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# Possibilities of Applying New Navigation Techniques in Military Equipment Testing

Maciej DORCZUK

*Military Institute of Armoured and Automotive Technology,*
*Tracked Vehicles Testing Laboratory*
*1 Okuniewska Str., 05-070 Sulejówek, Poland*
*Author's e-mail address and ORCID:*
*maciej.dorczuk@witpis.eu; https://orcid.org/0000-0003-2749-8411*

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**Abstract.** The article proposes the possibilities of testing military equipment using satellite navigation systems, as well as systems that aid such systems, used for determining the position of and indicating targets. The research employed modern civilian navigation devices using satellite navigation systems, as well as navigation aided by land-based reference stations. Using Trimble R8 and RT4000 devices in research is proposed. The possibilities of the RT4000 precise movement parameter measuring device within the scope of position determining using a portable reference station using the Trimble R4 receiver and Satel-TA18 radio (not the device's standard equipment) are presented.

**Keywords:** navigation, Trimble R4, Trimble R8, RT4000

## 1. INTRODUCTION

Satellite technologies date back to the second half of the previous century. The world's first Earth satellite launch (SPUTNIK 1, 4 October 1957) became a stimulus for the development of tracking methods, as well as those of determining objects' positions in orbit. The first navigation satellite, TRANSIT 1B, which came into service a mere three years after SPUTNIK's launch, ushered in the era of Global Navigation Satellite Systems (GNSSs), which is a common name for all navigation systems [1].

Presently, GNSS-1, or first-generation, navigation systems, can be distinguished:

- the global GPS NAVSTAR (Global Positioning System Navigation Satellite Time and Ranging) system;
- the global GLONASS system (*Russian: ГЛОНАСС, Globalnaya Navigatsyonnaya Sputnikovaya Sistiema*);
- the global Beidou-1 navigation system (COMPASS)
- the SBAS (Satellite Based Augmentation System) supporting satellite system;
- the GBAS (Ground Based Augmentation System) supporting ground system.

The second generation GNSS-2 system is meant to be an entirely civilian one, with its functioning based the GALILEO system, as well as the modernised GPS and GLONASS systems, the future global Chinese BeiDou-2 (COMPASS) system, and regional systems:

- India's IRNSS (Indian Regional Navigational Satellite System);
- Japan's QZSS (Quasi-Zenith Satellite System).

The second-generation GNSS-2 will also have existing and currently designed support systems:

- SBAS, i.a. India's GAGAN system
- GBS, i.a. continental, Australian's GRAS and the regional CORS, ASG-EUPOS.

The possibilities granted by the new navigation techniques are enormous, as attested by the fields they are used in. One of the areas that require the use of such new technologies is military equipment testing. Modern navigation techniques may be employed to, i.a., verify the proper functioning of military device prototypes using GPS navigation and inertial equipment.

## 2. USING NEW NAVIGATION TECHNIQUES FOR THE ASSESSMENT OF A PROTOTYPE RECOGNITION SYSTEM'S INDICATION PRECISION

In the research, a Trimble R8 receiver (Fig. 1) with a standard Trimble TSC3 controller (Fig. 2) was used to verify the correctness of a military recognition system's target indication. During the research, the Trimble R8 receiver was working in DGNSS real-time differential mode, based on the corrections coming from the ASG-EUPOS system, in order to increase the measurement precision. Differential mode operation allows for obtaining measurements with a precision of approx. 2 cm vertically and approx. 3 cm horizontally. The navigation system on a reconnaissance military vehicle was equipped with, i.a. a Hertz HGPS T receiver (Fig. 3), imaging devices, as well as target indicating devices (due to the recognition system technologies used, enumerating all of the devices is not justified). The differences between the Trimble R8 indications and the recognition system are presented in Table 1.

