AN AIRCRAFT T&E METHODOLOGY BASED ON THE IEEE 1451 FAMILY OF STANDARDS

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ABSTRACT

This paper describes a methodology for aircraft T&E processes that exploits the advantages of the IEEE 1451 family of standards, including the design, implementation, test, and maintenance of instrumentation systems. The methodology includes the use of handheld and desktop applications that support the design of sensor networks, commissioning of sensors, sensor health monitoring, sensor plug-and-play capability, alarm management, and reports. The methodology incorporates the use of existing instrumentation support systems that have traditionally been used for aircraft T&E processes.

KEYWORDS

Aircraft T&E, IEEE 1451, Smart Transducers, TEDS, Data Acquisition, Instrumentation Support Systems.

INTRODUCTION

The IEEE P1451 [1 – 5] is a family of standards for interfacing sensors and actuators to the digital world of microcontrollers, processors, and wired/wireless computer networks. The goals for the 1451 are to develop network-independent and vendor-independent transducer interfaces, to allow transducers to be replaced and moved with minimum effort, to eliminate error-prone, manual system configuration steps, and to introduce a minimal level of intelligence (i.e., self identification) into transducers by developing Transducer Electronic Data Sheets (TEDS) that remain together with the transducers during normal operation.

In the past, the use of the IEEE 1451 standard for aircraft T&E has been proposed and the benefits of this use have been documented [6 – 8]. However, the T&E methodological changes resulting from the adoption of the standard have not been addressed, especially in regard to the use of existing instrumentation support systems (ISSs). First, the basic operational scenario for installing and maintaining instrumentation systems will change. Even at the simplest level, the mechanism for attaching a transducer to an instrumentation system will change. The ability for the automated plug-and-play of transducers or networks requires intelligent support at the application level. The wide range of control that smart transducers provide – from fully manual to fully automated – will not only have to be developed but provided to the user or control application using simple APIs that will also have to be developed. Second, control applications can reside on a variety of different platforms ranging from dedicated hardware to handheld devices. It is necessary that applications for the configuration, testing, and statusing of smart transducers and their clusters are robust, secure, and platform-independent. Third, there must be support for both wired- and wireless-based sensor networks (the emerging 1451.5), as well as independence from available telemetry bandwidth. Finally, the controlling software modules must be component-based to make them plug-and-play compatible with any other vendor's ISS at multiple levels of system control.

In this paper we describe a methodology for aircraft T&E processes that exploits the advantages of the IEEE 1451 standard, including the design, implementation, test, and maintenance of instrumentation systems. The methodology includes the use of handheld and desktop applications that support the design of the sensor network, commissioning of sensors, sensor health monitoring, sensor plug-and-play capability, alarm management, and reports. The methodology incorporates the use of existing ISSs that have traditionally been used for aircraft T&E processes. The use of existing ISSs is important because they have been tailored for specific aircraft T&E needs. We will also describe a prototype of the **F**ramework for **I**ntelligent support of **S**mart **T**ransducers (FIST) that supports the methodology. Since the methodology requires the use of the FIST components, we will call the methodology the *FIST methodology*.

IEEE 1451-BASED AIRCRAFT T&E METHODOLOGY

Figure 1 shows a generic T&E process flow that consists of multiple cycles of "pretest → test → posttest → evaluate" [9].

