ARMY RESEARCH LABORATORY

Research Support for the Depth and Simultaneous Attack Battle Lab

by Steven Kovel and John Brand

ARL-SR-23 January 1995

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	January 1995	Final, January 1994–December 1994

4. TITLE AND SUBTITLE

Research Support for the Depth and Simultaneous Attack Battle Lab

5. FUNDING NUMBERS

DA PR: AH16
PE: 62120

6. AUTHOR(S)

Steven Kovel and John Brand

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
Attn: AMSRL-SS-M
2800 Powder Mill Road
Adelphi, MD 20783-1197

8. PERFORMING ORGANIZATION REPORT NUMBER

ARL-SR-23

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
2800 Powder Mill Road
Adelphi, MD 20783-1197

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

AMS code: 622120.H16
ARL PR: 5R8AR1

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

We performed an assessment of the 6.1/6.2 sensor technology programs that support four of the operational capability requirements (OCRs) related to real-time targeting, formulated by the Depth and Simultaneous Attack Battle Lab. The assessment focused on (1) how the research programs support the OCRs and (2) which research programs are required to support each OCR.

Four programs were found to have the greatest potential for supporting the OCRs: Automatic Target Detection-Recognition-Identification, Ladar Sensor and Signature Research, Smart Mines Sensor System, and Ultra-Wideband Foliage-Penetrating Synthetic Aperture Radar. These programs were selected based on the information generated by these sensor technologies. In addition, we identified the need for realistic war game simulations that incorporate these sensor program concepts, in order to quantitatively evaluate the concepts.

In assessing the support required by the OCRs, we found that automatic target recognition was the least mature link, and we recommend that the greatest effort be in developing this technology. Finally, we found that the battlefield damage assessment OCR requires a clearer definition before a technology assessment can be performed.

14. SUBJECT TERMS

Sensors, research, programs

15. NUMBER OF PAGES 69

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

Contents

Appendices

List

Executive Summary

In January 1994, the Depth and Simultaneous Attack (D&SA) Battle Lab tasked the Army Research Laboratory (ARL) to conduct an assessment of 6.1/6.2 sensor technology programs supporting the four operational capability requirements (OCRs) related to real-time targeting (RTT). Those four OCRs are as follows:

1. Operate during day or night, in all weather and on all terrains.

2. Locate, identify, and track passive and active targets throughout the depth of the battlefield.

3. Provide target data to facilitate battle damage assessment (BDA).

4. Reduce the need for man-in-the-loop analysis through automatic target recognition (ATR) and sensor fusion.

In May 1994, U.S. Army Armament Research, Development, and Engineering Center (ARDEC) conducted a science and technology (S&T) review of Army and various National Laboratory 6.3 through 6.7 programs that address the four OCRs. This report addresses a similar assessment of 6.1 and 6.2 programs.

Army, Navy, Air Force, and various National Laboratories were surveyed for relevant programs. We collected data on 52 programs from Army and Navy laboratories to examine their support of the four OCRs. In order to place these programs in proper perspective, we also assessed the technologies that support them.

This report documents the results of this assessment.

Program Recommendations

- We identified four program areas that have the potential to significantly affect D&SA missions:

— *Automatic Target Detection/Recognition/Identification (ATD/R/I) Programs.*— The development of automated state-of-the-art image analysis techniques can afford an ability to implement real-time processing of target acquisition data from single and multiple sensors such as second-generation thermal sensors, synthetic aperture radar (SAR), millimeter-wave (MMW) radar, and laser radar. The collection of related programs provides near-perfect targeting throughout the depth of the battlefield without requiring a man-in-the-loop.

Recently, radar and signal processing technologies have been developed that provide real-time SAR image formation and real-time automatic target recognition (ATR) for use on unmanned aerial vehicle (UAV) platforms. The above efforts are being performed at the 6.1 and 6.2 levels, under a 6.3-level program, the Synthetic Aperture Radar Target Recognition and Location System (STARLOS) and medium altitude endurance (MAE)/ UAV.

- *Ladar Sensor & Signature Research.*—The high-resolution information produced by this technology is of special importance for battle damage assessment (BDA) and target identification.
- *Smart Mines Sensor System.*—The use of acoustic techniques enables the system to function non-line-of-sight in a passive mode of operation, and generates unique targeting identification information.
- *Ultra-Wideband (UWB) Foliage-Penetrating (FOPEN) Synthetic Aperture Radar (SAR).*—The bandwidth of these radars enables them to penetrate foliage and other battlefield obscurants; this capability did not exist in past systems.

- In order to quantify the impact of the selected programs, we recommend that war-game simulations be conducted that incorporate the concepts being advanced. Each of the programs forwarded is technologically significant in its own right, but it is only in militarily important situations that the impact of the concept can be quantified.

Technology Recommendations

- Our assessment of the technologies required to support the OCRs revealed no major technology gaps—work is being conducted in all areas. However, considering the advancements in computer hardware and their use in the performance of ATR and signal processing, we recommend that the battle lab focus its near-term support on ATR/signal processing technology. ATR is presently the least mature link in target acquisition. Once the battle lab enhances this technology, its emphasis could shift to other technologies.
- One of the difficulties in this assessment was the lack of a clear definition of battle damage assessment (BDA). We recommend that the U.S. Army Training and Doctrine Command (TRADOC) initiate an effort to develop the sensor requirements for BDA.
- A program has been formulated by the Weapons Technology Directorate of ARL that would help to support the development of sensor requirements for BDA. However, funding has not been designated for this program through ARL. We recommend that TRADOC consider support of this BDA program.

General Observations

This report supports the D&SA battle lab in two major ways. First, it recommends four technological sensor program areas that the battle lab should consider and incorporate into future battle lab experiments. Second, it supplies an information base that the battle lab can use to help ARL determine technological areas that should be emphasized.

Traditionally, the results of 6.1 and 6.2 efforts are transitioned to the development community for use in the production of systems and are not directly accessed by the user community. The 6.1 and 6.2 programs can provide the battle labs access to simulations and test beds to use in assessing the impact of these technologies on warfighting. This connection between ARL and the battle lab has been initiated, and should be continued and enhanced.

1. Introduction

In January 1993, the Depth and Simultaneous Attack (D&SA) Battle Lab conducted a science & technology (S&T) review of programs that supported its mission area. That review identified 21 operational capability requirements (OCRs). In a January 1994 meeting between the D&SA battle lab and the Army Research Laboratory (ARL), four OCRs related to real-time targeting (RTT) were selected as significant topics for further review. Those four OCRs are as follows:

1. Operate during day or night, in all weather and on all terrains.
2. Locate, identify, and track passive and active targets throughout the depth of the battlefield.
3. Provide target data to facilitate battle damage assessment (BDA).
4. Reduce the need for man-in-the-loop analysis through automatic target recognition (ATR) and sensor fusion.

In May 1994, the U.S. Army Armament Research, Development, and Engineering Center (ARDEC) conducted an S&T review of Army and various National Laboratory 6.3 through 6.7 programs that address the four OCRs. This report addresses a similar assessment of 6.1 and 6.2 programs.

2. Methodology

In the first phase of this assessment, we assembled information on programs funded at the 6.1 and 6.2 level that the technical program managers felt would support the four OCRs. We sent letters requesting program information to the organizations contacted by ARDEC for the S&T review. These were primarily organizations that supported programs at the 6.3 funding level and above; to obtain information about programs at the lower funding levels, we contacted additional organizations, such as ARL directorates and several Air Force and Navy research organizations.

We looked at how the program information we obtained would relate to the four OCRs and identified the technologies supporting these programs (see sect. 4.1). Section 3 gives an assessment of which OCRs are supported. We conducted a technically complete but subjective assessment of program priorities. Appendix A lists all the program submissions and appendix B shows which programs support the OCRs. Appendix C contains program synopses that detail how each program supports the OCRs.

Next we prepared a system assessment (see sect. 4) that evaluated the OCRs and determined the technologies required to support each OCR. We then reviewed some current research and the expectations for the future. Several areas were identified that require further analysis.

3. Assessment of Programs

Organizations with sensor-related programs were asked to provide information on their research at the 6.1 and 6.2 funding levels that supports the four OCRs listed in section 1, and to designate which of the OCRs were addressed by the program. All the program responses received from those organizations (app A) were reviewed by an ARL panel. Not all the reported programs support the four OCRs, although they all support D&SA mission areas. A reduced list of programs (app B) indicates which of the four OCRs each program supports.

