The constructing of a solution for quick test firing at the ground artillery company

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ABSTRACT

Current research endeavours aimed at enhancing the efficacy of artillery firepower primarily concentrate on the application of auxiliary technologies for calculating and determining firing elements, as well as the exploration of innovative firing methods and regulations to conserve artillery shells. These initiatives do not directly investigate solutions to reduce the time required to determine effective elements for artillery. Consequently, this study proposes a solution that allows quick test firing and conserves rounds when directly testing ground artillery targets via the VRP712/S data transmission systems developed by the group that serves the Viettel defence industry. As a result, the authors have built a software system for quick test firing at the ground artillery company. In contrast to the conventional calculations of previous gunners, the proposed solution has been validated via firing exercises conducted at a ground artillery company utilising 152-D20 guns and 105 mm guns, yielding favourable results.

Keywords: Artillery; VRP712/S; RestSharp.

1. INTRODUCTION

In combat engagements, artillery firepower is decisive in securing advantages and is the army's primary lethal asset. Artillery is not only the first target that a competitor seeks to locate and destroy, but warring factions consistently devise methods to enhance their artillery firepower on the battlefield. Fire reconnaissance systems and high-tech weapons have experienced significant advancements and gained widespread popularity due to the capabilities of modern technology. Artillery, subsequent to discharge, can readily discern its own location; conversely, its substantial dimensions frequently render it susceptible to rapid destruction subsequent to revealing its whereabouts. Since the world concerns, the majority of the militaries of those countries are occupied with research aimed at reducing the time required to prepare elements and discharge effective fire in order to complete the artillery fire mission early and then withdraw from the battlefield [1].

The countries possessing advanced artillery shell manufacturing technology and enormous military prowess, including the United States, China, England, Germany, France, and automating element retrieval and artillery shell launching, as well as intelligent artillery shells, frequently strive to design, manufacture, or enhance new generations of artillery in order to precisely increase their effectiveness, automate calculation and command processes, develop self-propelled artillery shells, and so forth.

Vietnam has not allocated substantial resources to the development and production of intelligent artillery projectiles and modern artillery. As a consequence, these efforts have failed to yield important results. Using a variety of supporting technologies to calculate and determine firing elements, as well as developing new firing rules and methods to conserve artillery shells, is the sole focus of current research programmes aimed at enhancing the effectiveness of artillery weapons. There is no explicit objective of these initiatives to reduce the time required to determine which elements function optimally for artillery. The implementation of those investigations has spanned a considerable duration, primarily from 2000 to 2007. The application of old technology results in research products that are significantly dated, and the comparability of equipment configurations to user requirements in the current day cannot be guaranteed. Concurrently, shooting exercises employing already established shooting principles have comprised the majority of research efforts. The development of methods to speed up the identification of efficient firing elements to fulfil the requirements for modern warfare operations has received limited consideration. Furthermore, there is a lack of established equipment or systems capable of automating the firing of commands and reducing the duration required to issue orders during intermediate command stages. Moreover, research and application initiatives aimed at developing hardware and software for the computation of artillery firing elements remain incomplete, with an emphasis on resolving fundamental artillery shooting challenges rather than advanced investigations into optimisation and high-level accuracy issues in artillery element preparation. Practical implementation of research products is limited, which precludes their improvement and widespread use [2-4].

If modern warfare happens, enemy targets are typically extremely mobile, capable of appearing quickly and fluctuating, and motor vehicles are more armoured than before. Rapid detection and destruction of precise remote anti-personnel weapons and modern fire reconnaissance systems employed by the adversary are possible in response to our artillery barrage. To successfully perform their tasks in conflict, artillery must not only improve the power and precision of firepower, but also maintain force by quickly locating the correct element to fire efficiently (practice). The duration between the initial shoot and the conclusion of the final effective shot is restricted to a maximum of ten minutes, as determined by calculations, in order to guarantee safety and confidentiality. It has been established that the most effective method for identifying functional firing elements is to subject them to direct target testing, as evidenced by the examination of numerous papers detailing the manufacturing process of our army's firing elements and the practical application of weapon ammunition. Test firing with deviation correction may potentially be the most exacting and financially advantageous technique. Consequently, this approach will be widely implemented in military operations, rendering the investigation of methods to reduce the duration of direct test firing of targets a critical and imperative subject matter. In order to determine the correct firing element, this procedure involves utilising a test weapon to discharge one or more shots precisely at the target, followed by the computation of the necessary correction based on the outcomes of the test firings.

