



WHITE PAPER

Digital X-Ray Sensors for Military, Commercial, and Homeland Defense Applications

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Digital X-Ray Sensors for Commercial, Military, and Homeland Defense Applications

1.0 INTRODUCTION

The digital revolution that had its origins in the entertainment domain of the commercial sector during the latter part of the 21st century has made its presence known in the military, as part of the Digitization of the Battlefield, and is currently emerging in the network–centric environment of Homeland Security.

The advantage that digitization provides, in addition to the preservation of fidelity and quality, is the re-transmission capability of the data and/or information through a wide variety of instant, global, tactical or commercial communications. Compared to imagery that was acquired and stored on film, digitization provides orders of magnitude improvement in processing, fidelity, resolution, optimization, re-transmission, and substantial reduction in time and costs. The emergence of telemedicine in the Military and Homeland Defense environments has identified a critical need for a digital, man-portable X-Ray sensor. One Cares Built digital image can display much more data than one film equivalent by using the software, window, and level to keep revealing more data from the one exposure.

CACI International and Teammate, Cares Built, Inc. have developed a Digital X-Ray sensor that can be used to replace the old film based X-Ray machines with their cumbersome and expensive film and silver processing. The digital, lightweight, X-Ray sensor, due to its low power design can be easily integrated in small vehicles i.e. HMMWV or commercial ambulance. This will enhance the telemedicine capabilities of the Military and Homeland Defense, by placing the units closer to the location of the trauma victims. The digital transmission capability of the sensor images provides critical and timely information to doctors in the emergency rooms, well in advance of the arrival of the trauma victims.

In industrial applications, the Digital X-Ray sensor will identify manufacturing/packing defects in near real time, not visible to the naked eye or other currently available optical means. This provides savings through the identification of defective parts or products that would otherwise be shipped from the factory only to be returned as unacceptable. Finally, due to the high-resolution capability the Digital X-Ray sensor provides, it will be an indispensable tool at airports, rail and bus stations, border crossings, government buildings, post offices, court houses, and port facilities where non-intrusive examination of packages or cargo is required.

This white paper describes the capabilities and notional applications of the CACI/Cares Built Digital X-Ray sensor for the Military and Homeland Defense requirements.

2.0 BACKGROUND:

The events of 9/11 and subsequent military operations in South East Asia have brought to light some new requirements in the area of Digital X-Ray sensors for Combat Operations in an Urban Environment, as well as Homeland Defense, specifically to support First Responders. CACI and Teammate Cares Built, Inc. have accepted the challenge and developed a new sensor, with a revolutionary detector capability that meets the needs of the military, the First Responder community, as well as the medical and industrial sectors.

There are essentially four different detector technologies offered by the major manufacturers for their Digital Radiography (DR) products. Generally, even if a manufacturer offers several different DR products on the market, they all use the same basic image acquisition technology. The four basic categories are: amorphous silicon, amorphous selenium, charge-coupled devices (CCD), and complementary metal oxide semiconductor (CMOS).

Table #1 illustrates the type of technology used by each manufacturer.

Company	a-Silicon	a-Selenium	CCD	CMOS
Canon Medical				
Cares Built				
Eastman Kodak Health Imaging				
Fischer Imaging				
GE Medical				
Hologic				
Imaging Dynamics				
Imix				
Infinmed				
MMC International				
Nucletron				
Philips Medical				
Siemens Medical				
Swissray				
Wuestec				

Source: Frost & Sullivan

Table 1—Digital Radiography Detector Technologies by Company

a. **Amorphous Silicon:** In this approach, an amorphous silicon photodiode array is deposited onto a thin film transistor (TFT). This detects visible light from an overlying scintillator and converts this light into electrical charge. The diodes are connected to a field effect transistor that controls the charge read out. GE Medical Systems is the principle developer of this technology, although Siemens Medical and Philips Medical (through the amorphous silicon technology developed by Trixell in France) also base their DR models on amorphous silicon.

