RoboGuards Nab Bads, Track Tagged Goods

Mobile robots equipped with radio frequency identification and other sensors can detect intruders and hazards while tracking high-value inventory. But the search for the perfect RFID tag continues.

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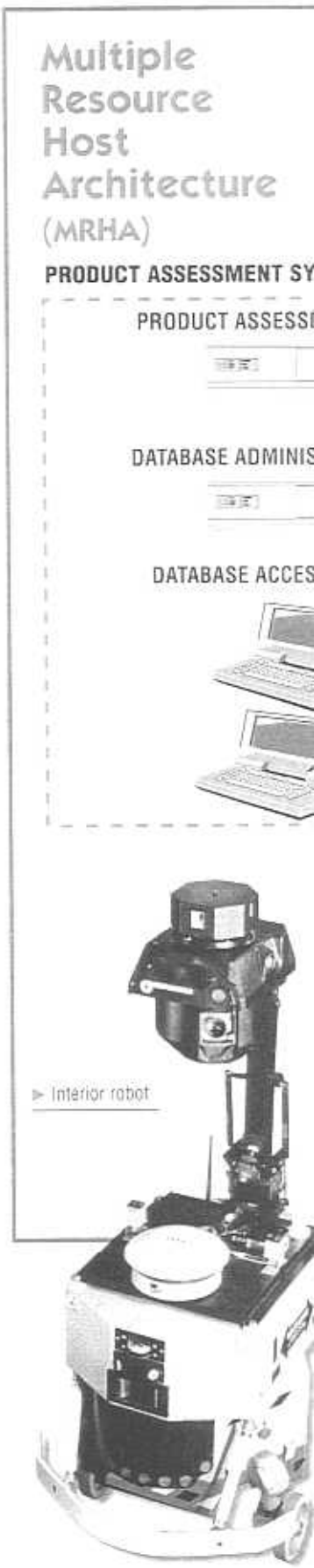
Mobile robots equipped with radio frequency identification (RFID) are one of the newest means employed by the military to guard and track billions of dollars' worth of sensitive inventory. One such system, now under development by the U.S. Department of Defense (DoD), promises to aid both physical security and inventory tracking at military storage sites.

The Mobile Detection Assessment and Response System, or MDARS, uses supervised, autonomous robots to patrol warehouses and storage yards. Different types of robotic systems are used depending on whether they are patrolling inside DoD equipment centers, office buildings, or hospitals, or outside at depots, airfields, and shipyards. Each robot navigates on its own using an onboard map of its designated patrol area. The robots can be specifically directed by an operator at a control console but are generally intended to patrol at random and report any problems they find.

MDARS is funded by the Army's Product Manager for Physical Security Equipment (PM-PSE), while technical management and expertise are provided by the Navy's Space and Naval Warfare (SPAWAR) Systems Center San Diego. Before units are fielded at DoD sites