Many programs do support the four OCRs. As should be expected, some OCRs have greater program support than others. BDA has the fewest supporting programs, even though over half of the relevant programs address this topic. It is very difficult to subjectively address the impact of these programs on the D&SA mission area. To actually quantify the impact of each of the programs, modeling and simulation would have to be performed. It is unlikely that a single scenario would encompass the capabilities of all the concepts presented; because of the scope of the concepts and the variety of missions to be performed by the D&SA battle lab, extensive simulation would be required.

4. Assessment of OCRs

4.1 Definition of Technologies

The four OCRs are performance requirements for the components of a system that form an information train. This train extends from a target to the commander on the battlefield. That is, a signal emanates from a target surrounded by a background, propagates through the intervening atmosphere that may contain objects that are similar to the desired target objects, is collected by a sensor, combined with other information in a data base, sent to a collection system, and, finally, evaluated and acted upon by a human decision maker (the commander).

Each OCR asks a different question about the information train. The first OCR concerns the influence of the environment on the information train. The second OCR concerns the information content of a single sensor in the system. The third OCR asks what changes occur in the initial signatures emanating from the target because of military actions. Finally, the fourth OCR concerns the relationships between information obtained from several sensors and other databases.

This assessment must first identify the technologies used at each stage of the information train, and then relate them to the questions posed by the OCR. *Technology*, according to Webster's II New Riverside University Dictionary, is *the body of knowledge available . . . that is of use in fashioning implements, practicing manual arts and skills, and extracting or collecting materials.*

We are thus trying to specify the bodies of knowledge needed at each stage of the information train.

To specify the target signature and its associated background, a body of knowledge is required that can describe and identify the significant signal characteristics of the target and the background. A representative technology that can support this need is computer modeling, whereby the model generates representations of the target under all significant military situations. A second representative technology is the development of a database that contains measured data of selected targets.

Propagation of a signal through the atmosphere is well understood and modeled, except for acoustic signals, where major research efforts are underway. The technologies related to propagation of a signal include atmospheric models and databases that portray the degradation of information by the scattering of the particular matter present. This degradation of information includes the influence of fog, rain, and snow.

Knowledge on sensors can be subdivided into several technologies, including radar, millimeter-wave (MMW), electro-optical (EO), acoustic, and ladar. These technologies can in turn be further subdivided into technologies that support the component parts of a sensor. In addition, there is a signal processing technology associated with these sensors, directed toward the improvement of the signal in the presence of random noise.

The final portion of the information train that is considered here is the signal processing required to place the information into a suitable format for use. Note that this leaves for a future assessment the technologies associated with the actual transmission of the signal to the user and associated with the presentation of the required information. This agrees with our original understanding with the D&SA battle lab on the extent of this assessment.

Technologies associated with the signal processing required for the detection, recognition, and identification of the target before presentation to the user can be broadly classified as automatic target recognition. The technologies are primarily directed at the identification of a desired target when in the presence of similar clutter targets. This involves the development of algorithms for filtering and combining the available information to select and identify the desired target information. In this definition of signal processing, we are ignoring the extraction of a signal from sensor noise. That form of processing is considered part of the sensor technology category.

The technologies identified are given in list 1.

List 1. Technologies supporting OCR-related programs.

Signature/background modeling
Signature/background database
Atmospheric propagation factors
Radar systems
Electro-optic (EO) systems
Forward-looking infrared (FLIR) systems
Acoustic systems
Ladar systems
Automatic target recognition (ATR) technologies

4.2 Relationship Between OCRs and Technologies

The first OCR, which deals with the effect of the environment on the performance of a sensor system, depends on target and background signature descriptions, signal propagation through the atmosphere, and the sensor technologies themselves. Note that the term "sensor system" is used here to highlight the potential requirement for several different sensors to meet the objectives of the OCR. Some sensors will offer an advantage over long atmospheric paths, other sensors can operate in a passive mode, and others can supply information in a non-line-of-sight situation. Depending on the military information requirement, different sensor capabilities and deployments will be needed to perform the mission.

The second OCR, which deals with the ability to identify and track targets, requires both sensor and algorithm technologies. Separating the desired target from the multitude of backgrounds that can surround the target requires very sophisticated processing techniques. In addition, extracting the information necessary to identify the target requires a high system resolution. Finally, not only are the methods for processing data important if valid target tracks are to be established, but also the speed and the accuracy of the hardware.

Technologies important to the third OCR, BDA, are both sensor and algorithm technologies. These are similar to the technologies for the second OCR, but the scenario is substantially different. In the second OCR, information is being sought on targets that *may* be in a potential battle area. In this third OCR, information is being sought on targets that *have been* attacked in the battle area. Advances in sensor technology are important to this OCR for two reasons. The first is the need to get the sensor into the proper locations to obtain the required information. This requires a very mobile, maneuverable sensor system. The second reason is the need to acquire and process the information with sufficient speed to supply the battlefield commander with useful information. Algorithm technology is needed in support of this OCR to determine the required information to produce a damage assessment. This latter topic requires further analysis because we do not know what specific information the battlefield commander needs to make a BDA, nor do we know what can be deduced for BDA from external appearances of a vehicle.

The fourth OCR, reducing the workload of the man-in-the-loop, relies primarily on signal processing technology. Combining information from several sensors and from other databases (obtained indirectly from other information sources) requires sophisticated signal processing. While the ultimate goal of this technology is to develop a system for the battlefield commander that can identify and track all targets with 100-percent certainty, a more realistic goal is to highlight the most critical targets on the battlefield and to reduce false alarms to a minimum.

4.3 Technology Summaries

In the preceding sections, we considered what technologies are required to support the information train for RTT and how those technologies relate to the four OCRs. In this section synopses are given of current efforts in support of the technology and expected future efforts.

4.3.1 Target and Background Signature Technology

When target acquisition is started, the first step is to identify a signal that, when received, will be classified as the acquired target. This *can* be performed by selecting the strongest signal the sensor receives. However, this is not wise from both logistic and fratricide viewpoints. The problem of target acquisition is made simpler if one can specify a priori what is to be sought. On the other hand, it is difficult and prohibitively costly to properly describe targets under all presentations (aspect angles), for all of the target's operational conditions, and for all the backgrounds that will encompass the targets.

Technology for the proper description of signatures and backgrounds is being actively pursued. Advancements are being made in both signature rendering and mathematical description of the signature metrics of the target relative to the background. Signature rendering (also known as synthetic scene generation) is a methodology for representing an object so that it can be stored within a database and retrieved for presentation at some later time. Signature metrics is a methodology for quantitatively specifying a target so that the target can be represented by a single characterization.

Signature rendering is accomplished using a number of different models, depending on the spectral band of interest. A model currently being developed is CREATION, a three-dimensional scene-generation model that generates complex three-dimensional landscapes (including trees, grass, and rocks) and includes representations of external targets generated by various infrared models, such as PRISM and GTSIG. Different representations are used for the different entities. The background is stored as altitude and feature maps with equally spaced longitude and latitude locations. Tree and rock formations are created with rule-based inputs that resemble fractal structures. Vehicle geometry and infrared signature predictions are read from FRED, PRISM, MAX, and GTSIG format files. Rendering of a millimeter scene is possible through the use of such models as XPATCH, MISCAT, and EMSARS.

In the area of signature metrics, where proper representation of targets is necessary and can be considered a requirement for low-observable targets, advancements are being made for imaging sensors that function in the visual and infrared spectral bands, including

(1) The development of a requirements translation model. This model aids in the generation of a signature specification for the design of a sensor or in the design requirements for the target a sensor is to detect. It also aids in the visualization of the end product.

(2) The development of a sensor-target duel model for engineering system performance analysis that determines the relationship between a sensor's ability to detect a target and the metric for the target's signature.

(3) A target acquisition sub-routine that will correctly depict low-observable parameters for insertion into combat models.

4.3.2 *Atmospheric Technology*

Propagation of optical and infrared energy is affected by atmospheric conditions. The atmosphere can degrade both the signal that needs to be detected and the background within which the signal is embedded. The Air Force atmospheric propagation model, Lowtran 7, has been a standard for many years for the visible and infrared parts of the spectrum. The Army's Electro-Optical Systems Atmospheric Effects Library (EOSAEL) includes this Air Force model, addresses numerous other atmospheric effects, and extends the atmospheric propagation capability to include acoustic signals and millimeter waves. In addition, EOSAEL is also capable of modeling the effect of numerous aerosol types, as well as isolated clouds.