Fig. 1. Trimble R8 receiver

Fig. 2. Trimble TSC3 controller

Fig. 3. Hertz HGPS receiver

Table 1. Differences between the Trimble R8 indications and the recognition system

| Target no. | | Coordinates determined using the Trimble 8 receiver | Coordinates determined using the prototype system | Indication difference [m] |
|---|---|---|---|---|
| **Target 1** | E (UTM) | 646 936.48 | 646 936 | 0.48 |
| | N (UTM) | 5 763 677.18 | 5 763 679 | -1.82 |
| | H (m) | 150.54 | 152 | -1.46 |
| **Target 2** | E (UTM) | 646 454.51 | 646 453 | 1.51 |
| | N (UTM) | 5 763 526.79 | 5 763 530 | -3.21 |
| | H (m) | 152.60 | 154 | -1.40 |
| **Target 3** | E (UTM) | 645 637.83 | 645 636 | 1.83 |
| | N (UTM) | 5 762 920.65 | 5 762 923 | -2.35 |
| | H (m) | 150.96 | 153 | -2.04 |

The results presented in Table 1 indicate the possibility of using devices employed chiefly for civilian land surveying measurements in the assessment and verification process of military recognition systems.

Supporting the DGPS measurement technique, which can also be used by civilian devices, enabled precise verification of the accuracy of the reconnaissance military system in relation to which high accuracy is required, however military reconnaissance systems in both peace and combat conditions cannot support their measurements using the DGPS technique.

## 3. USE OF THE NEW NAVIGATION TECHNOLOGIES IN ASSESSING THE PRECISION OF POSITION INDICATION BY MILITARY NAVIGATION SYSTEMS OPERATING IN NO-GPS MODE

In the tests, the Trimble R8 receiver (Fig. 1) with the Trimble TSC3 controller was used to verify the accuracy of the position display by the navigation system (Fig. 2). During the tests, in order to increase the accuracy of measurements, the receiver, as in the previous study, was connected to the ASG-EUPOS system. The navigation system on the military vehicle was equipped with a military Hertz HGPS T receiver (Fig. 3), an INU inertial system (Fig. 4), a VMS motion sensor (Fig. 5) and DCDU imaging devices (Fig. 6).

Fig. 4. INU inertial system

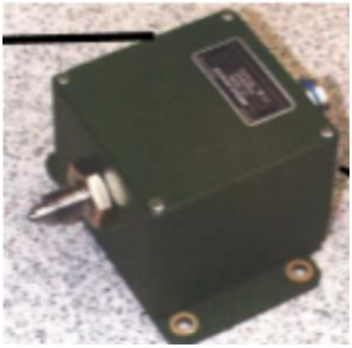

Fig. 5. VMS motion sensor

Fig. 6. DCDU

In order to verify the proper functioning of the INU and VMS units, the Hertz receivers were switched off during the test (in order to disconnect the GPS signals and check whether the system worked properly without the use of GPS). Before initiating the tests, the coordinates, read from the Trimble 8 receiver, were entered into the DCDU device. Afterwards, the PW1-1-2-PW1(PW2) route was completed, with the coordinates read from the DCDU and the Trimble R8 receiver afterwards.

The results are found in Table 2, with the determined indication divergences found in Table 3.

Table 2. The coordinates read from the DCDU and the Trimble R8 receiver afterwards

| **Measurement point** | **DCDU indications** | | | **Model indications of the Trimble R8 receiver** | | |
|---|---|---|---|---|---|---|
| | **N (UTM)** | **E (UTM)** | **H [m]** | **N (UTM)** | **E (UTM)** | **H [m]** |
| **PW 1** | 5 789 676 | 519 687 | 107 | 5 789 678.93 | 519 6 87.94 | 106.70 |
| **2** | 5 790 699 | 519 680 | 103 | 5 790 695.25 | 519 686.11 | 102.89 |
| **3** | 5 789 309 | 519 664 | 107 | 5 789 305.23 | 519 665.85 | 106.77 |
| **PW 1** | 5 789 676 | 519 684 | 107 | 5 789 678.93 | 519 687.94 | 106.70 |
| **PW 2** | PW2 was designated due to the impossibility of reaching point PW1 precisely. | | | 5 789 679.3 | 519 687.9 | 106.75 |

Table 3. Indication divergences between DCDU and Trimble R8

| **Measurement point** | **Indication divergences** | | |
|---|---|---|---|
| | | | |
| | N [m] | E [m] | H [m] |
| **PW 1** | -2.93 | -0.94 | 0.30 |
| **2** | 3.75 | -6.11 | 0.11 |
| **3** | 3.77 | -1.85 | 0.23 |
| **PW 2** | -2.93 | -3.94 | 0.30 |

The results presented in Tables 2 and 3 demonstrate the possibility of using devices employed mainly for civilian land surveying measurements in the process of assessment and verification of military navigation systems operating without the use of GPS signals.