GE Medical Systems’ technology is based on amorphous silicon and a scintillator coating of cesium iodide. These components are the result of research and development efforts that have cost over \$100M. One advantage of this approach is that this technology is probably the most amenable to real-time display. In addition, the amorphous silicon arrays can be manufactured in large, unitary sheets that do not have to be tiled. GE’s proprietary DR panel also has a high fill-factor of over 80%. This means that the area of the photodiode occupies over 80% of the entire area of the pixel. This allows the detector to capture a greater number of the emitted x-ray photons, which in turn leads to better radiation dose efficiency.

b. **Amorphous Selenium:** Digital radiography systems based on amorphous selenium technology are also viable, with the development pioneered by Direct Radiology (A subsidiary of Hologic). Here, amorphous selenium is deposited on the TFT, which can then directly absorb x-ray energy and convert it to charge, obviating the intermediate step of a scintillator to provide conversion to visible light. Fischer Imaging also incorporates this approach to digital radiography. The primary advantage of this approach is that the direct conversion to electronic charge limits the problem of light scatter. Sheets can be fabricated in large unitary arrays in the same manner as with amorphous silicon.

However, selenium arrays have the disadvantages of high toxicity during manufacturing, and persistent latent images that linger on the receptor (making real-time display difficult), as well as the tendency for noise-related image degradation.

c. **CCD Detector Technology:** Charged-coupled devices (CCDs) are small area detectors that must be bonded together to span the required imaging area. These are coupled with a scintillating phosphor and connected fiber-optically or in various optical arrangements so that the imaging area can be scanned and read. Swissray has been the major incorporator of CCD technology in its DR systems. The Swissray system uses four (4) CCDs tiled together in a proprietary optical configuration. It uses a scintillator material that is bonded to each CCD in the array. There are advantages to this approach. For one, CCD detectors are a tried and proven technology that has been used in digital medical imaging for years. Furthermore, data can be read from each of the modules simultaneously.

d. **CMOS Detector Technology:** CMOS (complementary metal oxide semiconductor) chips are widely used type of semiconductor, most commonly incorporated into desktop and laptop computers. Cares Built, however, has pioneered the use of CMOS chips as detector components for use in direct digital radiography. CMOS chips provide a type of digital memory that can hold data for long periods, using very little power, thus CMOS chips have been found to have characteristics favorable to imaging applications. CMOS image sensors are built in to an array of photosensitive diodes with on-chip image processing capabilities. Figure #1 provides a comparison of the various types of technologies / detectors.

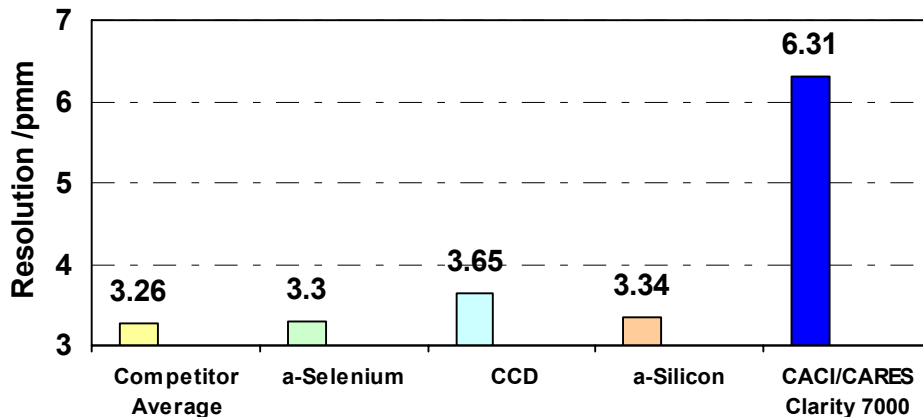


Figure 1—Comparison of Technology Resolutions

3.0 SENSOR SYSTEM DESIGN:

Nearly all industrial radiography applications utilize an industrial X-ray tube running at maximum kiloelectron volt (keV) and maximum tube current for a given filament spot size. The maximum keV allows for the most penetration while the maximum current provides more photons at the detector, whether it is thin film or solid state, it results in shortest exposure time and thus, greatest throughput. With the advent and steady proliferation of solid-state detector technologies, other variables come into play. The typical solid-state devices are not usable at very high keV (above 250keV) for fear of detector damage. Thus, penetration through typical metal objects was not possible with good results and high throughput.

The CMOS detector however, has changed the field. The CMOS allows higher keV source use, without detector damage due to clever shielding. In addition, because of the very high sensitivity of the CMOS, lower than expected keV energies may be used to yield results equivalent to the past.