Acoustic propagation modeling has advanced significantly from the early acoustic detection range prediction model (ADRPM). The most recent version of the scanning fast field acoustic propagation model has been incorporated into EOSAEL. This model produces a two-dimensional output of transmission loss as a function of range and azimuth, including the effects of wind, temperature profiles, and ground characteristics. Parabolic equation models have also been developed for fast prediction of transmission loss. Future work on the parabolic models will include the effects of complex terrain on propagation. Work is also underway to characterize acoustic background levels under a variety of environments and battlefield conditions.

Additional work is being performed on Environmental Effects for Distributed Interactive Simulation (E2DIS) Program, sponsored by the Defense Modeling and Simulation Office (DMSO). As part of this program, the Army is providing a high-fidelity model, WAVES, that will predict electro-optical propagation and illumination as a function of horizontal and vertical location under partly cloudy skies. This model determines the atmospheric path radiance and blurring due to optical turbulence and forward scattering. A number of high-fidelity models that predict the transmission, radiance, transport, and diffusion of smoke clouds produced by various Army munitions are also being incorporated into E2DIS. These visualization models will add atmospheric realism to the warfighter using distributed interactive simulation (DIS) capabilities.

By combining data obtained from satellite soundings, ground-based profilers, and unmanned aerial vehicles, the prototype mobile profiling system will be able to derive vertical profiles of wind, temperature, moisture, pressure, and density. Using these data as input, atmospheric analysis and battlescale forecasting techniques are being developed that fuse these data with digital terrain and other meteorological data to produce weather nowcasts and forecasts. This capability will improve spatial and temporal characterization of target-area meteorology and significantly improve the planning and execution of fire-support missions.

Several programs are in place to provide this meteorological information to the battlefield soldier. The programs include the Target Area Meteorological Sensor System (TAMSS), the Integrated Meteorological System (IMETS), and the Army Battle Command System (ABCS). These systems will include a 12-hr battlescale weather forecasting model and weather effects decision aids. The latter calculate target acquisition ranges and graphically display zones of weapon effectiveness.

4.3.3 *Radar/Millimeter-Wave Technology*

Even without the benefit of future research, radar technology supports real-time, all-weather detection, location, and classification of high-value stationary and moving targets. Radar ranges are normally short (on the order of tens of kilometers), but can be extended by placement of the system on a mobile platform such as an aircraft, UAV, or ground vehicle.

The short radar range capability is a function of both the waveform used and the power available from the exciter. The frequency content (bandwidth) of the waveform determines range resolution, while large antenna apertures or synthetic apertures produce better cross-range resolution. By making the resolution better, there is less clutter in a resolution cell to compete with the target, increasing the target-to-clutter ratio and making target detection more probable. Waveform diversity is also used for electronic counter-countermeasure (ECCM) protection. Transmitting low frequencies (tens to thousands of megahertz) and wide bandwidth (ultra-wideband) allows for penetration of foliage and ground, is less affected by atmospherics, and preserves the necessary resolution.

Ultra-wideband transmissions are achieved through step frequency or impulse techniques. Low-frequency radars generally require large antennas; wide bandwidth and high power increase the complexity of intercomponent connections. Transmitting higher frequencies uses smaller components and therefore leads to higher frequency radars mounted on small platforms (such as fire control radars on helicopters).

Advances in radar technology fall in two areas: components and processing. Radar sensor technology depends on developing components that are wider in bandwidth, more power efficient, and flexible enough to meet the various radar objectives. As component technology improves, sensors are asked to acquire more and more data, increasing the data acquisition, storage, and processing requirements. The desire for "real-time" processing pushes the state of the art in digital signal processors and massively parallel computers, but is limited by physical space, money, and available power.

4.3.4 *Electro-Optics Technology*

There are relatively few visual-spectrum, electro-optical target acquisition systems in U.S. service. The most important in the Army are part of the stabilized platform in the AH-64 Apache and the mast-mounted sight in the OH-58D Kiowa. The electro-optical sensors are combined with high magnification optics and provide both high-resolution imagery of targets and a tracking capability needed to aim a laser beam for target designation at ranges of several kilometers without its wandering or jittering off target. The television systems used in the Apache were relatively straightforward silicon target vidicons.

While electro-optics gives excellent resolution, it does not provide the field of view of direct-view optics. The advantage in target acquisition speed is somewhat less than proportional to the square of the field of view, corresponding to the area viewed in a single scene. By incorporating direct-view optics into the Apache, the target acquisition speed was substantially improved. The availability of high-definition television and large focal plane arrays of apparently arbitrary size may lead to future televisions of performance equal to telescopic direct-view optics, at a considerable weight savings.

These advantages also accrue to thermal systems. The ability to operate both independent of ambient light (thermal system) and with ambient light provides a powerful argument in favor of a multiband approach.

4.3.5 *Forward-Looking Infrared (FLIR) Technology*

The effective use of infrared technology for the "mastering of the night" has been well demonstrated by the results achieved during Desert Storm. Several technological factors are involved in providing this capability: detector material selections, production of large, uniform arrays of detectors, and cooling of the sensors.

Selection of materials is in part determined by the mission that has to be performed. The Army employs thermal night sights for crew-served guided missiles and vehicles. Primary wavelength band for these systems is 8 to 12 μm to take advantage of the strong radiative signals emitted by the threat, although 3 to 5 μm is beginning to be used in more systems. The wavelength band used by Army tactical thermal night sights is sufficiently long for the systems to be weather and smoke tolerant. The detectors used by the thermal night sights are linear arrays that are cooled to liquid nitrogen temperatures. The next generation of thermal sights, in development for the RAH-66 Comanche, uses a rectangular array (4 × 480) of detectors. The image is scanned back and forth on the array, which is only four elements wide. By summing the signal along the extra width, the array acts like a linear array with the image dwelling four times as long on an element. This procedure results in greater system sensitivity.

The next advance will be large format focal plane arrays. Arrays of 256 x 256 detectors are promised "soon," and efforts continue to extend these to 480 × 640. A manufacturing cost-reduction element for both 8- to 14-µm materials and other materials is underway. Some focal plane arrays are already in use. In the Javelin system, two different types of arrays are used. The Javelin missile has a 64 × 64 element array to track the target. The command launch unit has a four-element-wide linear array for excellent resolution and fast target acquisition. Once a target is acquired, the target is handed off to the missile seeker, which tracks the target using the 64 × 64 array in the nose of the missile.

Some development work is proceeding in the simultaneous use of two or more wavelength regimes, either combining the images or switching between the images. This is usually combined with image processing, relating to automatic target recognition (ATR) technology.

Cooling techniques are a major concern for infrared systems. A cooling system will add weight, size, maintenance problems, and cost to a system. It is possible to have either a cooled system or an uncooled system, although there will be a tradeoff with sensor sensitivity. The cooled arrays operate as photon detectors, while the uncooled arrays measure the temperature of the detector element in the presence of the radiant energy. The cooled sensors are much more sensitive to low-level signals and the response speeds are much faster than for uncooled; however, the uncooled systems are much smaller and lighter and require much less power to operate—and at a lower cost—than the cooled systems.

At present the cooled arrays that function in the 3- to 5-µm spectrum are HgCdTe (mercury cadmium telluride) or InSb (indium antimonide) arrays. These arrays require operational cooling to 90 K. Current efforts are working toward developing a sensor that will operate at 120 K. In the 8- to 10-µm spectral range, the prevalent sensor is HgCdTe. These must be cooled to 77 K.

Uncooled sensor arrays operate principally in the 7.5- to 14-µm spectral band. These sensors function as temperature sensors rather than photon detectors and are either ferroelectric or resistance bolometers. Uncooled ferroelectric arrays (245 × 328), operate at room temperature (23°C) with a stabilizer, and can resolve to 0.08-K noise equivalent temperature. These are now in early preproduction; production rates are expected soon.

Uncooled resistance bolometers, in array sizes of 240 × 336, also operate at room temperature (23°C) with a stabilizer. The temperature sensitivity of these sensors allows a temperature resolution to 0.04 K. These sensors are in a prototype state, with production beginning possibly in about one year.