The aid of DGPS, which can be used by civilian devices, made it possible to precisely verify the accuracy of the military inertial navigation system and confirmed its high precision.

## 4. USING NEW NAVIGATION TECHNIQUES TO DETERMINE THE PROFILE OF THE RANGE PATH

The research employed an RT4000 device in DGNSS real time differential mode in order to determine the profile of the range path. The reference station used operated based on a Trimble R4 receiver and a Satel-TA18 radio. The reference station's benchmark coordinates were determined using a Trimble R8 receiver, then entered into the Trimble R4 receiver.

The Trimble R4 receiver and the Satel-Ta18 radio, operating in reference station mode, are not part of the standard RT4000 equipment. The aim of the configuration proposed and used was to increase range of the radio communications between the Trimble R8 and the reference station, which was a prerequisite for achieving the expected measurement results. The RT-Base S GNSS reference station, being part of the RT4000 equipment, secures connectivity within a radius of 3-4 km in a range of conditions, which rendered testing impossible. A diagram of the measurement system is shown in Figure 7.

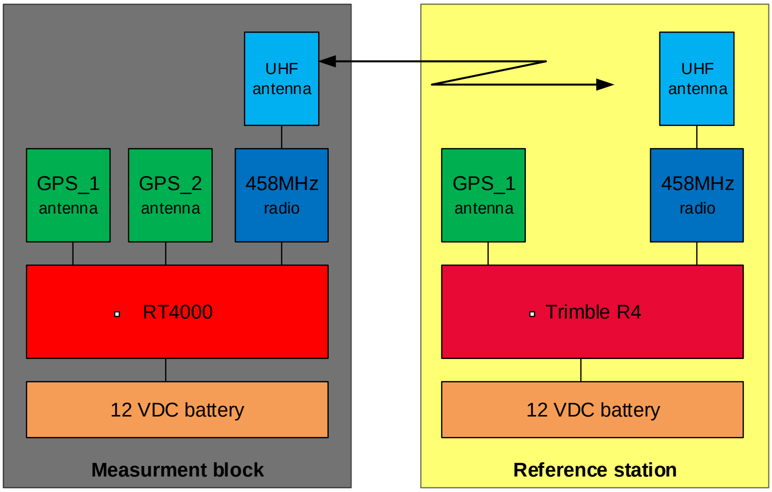

Fig. 7. The structure of the system used for measuring the unevenness of the terrain.

During the testing, a measurement block with the RT4000 (Fig. 8) was mounted on a single-axis trailer (Fig. 10), with the reference station (Fig. 9) set up in a place that allowed it to observe the greatest number of satellites possible within 5 km from the measurement system.

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Fig. 8. View of the reference station being part of the standard equipment (RT-Base S GNSS), as well as devices for precise RT4000 motion parameter measurement.

Fig. 9. Mobile reference station (Trimble R4 and Satel-TA18 radio)

Fig. 10. The RT4000 device mounted on a single-axis trailer

During the movement of the trailer above 10 km/h, 9 to 12 satellites were observed, with the achieved XYZ coordinate determination precision at approx. 15-25 cm. With the velocity between 5 and 7 km/h, 15 to 19 satellites were observed, with the achieved XYZ coordinate determination precision at approx. 2.5 cm.

Figure 11 presents the course of the path used for the measurements. The velocity of the research subject was between 5 and 7 km/h.