Coupled with a very high tube filament current medical X-Ray tube, very short exposure times are possible. These shorter exposure times mean lower system electronic noise and lower initial keV usage resulting in much less scatter at the detector. These two effects combine to result in an equal quality image in a fraction of the time and energy.

The CACI /Cares Built CMOS Detector system has three major components:

1. The source, which consists of a 150keV medical tube with rotating anode for heat dissipation with an 80KW output
2. The detector panel, which consists of a series of modular “camera” units have a hexagonal shape and overlap each other with the resultant images “laced” together in software. Figure # 2 depicts the hexagonal configuration. A detector panel in almost any ratio of length to width accommodates special shapes of items to be x-rayed. Figure # 3 depicts the CMOS detector arrangement.
3. The computers of which there are two, one captures the CMOS panel data and processes it into an image, and the second acts as the central computer displaying processed images and acting as the control center for the entire system. Figure # 4 depicts the notional system configuration.

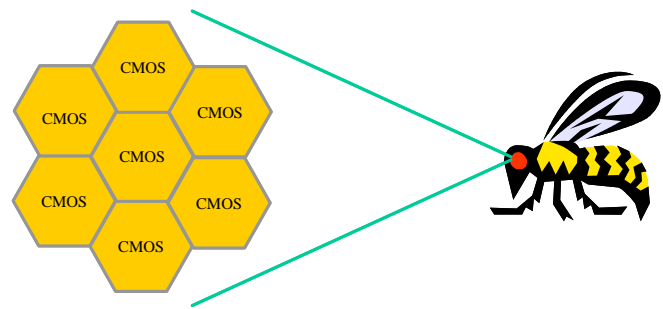


Figure 2—The "eye of the insect" Segmented Concept

The CACI/Cares Built Digital X-ray system has been evaluated by several government organizations utilizing a variety of test materials such as complex artillery fuses, ceramic and other materials. The resolution of the images provided was found to be superior to any other currently available systems. Figure # 5 depicts an actual image (7,000 x 7,000) resolution, 49,000,000 pixels of information, which is five times greater than any other competitor on the market today. This digital image is captured in milliseconds with a raw image within 6 seconds. The final is ready for transmission within 29 seconds. Parallel processing allows images to continue being taken as previous ones are being processed.