4.3.6 *Acoustic Technology*

In the past few years, there has been considerable improvement in acoustic technology capability and its suitability for use on the battlefield. Acoustic technology has several key advantages: it is low cost, totally passive, and can detect non-line-of-sight targets. Important advances in the past few years have extended the range of acoustic sensors from a few hundred meters to several kilometers. There are several Army-funded programs that will use acoustic sensors both as primary and cueing sensors. These programs include the Intelligent Minefield Automatic Target Detection (ATD), Remote Sentry ATD, and Scout Sensor Suite ATD, all part of the Rapid Force Projection Initiative (RFPI).

Acoustic sensors consist of an array of between 3 and 16 microphones, a signal processor to evaluate the acoustic data, and a communications link connecting the sensor to a command and control network. In general, the capabilities of acoustic sensor systems include the following:

- Line of bearing to a target
- Target tracking
- Target classification and/or identification
- Target location (from multiple sensor lines of bearing)

There are several key areas of acoustic technology that must continue to be addressed to make it useful on the battlefield. These areas include the following:

Platform Noise Reduction.—In order to make acoustics a viable sensor technology on moving vehicles, steps must be taken to eliminate local vehicle noise so that more distant targets can be detected. There are several technology base efforts focused in this area, but considerably more effort is needed to allow a system to be fielded.

Vehicle Target Identification.—There have been considerable advances in vehicle target identification algorithms. Techniques include template-matching algorithms and neural networks. Vehicle target identification accuracies of 70 to 90 percent have been demonstrated. Some algorithms can identify specific targets, while others classify targets as wheeled or tracked. All these algorithms rely on the continuous nature of engine noise, tread slap, etc, so a target must have a continuous emission to be identified. One key to target identification algorithms is the need for robust signature measurements on all possible vehicles. Some specific databases exist, but no single comprehensive database has yet been assembled.

Acoustic Beam Forming.—What allows long-range acoustic detection is the capability to form narrow acoustic "beams" in a particular direction. This means that only sound from that specific direction will be heard. The narrower the beam, the longer the range that is possible and the lower the levels of the noise. Considerable work has been conducted in this area since the development of powerful, low-cost signal processors.

There are some important shortcomings to acoustic sensors. The detection range of acoustic sensors varies widely with atmospheric conditions. Temperature, wind, and humidity variations can affect the range of detection by a factor of two or more. Wind can also reduce the effectiveness of acoustic sensors by creating noise at the microphones that obscures target sounds.

There are several key technical issues to consider in acoustic sensor systems. One important consideration is the nature of the sound emanating from the targets of interest. Impulsive events such as gunfire, artillery projectile impacts, etc, are harder to identify than continuous targets such as engine noise. Correlating the results of multiple sensors to obtain triangulation information and an accurate target location is more realizable for continuous targets.

4.3.7 *Ladar Technology*

Ladar is an active sensor, which means that the ladar illuminates the target with a light source with a specific carrier frequency and modulation format. Light that is reflected from the target and detected by the ladar is processed in such a way that separates it from the background light and determines target range and angle. For this reason, ladar is equally suitable for day or night operation. Ladars suffer severe performance degradation in fog or clouds because of the low transmission of light through these environments. Low- or moderate-performance degradation is observed in rain/snow or haze conditions.

The direct detection of targets to 500 km with ladar is not likely to be feasible because the probability of encountering good atmospheric conditions over 500 km distances is not high. Ladars, however, should work well from aerial platforms that are flown to within a few kilometers of the target. Numerous systems have demonstrated this. Ladar imagery collected from an aerial platform is highly resolved in angle and range and therefore requires substantial data storage and processing capability.

The high angular and range-resolution capabilities of ladar enable the formation of three-dimensional target images, which contain more information than two-dimensional images. Recent research has shown that this additional information can be exploited by ATR algorithms to increase the probability of detection/classification /identification and reduce the probability of false alarm. ATR algorithm research—fusing ladar and FLIR data—has shown that the performance of the ATR using the fused data, over the ATR using FLIR data alone, is dramatically improved.

At this time, pixel sizes that can be achieved on a target at several kilometers are roughly 1 ft in diameter, which should be sufficient to detect major damage to a target using human or machine techniques. Successful BDA may require detecting holes in armored vehicles that are smaller than the present angular resolution capability.

4.3.8 *Automatic Target Recognition Technology*

Current achievements in ATR are based upon phenomenological descriptions of the target and background. Using these descriptions, simple targets can be reliably detected against simple backgrounds, as can complex targets. However, as soon as the background becomes more complex and structured, the reliability of any detection is substantially reduced, if it can be accomplished at all. Over the last few years, the area of computer vision has seen some limited success against highly controlled vision problems, such as those of industrial parts inspection, where the environment can be tightly controlled. Methodologies that have recently shown promise in solving complex vision problems include model-based and hybrid model-based neural network approaches. These approaches have produced excellent results on problems such as handwriting and speech recognition.

Model-based approaches require good modeling capabilities for both the targets of interest and clutter. Modeling capabilities have been used in developing (1) a model-based single-sensor FLIR algorithm and (2) a model-based multi-sensor FLIR and laser radar algorithm based on only target silhouette. A FLIR sensor by itself generates a signal that corresponds to the geometry of the target through only the silhouette. The laser radar adds target geometry that corresponds to both the target silhouette and the internal target signature. The magnitude of this modeling task can be readily appreciated. Thermal target signatures are extremely variable. They are affected by changes in the diurnal cycle, weather, target activity, etc, making the total number of possible signatures for each target very large.

In order to accomplish future improvements in automatic target detection/recognition/identification (ATD/R/I), our current ATD/R/I algorithm development program is based on a firm foundation of scientific principles. These principles include sensor physics, the use of target signature and clutter phenomenology, and the use of an interdisciplinary approach to algorithm development. By following this approach, future systems will be more capable of detecting a target at longer ranges, less likely to acquire a clutter object that resembles the desired target, and capable of supplying more information about the state of targets that are of military interest.

5. Conclusions

After reviewing all the programs being performed at the 6.1 and 6.2 funding levels, we found that they are all excellent concepts that should be supported and further developed. However, because of the potential for improvement in the information that can be made available to the D&SA battlefield commander, and also because of the potential for that information to affect battlefield results, we recommend that the following programs have the lead interest:

Automatic target detection/recognition/identification programs.—The development of automated state-of-the-art image analysis techniques can afford an ability to implement real-time processing of target acquisition data from single and multiple sensors such as second-generation thermal sensors, MMW radar, and laser radar. The collection of related programs provides near-perfect targeting throughout the depth of the battlefield without requiring a man in the loop.

Ladar sensor and signature research.—Selected because the high-resolution information that this technology can produce is of special importance to BDA and target identification.

Smart Mines Sensor System.—Selected because of the use of acoustic techniques as part of the system. This enables the system to function non-line-of-sight, and supplies a different mode of information for target acquisition processing. The Army has tended to move away from acoustic technology and it needs some "basic research" exploration to determine if the trend is valid.

Ultra-Wideband Foliage-Penetrating Synthetic Aperture Radar.—Selected because, in this mode of operation, the radars have the (potential) ability to penetrate foliage and other battlefield obscurants. This capability did not exist in past systems.

We recommend that these advanced sensor technologies be incorporated in war game simulations to develop a quantitative assessment of the impact of these sensor concepts. A variety of scenarios will have to be considered, because no single sensor is appropriate for all situations. For example, a foliage-penetrating radar is not the best choice for use in Saudi Arabia.

Based upon the review of technologies, no specific technology was identified either as a bottle-neck or as being ignored. All technologies are being supported. However, some problem areas were identified that need additional examination.

When the technology support for BDA was being addressed, no definition could be found of what information was required by the battlefield commander. In addition, no information was available on what can be deduced about the internal capabilities of a vehicle from information on the external appearance. A program plan to address both these questions is being prepared by ARL. However, the ability to execute these plans will depend on the resources available in the next fiscal year.

The newest technological concepts have occurred in the field of signal processing: neural networks and chaos theory. Part of this progress has been due to hardware improvements in computers that are required to process the sophisticated algorithms associated with these concepts. The compactness of the latest computer systems makes it plausible to use sophisticated processing concepts in militarily deployable sensor systems. We recommend that for the near term, the signal processing technology be given strong support.

Acknowledgements

The authors wish to acknowledge the support of the many individuals who helped to collect, review, assess, and assemble the information presented here. In particular, special thanks are owed to the members of the working group: Eric Adler, John Eicke, Geoffrey Goldman, George Jones, Barry Stann, and CPT Keith Sturgess, who read through all the program descriptions that were submitted. Additional thanks are owed to Edward Burke and Richard Slife, for the reviews performed on the report, as well as for their helpful suggestions. Finally, we wish to thank MAJ Jack Owens for his efforts to keep the report moving through the analysis and to ensure that it supports the military needs of the Army.