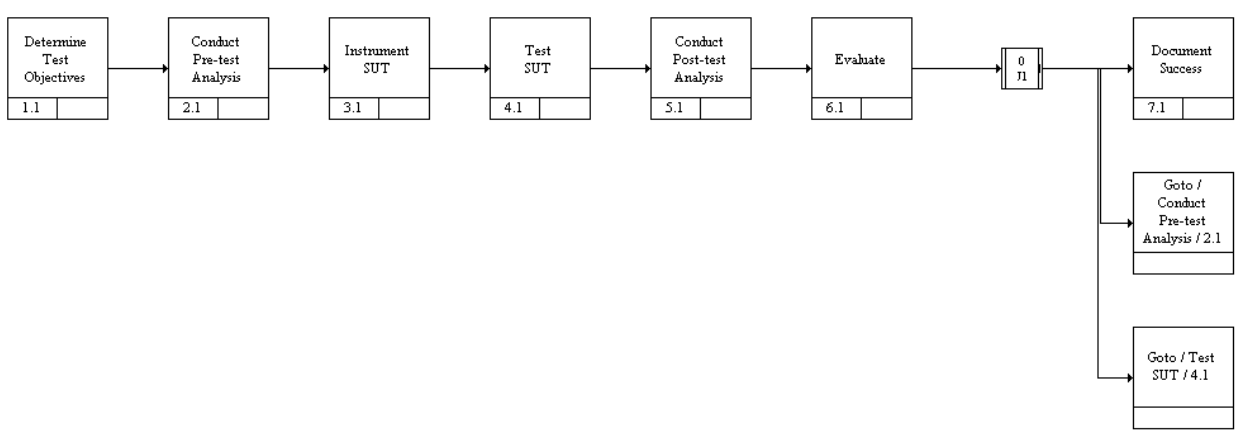

Figure 1: The Generic T&E Process Flow

In the case of aircraft T&E processes, pre-test analysis includes the design of the instrumentation system that will be used to evaluate the SUT. This is typically managed by the flight test engineer. Once the design has been validated, an instrumentation technician then implements the design on the system under test (SUT). Once the implemented instrumentation system on the SUT is modeled in an ISS such as ILIAD [10], it is verified by the flight test engineer. The existing process flow for the test instrumentation design and implementation is shown in Figure 2.

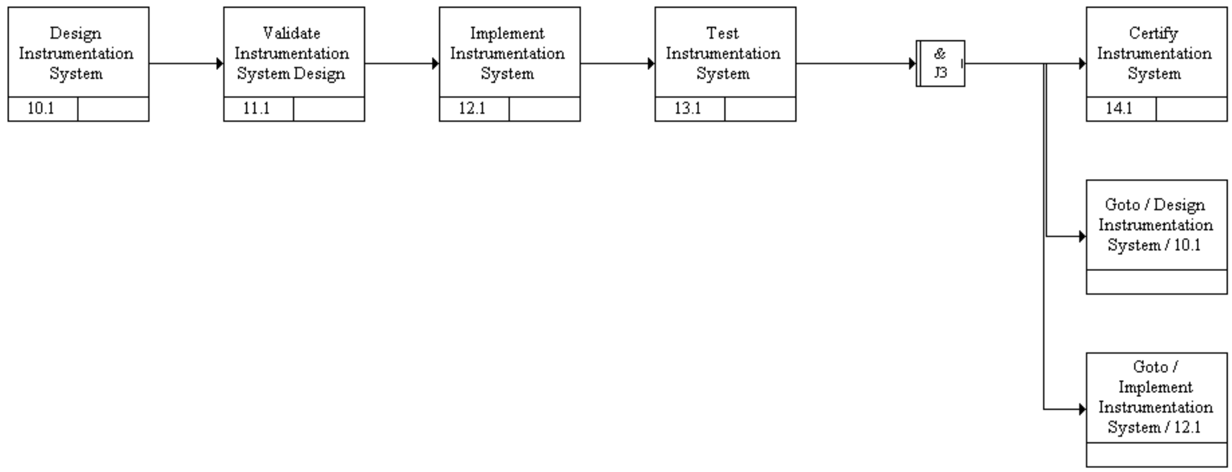

Figure 2: AS-IS T&E Instrumentation Process

Note that the process steps “Implement Instrumentation System” and “Test Instrumentation System” have traditionally been primarily manual processes. With the introduction of the IEEE 1451-based smart sensors, the T&E processes can be semiautomated. We model the TO-BE process flow equivalent of Figure 2 in Figure 3.