2. PROPOSE SOLUTION

2.1. Theoretical basis of artillery test firing

According to the current shooting rules manual, the following actions must be followed during a test fire to correct for deviation utilising a rangefinder, optical convergence, and visual determination (all of which are common weapons today): (1) Take the first element and fire a single shot with the lead gun. Based on the results of accurately observing shots, measuring deviations, and determining the amount of repair for artillery, (2) switch to effective fire if the amount of repair is less than 100 metres in range and 10 mil in direction; (3) continue to fire one shot until the conditions for effective firing are met. The current basic method for calculating test firing elements and conducting test firings, as reported by the Artillery Command, requires approximately three test firings to satisfy the requirements for switching to effective firing. In general, without considering rocket artillery, common indirect fire artillery varieties of our army, including 105 mm, 122-D30, 152-D20, and 130-M46, are capable of performing preliminary time calculations as follows [6, 7]:

- The time to fire after seeing an exploding bullet or explosive cluster is estimated as follows:

$$t_c = t_{QS} + t_{CH} \approx 60\ sec \tag{1}$$

Where:

- t_{QS} : Time to observe results and calculate correction amout (≈ 30 sec);
- t_{CH}: The amount of time it takes for the leader to give verbal orders to soldiers on the battlefield to do things like load bullets, get elements, etc., until the next shot is fired (≈ 30 sec)

- Time to perform 01 effective shot (each battery performs 04 quick shots): $t_{01\ HL} \approx$ 60 sec.

- Bullet flight time (average): $t_R \approx 30s$

- The time elapsed between the launch of a test shot and the command to fire the next shot (which could be a test shot or an effective shot):

$$T_{test\ shot} = t_{pre.shoot} + t_R = 60 + 30 = 90s \tag{2}$$

The time elapsed between the start of an effective series of fire and the verbal command for the next effective series of fire (plus the duration of the series of rounds) is:

$$T_{effective\ shot} = t_{01\ HL} + t_{pre.shoot} + t_R = 60 + 60 + 30 = 150s \tag{3}$$

As a result, if you meet the criteria of leaving the battlefield 10 minutes after firing the first shot and follow current rules, the effective time and number of bullets fired are calculated as follows:

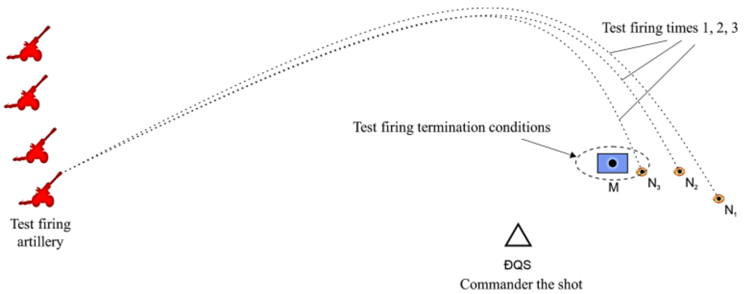

Figure 1. *Illustration of a company-level test firing process in accordance with current standards (03 shots).*

The test firing process takes a long time, and frequent test firings make it easier for the enemy to discover our battleground. Meanwhile, intervention to lower the time of each shot is not possible because $\boldsymbol{t_R}$, $\boldsymbol{t_{QS}}$, $\boldsymbol{t_{CH}}$ and $\boldsymbol{t_{01HL}}$ can no longer be reduced. To reduce test firing time, the most important thing is to keep the number of test shots to a minimum (at least). Assuming we can limit the number of test firings to one and calculate the necessary correction amount to transition to effective firing, we will achieve the following firepower effectiveness:

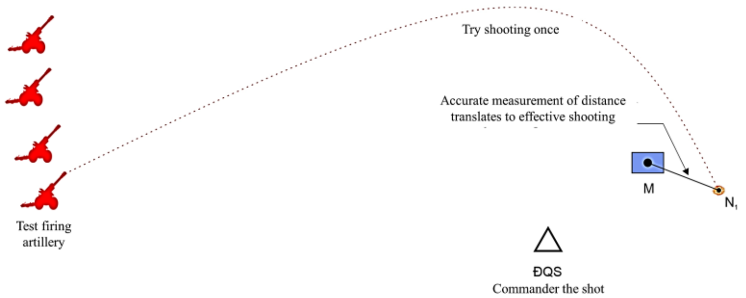

Figure 2. *Illustration of test firing technique corrected for company level variance (1 shot).*

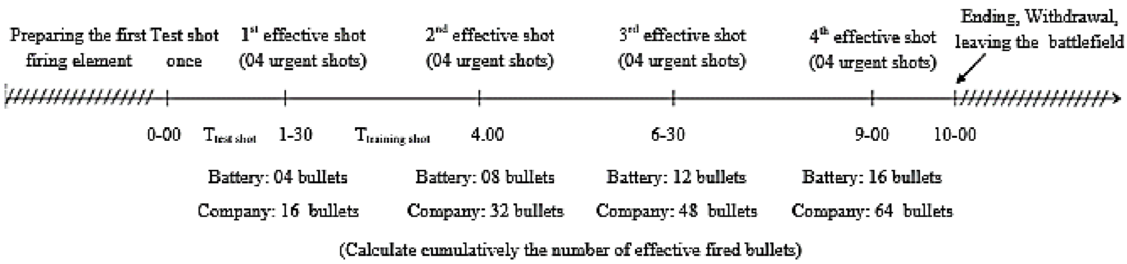

Figure 3. *Illustration of test shot interval corrected for company-level deviation.*

Comparing, we can see that if we reduce the number of test shots to 1 time, it will bring many advantages, in a period of 10 minutes, we will be able to conduct more than 1 effective series of shots (because when testing 03 times, the 3rd series of effective shots can only be fired 02 shots/gun) to increase the lethal power. On the other hand, if we compare the time to complete the shooting mission, when the number of test firings is reduced to 1 time, people and artillery weapons will be able to restore and leave the battlefield about 3 minutes sooner while still being able to complete the same shooting task compared to the current method.

According to current combat needs, command automation in artillery is critical, necessitating the installation of numerous synchronous solutions, such as the automation of the firing element calculation process and quick test shooting in ground artillery companies. This requirement requires the software system to support the synchronous and automatic calculation of firing elements in company-level ground artillery exercises, such as standardising firing table data, calculating explosion point coordinates, targeting, calculating the firing element, calculating the individual correction amount, and calculating the element taken onto the cannon using trigonometric mathematics. Figure 4 depicts the algorithm for computing target coordinates and explosion point coordinates.

