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Interconnection Study of Joint Tactical Communications Systems

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Abstract

The tactical communications system should be be interoperable with other allied networks and strategic networks for joint operation. Also, new equipment will invariably need to interoperate with current in-service equipment. In order to interconnect tactical communications systems between U.S. Forces and ROK Army, they conducted the interoperability test of two systems. In this paper we present the interoperability issues of joint tactical communications systems, the SAI physical level interface compatibility with the NAI, the network configuration for interoperability test and test results.

Keywords: Component, C4ISR, Interoperability, Land Operation, STANAG

1. Introduction

The dramatic growth in digital communication information communication technology that has taken place over the last two decades has made it possible to develop very sophisticated and versatile system that allows secure voice and data traffic on the battlefield. A key to achieving supremacy on the battlefield is to have efficient C4I (Command, Control, Communications, Computers, and Intelligence) system and communication is a critical factor for the success of any military operation[1]. Efficient tactical switching networks now form the backbone of any modern army, enabling dispersed units to communicate with each other and with the different command centers, as well as allowing the safe and timely distribution of commands, operational data and battle intelligence. According to the air land battlefield concept, with the recent technological advances, a new pattern is emerging as resilient high performance trunk communications systems are introduced to interconnect higher command echelons and the fighting arms. These trunk systems are serving to transfer battlefield intelligence rapidly and accurately from its sources to those who need to use it urgently and to computerized databases. Moreover, with the many varieties of new intelligence gathering, target acquisition and weapon systems currently entering services, trunk communications are increasingly being used coordinate and deploy these in a more effective and integrated manner. For modern armies require a substantial change in structure and use of high performance technology, robust and seamless tactical communication systems are needed. Several interoperability forum have been established to achieve better cooperation between the United States and NATO countries through coordinating of their various C4I systems. European governments and U.S. need to move more quickly in the NATO Standardization Agreement (STANAG) framework and need to urge that coverage be broadened to include standards for C4I. Communications equipment and systems for the strategic military environment will be and are being developed to support the tactical commander. In tactical and strategic communications in the battlefield, care must be taken to ensure compatibility and interoperability of networks and systems among the communities. There are two types of battlefield communications: communications above battalion for high capacity and duplex links with headquarters, and battlefield communications below

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battalion for flexibility and responsiveness to perform the tactical missions[2]. The principles of modern armies have been developed over several years to provide guidance for the provision of tactical communications systems to support air-land operations. Interoperability issue is very difficult to solve and implement in tactical networks and is essential if information is to be able to flow seamlessly between any two points, and to be interoperable with not only other tactical and strategic networks, but also other ally networks in the battlespace. Also new equipment should be added easily to interoperate with current in-service military equipment[3]. The analog-based NATO STANAG 5040 which is automatic and semi-automatic interfaces to achieve interopera-bility between the national switched telecommunications systems of the Combat Zone was still the standard agreement for interfacing, and tactical voice systems. The EUROCOM recommendations, which stem from an international recognition of the special needs of tactical communications, have now become the most internationally accepted standard for military communications following their introduction in many NATO nations including U.S. Because of the severe congestion of the military frequency bands, it was decided to adopt spectrum efficient Continuously Variable Slope Delta (CVSD) speech encoding, rather than the traditional Pulse Code Modulation (PCM) as used in civil systems. This led to the subsequent adoption of a completely different technique for digital switching. ROKA (Republic of Korea Army) had developed the area and range extension networks, SPIDER, for tactical communication using this technique. The SPIDER switching and distributing system, designed to form the basis of any modern secure survivable digital area communications network, can interoperate with other types of digital switching systems including U.S. TRI-TAC/MSE system, civil PABXs networks.

In order to enhance the interoperability of tactical communications between U.S. Forces and ROKA, they conducted the interoperability test of two systems. The objective of the test was to verify the compatibility of the NATO Analog Interface (NAI) and SPIDER Analog Interface (SAI) device developed by Agency for Defense Development (ADD) and capabilities of the NAI-SAI trunk circuit to support U.S. and ROK tactical common user communications systems[4].

In this paper we present the interoperability issues of joint tactical communications systems, the SAI physical level interface compatibility with the NAI, the network configuration for interoperability test and test results.