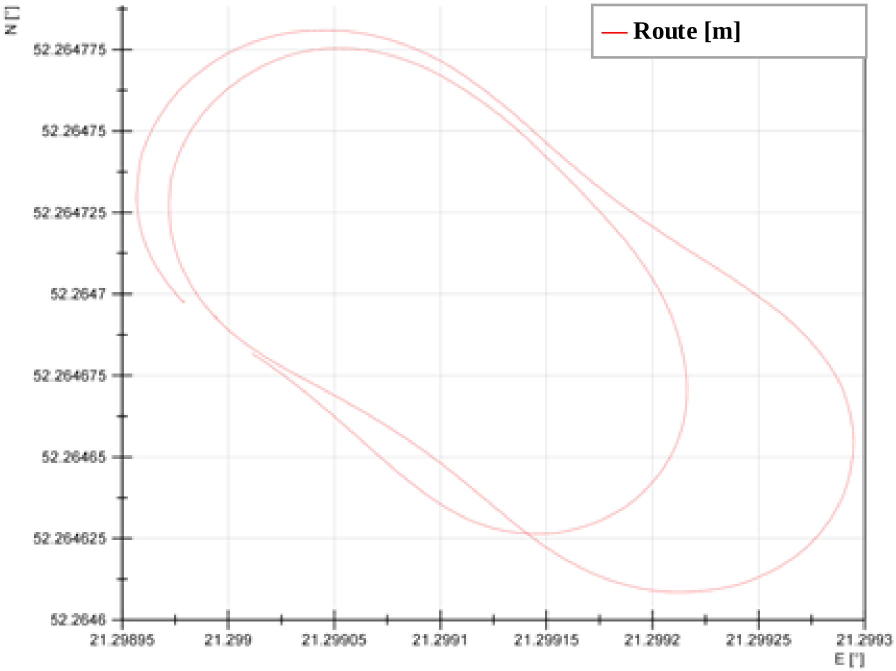

Fig. 11. The path

The progressions of the registered changes: the range path's altitude, the trailer's velocity, and the precision achieved in relation to the path travelled are presented in Figure 12.

The progressions of the registered changes: the range path's geographical latitude and longitude, the trailer's velocity, and the precision achieved in relation to the path travelled are presented in Figure 13.

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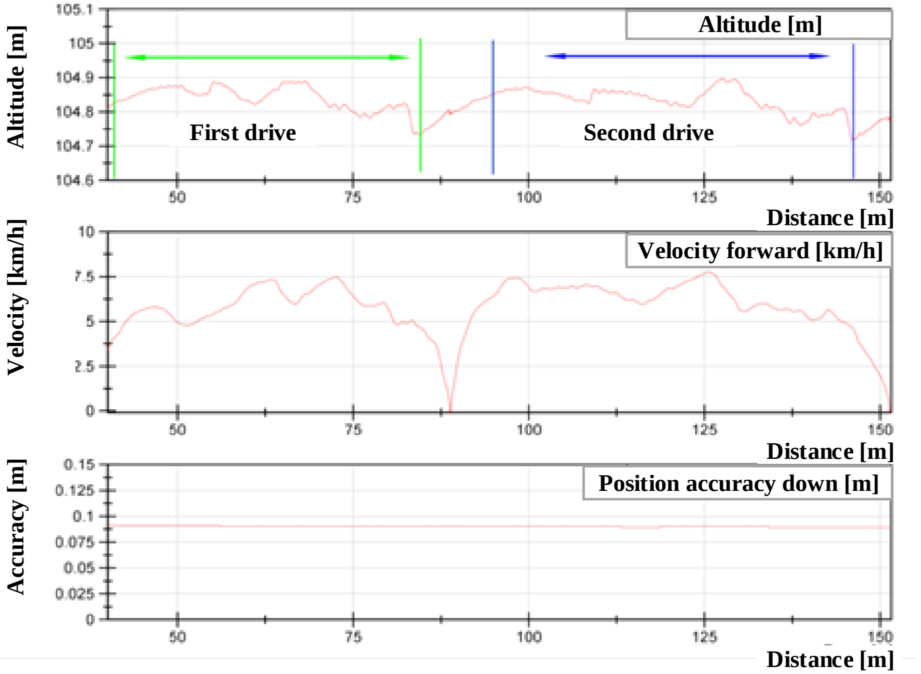

Fig. 12. The registered changes of the altitude of the range path, velocity, and precision

The tests also registered the number of the observed navigation system satellites. Figure 14 shows the number of the satellites observed during the drives, as well as the precision of determining the coordinates in relation to the path. The described progressions were registered in order to present the influence of the number of satellites being tracked (dependent variable) on the precision of coordinate determination (independent variable).

The tests conducted and the adopted method, aiming to determine the profile of the ranged path, have proven successful. The RT4000 device used, simultaneously aided by:

- A GPS navigation system;
- the DGPS method based on a reference station configured using a Trimble R4 receiver and a Satel-TA18 radio (not being part of the RT4000 standard equipment);

fulfilled the presented requirement and allowed for registering data at over 5 km from the reference station, with a precision acceptable for the purpose of the testing.