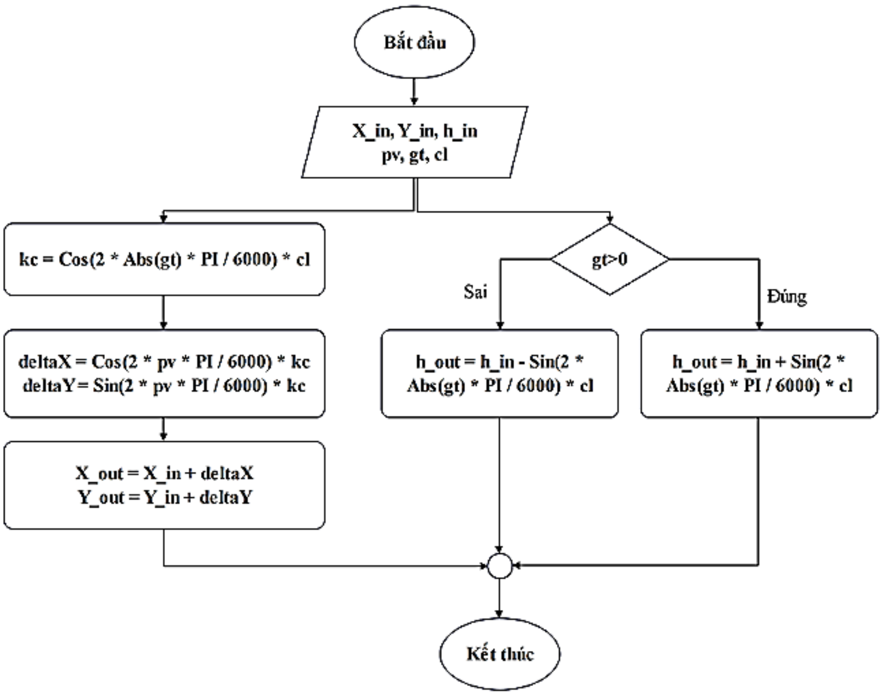

Figure 4. *The algorithm for computing target coordinates and explosion point coordinates.*

2.2. Proposed solution model

The proposed solution model includes battery computers and battlefield command computers connected wired together via a signal converter to ensure security; information and digital data between the firing conning-tower and the battlefield are deployed by information squads according to combat staff to ensure transmission lines as shown in figure 5:

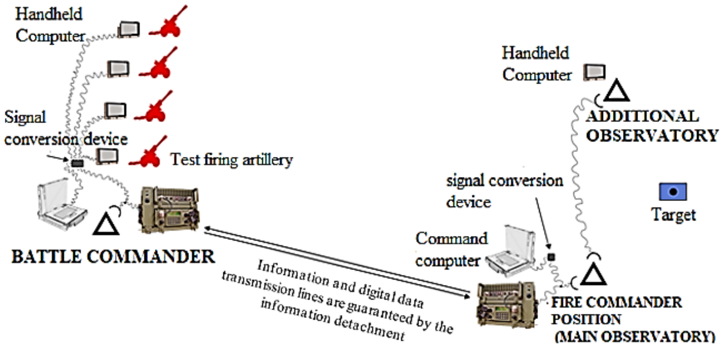

Figure 5. *Illustration of the layout diagram of a set of specialized computing equipment serving at company-level shooting.*

In particular, the overall model of the proposed solution is described in figure 6. The system solution is developed and integrated based on the VRP712/S data transmission machine system of Viettel defense industry Group, which can use protocols on API (Application Programming Interface), allowing to execute login, transmission configuration, data push, transmission or transmission stop setup [8]. This system includes 4 software subsystems installed on different computer devices, including:

- Software for commanding an artillery company (Symbol PM1 - figure 6): is the central command software (installed on the computer at the commanding position), usually in charge of the Company Commander, including the system of functions to automate firing command tasks in the case of direct test firing of targets at the artillery company level; transmit command orders to the battlefield in the form of announcements via the VRP712/S machine system; receive and automatically display information from the battlefield to process and calculate elements serving the firing command; manage 105 mm and 152 D20 artillery firing board data. In addition, the software also has the ability to manage the results of shooting missions.

- Software for commanding artillery battlefield (Symbol PM2 - figure 6): is software for commanding firing squads at battlefields, usually in charge of the Deputy Company Commander, including a system of functions in order to automate the firing command mission at the battlefield in the case of direct test firing of targets at the artillery company level such as: receiving orders to execute, reporting the situation to the command position and transmit command orders to handheld computers of 04 batteries; receive information about the firing mission, the first firing element, and the effective firing element from the company commander.

- Software for performing artillery measurement (Symbol PM3 - figure 6): calculates the coordinates of the target and the explosion point coordinates; transmits target coordinates and explosion point information to the Command Post.