2. Related Works

System description and interoperability test sometimes communicator's mission is expressed as 'An arm for the commander'. An analysis of the process through which commander makes his decisions and casts them into action makes this basic statement quite clear. This process can be split into four progressive steps; 1. The acquisition of information both on friendly and enemy situations, field and capabilities, 2. The decision making, 3. The communications of orders to all the forces involved, 4. The execution command and control exercises. Among those four major steps, three of them supposes tight and reliable communications between the commander and the units deployed within his own area of responsibility as well as in adjacent areas. In fact, in the actual development of combat operations, the commander must, during a short time, make a series of decisions to match and finally control the development of the situation. It is thus vital that the communications system matched closely the commander's need. The mission of the former special corps of messengers lies now in the hands of the signal men, which are in charge of the deployment, operation and maintenance of the command links by using a specific weapon, the tactical communication network they operate. In modern warfare, a large volume of information comes from modern investigation means, owing to surface and air moving capability and short air forces response while at the same time acquisition delays have shrunk to a minimum. To elude enemy observation and be successful, friendly forces must be driven into actions within the shortest delays made possible both by mobility and the high rate and long range of supporting fires. At the same time, owing to the necessary convergence of the efforts of various units scattered over the combat zone, the number of authorities which must be able to be in direct touch with the commander and his staff is increasing, while the distance between both levels of command can be very important. To reduce a minimum the time delay running between information acquisition and the forces response, thus greatly increasing efforts towards success the time expense out coming from the operation of communications must be made the shortest, if not practically suppressed. The choice of the communication system is then of the utmost importance. When building up such a project, the personnel and the budget shares the main factors which will determine to what extent the goal assigned by the commander will be achieved and how much the efficiency of other combat forces will be enhanced. The armed forces organization, the tactical doctrine the number and qualification of the personnel available, all those factors must be taken into account in the design of the tactical network and to determine its optimum size considering at the same time: the maximum delay required to put together two given subscribers within the network, the maximum number of subscribers to be booked at the same time within the network, the mobility of subscribers and of the forces taken as a whole. To meet these requirements, many modern tactical communications systems have been developed in NATO countries. They are U.K. PTARMIGAN/MRS, France RITA 2000, Germany AUTOKO 90, Italy SOTRIN, U.S. TRI-TAC/MSE, and ROK SPIDER systems[2]. All of them meet all these requirements and also provide high degree of survivability. The U.S MSE system for lower battlefield echelons provides full connectivity between warfighters and their commanders in the battlefield, and U.S. TRI-TAC for upper echelons provides a theater-wide communications backbone network between tactical and strategic Army and Joint echelons[6]. Ali and Wexler introduced the operational concept of WIN-T (Warfighter Information Network-Tactical) for future U.S. Army network. The WIN-T network was to provide the follow-on tactical communications system to replace MSE system and to connect the warfighter to the Global Information Grid[5]. Wentz presented Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) systems and services and interoperability considerations of tactical communications system[1]. Prior and co-authors described tactical network integration test framework to study interoperability on a small number of high fidelity emulation nodes[7]. The STANAGS are NATO publications to define NATO automatic and semi-automatic interfaces between the national switched telecommunications systems of the combat zone and between these systems and the NATO integrated communications system (NICS)[8]. The STANAG 5040 provided interfacing tactical and strategic voice network, IVSN (initial voice switched network). There were interface problems between the U.S. TTC-39D tactical switch and problems with the Ericsson MD-110 switch used by the U.N. and Implementation Force (IFOR). U.K. developed the Interim Digital Interface PTARMIGAN (IDIP) to provide a digital interface between the UK PTARMIGAN and the U.S. TRI-TAC/MSE tactical systems[9].