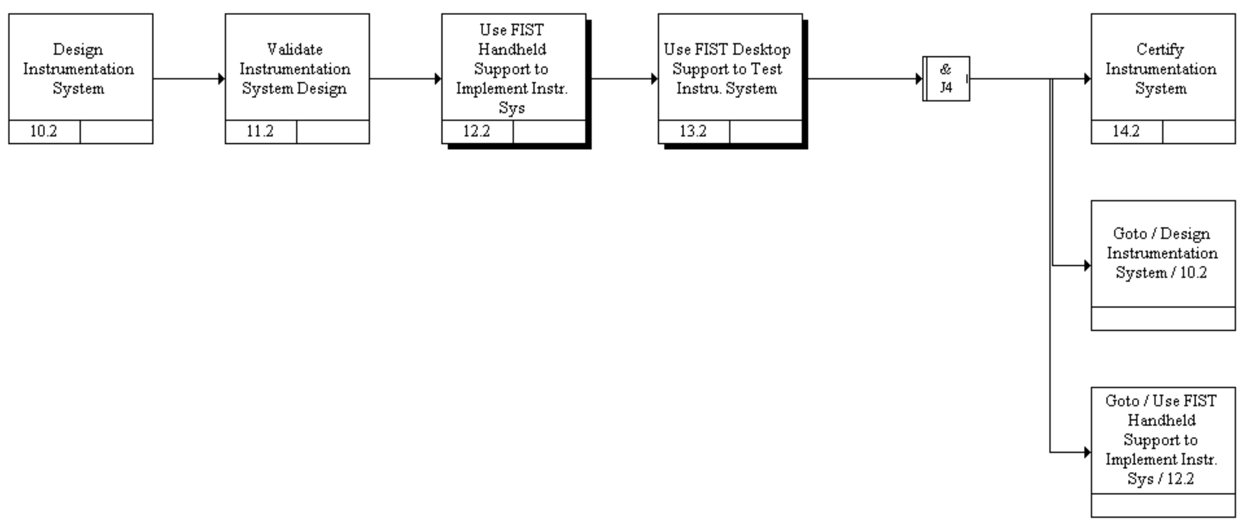

Figure 3: TO-BE T&E Instrumentation Process using FIST

For example, the “Implement Instrumentation System” now becomes the process shown in Figure 4.

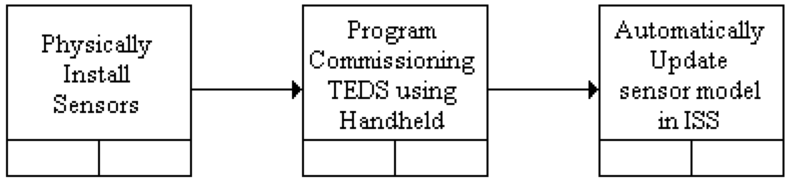

Figure 4: TO-BE "Implement Instrumentation System" Process

An example TO-BE "Test Instrumentation System" is shown in

Figure 5.

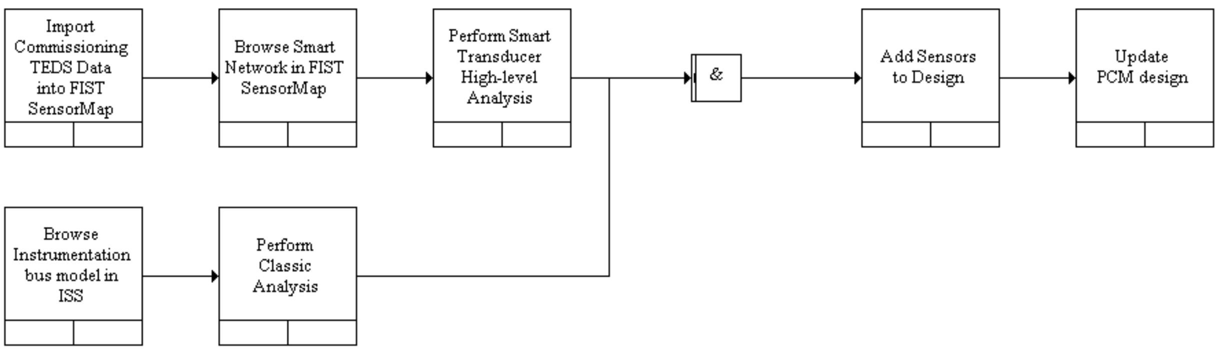

Figure 5: TO-BE "Test Instrumentation System" Process

However, current ISSs such as ILIAD do not possess the capability to support smart sensors and do not support the above TO-BE methodology. Also, while the aircraft system is under test (in flight), there is no current process for testing the health of the instrumentation other than at the highest level: a process for detailed, sensor-level health monitoring of the instrumentation system does not currently exist. Finally, smart sensors permit the flight-test engineer to perform postflight analysis of the sensor network health as well in an automated manner.

In order to support the TO-BE methodology, current ISSs must be extended to support the wireless monitoring and commissioning of individual sensors, as well as the monitoring and analysis of the installed sensor network as a whole, throughout the preflight, flight, and postflight test phases.