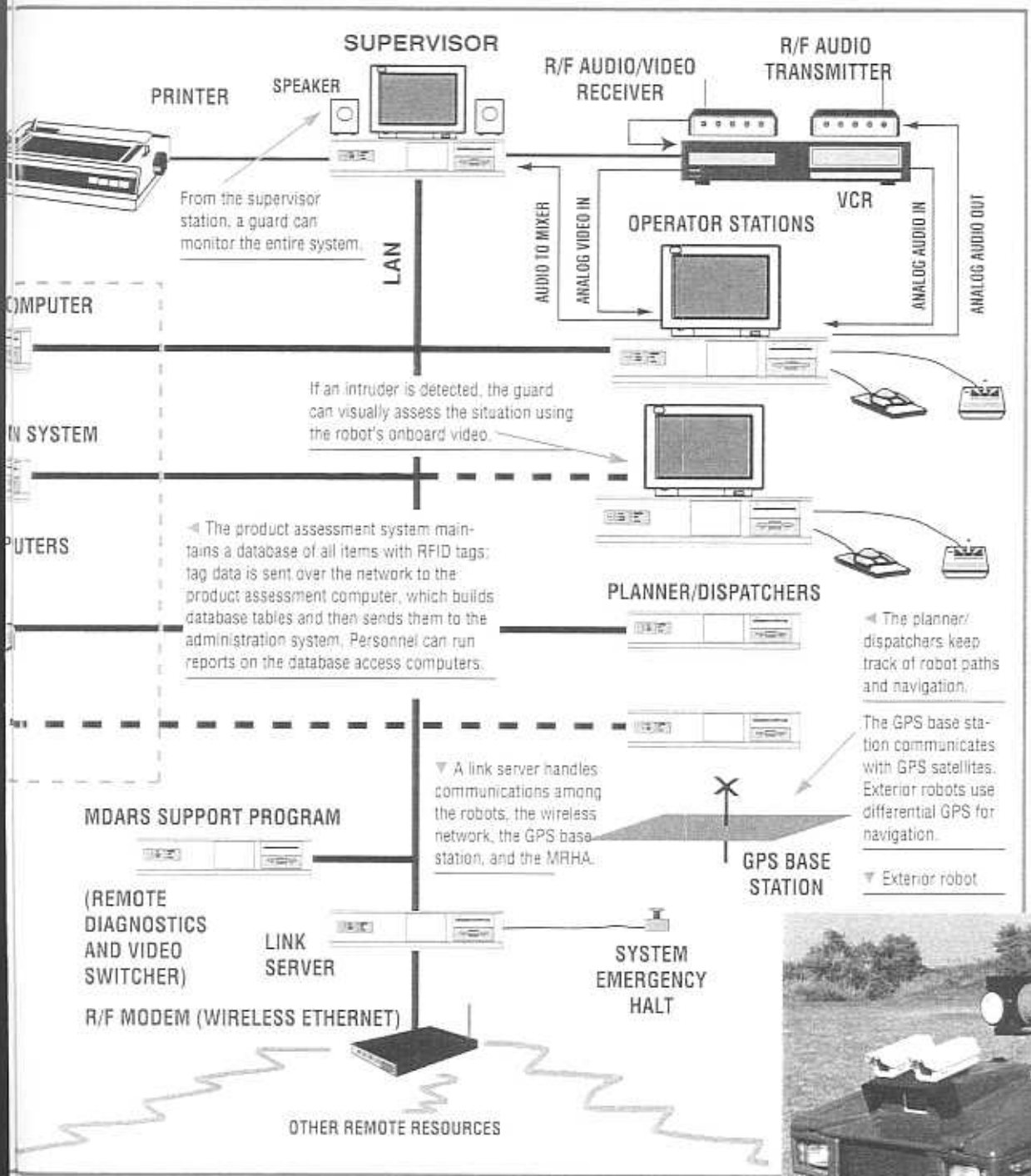


▶ Interior robot

PROJECT PROFILE ... U.S. Department of Defense ... Washington DC

Objective: Detect intruders and environmental hazards; track presence and location of high-value inventory.

System Suppliers: CyberMotion, Micron Communications, Robotic Systems Technology, Savi Technology (technical support provided by Computer Sciences Corp.)



THE MRHA USES NUMEROUS TECHNOLOGIES, including mobile robots, RFID, and motion and other sensors, to detect intruders and track inventory. Figure courtesy of Space and Naval Warfare Systems Center San Diego. (Dotted black lines represent optional components.)

throughout the U.S., MDARS is undergoing substantial testing. The interior version has been put through its paces at the Defense Distribution Depot warehouse at Anniston Army Depot in Alabama, while the exterior system is being tested at Aberdeen Proving Grounds in Maryland.

The heart of MDARS is a cluster of processors providing robot coordination and housing the system's inventory information in a database. The

Multiple Resource Host Architecture (MRHA) provides the user interface, employed by security guards as well as inventory management personnel to monitor the system and respond to situations as they arise. The MRHA's components are off-the-shelf Pentium II-based PCs running Windows NT; the architecture can currently control up to eight interior and exterior robotic vehicles, with further expansion possible. The number of PCs per site depends on the setting's size, with smaller sites needing fewer PCs; the system is flexible and can be easily configured for the size of any site.

Dual Robotic Platforms

MDARS' interior and exterior robots have unique capabilities adapted for their respective target environments, but their basic functions are the same. A major part of the overall mission is physical security. Each of these state-of-the-art robots carries sophisticated motion sensors and passive-infrared (PIR) sensors that can detect a potential intruder. If they do, the robot raises an alarm, and an onboard video camera zeroes in on the source of the suspected disturbance. Interior robots can also detect environmental hazards by sensing fire, smoke, water leaks, or chemical spills.

The exterior version performs automated barrier assessment, remotely reading the status of high-security locking devices on containers or entry doors. Each of these heavy-duty locks is equipped with a magnetic switch interfaced to a modified RFID tag, which senses whether the lock is open or closed. During patrol, the robotic vehicle reads each lock's serial number and status, as transmitted by the RFID tag, and sends this information on to MDARS' central control system. If the robot finds a lock open, it raises an alarm so that a guard can investigate.

Both interior and exterior vehicles also do inventory tracking via RFID. Throughout the storage facility, RFID tags are attached to high-value, controlled, or special-interest items. (Weapons are controlled items, for example, while night-vision goggles are both high value and special interest.) Each robot carries an RFID interrogator, which it activates at prescheduled stops to collect data from all RFID tags in its vicinity. It uploads this data to MDARS' central system (the MRHA), where it is stored in a database.