- Software for artillery battery (Symbol PM4 - figure 6): is software that supports battery command, usually in charge of the battery commander, including functions such as transmitting information about the direction of the batteries to the battlefield commander; receiving and calculating information about individual repair amounts and elements taken onto the cannon.

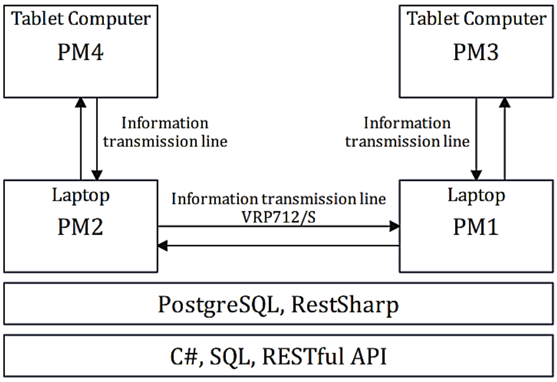

Figure 6. *Illustration of the proposed solution overview model.*

The proposed solution supporting rapid test firing at the ground artillery company level communicates with the VRP712/S machine system based on HTTPS protocols, in which the VRP712/S software plays the server role, while the software supporting rapid test firing at ground artillery company level plays the client role. The structure of the messages is written as a RESTful API. All messages have Session ID transmission session information and the transmission or reception process is indexed to query the transmission processes. Figure 7 illustrates the transmission and reception model of the proposed solution through Viettel's VRP712/S data transmitter, in which information streams are processed as follows:

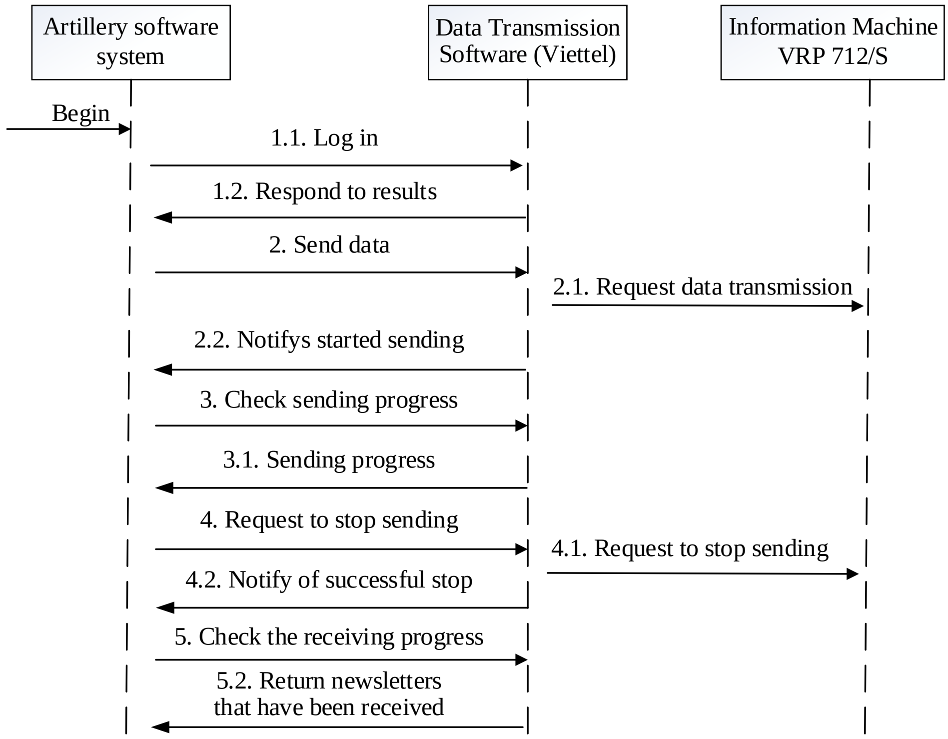

Figure 7. *Illustration of the transmission and reception model of the proposed solution through Viettel's VRP712/S data transmitter.*

The proposed solution for supporting quick test shooting at the ground artillery company level is constructed on the foundations listed below.