3. System Description And Interoperability Test

ROKA SPIDER system provides communications to cover a wide area for highly mobile military forces. The principle of operation is shown in Figure 1 which gives a simplified view of a deployed network. The nominal area coverage network in peninsula consists of 32 communication nodes. Interconnected military truck-mounted elements provide a mobile and survivable communications system which are linked by wire and/or wireless network for communications between the more static headquarters. The tactical area is covered by a lattice of Node Controllers (NCs) normally located away from headquarters or other concentrations of subscribers. The switches in NC are interconnected by secure multichannel VHF (very high frequency) Line of Sight (LOS) radio links. The NCs are supported by the extensive databases held at the switches, which also handle all aspects of search and routing. All elements of the network are vehicle mounted, rugged and can be rapidly moved. Switching is carried out at each NC under computer control, accessing as required extensive local and network-wide databases. The lattice configuration gives the redundancy necessary to ensure continued reliable operation even under heavily damaged situations. All subscribers on the network are provided with an extensive range of facilities. Most secure fundamental of these is the provision of fully secure all digital 32 kb/s circuit-switching with packet overlay. These allow traffic to be voice, teletype, facsimile or data. With a deducible directory the common user can make local or trunk calls, as two party, conference or broadcast. Calls may be at routine, priority or flash precedence as allowed by the system managers. Call hold, forward, or transfer features are provided together with abbreviated dialing. System interfaces allow calls to civil or other military networks including U.S. TRI-TAC/MSE. In addition Store and Forward (S and F) packet switches are provided. This allows multi-address teletype messages to be sent with delivery delayed if necessary due to a recipient's temporary absence from the network. The NC switch is based on a dual processor control element together with the hardware necessary for the switching, routing, signaling, multiplexing, interfacing and supervisory functions[2]. System Controller (SC) and S and F both make use of the same control element and many items of switch hardware. Large headquarters are also served by the same operating in the role of major access switch, extension node. This extension node is normally connected to the NCs by multichannel radio. The NC and the SC are housed on a single 5/4 ton vehicle and are controlled by two or three operators. Smaller groups can be served by a Unit Level Switch (ULS) which is connected to a NC by a multichannel radio link. Normally the ULS has a standby link to another NC. A major feature of the SPIDER system is the extension of all service facilities to subscribers operating away from headquarters and likely to require service while mobile. The Mobile Radio Terminal (MRT) is connected to the NC by the Radio Access Point (RAP). And Combat Net Radio (CNR) such as PRC-999K can be connected to the RAP by Combat Net Radio Interface (CNRI). The RAP provides duplex radio channels in the VHF band, between the subscribers and the NC. The mobile subscribers needs no knowledge of the system design nor of the actual network connectivity or frequencies. He is free to move in response to his operational needs while retaining all the communications facilities available at headquarters.

The NCs are linked together by meshing links to set up a net spread over the large unit responsibility area. These nets fold or unfold on the battlefield according to orders issues by the signal commander to follow the rhythm of operations. Isolated or grouped subscribers are able to move within the net coverage with the utmost freedom. They bind themselves at will to the nearest NC provided they are within radio range. Moves of the network are executed by positioning NCs removed from formal positions will constitute a reserve for next moves. In this method, NC composing an initial network pattern are kept in operation, unmoved, as long as necessary. For example, in a forward move, a given front line NC may after some time, though being kept in the same place, become a rear line NC as a result of the new position of the center of the large unit. When the forward move comes to such an extent as to make this NC useless, it will be kept as a reserve. The communications means and the combat units maneuvers are thus separate if not strictly independent. Owing to the grid structure of the network, routing capabilities are preserved, in spite of destructions, electronic warfare actions or traffic saturation. Call dissemination capitalizes on this structural advantage to find out automatically the best available route between two subscribers. The call dissemination procedure enables any users, weather linked to the network by radio or by cable, to achieve immediate and automatic connection with any other one, not being aware of the called user's position, without any constraint resulting from the distance, provided there remains at least one available route between both. Each subscriber is given a directory number which is determined after his tactical function. This number remains unchanged within the whole area covered by SPIDER network, and is independent from the basic equipment involved. To initiate the procedure, the user must book in by himself. To fulfill this purpose, he must dial his directory number on his telephone set keyboard and this number is then inscribed within the memory of the nearest switch. Previous to this operation,