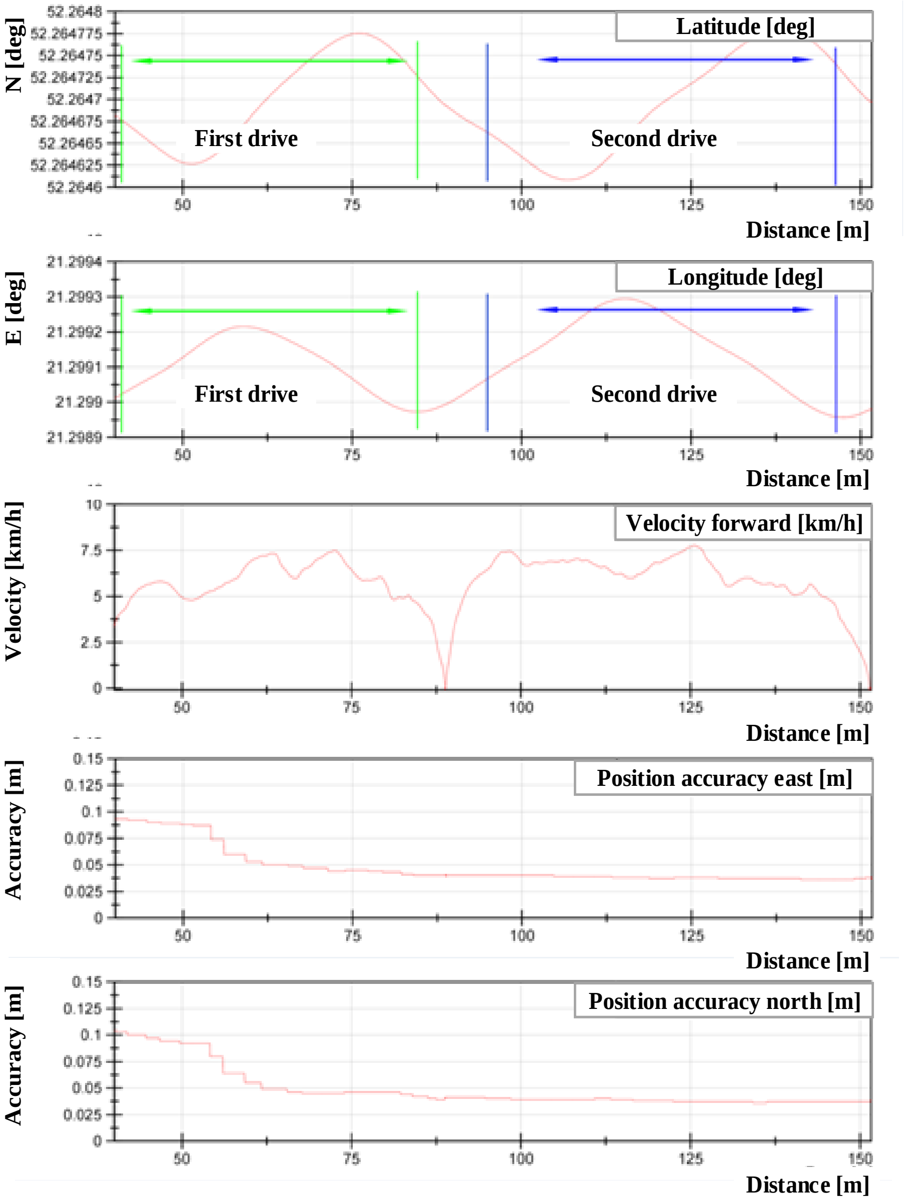

Fig. 13. The progressions of the registered changes: the range path’s geographical latitude and longitude, the trailer’s velocity, and the precision achieved in relation to the path travelled