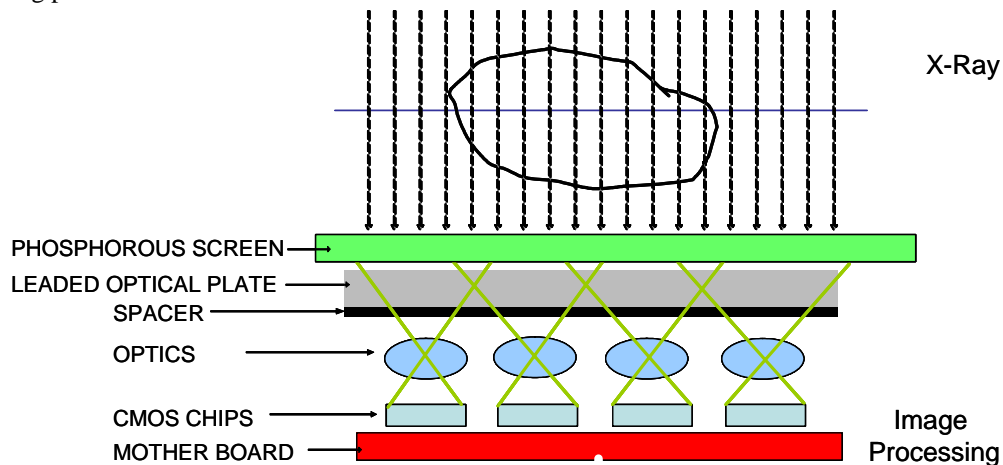


Figure 3—CMOS Detector Process

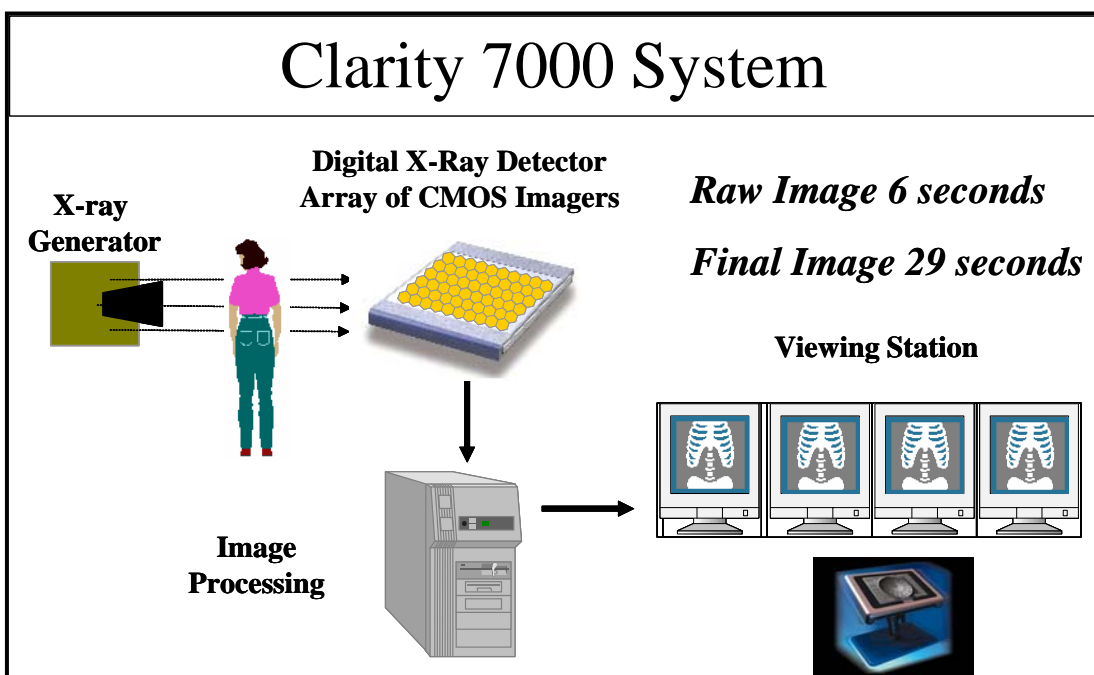


Figure 4—Notional Configuration

- **Digital x-ray image \geq film**
- The Clarity 7000 produces
 - 7K x 7K resolution image
 - 49 million pixels of information
 - over 5x greater than any leader competitor

Figure 5—Actual Digital X-Ray Image Quality

4.0 DEPLOYMENT CONFIGURATIONS

The modular design of the CACI / Cares Built, enables the sensor to be constructed in any shape in order to accommodate the length and width of the items X-rayed. The detectors are interchangeable across the sensor array. The hexagonal arrangement and processing algorithms provide a failsafe capability. If a specific detector fails for any reason, it can be replaced from other parts of the array that are less critical. However, even if it remains in place, the processing will provide some overlap, leaving only a very small portion of the image missing.

The nominal configuration of the sensor consists of a 17”Lx17”Wx4”D array that weighs approximately 47 lbs. In this configuration, the CACI/CARES sensor can be fitted onto an x-ray table replacing the existing sensor without any major modifications. The sensor design, due to its modularity, can be made to fit any shape for which an image needs to be taken. Figure #6 provides the system component description and technical specifications for each component.

The sensor can also be used in an industrial application with the X-ray table configured adjacent to a Quality Assurance (QA) assembly line. Subsequent to tagging them with an identifying number and X-raying them, they can be accepted or rejected. Information collected on each item that was examined will be stored in a database for reference should an item be returned for re examination to compare its condition with the original status. Change detection algorithms can be used to make an automatic comparison to identify defects not evident to the naked eye. Figure #7 indicates this notional configuration.

Prototype Systems Integration Schedule, Figure 8, details our schedule for production of 1-5 units, which is approximately xxx 11 months after receipt of contract (a shorter system development schedule may be possible with special consideration).