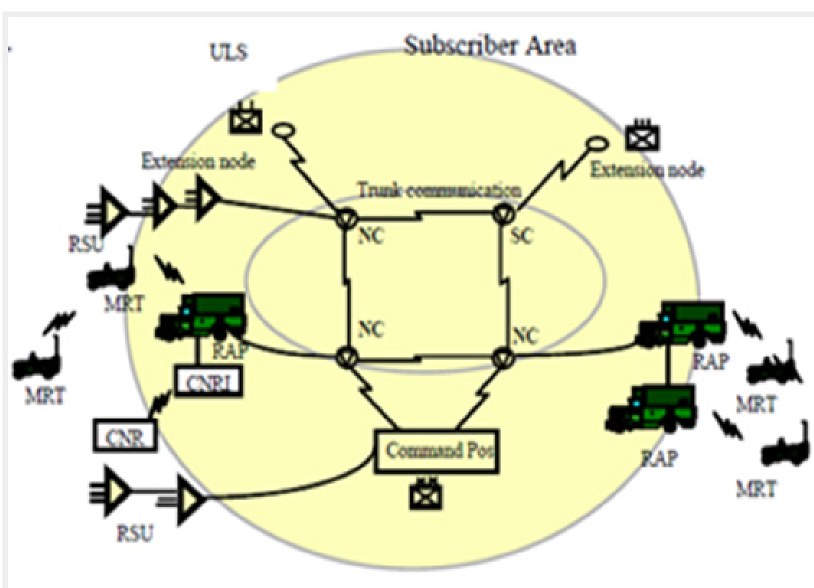


Figure 1. SPIDER trunk network.

for security reasons the large unit signal commander must have provided the network switch memory with all the allowed directory numbers. After booking in by dialing his telephone set, the user is already enabled to obtain any communication. This routing scheme is called flood search routing, in which a packet is transmitted on all links from the source to neighboring nodes, and then the neighboring nodes repeat this process until that the destination node recognizes the required directory number and responds with its own identity[10].

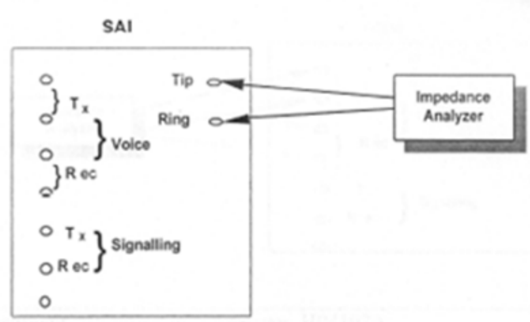
The ROKA and the U.S. Forces Korea (USFK) conducted interoperability test in Korea. The purpose of the test was to create a seamless interface between the U.S. and the ROKA tactical networks for joint operation. The MSC 500K SPIDER switch consisting of the AN/TTC 95K node management terminal and cable assemblies provides tactical C4I for ROKA. The U.S. single shelter switch operates on a local database and supports multiple wire line interfaces, but the SPIDER does not operate on a local database. With the same junction box, the SPIDER terminates subscribers and inter-nodal links which use the signal entry panel by coaxial cable. In the previous test on June 2003, the interface was phased out due to equipment shortages. And dialing scheme between the SPIDER and the MSE networks were different. The U.S. network operated at a 13 digit dialing numbers. For test purpose only, they agreed to modify dialing numbers from 13 to 10 digits by deleting 3 digits NATO code. With NAI and SAI devices as shown in Figure 2 and Figure 3, they conducted interoperability test. These test included 1. Measurement of SAI electrical characteristics (test item 1-1.1) 2. NAI and SAI compatibility test, 3. Verification of switching systems and network level interoperability, and 4. Operational feasibility of using the NAI-SAI trunk circuit to support non-voice communications such as personal computer based data communications and facsimile operation. In this paper the details and results of the NAI and the SAI compatibility test are presented. There are two different NAI, CV-4002 and CV-3478 which are designed to comply the NATO interface specifications, STANAG 5040. The CV-4002 is an analog trunk interface for the digital of the MSE switch, TTC-47. The CV-3478 is for the analog trunk of the TRI-TAC switch, TTC-39D. Test item 1-1.1 is to measure the SAI physical level electrical characteristics and the results are shown in Figure 2. From the test we get the results that the characteristic impedance of SAI, Z_o, are 600 Ω ±1.2% for the frequency range between 300 Hz and 3400 Hz. The measured characteristic impedance of the SAI tip-ring line is acceptable ±.