The interior robot, designed and built by Cybermotion Inc., is self navigating. Once provided with a map of the assigned warehouse, it patrols up and down the aisles in a pseudo-random fashion, reporting any security problems it encounters. It uses both Doppler radar and passive-infrared motion detection to sense possible intruders. For inventory tracking, MDARS' interior prototypes are currently outfitted with Savi Model CP-1010A-1 interrogators. Several of

these robots can patrol simultaneously, providing complete coverage of multiple warehouse interiors.

The exterior platform was designed and built by Robotic Systems Technology. This diesel-powered, hydrostatic-drive vehicle uses differential GPS position information to patrol a designated area. Multiple sensors, sensitive to purposeful motion (ignoring, for example, a tree blowing in the wind), enable it to detect intruders. It carries a Micron Communications MicroStamp 4100-20 interrogator for reading RFID tags, both for inventory tracking and for querying the status of locks. Two directional, bistatic antennae are mounted on each side of the vehicle for communication with RFID tags.

Inventory Tracking

As noted above, information collected from RFID tags is stored in a relational database in the MRHA. A user-friendly interface lets warehouse personnel access data and get regular or ad hoc reports on items being tracked. Typical output is in the form of an exception report highlighting potential problems, such as products missing from the facility or moved from their expected locations.

Personnel can also use the system to look up the perceived location of a found item, not just the location where it is expected to be. (Location information is available in both text and map forms.) MDARS saves readings from three robot interrogations in the database and then uses triangulation to compute an item's perceived location. If other information is available, the system can use it to refine the location estimate.

In the interior system, for example, the Savi interrogator provides received signal strength (which is inversely proportional to the square of the distance from the interrogator) for each tag reading. In calculating perceived location, the system uses this signal strength as a weighting factor in its estimate: It computes the perceived location as closer to those positions from which higher signal strengths were received than to those positions where signal strengths were lower. The Micron tags and interrogator used in the exterior system, on the other hand, don't provide signal strength but do offer directional information from the multiple antennae used to interrogate the tags. Improving the system's ability to accurately assess the location of each tagged item is an area of ongoing development for SPAWAR engineers.

Using the system's available reports, depot personnel can spot problems in near-real time, letting them quickly investigate any discrepancies. If a

RESOURCES

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Robotic Systems Technology
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product tag is reported as not responding, security personnel can immediately begin searching for the missing item by attempting to locate the RFID tag with one of the handheld or vehicle-mounted mobile interrogators that are now commercially available. In the past, it sometimes took months or even years for managers using conventional inventory methods to learn that an item was missing. With RFID tracking, that will no longer be the case.

RFID Tags: Active, Passive, And In Between

One general way of categorizing RFID tags is active versus passive: Active tags have batteries; passive tags do not. Batteries allow active tag reading at longer distances, but also mean that such tags are larger and more expensive than passive tags. Passive tags derive their energy from the interrogator's transmission rather than an embedded battery and thus can be smaller than active tags.

And whereas passive tags generally have significantly shorter read ranges than active tags, they are also less expensive and require less maintenance than active tags. No batteries to change also means that passive tags make better candidates for permanent embedding in or affixing to items.

Somewhere in between active and passive tags are so-called hybrid tags. A hybrid tag contains a battery, but the battery is used strictly to activate the tag so that it can look for an inter-

rogator signal, not to transmit a reply. Like a passive tag, a hybrid tag uses power from the interrogator's transmission to return a signal. Two types of tags and their associated interrogators have been used in MDARS systems to date. The interior system's Savi TyTag is an active tag, while Micron's MicroStamp, used in the exterior robots, is a hybrid tag.

In testing at Anniston, the active Savi TyTag has been reliably read at up to 80 feet from the interrogator, even with significant obstacles blocking the signal. The TyTag's disadvantages are its relatively large size (3.5 inches by 2.5 inches by 1.75 inches) and short battery life (approximately one to two years) and is being phased out by the manufacturer. As noted above, the Savi interrogator reports signal strength with each tag it reads, which facilitates location estimation.

Measuring 2.2 by 1.3 by 0.3 inches, the Micron MicroStamp hybrid used with MDARS' exterior platform is smaller than the TyTag. The MicroStamp has a longer battery life than the TyTag—two to three years, according to the manufacturer—but also a more limited read range, shown in testing to be 18 to 20 feet with an unobstructed line of sight. At press time, the MicroStamp had not yet been tested with MDARS in a cluttered environment. Because directional antennae are used to read these tags, azimuth information is available, which may help with location estimation.