Platform PostgreSQL: PostgreSQL is an object-relational database management system that was developed at the University of California as part of the POSTGRES initiative. PostgreSQL is currently the most widely used open-source database management system. The POSTGRES project, led by Professor Michael Stonebraker, is supported by the Defence Advanced Research Projects Agency (DARPA), the Army Research Office (ARO), and the Science Foundation. The National Science Foundation (NSF) and ESL corporations funded POSTGRES, which began to be implemented in 1986. POSTGRES describes the storage manager's principles, data model, system design, rules, and architecture. PostgreSQL has been used to power a wide range of production and research applications, including financial data processing systems, jet engine performance monitoring programmes, astronomical tracking databases, health information databases, and a number of geographic information systems. POSTGRES has also been used as a teaching tool at many universities [9].

RestSharp library: RestSharp is packed with functions, open-source HTTP client library that supports all DotNet technologies. RestSharp is used to construct powerful apps by making it simple to interface with community APIs and quickly retrieve data, saving time with a clean, simple interface. This is a popular REST tool that many programmers use nowadays. RestSharp provides GET, PUT, Head, POST, and DELETE operations, as well as automatic XML and JSON processing. RestSharp is used to handle simple, repetitive operations in order to reduce the user's workload [10].

3. RESULTS AND DISCUSSION

The authors developed a software solution to facilitate company-level quick test shooting for 105 mm and 152-D20 guns, in which 105 mm and 152-D20 artillery firing table data is standardised and stored on the PostgreSQL database management system (figure 8).

Cự ly	Máy ngắm			Bao bọc hẹp	Lượng thay đổi tầm khi góc bắn thay đổi 1 ligiac	Khoảng lệch khái nhiên			Lượng sửa									Góc cao	Góc rơi	Tốc độ rơi	Thời gian đạn bay	Độ cao tra TBK TTB	Độ cao đường đạn	Cự ly
									Hướng		Tâm													
	Quang học	Cơ khí				Tầm	Chiều cao	Hướng	Độ dạt	Gió ngang	Gió dọc	Áp suất không khí	Nhiệt độ không khí	Sơ tốc 1%	Nhiệt độ liều 10°	Trọng lượng đạn 1 dấu							
D	**TT**	**TT**	**GT**	**B**	**ΔXLz**	**Ld**	**Lc**	**Lh**	**Z**	**ΔZn**	**ΔXd**	**ΔXAp**	**ΔXt°k**	**ΔXVo**	**ΔXt°l**	**ΔXn**	**α**	**θr**	**Vr**	**Tr**	**Ytb**	**YD**	**D**
m	*vạch*	*vạch*	*ligiac*	*ligiac*	*m*	*m*	*m*	*m*	*ligiac*	*ligiac*	*m*	*m*	*m*	*m*	*m*	*m*	*Độ phút*	*độ*	*m/s*	*giây*	*m*	*m*	*m*
200	2	4	2	1	87	22	0,0	0,0	0	0	0	0	0	4	6	+1	0 08	0,1	645	0,3		0,1	200
400	4	8	4	1	86	22	0,1	0,1	0	0	0	0	0	8	13	+1	0 16	0,3	636	0,6		0,5	400
600	6	12	7	1	85	21	0,1	0,1	0	0	1	0	1	12	19	+2	0 24	0,4	626	0,9		1,1	600
800	8	16	9	1	84	21	0,2	0,1	0	0	1	1	1	16	26	+2	0 33	0,6	616	1,2		2,0	800
1000	10	20	12	1	83	21	0,2	0,2	0	1	1	1	2	20	32	+3	0 42	0,7	606	1,6		3,2	1000
200	12	24	14	1	82	21	0,3	0,2	0	1	2	1	2	23	38	+3	0 50	0,9	597	2,0		4,6	200
400	14	28	16	1	80	21	0,4	0,2	0	1	2	1	3	27	44	+4	0 59	1,1	588	2,2		6,3	400
600	16	32	19	1	78	21	0,4	0,2	0	1	3	2	4	31	49	+4	1 08	1,2	579	2,7	0	8,3	600