Test Item Number: 1-1.1

Test Objective: Measure tip-ring line characteristic impedance

STANAG Specification: Characteristic Impedance Z_0 = 600 Ω

Test Configuration:



Measuring instrument: HP (HP) Impedance Analyzer, HP4192A

Measurements:

Frequency (	Channel 1 T-R (Ω)	Channel 2 T-R (Ω)	Frequency (	Channel 1 T-R (Ω)	Channel 2 T-R (Ω)
300	595	596	2100	601	602
600	594	595	2400	602	603
900	596	597	2700	604	604
1200	597	598	3000	605	605
1500	599	599	3400	607	607
1800	600	600			

Figure 2. The measurement of the SAI physical level electrical characteristics.

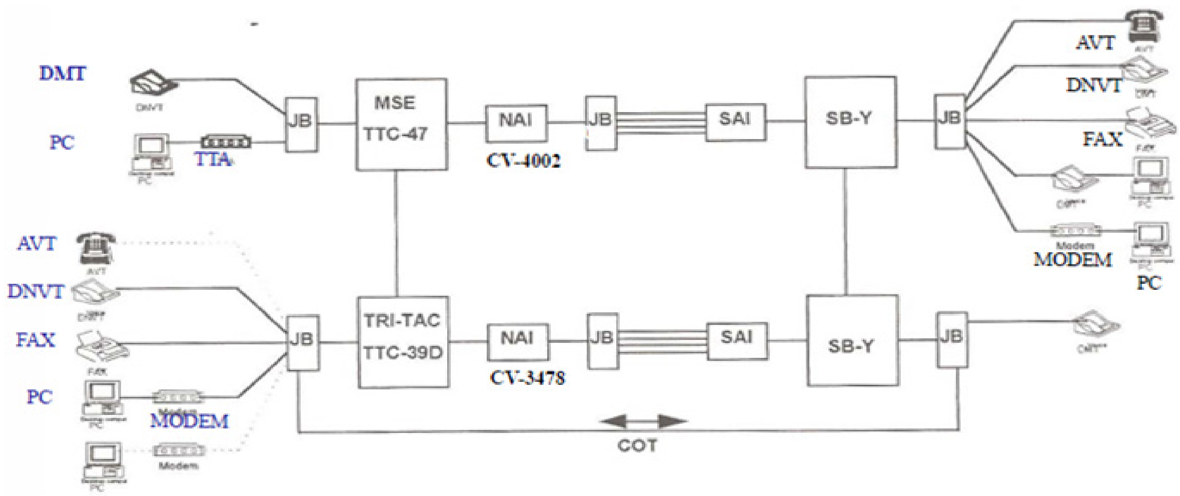


Figure 3. Network configuration for interoperability test.

The network configuration for interoperability test is given in Figure 3. During the network setup, it was discovered that the SAI and CV-3478 was not compatible: the SB-Y call for TTC-39D went through successfully but TRI-TAC call for SB-Y did not. A control signal analysis revealed that when a TTC-39D call was initiated, the CV-3478 sent a seize signal to the SAI and the SAI responded by sending a seize acknowledgement. However, the TTC-39D sent address digits immediately after it's seize without waiting for a seize acknowledgement from the SAI as shown in Figure 4. The SB-Y's time delay for its seize acknowledgement after the reception of a seize signal, the TTC 39D's seize signal in Figure 4, is required for the call originating switch to be able to discriminate the seize acknowledgement signal from a double seizure signal. STANAG 5040 specifies the seize acknowledgement delay time, discrimination time, as 2277 ± 228 ms.

On the other hand, the test crew interconnected successfully the SB-Y and TTC-39D via a SAI and CV-4002 link. The complete list of compatibility test results from 2) NAI and SAI interconnection is presented in Table 1.

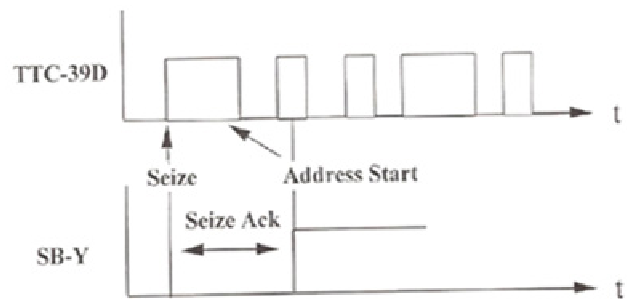


Figure 4. Handshake when TTC- 39D calls SB-Y.