In general, the ideal RFID tag (small, inexpensive, requiring low to no maintenance, but with an adequate read range for operation in an environment with densely packed or widely distributed items) for an application such as MDARS has not yet been developed. The DoD's Program Manager for Automatic Identification Technology (PM-AIT) is working with manufacturers to encourage development of tags that will fit the U.S. military's needs more closely.

Preliminary RFID Test Results

To determine the feasibility of using RFID for inventory tracking in DoD storage facilities, the Savi TyTag was tested extensively at the MDARS Interior Early User Appraisal facility at Anniston Army Depot. Several types of assessments were conducted to answer the following questions:

- **How well will tags be seen in this environment of densely packed crates containing a heavy concentration of metal objects?** Tags were attached to the exterior surfaces of wooden crates, in progressively more hidden positions relative to the interrogator. In the worst-case scenario, tags were inserted between crates, which were stacked three high and six or seven deep, with the farthest tag at least 26 feet from the interrogator. The results of these tests showed very good tag visibility: In this worst-case scenario, 50 of 52 tags (96 percent) were seen. The two tags that were missed were farthest from the interrogator (26 feet away).
- **How well will tags' perceived locations be assessed?** Examiners distributed 117 tags throughout the warehouse, and the robot followed its usual patrol route. Location estimation was performed on all tags, and results showed an average difference of about 15 feet between actual and assessed location, well within the MDARS target specification.
- **Will there be any problem reading densely packed tags?** Seventy-three active tags were packed in a box, about an inch apart, all oriented in the same direction. The interrogator mounted on the interior robot read 100 percent of the tags from about 6 feet away.
- **Will tags have to be placed at certain orientations relative to the interrogator to be read properly?** Tags were situated in the patrol area, first parallel to the robot path, then perpendicular. Overall results were similar, with a slight improvement (10 percent) in tag readability when tags were arranged perpendicular to the path versus parallel.

Preliminary RFID testing was also performed at the Aberdeen Proving Grounds site using the Micron Micro-Stamp hybrid tags and with a Micron interrogator mounted on the MDARS exterior robot. (Because this is a much more recent installation than Anniston, only preliminary visibility tests have been conducted to date.) Initial tests show that the Micron tags can be reliably read at a distance of 18 feet from the interrogator, as long as tags are in the line of sight and not affixed directly to metal objects (or composite objects with high metallic content). Offsetting tags from metallic objects by about an inch (with nonmetallic spacers, for example) improves their readability.

Cost Benefits

MDARS' mobile interrogation approach to inventory tracking, as opposed to the more conventional method of mounting interrogators in fixed positions, provides important advantages for large installations such as those maintained by the DoD:

- First, significant cost savings are achieved, because one interior robot carrying an interrogator can patrol a building on the order of 20 football fields in size, while an exterior vehicle can patrol up to 20 to 30 square miles. The number of fixed interrogators required for these environments would range from ten to literally thousands, depending on the range of the RFID tags being used.
- Another important advantage is the interrogation pattern's flexibility. For example, if warehouse personnel would like to reduce the distance between interrogations in one area to provide more accurate location reporting for small objects, the robot's path program can be easily modified. Changes to a fixed interrogator system, on the other hand, would require time-consuming, costly hardware and cabling modifications.
- Additional savings are realized by combining physical security, environmental sensing, and automated inventory functions into one common multifunctional hardware configuration.

Current Tags: Not Quite It

One of the technical challenges facing MDARS is the problem of finding cost-effective, capable RFID tags. Ideally, tags should be small enough to attach to items such as rifles or night-vision goggles, with the goal of eventually embedding tags into selected inventory during manufacturing. These tags must be able to meet DoD's ultimate goal of hands-free, covert, and random tracking of sensitive, high-value, or controlled items. To accomplish this, tags must be read from quite a distance, typically up to 50 feet. Finally, for cost-effective maintenance, tags should either have long-lasting batteries (five years or more) or require no batteries at all and simply derive power from the interrogator's transmission.

Some means of location estimation is required, along with tamper resistance, so that the product cannot be removed while leaving the tag in place (or without at least the tag's raising some alarm). Finally, MDARS tags must fit smoothly into overall DoD policy, as defined by the PM-AIT, and into existing DoD inventory management operations. Warehouses may be using other RFID applications, for example, in which case frequency conflicts must be avoided.

The DoD has concluded, however, that MDARS' potential benefits far outweigh its risks and is thus moving ahead to place these systems at selected sites. As we enter the 21st century, MDARS will be further refined, and RFID technology will continue to mature, resulting in even more profound cost effectiveness. IDS

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