Figure 6 – Industrial Direct Digital Imaging System

Part Number: System Name	CBI-IPHRD, Model 17X6, CB Single Detector
Component Description:	Single 14”x12” digital detector with user interface computer, power supplies and cabling
Technical Specifications:	<p>CBI-IPHRD (model 14x12), Direct Digital System Preliminary Specification</p> <p>General:</p> <ul style="list-style-type: none"> • <i>Potential resolutions are equal to radiographic screen combinations at high latitude, wide dynamic range virtually unlimited contrast and brightness control and with lower dose than conventional film screen combinations</i> • <i>Serviceable to the component level with no half-life as is the case with lower performance digital systems</i> • <i>Field of View: 14x12</i> • <i>Number of pixels: 7000x7000 = 49,000,000 pixel resolution</i> • <i>Resolution: Nyquist Limit above 61/p</i> • <i>Thickness: 1.9 inches</i> • <i>Gray Scale: 35dB, 12 Bit, 4,096 shades of gray</i> • <i>Capable of imaging at variable SID (Source to Image Distance) including off center and angulated exposures</i> • <i>Power: 120/220</i>

	<p>Compatible with existing install base</p> <p>Proprietary imaging software for CBI-IPHRD</p> <ul style="list-style-type: none"> • <i>User interface including Window, Level, Dual Zoom</i> • <i>Pan Scroll and Edge Enhancing</i> • <i>1 flat screen technologist monitor</i> • <i>Power supply</i>
CBCBI01290101 Cable:	Power Supply 25'
Component Description:	25 foot cable for power supply. Cables for detector to power supply.
Technical Specifications:	CBICBI01160103 5V Power Supply to CBI-IPHRD
Component Description:	Wall mounted 5V input on Logic Prep, 5V input on Exposure, Switch closure for Enable Input on Enable, 120V supply, 20A
Technical Specifications:	CBICBI011700104 Data Cables, USB2 15''
Component Description:	75' SCSI LVD Shielded Cable (two supplied with each system)
Technical Specifications	CBICBI02100101 17'' LCD Monitor
Component Description:	Samsung 17'' LCD-TFT monitor. The 770TFT delivers a 1280x1024 resolution, giving you color clarity and crisp razor-sharp images. Its advanced image scaling offers an auto adjust feature in addition to a full array of advanced user controls
Features:	<ul style="list-style-type: none"> • Image type – Non-Interlaced • Color Support • Max Resolution – 1280x1024 (multi scan) • Dot Pitch – 0.26 mm • Diagonal size (Viewable Size) (17'') • Video Input – None • Built-in Devices – None • System Requirements – None • Device Type – Flat Panel Display/TFT Active Matrix • Audio Input – None • Input Device – None • Power – None • Audio Output – None
Dimensions (WxDxH)/Weight	43.9cm x 22.1 cm x 45.7 cm/8.4 kg, Form Factor – Desktop proprietary
Technical Specifications:	CBICBI02010101 Processor Computer
Component Description:	Image processing computer for Clarity 7000. Computer, keyboard, mouse, interface PCI cards (no monitor)

<p>Technical Specifications:</p>	<p>Hardware:</p> <ul style="list-style-type: none"> • Dual 933Mhz Pentium 3 Processor • I/O Interface Board • 1 Gigabyte RAM Memory • 30 Gigabyte Hard Drive • Graphics Accelerator Card (Gforce) • Standard Keyboard • Wheel Mouse (two button plus center wheel) • PCI Detector Interface Cards • Ethernet 10/100 PCI Card • 3.5" Floppy Drive • CDROM Drive • Full Tower with 400 Watt Power Supply • 1 Data SCUZZY Interface Board <p>Software:</p> <ul style="list-style-type: none"> • Windows 2000 Professional
<p>X-Ray Generator:</p>	<ul style="list-style-type: none"> • 80 KW • Transformer 440/480V • Console • 20M Console Cable • Console Base
<p>X-Ray Tube:</p>	<ul style="list-style-type: none"> • PX 1551 • FS 0.6/1.2 • TA 12.5' • KW 44/120 • KVp 150
<p>HV Cables:</p>	<ul style="list-style-type: none"> • 30 foot
<p>Heat Exchanger:</p>	<ul style="list-style-type: none"> • Model 201-00
<p>Linear MC-1550-C Manual Collimeter</p>	<ul style="list-style-type: none"> • Model 70-63100NC (non-certified)
<p>Floor Mount Stationary Tube Stand</p>	<ul style="list-style-type: none"> • Model 03-000, Trunnion Mount for PX 1551