Figure 8. *Illustration of information fields in the firing element lookup table of artillery 152-D20.*

Figure 9. *Illustration of the main interfaces of the software system supporting quick test firing at the ground artillery company level.*

The software solution for supporting rapid test shooting at the ground artillery company level is built using Visual Studio 2019, C#, SQL programming language, and Restful API. Figure 9 depicts the major interfaces of the software system facilitating quick test shooting at the ground artillery company level. Specifically, Symbol 1 is the main interface of the artillery company firing command software; Symbol 2 is the main interface of the ground artillery firing command software; Symbol 3 is the main interface of the artillery measurement software; and Symbol 4 is the main interface of the ground artillery battery command software.

This software system has been installed on laptop computers (Company Commander, Field Commander) with configuration: Intel (R) Core (TM) i5-6300U CPU @ 2.4 GHz (4 GPUs) ~2.5GHz, 8 GB RAM, 256 GB SSD hard drive and handheld computers (Battery) with configuration: Intel (R) Celeron (R) N4000 CPU @ 1.10GHz (2GPUs) ~1.1GHz, 4 GB RAM, 128 GB SSD hard drive; Runs on Windows 10 operating systems for laptops and handheld devices. The results of testing the software system were evaluated based on the criteria of the ability to transmit and receive information through the VRP712/S system (Viettel) and the ability to calculate artillery parameter values during test firing. Ground artillery company level for 105 mm artillery and 152-D20 artillery.

Ability to transmit and receive information via VRP712/S system (Viettel)

Figure 10. *Illustration of the developed system test in a mountainous area.*

Table 1 shows the test results for the software system's ability to send and receive information, allowing for quick test shooting at the ground artillery company level. The testing was done in a variety of terrains, including hilly and urban settings, to confirm compliance with artillery company-level training elements. The test ranges from 7 to 11 km; the transmission capacity is around 100 characters, which corresponds to information concerning artillery practice shooting missions. The resulting transmission time ranges from 5 to 10 seconds, depending on the topography (obstruction, distance, and signal transmission capability of the VRP712/S device).

Table 1. *Testing the ability to transmit and receive information from the developed system.*

No	Characteristics	Value
1	Test terrain	Hilly and urban areas
2	Number of trials	14
3	Transmission distance	7 – 11 km
4	Transmit and receive frequency	55.5 MHz
5	Transfer rate (BitRace)	240
6	Transmission capacity	About 100 characters
7	Transmission and reception time	5 – 10 sec

Ability to calculate artillery parameter values

- The following artillery parameter values were used to assess the accuracy of the software system, allowing rapid test fire at the ground artillery company level.

- First shot element: Propellant charge required(CHG), Angle of elevation hoặc Quadrant Elevation (QE), Azimuth of fire (AF).
- Effect shot element: QE, Deflection (DF) (GT2, LSH)
- Amount of fire practice: Gun 2 (G2), Gun 3 (G3), Gun 4 (G4).
- LSR and element take up artillery: CHG, QE, Azimuth to howitzer (AH).

To evaluate the accuracy of the above artillery parameter values, the research team developed different calculation exercises for 105 mm artillery and 152-Đ20 artillery. Then, evaluate the difference in calculations between the software system and the manual calculation results of the gunners. The results showed that the artillery parameter values calculated by the software system and the gunners only differed by 1 - 2 logics (calculation unit in Artillery). This difference is due to the process of rounding values by gunners when looking up data in the Artillery firing table. Table 2 illustrates the results of calculating the parameter values for the 105 mm artillery. In this case, some of the input values are as follows:

- Standard bearing: 60-00;
- Observatory coordinates (XQ, YQ, hQ): 14100, 30300, 50;
- Battlefield coordinates (XF, YF, hF): 10450, 30550, 50;
- Target coordinates (XM, YM, hM): 17800, 31850, 50;
- Explosion point coordinates (XN, YN, hN): 17697, 31672, 50;
- Firing condition information includes tK: 27, Vg: 8, PVg: 13-00, AP(K): 740, t(L): 27, Difference (V0): 0.6.