Based on the measurements, frequency bandwidth of SAI after installing a band-pass filter and most parameters meet the STANAG specifications. Only the maximum level for linear operation did not meet the STANAG requirement (-2 dBm).

We also measured the return loss of the SAI signal from the SAI and the NAI connection with HP 4945A Transmission Impairment Measurement Set (TIMS) as shown in Figure 5.

With input signal of -20 dBm at 820 Hz, output signal

Table 1. Nai and Sai compatibility test results

Test Items/STANAG	Test Results	Test Items/STANAG	Test Results
Characteristic Impedance: Zo = 600Ω	600Ω ±1.2%	Pause time(Tp): 2783ms ±10%	3.9s ±10%
Freq. bandwidth: 300 ~3400Hz	160~3435Hz	Discrimination(Td): 2277ms ±10%	2250s ±10%
Return loss from NAI-SAI port	32.3dB	Seize cycle: 2505ms < T_1< 5511ms	3.2s
Return loss from SAI-SB-Y port	10.5dB		
SAI insertion loss within up to -2dBm	0+0.5dB	Release cycle: 0 < T_8< 5511ms	3.4s
dynamic range: 0±0.5 dB	0-0.1dB		
Max. level for linear operation: -2dBm	7dBm	Note: SAI electrical interface characteristics	

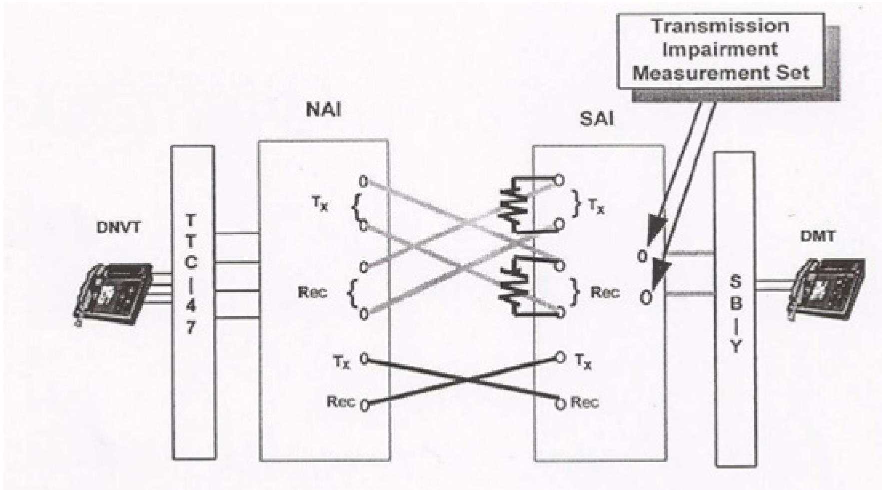


Figure 5. Measurement of the return loss of the SAI signal.

is -30.5 dBm, and return loss is 17.5 dB which satisfies the STANAG specification of 18 dB. Most electrical parameters of the SAI met the NATO STANAG 5040 and the SAI was compatible with the CV-4002. There are two problems of dialing sequence between two networks. First, once a call exits the tactical network, the call does not reenter the previous network. Second, when a call is made and terminated, the SPIDER switch sometimes does not release the trunk. These two problems were fixed by Agency for Defense Development (ADD) after the test and were reported to ROK Staff from Combined Forces Command (CFC) and the Program Manager (PM) for Joint Area Tactical Communications (JATC). Overall, the interoperability test of joint tactical communications systems was successful to better understand and to confirm various interoperability issues.

4. Conclusions

Interoperability issue is very difficult to solve and implement in tactical networks and is essential if information is to be able to flow seamlessly between any two points, and to be interoperable with not only other tactical and strategic networks, but also other allies' networks in the battlespace.

In this paper we present the interoperability issues of joint tactical communications systems, the SAI physical level interface compatibility with the NAI, the network configuration for interoperability test and test results. The objective of the test was to verify the compatibility of NATO NAI and SPIDER SAI device according to STANAG 5040. Most electrical parameters of the SAI met the NATO STANAG 5040 and the SAI was compatible with the CV-4002. The interoperability of the ROKA SPIDER and the U.S. TRI-TAC/MSE systems was confirmed in this test.

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