in Yugoslavia, Iraq, Afghanistan, and Syria have shown that European armed forces are insufficiently equipped to meet the objectives of modern war [20]. In particular, low levels of investment in research seriously jeopardize the technological capacity of industry to prepare for the future. At the same time, it is becoming increasingly difficult for European companies to compete with large US defense corporations, which benefit from a huge, coherent, and well-protected domestic market and a steadily growing US defense budget.

The decisions taken in recent years by the leaders of the NATO bloc envisage further development of military capabilities. In particular, a major programme of the modernization of weapons and military equipment for ground forces is planned in the participating countries, including Poland.

According to some experts, the high requirements for modern weapons systems require the solution of many complex problems, both during their development and the production process. For example, the press publications indicated that the tactical and technical requirements of the American anti-missile system SAM-D are so complex and diverse that, according to the creators themselves, this complex turned into a "surface aircraft carrier." As a result, there is a delay in the timing and cost overrun of the planned measures for development, and a significant excess of the actual production costs over the planned ones [21].

A large number of companies are usually involved in the development and production of each model of weapons and military equipment. According to military
experts, coordination between them is very difficult. At the same time, the structure of the 'life cycle' of armaments has changed in developed countries. For example, during the Second World War, the life cycle of weapons and military equipment models was approximately twice as long as the development period. Today, the average time taken to develop prototypes of new weapons is between eight and ten years, and their effective use is between seven and eight years. Military experts point out that not all new weapons and military equipment meet modern requirements. For example, 38 weapons have been tested in the US, and 10 of them have been found to have tactical and technical characteristics that are significantly lower than those established by the Ministry of Defense. It is worth noting that the cost of developing and producing each successive generation of weapons and prototypes of military equipment is much higher than in previous generation. Thus, the cost of production of the same type of military products tripled between 1961 and 1971. The increasing complexity of weapons and military equipment systems leads to a significant increase in the cost of maintenance and repair. For example, the maintenance and repair workload of modern US self-propelled artillery installations is 53% higher than that of WWII self-propelled guns. The cost of the annual service of the Leopard tank, including the use of spare parts, amounts to over 40 thousand euros, which is 5% of its production costs.

In recent years, the military leadership of the countries (members of the NATO bloc) have attached great importance to the improvement of the quality of military production, the product’s durability, and other operational indicators. One of the mandatory tactical and technical requirements of the American army is the ease of maintenance and the repair of weapons. The U.S. Department of Defense issued a special directive containing rules for the development of new weapons systems. It stresses that it is necessary to carefully develop tactical and technical requirements in order to extend the life of these systems, as well as to reduce the number of personnel involved in operations in the broad sense of the term [22].

Foreign military experts see a reduction in the cost of designing and manufacturing weapons as standardization and unification. Much work is being done in NATO countries to develop multi-fuel engines in order to reduce the number of fuel types. For example, Bundeswehr is planning to supply only four types of fuel in the coming years (until recently there were eight).

Increasing attention is being paid to the standardization of parts, components, and assemblies, as well as to the standardization of tools needed for their maintenance and repair. As a result, the development, production, and maintenance costs of weapons should be significantly reduced. In addition, the Alliance pays considerable attention to solving the problem of ensuring the reliability of arms models and military equipment. This is due to the increased structural and technological complexity of the models using different components and parts (mechanical, electronic, optical, etc.). It is not difficult to notice that the high operational reliability of weapons depends, to a large extent, on the quality of their production. Therefore, one of the latest organizational solutions in the U.S. for the
production of military products is its supply according to the solutions applied by the first supplier.

In order to improve structural and technological solutions in the development of weapons, a large number of field tests of prototypes in various climatic conditions, including the Arctic, were conducted. Carrying out such tests takes a lot of time, so the allies started to strive to replace them by full-scale laboratory tests, which allow shortening the total time of development of new types of weapons and military equipment. One of the problems facing weapon developers is estimating the reserves of spare parts, tools, and accessories necessary for its reliable operation. Research in this field has been conducted in the USA. Based on the research, each year, the U.S. Department of Defense spends more than $1.5 billion on ensuring the reliability of weapons and military equipment in field conditions. Due to ageing, wear and tear, and other causes, and a large number of weapons are taken out of a state of readiness (almost 4% of total costs).

In solving many problems related to the development, production, and operation of weapons and military equipment in NATO countries, mutual cooperation has helped in recent years, and the number of new models and the number of cooperating countries has increased.