Appendix A.—Organizational Support for Real-Time Targeting

Table A-1 is a complete listing of all the programs that were submitted in response to our request for programs supporting the four operational capability requirements (OCRs) related to real-time targeting (RTT).

Appendix A

Table A-1. Program submissions.

Programs	Organization
Automatic Target Recognition (ATR) and Information Fusion	ARO
Microwave and Millimeter-Wave (MMW) Circuits	ARO
MMW Polarimetric Clutter	ARO
Fusion of Multiple Sensing Modalities	ARO
Photorefractive Fibers for Optical Hardware	ARO
Power Multiplexing	CECOM
Signals Intelligence/Moving Target Indicator	CECOM
Noncooperative Target Recognition	MICOM
MMW Anti-Armor Target Detector	ARL/S^3I
Optical Fuzing Research	ARL/S^3I
MMW Air Target Guidance Integrated Fuzing	ARL/S^3I
MMW Signatures and Instrumentation	ARL/S^3I
Remote Sensing Research	ARL/S^3I
Multi-Spectral Modeling & Simulation Program	ARL/S^3I
Real-Aperture Stationary Target Radar	ARL/S^3I
Affordable Lightweight Enabling Radar Technology	ARL/S^3I
Ultra Wideband Foliage-Penetrating (FOPEN) Synthetic Aperture Radar (SAR)	ARL/S^3I
Smart Mines Sensor System	ARL/S^3I
GPS Registration Fuze	ARL/S^3I
GPS Projectile Guidance	ARL/S^3I
Information-Based Complexity ATR Algorithm	ARL/S^3I
Microwave Detection of Buried Mines	ARL/S^3I
Second-Generation Model-Based Multi-Sensor Fusion	ARL/S^3I
Multi-Spectral Synthetic Scene Generation	ARL/S^3I
Smart Focal Plane Algorithm Research	ARL/S^3I
Ladar Sensor and Signature Research	ARL/S^3I
MMW Low-Angle Tracking	ARL/S^3I
Integrated Soldier's Engagement System	ARL/S^3I
Electrostatic Sensing	ARL/S^3I
Target Area Meteorological Sensor System (TAMSS)	ARL/BED
Remote Atmospheric Sounding Research	ARL/BED
Advanced ATR Processing and Algorithm Exploitation	CECOM
Smart Focal Plane Arrays	CECOM
Advanced Optics and Display Applications	CECOM
Advance Image Intensifiers/Optics	CECOM
Advanced Target Cueing/Recognition Engine	CECOM
Precision Strike ATR	CECOM
Passive Microwave Camera	CECOM
Diverse Wavelength Laser Source	CECOM
Multi-Wavelength Multi-Function User	CECOM
Low-Cost, Low-Observable Multi-Spectral Technology	CECOM
Modular, High-Density, High-Performance Processor Technology	CECOM
Battlefield Imaging Projectile System (BIPS)	ARDEC
Infrared Spectral/Spectroscopy Analytical Technology	CRDEC
Shared Aperture Sensor System (SASSY)	NAWC
Multi-Source Aircraft Classification (MUSAC)	NAWC
Airborne Surveillance	NAWC

Table A-1. Program submissions (cont'd).

Programs	Organization
Fuzzy Logic Image Processing and Analysis	NAWC
Neural Net Modeling for Image Analysis	NAWC
Fuzzy Logic for Multisensor Multitarget Tracking in ASW	NAWC
Transportation Infrastructure Plan and Assessment	WES
Hardened Structures—S/V Analysis	WES

ARO—Army Research Office
CECOM—U.S. Army Communications-Electronics Command
MICOM—U.S. Army Missile Command
ARL—U.S. Army Research Laboratory
S^3I—Sensors, Signatures, Signal and Information Processing Directorate
BED—Battlefield Environment Directorate
ARDEC—U.S. Army Armament Research, Development, and Engineering Center
CRDEC—U.S. Army Chemical Research, Development, and Engineering Center
NAWC—Naval Air Warfare Center
WES—Waterway Environmental Station

Appendix B.—Program Support for Operational Capability Requirements

Table B-1 is a reduced list of programs selected from those given in appendix A. The programs in this appendix were selected based on their direct support of the operational capability requirements (OCRs). In addition, table B-1 shows which OCRs were supported by each program.

Table B-1. Program support for OCRs.

Project title number	Programs	All-weather/ day-night	Detection and track	Battle damage assessment	ATR/ reduction of man in the loop
1	Automatic Target Recognition (ATR) and Information Fusion				x
2	Microwave and Millimeter-Wave (MMW) Circuits		x	x	x
3	MMW Polarimetric Clutter	x	x	x	x
4	Fusion of Multiple Sensing Modalities		x	x	x
5	Photorefractive Fibers for Optical Hardware		x	x	x
6	Power Multiplexing	x	x		
7	Signals Intelligence/Moving Target Indicator	x	x		x
8	Noncooperative Target Recognition		x	x	x
9	MMW Anti-Armor Target Detector	x	x		x
10	MMW Signatures and Instrumentation		x		
11	Remote Sensing Research	x	x	x	x
12	Multi-Spectral Modeling and Simulation Program		x		
13	Real Aperture Stationary Target Radar	x	x		x
14	Affordable Lightweight Enabling Radar Technology	x	x		x
15	Ultra Wideband Foliage-Penetrating Synthetic Aperture Radar	x	x	x	x
16	Smart Mines Sensor System	x	x		
17	Information-Based Complexity ATR Algorithm	x	x	x	x
18	Microwave Detection of Buried Mines	x	x	x	
19	Second Gen. Model-Based Multi-Sensor Fusion	x			x
20	Multi-Spectral Synthetic Scene Generation		x		
21	Smart Focal Plane Algorithm Research	x	x	x	x
22	Ladar Sensor and Signature Research	x	x		
23	MMW Low Angle Tracking	x	x		
24	Target Area MET Sensor System (TAMSS)	x	x	x	x
25	Remote Atmospheric Sounding Research	x	x		
26	Advanced ATR Processing & Algorithm Exploit.	x	x	x	x
27	Smart Focal Plane Arrays	x	x	x	x
28	Advanced Optics & Display Applications	x	x	x	x
29	Advance Image Intensifiers/Optics	x	x	x	x
30	Advanced Target Cueing/Recognition Engine	x	x	x	x
31	Precision Strike ATR	x	x	x	x
32	Passive Microwave Camera	x		x	
33	Low Cost, Low Observable Multi-Spectral Technology	x	x		x
34	Modular, High-Density, High-Performance Processor Technology	x	x	x	x
35	Battlefield Imaging Projectile System (BIPS)		x	x	x
36	Infrared Spectral/Spectroscopy Analytical Technology			x	
37	Shared Aperture Sensor System (SASSY)		x	x	
38	Multi-Source Aircraft Classification (MUSAC)				x
39	Airborne Surveillance				x
40	Fuzzy Logic Image Processing and Analysis		x		x
41	Neural Net Modeling for Image Analysis		x		x
42	Fuzzy Logic for Multisensor Multitarget Tracking in ASW		x		
43	Transportation Infrastructure Plan and Assessment		x		
44	Hardened Structures—S/V Analysis			x	

Appendix C.—Program Synopses

The format for the information contained in this appendix is based on the four operational capability requirements (OCRs). For each of the OCRs, all programs that support the topic are listed. The number assigned to each project title in this appendix corresponds to the numbered list of programs given in table B-1 of appendix B. For each program, a synopsis of the program and a brief discussion of how the program supports the OCR is given.

OCR: **All-Weather/Day-Night**

Program title: (3) *Millimeter-Wave Polarimetric Clutter Program*

Synopsis: This program is directed toward measurement of the polarization characteristics of a variety of background clutter. The key to distinguishing a target from its background is to know the properties of both the background and the target. A knowledge of the background can allow selection of distinguishing target characteristics. A reflected radar pulse from a surface can experience a change in its polarization. These changes in polarization depend on the surface material, the geometry of the surface, and the wavelength and polarization of the incident radar wave. Different types of vegetation or terrain can have different surface geometries, characteristic lengths (related to, for instance, leaf size and grouping, rock size and type, etc), or composition. These change with the seasons, and may even change with diurnal cycle (mimosa foliage, for example). Measurements of the mixture of polarizations from real objects or terrain allow selection of polarizations, wavelengths, or discrimination algorithms that can tell targets from background.