Table 2. *Illustrates the results of calculating the parameter values for the 105 mm artillery.*

No	Parameters		Developed system	Gunner	Deviation (elongation)
1	First shot element	CHG	6	6	0
		QE	4-30	4-31	0-01
		AF	1-65	1-65	0
2	Effect shot element	QE	4-41	4-43	0-02
		DF	0-21	0-21	0
3	Amount of fire practice	G2	0-08	0-07	0-01
		G3	0-14	0-13	0-01
		G4	0-21	0-19	0-02
4	LSR and the element took up artillery	CHG	6	6	0
		QE	4-30	4-31	0-01
		AH	8-05	8-04	0-01

Previously, during artillery exercises, gunners had to solve artillery requirements using pocket calculators and manually look up artillery shooting tables. As a result, the time it takes for the batteries to communicate with the battlefield commander and headquarters is usually just a few minutes in duration. This greatly reduces the shot's effectiveness, safety, secrecy, and precision. With the software system facilitating quick test fire, it has achieved a breakthrough in the current company-level ground artillery rehearsal process. Based on integration with the VRP712/S information transmission system of the industrial group Viettel, the software solution enables speedy processing, automatic computation of artillery missions, and synchronisation of the firing command process.

4. CONCLUSIONS

The proposed system solution supporting rapid test firing at the ground artillery company level has demonstrated its effectiveness, accuracy, and high practicality in shortening the time to determine effective firing elements through direct target test firing for 105 mm artillery and 152-D20 artillery. The results of this research have shown a close combination of theoretical research, practical surveys, and assessment of scientific and technological development trends for artillery troops. Thereby, contributing to supporting automation capabilities in company-level artillery exercises, as well as the ability to apply information technology solutions in artillery command activities in general. This is the premise that the authors will continue to improve and add artillery functionalities to ensure that the software system can support the process of commanding artillery fire at many different levels with many different types of artillery together.

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TÓM TẮT

Xây dựng giải pháp hỗ trợ bắn thử nhanh cấp đại đội pháo binh mặt đất

Hiện nay, bên cạnh các nhiệm vụ nghiên cứu cải tiến nâng cao khả năng cơ động, tăng tầm đạn pháo thì các công trình nghiên cứu giúp nâng cao hiệu quả hỏa lực pháo binh mới chỉ tập trung vào ứng dụng một số công nghệ hỗ trợ tính toán, xác định phần tử bắn hoặc nghiên cứu đổi mới phương pháp, quy tắc bắn nhằm tiết kiệm đạn pháo mà chưa trực tiếp nghiên cứu về các giải pháp nhằm rút ngắn thời gian xác định phần tử hiệu lực cho pháo binh. Bởi vậy, nghiên cứu này sẽ trình bày về giải pháp hệ thống phần mềm hỗ trợ bắn thử nhanh, tiết kiệm đạn khi bắn thử trực tiếp mục tiêu của pháo binh mặt đất thông qua các hệ thống máy truyền số liệu VRP712/S của tập đoàn công nghiệp quốc phòng Viettel. Kết quả nghiên cứu là nhóm tác giả đã xây dựng được hệ thống phần mềm hỗ trợ bắn thử nhanh cấp đại đội pháo binh mặt đất. Giải pháp đề xuất đã được thử nghiệm thông qua việc diễn tập bắn đạn cấp đại đội pháo binh mặt đất, sử dụng pháo 105 mm *và pháo 152-Đ20, mang lại tính khả quan, với độ chính xác cao so với việc tính toán truyền thống của các pháo thủ trước đây.*

Từ khóa: Pháo binh; VRP712/S; RestSharp.