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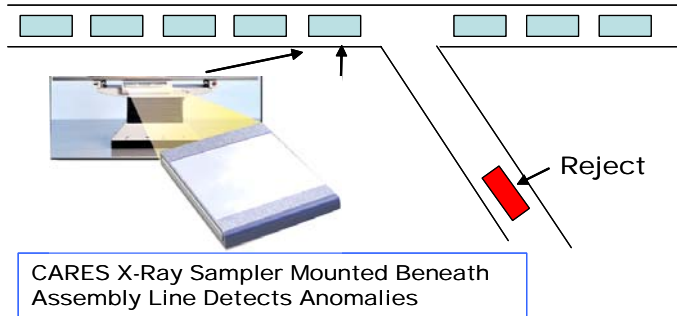


Figure 7—Assembly Line Configuration

5.0 PROTOTYPE SYSTEM INTEGRATION SCHEDULE

Figure 8 details our schedule for production of up to 5 Cares Built Digital X-Ray Sensors

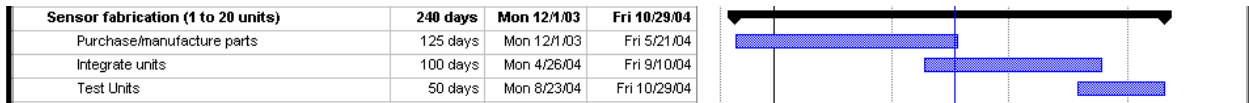


Figure 8– Notional Project Schedule

6.0 PROTOTYPE SYSTEM COST ESTIMATE

Based on the general requirements provided by Mr. Michael Semenoro, Electronic Engineer, I2WD, CERDEC, RD&E Command on 23 January 2004, the estimated cost for delivery and installation of an X-Ray Sensor System to include system descriptive manual, and operator’s manual and one day of training on the use of the system is \$350,000.00. Maintenance costs will be costed on a time and materials basis

7.0 CACI INTERNATIONAL INC CAPABILITES AND FACILITIES

CACI is an international Information technology company products and services corporation. It was founded in 1962 pioneering in Modeling and Simulation software. The company has been publicly owned since 1968 and trades on the New York Stock exchange under the symbol “CAI.” CACI, a member of the Russell 2000 and S&P

CACI is an international Information technology company products and services corporation. It was founded in 1962 pioneering in Modeling and Simulation software. The company has been publicly owned since 1968 and trades on the New York Stock exchange under the symbol “CAI.” CACI, a member of the Russell 2000 and S&P SmallCap 600 indices, provides dynamic careers for approximately 6900 employees working in more than 100 offices worldwide. CACI is the IT provider for a networked world

“Washington Technology” has placed CACI 18th in the top 100 Federal Prime IT contractors. In the course of its forty-two years, CACI has diversified into a variety of areas beyond Modeling and Simulation. They include Systems Integration, Managed Network Services, Information Assurance, Engineering and Logistics, Intelligence Solutions, Knowledge Management and Homeland Security.

The company has six business groups. They include the Integrated Engineering Business Group, Assured Information Solutions Group, Telecommunications and Information Assurance Group, Research and Technology

Systems Group, Federal Systems Integration Group, and the Vision & Solution Center and Project Resource Group. In addition to supporting all of the military services within the Department of Defense under a variety of contracts, CACI also supports many Federal Agencies. CACI is an SEI CMM Level 3 Software Developer and is ISO 9001:2000 Certified (Certificate No. CERT-05995-2003-AQ-HOU-RAB).

The Information Dominance Systems (IDS) Division Group is located in Eatontown, NJ and has over 210 employees. IDS provides primary support to a variety of customers at the Headquarters Communications and Electronics Command (HQ CECOM), Ft. Monmouth, NJ and specifically, to the Intelligence and Information Warfare Directorate (I2WD) of the CECOM R&D Center, under the Technical Engineering Fabrication Operations and Support (TEFOS) five-year Indefinite Delivery Indefinite Quantity (IDIQ) \$500M contract. IDS also supports the Software Engineering Center (SEC) as a sub contractor to Northrop Grumman under the Software and Systems Engineering Support (SSES) 10 year \$1.3B contract and R2CSR, another multi year \$1.0B contract and the recently won Genesis II five year \$154M contract supporting INSCOM.

The IDS Division Group supports a number of Program Executive Officers (PEOs) residents at Ft. Monmouth (e.g., PEO-IEW&S and PEO-C3T) and a number of Project Managers under those PEOs. The IDS Staff has demonstrated expertise in multiple technical disciplines and actively support over 50 Task Orders in C4ISR. A majority of the staff holds clearances at the secret or above level.