The TO-BE methodology for installing "Implement Instrumentation System" shown in Figure 4 has been supported in the FIST framework by means of the support for commissioning TEDS on a personal digital assistant (PDA) over a wireless network as shown in Figure 6.

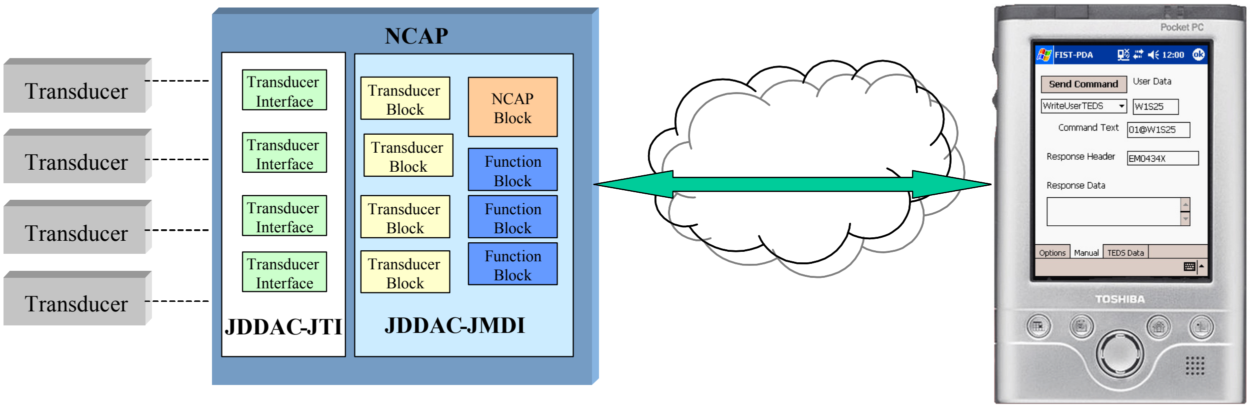

Figure 6: FIST Commissioning TEDS support using a Handheld Device

Also, the TO-BE "Test Instrumentation System" shown in

Figure 5 is supported through the use of the desktop component of FIST, which we call SensorMap, as shown in Figure 7.

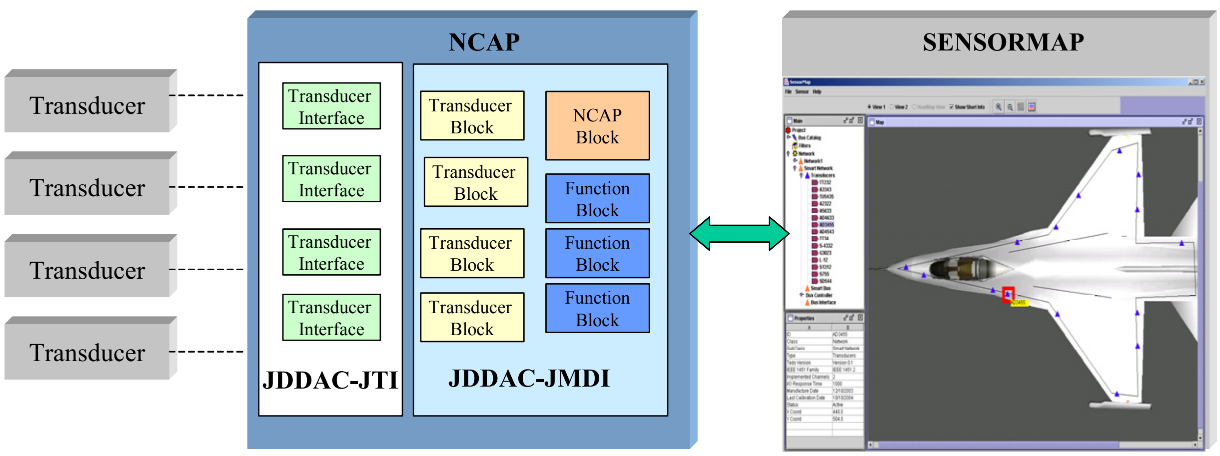

Figure 7: FIST SensorMap

FRAMEWORK FOR INTELLIGENT SUPPORT OF SMART TRANSDUCERS

FIST is composed of various reusable components for graphical user interfaces, security, and intelligence support for both low-level (controller-to-transducer, transducer-to-transducer) and high-level (knowledge or action-enabling information) smart transducers. FIST components can be plugged into (or tightly interact with) existing and future ISSs via a simple API. The high-level physical architecture of FIST is shown in Figure 8. This architecture supports smart sensor capabilities based on the IEEE 1451 standards to ISSs and also includes hand-held support for low-level IEEE 1451-based transducer capabilities such as reading TEDS and writing user-areas of TEDS, as shown in Figure 6.