Active military and economic cooperation is most noticeable in the countries of Western Europe. The industry of these countries is not inferior to that of the USA, not only in terms of assortment, but also in terms of the quantities of traditional weapons produced. France, the United Kingdom, Germany, Sweden, and Italy account for almost 100% of the joint production of NATO and EU member states' strategic rockets, tanks, artillery vehicles, self-propelled guns, anti-tank and air-raid missiles, and the launchers for them, 80% of manufactured combat aircraft and helicopters, and 60% of armoured transporters, combat machines, and other armoured vehicles. Therefore, these countries base their production capacity mainly on international cooperative supplies of parts and components.

Table II shows that Polish companies are not included in the cooperation in defense products with US companies.

In order to accelerate the development, production, and disposal processes, NATO governing bodies have decided to divide the functions between the countries in the field of missile development. Therefore, Germany is currently responsible for the development of air-to-ground missiles, and France is currently responsible for ATGM guided missiles. An agreement was reached between the countries of the European NATO group on the joint development and production of more than ten weapons (military aircraft, tanks, rocket and artillery systems, etc.). In order to solve problems with the development of this type of weapons and military equipment, personnel exchanges are practiced, languages of NATO countries are taught, and training is provided on the knowledge of achievements in the field of logistics and the use of warehouses.
TABLE II. EXAMPLES OF COOPERATION OF EU ARMAMENTS COMPANIES WITH COMPANIES FROM THE USA [23].

<table>
<thead>
<tr>
<th>Country</th>
<th>Company name</th>
<th>Country</th>
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<tbody>
<tr>
<td>Germany (6)</td>
<td>AEG Telefunken, Nokia Siemens, Siemens, BAE Systems, Thales, EADS</td>
<td>USA (24)</td>
<td>IDEAS, ECM, Finmeccanica, Umicore, Thales, EADS, BAE Systems, Lockheed Martin</td>
</tr>
<tr>
<td>France (5)</td>
<td>Dassault Aviation, Thales, Safran, Eurocopter, Matra</td>
<td></td>
<td>Dassault Aviation, Thales, Safran, Eurocopter, Matra</td>
</tr>
<tr>
<td>Italy (3)</td>
<td>Finmeccanica, Leonardo, Finmeccanica</td>
<td></td>
<td>Finmeccanica, Leonardo, Finmeccanica</td>
</tr>
<tr>
<td>UK (6)</td>
<td>BAE Systems, Rolls-Royce, Thales, QinetiQ, QinetiQ, QinetiQ</td>
<td></td>
<td>BAE Systems, Rolls-Royce, Thales, QinetiQ, QinetiQ, QinetiQ</td>
</tr>
<tr>
<td>Sweden (1)</td>
<td>SAAB</td>
<td></td>
<td>SAAB</td>
</tr>
<tr>
<td>&quot;Europe&quot; (3)</td>
<td>Airbus, Thales, EADS (now Airbus Defence)</td>
<td></td>
<td>Airbus, Thales, EADS (now Airbus Defence)</td>
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The activation of military-industrial cooperation of Western European countries is conducive to the following:

- A strong increase in the size and complexity of the structures of military needs in the conditions of globalization;
- The emergence of more modern and expensive weapons;
- An increase in the share of R&D expenditure in the production costs;
- The need to employ a highly qualified workforce;
- The impossibility for one country to organize the production of all types of weapons;
- The need to deepen the standardization and unification of armaments and military technology within NATO;
- The efforts of EU countries to create a unified base on the European stage that is in line with the new strategic concept of NATO; and,
An increase in the competitiveness of the Gross Regional Product (GRP) and seeking to balance European trade with the US.

For nearly half a century, licensed production of weapons, including tactical missiles AGM-65D Maverick air-to-ground (caliber 300 mm) that were developed by Hughes Aircraft (now Raytheon USA), has been organized in European countries. Belgium, Denmark, Germany, the Netherlands, and Turkey also participated in the programme, under the overall management of the Italian company Selena. From 1972 until the end of production in 2000, more than 75 thousand Maverick [24] missiles of various types were manufactured. In recent years, the internal arms markets have been shrinking; therefore, it is important to increase the export capabilities of defense companies in EU countries. Therefore, sales of licenses and co-production are increasing, billing forms are modernizing, and new export models of weapons are being developed (Fig. 5).

![Comparison of defense spending](image)

The graph in Figure 4 shows that the military powers have increased their spending on armaments. China has the highest dynamics of spending on these objectives, while the United States still spends the most on defense.