IDS CACI occupies approximately 85,000 square feet of space. As shown in Figure 10, the facility includes:

- An approved Sensitive Compartmented Information Facility (SCIF) with a high bay area for sensor integration on vehicles.
- A Special Access Program (SAP) integration area, at the secret level.
- A screen room for RF testing.
- A high bay area for fabrication and integration of shelters, vehicles and sensors.
- A Sense Through The Wall (STTW) Radar Test facility,
- Soon to be established radiological laboratory,
- Secure storage facilities,
- RF Wireless Technology Laboratory,
- Software Engineering Laboratory,
- Modeling and Simulation Laboratory,
- Four conference rooms and
- A fully equipped training classroom.

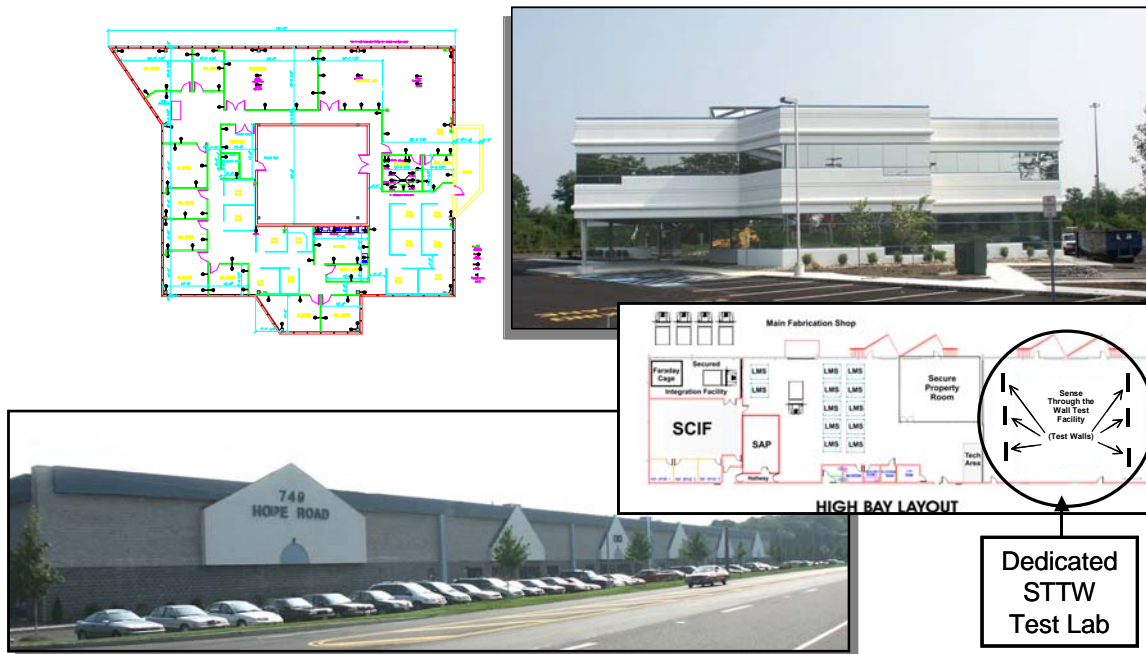


Figure 9—Eatontown IDS CACI Facilities

Consideration is also being given to the establishment of a Homeland Security laboratory where in conjunction with the government, COTS and emerging technologies could be integrated into solutions that would support State and local Agencies in Homeland Defense initiatives.

8.0 CARES BUILT, INC.

Cares Built is a woman operated small HUBZone company located in Keyport, New Jersey. The company was incorporated in October 1996 and started as a family operated service and analogue company. Cares Built Inc. has been primarily funded by private individuals. The State of New Jersey has also supported the company with a seed loan. The company initially provided technical support for X-ray machines,

The “Clarity 7000”Technology for the medical detector was researched, developed and eventually patented. It has received FDA clearance and has been marketed as a replacement sensor to the current film X-ray machines. In 2003 the company decided to expand its business base beyond the medical field and established a strategic partnership with CACI International. Cares is reviewing plans to co-locate with CACI in early 2004 and expand the application of the CLARITY 7000 sensor technology into DoD and industrial sensors.

POCs: For more information, please contact:

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