Another FIST component is the FIST SensorMap, which consists of visualization and IEEE 1451.X-based support that can interact with existing ISSs such as ILIAD in order for the flight test engineer to validate and verify the implemented sensor network instrumentation system. Basically, this component is the support for the TO-BE "Test Instrumentation System" shown in Figure 5, and is the visualization component shown on the right in Figure 7.

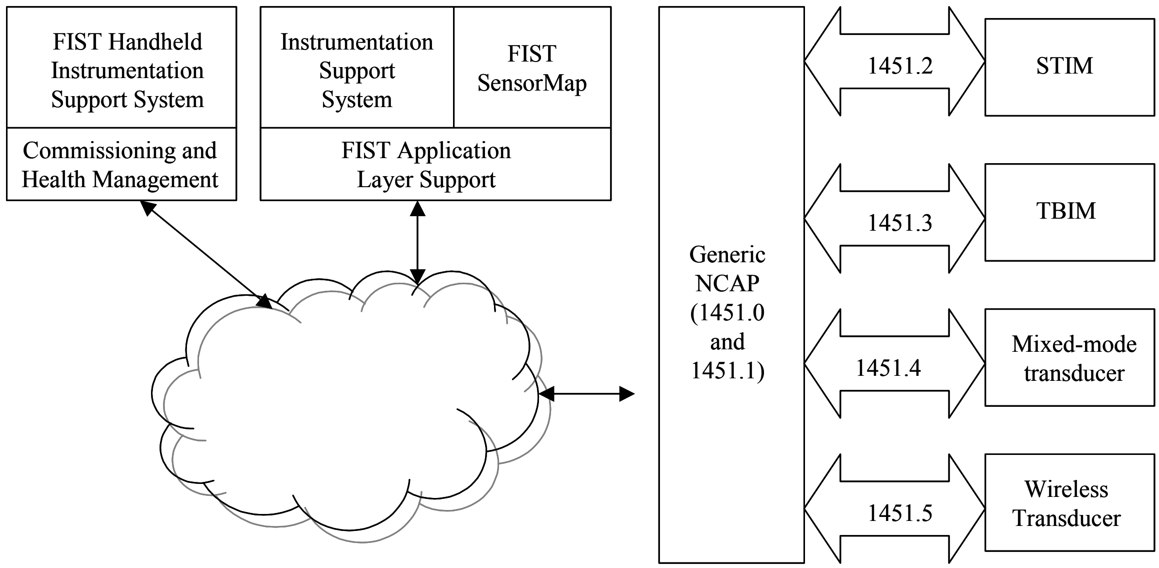

Figure 8: High-Level FIST Physical Architecture

As seen in Figure 7, SensorMap makes use of JDDAC [11], an open-source Java-based API that implements 1451.1 and 1451.2, to communicate with smart transducers. JDDAC provides network ports that allow communication through publish-subscribe or client-server mechanisms. These network port interfaces offer abstractions to reduce the complexity of dealing with sensors and actuators at the edge of the network. JDDAC also provides transducer blocks that can be customized for different types of transducers. Finally, transducer interfaces provide seamless communication with the physical world.

SensorMap provides a visual map for transducers, thus enabling a fast and intuitive way to access transducer information. In SensorMap, the left panel shows a tree view of the instrumentation system that includes the bus networks. The right panel can contain a wire-frame, vector, or raster image that has the position of each sensor relative to the structure of the aircraft. The left panel of SensorMap can display various transducer network configurations.

For example, in the case of the AATIS/miniAATIS/CAIS [12] based networks, selecting a particular node in the tree view would display the corresponding properties of the selected item in the lower left grid. This functionality would be available by accessing the instrumentation network model using the API or data sources of the ISSs such as ILIAD.