Rationale: *All-Weather/Day-Night.* Propagation of radar signals is insensitive to the daily illumination cycle, so this program will affect day-night capability. Millimeter-wave (MMW) frequencies (35 and 95 GHz) penetrate precipitation and fog with a minimal loss of power (1 dB/km for light rain). This program will develop the information needed to use different algorithms to optimize target detection for all weather conditions.

Also listed under *Detection and Track.*
Battle Damage Assessment (BDA).
ATR/Reduction of Man in the Loop.

Program title: (6) *Power Multiplexing*

Synopsis: The power multiplexing technique is a means of sorting signals based on signal strength. The intent is to separate signal from natural and artificial noise or interference from other nearby channels. The technique is applicable to single-channel and frequency-hopping operation. The technique potentially will provide increased anti-jam capability, reduce co-site interference, allow multiple reuse of the frequency spectrum, and facilitate covert communication links.

Rationale: *All-Weather/Day-Night.* This technique does not specifically address day-night or all-weather capabilities, but does enhance the capability of radio communications, which are not greatly affected by diurnal variations or (sometimes) weather, and are not affected at all by obscurants.

Also listed under *Detection and Track.*

Program title: (7) *Signals Intelligence/Moving Target Indicator (SIGINT/MTI) Correlation*

Synopsis: This technique will exploit the disparate capabilities in MTI radar and SIGINT by combining them. One system can cue the other and provide a target detection with greater speed and confidence. The project will develop a database and sensor fusion algorithms. Both communications intelligence and electronic intelligence will be used. The types of radio signals—and, if not encrypted, the content of radio signals—will also aid target characterization and, possibly, identification. Signal types may also aid in target characterization and prioritization.

Rationale: *All-Weather/Day-Night.* This technique enhances the capabilities of all-weather, day-night sensors, by combining the information obtained by each.

Also listed under *Detection and Track.*
ATR/Reduction of Man in the Loop.

Program title: (9) *MMW Anti-Armor Target Detector*

Synopsis: This program is developing MMW monopulse radar algorithms that can be used to track military vehicles at medium ranges. At closer ranges (100 to 250 m) the guidance system is more sensitive to radar aimpoint errors caused by target interference effects. At near-field ranges only a portion of the target is illuminated, so different guidance techniques are required. Analysis of monopulse radar tracking data should indicate how well various tracking algorithms perform.

Rationale: *All-Weather/Day-Night.* Several MMW frequencies operate in all weather conditions with minimal attenuation. This program will improve aimpoint accuracies for target acquisition systems.

Also listed under *Detection and Track.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (11) *Remote Sensing Research*

Synopsis: This project is an investigation into the nature of radar clutter and improved techniques for finding military targets in natural backgrounds. The focus is on synthetic aperture radar (SAR).

Rationale: *All-Weather/Day-Night.* These radars are relatively unaffected by the diurnal cycle and by weather. A better understanding of clutter will allow improved capability under those conditions.

Also listed under *Detection and Track.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (13) *Real Aperture Stationary Target Radar*

Synopsis: The key to achieving high target detection probabilities with low false alarm rates for stationary targets is the development of enhanced automatic target recognition (ATR) algorithms. These algorithms must be trained on extensive databases of targets and clutter and trained to look for the most effective discriminants between the targets and clutter. These ATR algorithms are being applied to MMW radar data for target acquisition for airborne and ground-based weapon systems.

Rationale: *All-Weather/Day-Night.* Radar is indifferent to daily illumination cycles, and the MMW frequencies used penetrate rain and fog with a minimal loss of power. This program will develop algorithms for the performance of target acquisition.

Also listed under *Detection and Track.*
ATR/Reduction of Man in the Loop.

Program title: (14) *Affordable Lightweight Enabling Radar Technology*

Synopsis: To operate in the battlefield electronic countermeasure (ECM) environment, today's and tomorrow's radars will need frequency agility, as well as faster data acquisition, digitization, and processing, in ever smaller packages to meet the user requirements. This project concentrates on state-of-the-art direct digital synthesis of wideband novel waveforms, high-speed analog-to-digital (A/D) converters, and the creation of open architecture processor systems that use advanced rapid software prototyping tools. These radar components would support MTI radars, ultra-wideband (UWB) radars, short-range unmanned aerial vehicles (UAV), and corps surface-to-air missiles (SAMs).

Rationale: *All-Weather/Day-Night.* Radar is indifferent to daily illumination cycles, and the frequencies used penetrate rain and fog with a minimal loss of power.

Also listed under *Detection and Track.*
ATR/Reduction of Man in the Loop.

Program title: (15) *Ultra Wideband Foliage-Penetrating Synthetic Aperture Radar*

Synopsis: The Department of Defense (DoD) has had an interest in detecting targets camouflaged or hidden by foliage since before the Vietnam War. The technology used to attempt foliage-penetration (FOPEN) in this case is the use of a UWB radar that uses low frequencies (40 to 1100 MHz) to penetrate the foliage. The wide bandwidth is used to achieve high resolution in range, while the SAR is used to achieve high resolution in azimuth. In addition, this program is developing target recognition algorithms.

Rationale: *All-Weather/Day-Night.* Radar is indifferent to daily illumination cycles, and the frequencies used penetrate rain and fog with a minimal loss of power. These frequencies penetrate foliage, camouflage, and various depths of soil with larger power losses.

Also listed under *Detection and Track.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (16) *Smart Mines Sensor System*

Synopsis: This is a development program to fulfill operational needs N063, Controllable Mine System, and N059, Robotic Smart Minefield. The program will gather target and clutter acoustic data and develop a testbed system. The system will be able to locate, discriminate, and engage targets.

Rationale: *All-Weather/Day-Night.* The intelligent minefield will be insensitive to diurnal cycle and relatively insensitive to moderate weather. The communication to the home controller will be insensitive to weather.

Also listed under *Detection and Track.*

Program title: (17) *Information-Based Complexity ATR Algorithm*

Synopsis: This theoretical investigation may, if successful, allow ATR to be performed better than currently possible.

Rationale: *All-Weather/Day-Night.* The ATR algorithm will lend itself to sensors such as thermal imagers or radars that are less sensitive or insensitive to weather.

Also listed under *Detection and Track.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (18) *Microwave Detection of Buried Mines*

Synopsis: DoD has had an interest in detecting buried mines since before WWI. The technology used to attempt ground penetration in this case is UWB radar, which uses low frequencies (40 to 1100 MHz) to penetrate the ground, wide bandwidth to achieve high resolution in range, and a SAR to achieve high resolution in azimuth. Ground penetration radars (GPRs) detect changes in dielectric constant, which means that metal/ground interfaces should be relatively easily detected, while plastic/ground interfaces will be much more difficult to detect. GPRs should provide usable data to depths of one to tens of meters, depending on the particular soil composition and moisture content. Target recognition algorithms are in their infancy.

Rationale: *All-Weather/Day-Night.* Radar is indifferent to daily illumination cycles, and the frequencies used penetrate rain and fog with a minimal loss of power. These frequencies penetrate foliage, camouflage, and various depths of soil with larger power losses.

Also listed under *Detection and Track.*
BDA.

Program title: (19) *Second-Generation Model-Based Multi-Sensor Fusion*

Synopsis: This program is developing a thermal-sight/laser-radar ATR algorithm that will enable fast detection timelines using two sensors insensitive to diurnal cycles. The increased thermal clutter during the day can be reduced in effect by the laser radar, which is unaffected by thermal clutter. The combination is, however, sensitive to weather extremes (obscuration).

Rationale: *All-Weather/Day-Night.* The sensor fusion effort will allow operation of a laser radar, which is day-night, but may be affected by the weather, with a thermal system, which is substantially degraded only by extreme weather. This system is not truly all-weather, but should be robust, especially if gating the return laser-radar signal allows scatter from obscuration before the target to be ignored.

Also listed under *ATR/Reduction of Man in the Loop.*

Program title: (21) *Smart Focal Plane Algorithm Research*

Synopsis: The organic eye does a great deal of visual processing involving perception in the retinal nerve mass in the eye, largely in the region of most acute vision, the fovea. This program tries to emulate the eye using a smart focal plane array to embed a great deal of data processing in a decentralized way that is inherently parallel. That is, processing the data bit by bit in a single processor would take much longer than processing it in parallel where it is sensed. This also facilitates the inherent comparison provided by signal comparison from adjacent visual sensing clusters. Initially, the sensor chosen would be a second-generation thermal sight.