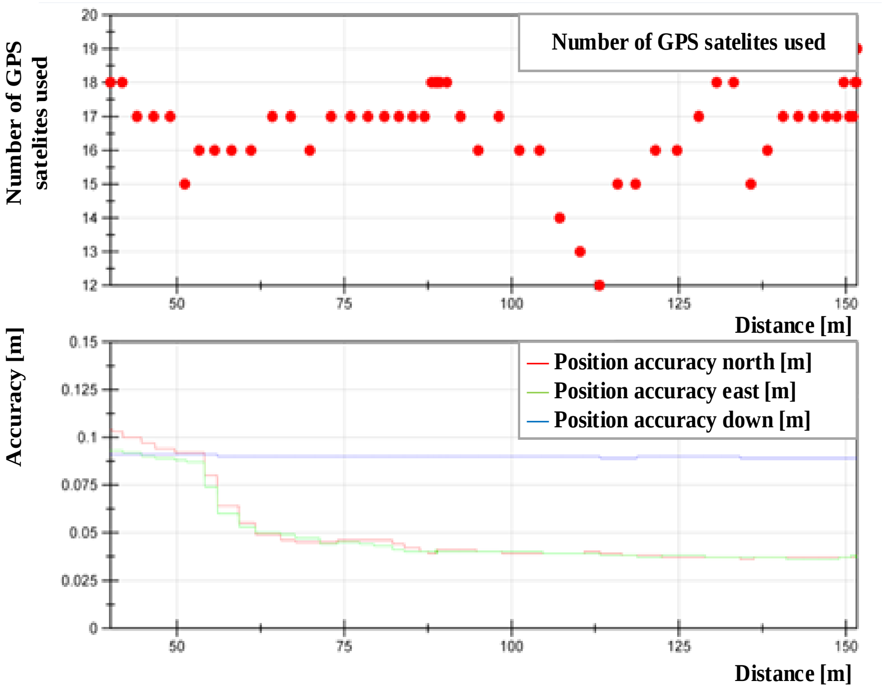

Fig. 14. The number of the satellites tracked in relation to the path and precision of coordinate determination for driving at approx. 5 km/h

The observed influence of the velocity of the moving object (trailer) had an influence on the dependent variable (the number of satellites tracked), which reduced the precision of the registered data as a result. While the maximum velocity of 5 km/h was maintained, the measurement system was aided by data coming from 17-19 satellites and the reference station, enabling it to obtain measurement precisions acceptable for the purposes of testing the measurement’s precision.

## 5. CONCLUSION

The military use of the GPS is very broad; all the Polish Armed Forces use GPS receivers, with the main fields of application being:

- updating maps in order to increase situational awareness;
- aiding rescue actions: determining the locations of wounded soldiers, shot-down pilots, and damaged equipment quickly and precisely enables the military rescue services to undertake action and complete their tasks quickly;

- locating soldiers: owing to locators, a soldier present in enemy territory knows their own location, but the information is also relayed to command;
- destroying the enemy's strategic targets: the precise determination of the target's position allows for destroying it using as little fire power as possible.
- guiding homing missiles: building navigation receivers into homing missiles allows for striking targets with a precision as high as 1 m.

The examples of using some of the currently most modern GPS systems aided with the DGPS technique and inertial units presented in the article shows the levels of precision that can be obtained.

The presented possibilities of using a Trimble R8 receiver show the potential of its use in testing military recognition and navigation systems, both those using GPS signals and not, anywhere in the country. Such use may markedly decrease the costs of military equipment testing, while allowing for achieving high precision.

The presented field of the use of the RT4000 precise motion parameter measurement device in the configuration using the proposed reference station is but one of the many possible fields of its application. In the full configuration, the device has impressive capabilities and is always used during military equipment tests that require high dynamic and static measurement precision, i.a. for measuring the motion parameters of military objects both on land and sea (sailing speed, time required to reach full operational speed, stopping distance, turning circles on land and on water, object pitches and rolls during sailing, etc.).

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# Możliwości zastosowania nowych technik nawigacji w badaniach sprzętu wojskowego

Maciej DORCZUK

*Wojskowy Instytut Techniki Pancernej i Samochodowej*
*ul. Okuniewska 1, 05-070 Sulejówek*

**Streszczenie.** W artykule zaproponowano możliwości prowadzenia badań sprzętu wojskowego, w których wykorzystuje się systemy nawigacji satelitarnej oraz systemy wspomagające systemy nawigacji satelitarnej służące do określania pozycji oraz wskazywania celów. W baniach wykorzystano cywilne nowoczesne urządzenia nawigacyjne korzystające z systemów nawigacji satelitarnej oraz nawigacji wspomaganej referencyjnymi stacjami naziemnymi. Zaproponowano możliwości zastosowania urządzeń Trimble R8 i RT4000 w badaniach sprzętu wojskowego. Przedstawiono możliwość urządzenia do precyzyjnych pomiarów parametrów ruchu RT4000 w zakresie dokładności określania pozycji przy zastosowaniu przenośnej stacji referencyjnej wykorzystującej odbiornik Trimble R4 i radio Satel-TA18, które nie są standardowym wyposażaniem RT4000.

**Słowa kluczowe:** nawigacja, Trimble R4, Trimble R8, RT4000