On the other hand, SensorMap provides support for IEEE 1451-based smart sensor networks as well, as shown in Figure 9. For this type of support, the locating of sensors on the wire-frame or raster image would take place automatically by invoking the smart network infrastructure (NCAP) and accessing the user TEDS data that includes the commissioning information. In addition, upon selecting a particular sensor, the SensorMap invokes the NCAP, accesses the TEDS, parses it, and displays it in the lower left grid. In order to achieve this, Sensor Map uses the JDDAC infrastructure as shown in Figure 7. This support is possible throughout the testing lifecycle of the sensor network – pre-flight, flight, and post-flight – as long as there is access to the NCAP that is connected to the sensor network.

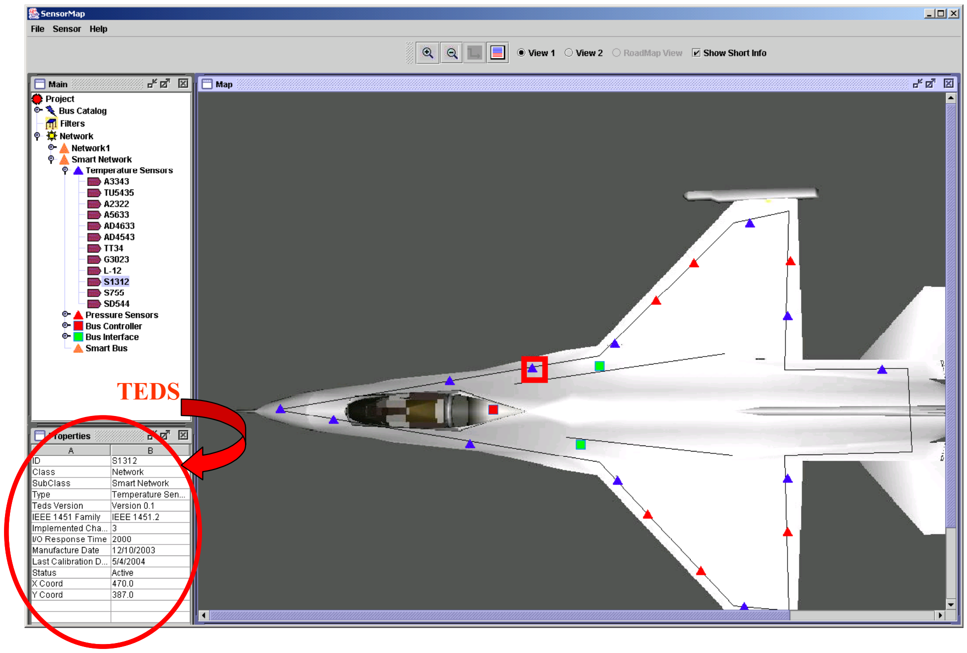

Figure 9: FIST SensorMap Displaying the Smart Network

In Figure 9, the sensors are arranged according to type. For example, the figure shows temperature sensors expanded and the pressure sensors collapsed. Icons can be assigned to a particular sensor type; in our example, temperature sensors are denoted by a blue triangle while pressure sensors are denoted by a red triangle. The lower-left grid panel can display a report of an entire group or type of sensor. Sensors can also be arranged according to whether or not they are connected to an NCAP. By supporting both traditional sensor networks and IEEE 1451-based smart sensor networks, SensorMap can support the visualization and browsing of an instrumentation system that has both types of networks.

CONCLUSION

In this paper we have described a methodology for aircraft T&E processes that exploits the advantages of the IEEE 1451 family of standards. This methodology includes the design, implementation, test, and maintenance phases of the of instrumentation systems. The methodology includes the use of software components for handheld and desktop applications that support the design of the sensor network, commissioning of sensors, sensor health monitoring, sensor plug-and-play capability, alarm management, and reports. The methodology incorporates the use of existing ISSs that have traditionally been used for aircraft T&E processes. The benefits of this methodology and software framework include rapid, customized smart transducer applications that result in reduced cost and increased reliability for both the sensor network and the system being instrumented. This will have a very positive impact on aircraft T&E environments such as ground-based and airborne T&E missions. The smart transducer methodology and supporting framework can be used in other applications, including condition based maintenance and sensor networks relating to homeland security and chemical, biological, radiological, nuclear, and high-yield explosives defense.

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