Rationale: *All-Weather/Day-Night.* The scheme is to be implemented in a day-night sensor, which is severely degraded only by weather extremes.

Also listed under *Detection and Track.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (22) *Ladar Sensor and Signature Research*

Synopsis: The laser radar (ladar) has been a research tool for some time. Rangefinders are a ladar capable of range only, with no capability of determining what is bouncing the light back to the detector. Ladar research focuses on developing a ladar that will provide enough range resolution and angular resolution to actually image the scene. Algorithms would then compare the three-dimensional return with target profiles.

Rationale: *All-Weather/Day-Night.* The ladar is relatively tolerant to diurnal cycle. Turbulence is a factor, however. The high-range resolution ladar can gate out (ignore) light bouncing off obscurants (smoke, rain, fog) outside the immediate vicinity of the target, and so is robust to, but affected by extremes of, weather and man-made obscurants.

Also listed under *Detection and Track.*

Program title: (23) *MMW Low-Angle Tracking*

Synopsis: Low-angle tracking of vehicles must overcome the effects of multipath and interference caused by ground clutter. Other obstacles are low-angle detection and identification. Targets can reduce their vulnerability by hiding in vegetation and low-lying regions. MMW radars can penetrate sparse vegetation, but cannot penetrate thick vegetation or hilly terrain.

Rationale: *All-Weather/Day-Night.* MMW radars are relatively unaffected by weather effects and are not affected by the diurnal cycle. This program will facilitate use of the MMW technology in real terrain in geometries typical of battle.

Also listed under *Detection and Track.*

Program title: (25) *Remote Atmospheric Sounding Research*

Synopsis: This is a multispectral approach to remote sensing of the air mass combined with an artificial intelligence approach to diagnosis and analysis. Neural nets will be used to integrate the data and draw conclusions. Temperature and moisture content will be sensed. Sensors will include passive radiometers, radio acoustic sounders, and satellite temperature sensors.

Rationale: *All-Weather/Day-Night.* Using sensors to penetrate the weather will be enhanced by the ability to tailor sensors to the weather before it happens.

Also listed under *Detection and Track.*

Program title: (26) *Advanced ATR Processing and Algorithm Exploitation*

Synopsis: This is a synthetic environment to allow optimization of ATR algorithms and their architectures. It is a follow-on to another program ending in FY95. Once optimized for performance, algorithms are mapped into large-scale, programmable image processors such as advanced target cueing/recognition engine (ATCURE) (see project 30).

Rationale: *All-Weather/Day-Night.* The software necessary for ATRs and their sensors to be optimized for bad weather or obscurants would be facilitated by this program.

Also listed under *Detection and Track.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (27) *Smart Focal Plane Arrays*

Synopsis: This is a basic research effort to develop the technology to implement in focal plane arrays the kind of image processing that occurs in the human retina. The new architectures and materials should allow the implementation of substantial processing of the image in the small region just behind the light-sensitive elements in a focal plane array. The light-sensitive elements must be close together in order to attain high resolution; this physical limitation on space means structures must be smaller or better packed to get the processing power necessary into the package.

Rationale: *All-Weather/Day-Night*. Improving the ability of focal plane arrays to compensate for laser dazzle or to highlight/cue targets for the observer or a fire control computer, or, in the case of a munition, the guidance computer/autopilot, should improve accuracy and decrease timelines. Weather or obscurants may be offset by processing to work on minimal remaining information in the image.

Also listed under *Detection and Track.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (28) *Advanced Optics and Display Information*

Synopsis: This is a program to exploit the possibilities in modern optics to increase the capabilities of telescopic elements and display optics. Telescopic elements are found in direct-view optics (ordinary telescopic sights), in image intensifier night vision devices, TVs, and thermal viewing systems. (Thermal devices use optical materials that do not usually transmit visible light well.) Technologies to be exploited include holographic optics, graded index optics, and binary optics. These allow remarkable savings in weight and complexity of optical systems by using components made of light materials, and by eliminating or combining optical elements and the structures that support them. For instance, in holographic optics a hologram acts like one or more ordinary elements—for example, acting as a laser filter and several lenses combined—and might be as light as a piece of plastic wrap. Graded index optics varies the index of refraction (light-bending capability) of a glass optical element, so that an optical element such as a lens has the index of refraction changing in the glass, reducing image distortions (aberrations). Binary optics are otherwise conventional lenses or mirrors with tiny grooves etched in the material to diffract light, combining two or more optical functions in one element.

Rationale: *All-Weather/Day-Night*. The combination of technologies should allow better, lighter weight optics for sensors. They will not of themselves, aid weather and obscurant penetration.

Also listed under *Detection and Track.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (29) *Advanced Image Intensifiers/Optics—Aviation*

Synopsis: This is primarily a technology application effort to improve cost, weight, and performance of aviation night-vision goggles (NVGs). The improved optics techniques discussed in program (28), advanced optics and display applications, also apply to the NVGs. Improved light-amplifying tubes and fiber optics will be used.

Rationale: *All-Weather/Day-Night.* The NVGs will perform better in reduced light conditions.

Also listed under *Detection and Track.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (30) *Advanced target cueing/recognition engine (ATCURE)*

Synopsis: This program is intended to develop miniaturized ATR/ advanced target cueing means. The architecture will be extremely compact and extremely high speed.

Rationale: *All-Weather/Day-Night.* A system that can work with degraded imagery would allow a system to be more robust to weather effects.

Also listed under *Detection and Track.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (31) *Precision Strike ATR*

Synopsis: This program is a Department of the Army (DA)-mandated increase to a program for the integration and assessment of fusion algorithms into a specific processor. It is primarily focused on radar/thermal sight.

Rationale: *All-Weather/Day-Night.* Radar is weather and obscurant tolerant and insensitive to illumination. Thermal sights are robust to those effects.

Also listed under *Detection and Track.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (32) *Passive Microwave Camera*

Synopsis: A passive "microwave" (actually MMW) camera receives the MMW radiation reflected by or given off by material targets. The passive camera is limited to the resolution defined by the receiving antenna size. The usual MMW techniques for improved resolution in active systems cannot be used. A passive microwave/MMW camera has limited application. It has all-weather capability, but poor resolution compared to a passive infrared camera. This technology can be used for short-range detection and tracking of metallic targets or a medium-range imaging of gross features. Possible applications are terminal guidance, landing aircraft aid, overwatch detector, and possibly an imager in a UAV.

Rationale: *All-Weather/Day-Night.* A passive MMW camera would be relatively unaffected by weather conditions.

Also listed under *Detection and Track.*

Program title: (33) *Low-Cost, Low-Observable Multi-Spectral Technology*

Synopsis: This program's goal is to develop analytical modeling techniques to evaluate the effects on detection, recognition, and identification of low-observable objects using thermal imaging systems. By correcting current Army models to correctly predict target contrast, size, and background clutter simulations, we will be able to correctly predict sensor performance against "stealthy" objects.

Rationale: *All-Weather/Day-Night.* This modeling will predict performance of sensors that are capable of operating day and night and in some limited poor weather conditions. Therefore, this model will aid in the evaluation of the ability of sensors to meet the requirements of this OCR.

Also listed under *Detection and Track.*
ATR/Reduction of Man in the Loop.

Program title: (34) *Modular, High-Density, High-Performance Processor Technology*

Synopsis: This is a follow-on to a program ending in FY95. It is intended to develop very small, light, high-speed processors for ATR. Acquisition timelines should be shortened, and reduced size should allow proliferation of the capability into areas not exploited.

Rationale: *All-Weather/Day-Night.* The ATR capability should allow sensors to be more robust to weather and obscurant degradation. Proliferation of sensors onto more platforms should allow sensors to be more expendable and close the range to target, negating to some degree the effects of weather and obscurants.

Also listed under *Detection and Track.*
BDA.
ATR/Reduction of Man in the Loop.

OCR: **Detection and Track**

Program title: (2) *Microwave and Millimeter-Wave Circuits*

Synopsis: The advantages of MMW include the ability to generate narrow beams of radiation with physically small and hence light antennae and transceivers, and the ability to resolve small objects, which also allows discrimination of targets based on internal detail better than with longer wavelength radars.