The future is likely to bring a wide range of new threats from emerging technologies or new, creative and innovative tactics, techniques, procedures, capabilities, or doctrines. Without incurring the costs of research and development, hostile actors can exploit technological progress and translate it into capabilities that threaten the NATO bloc. Examples of areas where technology can revolutionize warfare include sub-surface and underground operations, group techniques (swarms), space weapons, targeted energy, autonomous systems and sensors,
quantum technologies, unmanned systems, electromagnetic projectiles, renewable energy, artificial intelligence, component manufacturing (3D printing), and biotechnologies and nanotechnologies. The armed forces must be able to identify, monitor, and understand new threats and order protection measures.

Both state and non-state organizations, including political and criminal groups, will pose future dangers. While many of these threats already exist, future technological changes and the characteristics of future cities will exacerbate them even further. Technological advances will allow increasing the capabilities of new unmanned aerial vehicles, to develop 3D weapon systems, to develop intelligent IEDs and, indirectly, firearms. Parties are expected to adopt group tactics at the level of individual weapons (weapons swarm) and using battle clusters that aggregate and disaggregate when needed by concentrating and dispersing in response to changes in the tactical environment. Urban environments, with their infrastructure and systems, are already being targeted by enemy action, requiring security and protection, as well as investment in expertise to keep cities operating. Separating the population from weapons and defense systems with increasing electronic communications will enable opponents to disrupt or control larger areas of urban infrastructure with less force.

Figure 5. An example of cooperation between defense industries of the USA and Great Britain [26].

New threats create new challenges for governments. The long-awaited reconstructions of the EU's defense industries still have a lot of work to do in various areas, including, in particular, the review of the principles of a comprehensive defense policy and the dimensioning of the needs of EU members' armed forces,
discussion and adoption of relevant laws in parliaments, better use of civil-military dual-use synergies, and synchronized research by numerous and different scientific and research centres. Continuing along this path, Europe may be able to achieve strategic autonomy and become a security provider rather than a security consumer.

CONCLUSIONS

The visible competitive struggle of U.S. and European armaments companies has so far been focused on the FMRAAM (U.S.) long range rocket outlook programs against the Meteor rocket and the AIM-9X short range rocket against the ASRAAM rocket. In this fight, the EU’s efforts have been directed towards establishing a US-independent capability for guided missiles, as evidenced by the dynamism and volume of funding for new European developments. Despite these efforts, US corporations are winning the battle. This does not mean that, as a member of the European Union, we should only buy missiles from outside the EU (Norwegian, American, Israeli), and then we ourselves are excluded from the supply chain.

It is necessary to rebuild the capacity of the Polish defense industry as soon as possible (i.e. one in which the Polish State has the ability to decide, as a result of ownership supervision). Polish Defense Industry enterprises should focus on the production of their own products (supported by licenses) and the integration of systems (supplemented by the supply of equipment compliant with the applicable standards). What we are currently producing are mostly technologically outdated products, which do not have much in common with the innovative global trend. Changes now require a revolutionary approach and evolutionary changes that are slowly taking place in institutions known to authors that will prepare Poland to defend itself (mortgage) fifteen years after the end of the Third World War.

Observance of standards (STANAG, MIL, NO, EU Directives) currently gives Poland great benefits [6] and allows starting production of advanced rocket equipment on the basis of supplies from global manufacturers and integration of systems in Polish Industry Enterprises. Then, too, the problem of the lack of source code for the programs is reduced. Poland, which is now a front country, must be able to defend itself in order not to suffer such huge losses as during the Second World War (the allied concept of defense does not have to prove itself; until now, the validity of this concept has not been confirmed). Therefore, the authors draw attention to the benefits for Polish society resulting from the development of an anti-aircraft system for the Narew programme by Polish companies and serving primarily to secure the air defense of the country. Corporate lobbyists should not write requirements for weapon systems, because the only weapon system compliant with their requirements will be those that are offered by the corporations that hired the lobbyists.
Non-compliance with the principles of standardization and normalization leads, in the case of purchased weapons, to long-standing problems with the integration of purchased missiles with combat vehicles or with helicopters. In Polish literature in [17] prof. Jerzy Łunarski presents basic information about standardization and normalization, which is sufficient to understand their principles and application and practical use in undertaken activities, as well as their impact on quality assurance. In [18], the authors present the fundamental differences between standardization and normalization in a table.

Economic effects of the implementation of the WICHER rocket program for domestic and foreign beneficiaries at a total cost of 520 million PLN.

Economic effects of purchasing a rocket license for the NAREW program for domestic and foreign beneficiaries at a total cost of 670 million PLN.

Figure 6. Difference in economic effects for obtaining the missile system of the NAREW program by two methods (given amounts refer to the same assumptions) [27].

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