Rationale: *Detection and Track.* The ability to discriminate between types of target, or between targets and background, depends on the amount of information in the returned signal. MMW radars can resolve tremendous detail and, due to their physically small size, can be put on platforms and hence be proliferated in ways not previously possible.

Also listed under *All-Weather/Day-Night.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (3) *Millimeter-Wave Polarimetric Clutter Program*

Synopsis: This program is directed toward the measurement of the polarization characteristics of a variety of background clutter. The key to distinguishing a target from its background is to know the properties both of the background and of the target. A knowledge of the background can allow selection of distinguishing target characteristics. A reflected radar pulse from a surface can experience a change in its polarization. These changes in polarization depend on the surface material, the geometry of the surface, and the wavelength and polarization of the incident radar wave. Different types of vegetation or terrain can have different surface geometries, characteristic lengths (related to, for instance, leaf size and grouping, rock size and type, etc), or composition. These change with seasons, and may even change with diurnal cycle (mimosa foliage, for example). Measurements of the mixture of polarizations from real objects or terrain allow selection of polarizations, wavelengths, or discrimination algorithms that can tell targets from background.

Rationale: *Detection and Track.* The use of MMW allows physically smaller systems and, for a given size, greater precision in target location (beam width, pulse length). The smaller wavelength also allows the sensor to pick up physically smaller objects in a target that may allow better target discrimination (presence or absence of skirts, number and size of roadwheels, dimensions of tube, etc).

Also listed under *All-Weather/Day-Night.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (4) *Fusion of Multiple-Sensing Modalities for Machine Vision*

Synopsis: Machine vision is a means of not only ATR, but also of analysis of the perceived target to extract key characteristics. In industry these characteristics allow quality control inspection (decision: yes—release to packaging; no—scrap; no—rework, etc) or positioning of tools. The military analog is target classification and prioritization and engagement planning.

Rationale: *Detection and Track.* Automatic target detection (ATD) and tracking are related to industrial processes involving machine vision. Machine functions could range from simple cueing to full ATR. Analysis of the target signature, which could be visual or thermal, and, hence easily related to daily experience, or a complicated radar signature with only subtle differences in factors not easily displayed or trained to, such as polarization ratio, would be better done by machine.

Also listed under *BDA.*
ATR/Reduction of Man in the Loop.

Program title: (5) *Study of Photorefractive Fibers for Optical Interconnects, Switches, and Massive Memories*

Synopsis: These are the nuts and bolts (enabling technologies) of the next really big advance in computer speed and capacity. Target analysis will require enormous memories and very high speed to process the available data in real time. Computers presently are limited by, among other things, the speed at which charges drift through the semiconductors. This is far short of the speed of light. Some semiconductors, such as gallium arsenide, have higher charge velocities than silicon, which is presently the mainstay of computing and memories.

Rationale: *Reduction of Man in the Loop.* To replace the analytical powers of a human observer and process signals representing swathes of terrain kilometers wide and hundreds of kilometers per hour in real time will require great computing speed and very large memory capacity.

Also listed under *BDA.*
ATR/Reduction of Man in the Loop.

Program title: (6) *Power Multiplexing*

Synopsis: The power multiplexing technique is a means of sorting signals based on signal strength. The intent is to separate signals from natural and artificial noise or interference from other, nearby channels. The technique is applicable to single-channel and frequency-hopping operation. The technique potentially will provide increased anti-jam capability, reduce co-site interference, allow multiple reuse of the frequency spectrum, and facilitate covert communication links.

Rationale: *Detection and Track.* This technique does not directly address detection and tracking capabilities, but does enhance the capability of radio communications, which are necessary for the detection and tracking chain of events to occur.

Also listed under *All-Weather/Day-Night.*

Program title: (7) *Signals Intelligence/Moving Target Indicator (SIGINT/MTI) Correlation*

Synopsis: This technique will exploit the disparate capabilities in MTI radar and signal intelligence by combining them to cue each other and provide a target detection with greater speed and confidence. The project will develop a database and sensor fusion algorithms. Both communications intelligence and electronic intelligence will be used. The types of radio signals—and, if not encrypted, the content of radio signals—will also aid target characterization and, possibly, identification. Signal types may also aid in target characterization and prioritization.

Rationale: *Detection and Track.* This technique enhances sensor capabilities by combining the information obtained by each. The capability of signal intelligence to cue MTI radar, to help sort and classify track files, and to aid in prioritizing attacks is potentially immense.

Also listed under *All-Weather/Day-Night.*
ATR/Reduction of Man in the Loop.

Program title: (8) *Noncooperative Target Recognition*

Synopsis: High-range resolution radar has the potential to provide maps of scattering intensity versus range that may be characteristic of different targets. This program is directed toward air and reentry vehicles, and is intended to develop algorithms and target response database for use with a ground-based radar. The technique may be applicable to ground targets as well, or to air vehicles on or near the ground.

Rationale: *Detection and Track.* The capability to determine the target type from the range return would allow identification and, hence, the ability to prioritize the target for attack. The possibility also exists that, in cases involving combat with dissimilarly equipped enemies, fratricide could be avoided, even at long ranges where tactical Identification—Friend or Foe (IFF) units probably would not function.

Also listed under *BDA.*
ATR/Reduction of Man in the Loop.

Program title: (9) *MMW Anti-Armor Target Detector*

Synopsis: Relatively simple MMW monopulse radar algorithms can be used to track military vehicles at medium ranges. At closer ranges (100 to 250 m) the guidance system is more sensitive to radar aimpoint errors caused by target inference effects. At near-field ranges only a portion of the target is illuminated; therefore, different guidance techniques are required. Analysis of monopulse radar tracking data should indicate how well various tracking algorithms perform.

Rationale: *Detection and Track.* Current MMW technology can detect passive and active targets in favorable conditions at a maximum range of about 5 km. At approximately 1 to 2 km, target discrimination can be performed. Target identification is a difficult task at any range.

Also listed in *All-Weather/Day-Night.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (10) *MMW Signatures and Instrumentation*

Synopsis: A guidance integrated fuze will use the guidance hardware to trigger the explosive. This should reduce the size and weight of the seeker. Developing an accurate and computationally efficient target model may be difficult because of the high variability of near-field measurements. To develop this technology, accurate near-field target models are needed. A 35-GHz radar measuring targets on a turntable mounted on a rail system will enable collection of a comprehensive target database.

Rationale: *Detection and Track.* The ability of a fuze to function reliably depends on detection.

Not elsewhere listed.

Program title: (11) *Remote Sensing Research*

Synopsis: This project is an investigation into the nature of radar clutter and improved techniques for finding military targets in natural backgrounds. The focus is on SAR.

Rationale: *Detection and Track.* These radars are relatively unaffected by the diurnal cycle and by weather. A better understanding of clutter will allow improved capability under those conditions.

Also listed under *All-Weather/Day-Night.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (12) *Multispectral Signature Modeling and Simulation Program*

Synopsis: This is a project to capitalize on work performed in other programs concerning signature modeling. The program will compare field-gathered signature data with signature data predicted by radar and acoustic signature prediction routines.

Rationale: *Detection and Track.* Reduction in data gathering by reliance on repeatable, validated models will speed response to new situations and aid model development.

Not listed elsewhere.

Program title: (13) *Real-Aperture Stationary Target Radar*

Synopsis: The key to achieving high target detection probabilities with low false alarm rates for stationary targets is the development of enhanced ATR algorithms. These algorithms must be trained on extensive databases of targets and clutter and must be trained to look for the most effective discriminants between the targets and clutter. These ATR algorithms are being applied to MMW radar data for target acquisition for airborne and ground-based weapon systems.

Rationale: *Detection and Track.* Radar with high-range resolution and extensive ATR algorithms is well suited to detecting stationary targets.

Also listed under *All-Weather/Day-Night.*
ATR/Reduction of Man in the Loop.

Program title: (14) *Affordable Lightweight Enabling Radar Technology*

Synopsis: To operate in the battlefield ECM environment, today's and tomorrow's radars will need frequency agility, as well as faster data acquisition, digitization, and processing, in ever smaller packages to meet the user requirements. This project concentrates on state-of-the-art direct digital synthesis of wideband novel waveforms, high-speed A/D converters, and the creation of open architecture processor systems that use advanced rapid software prototyping tools. These radar components would support MTI radars, UWB radars, short-range UAV, and corps SAM.

Rationale: *Detection and Track.* The radar components being developed in this program are designed to operate in a moving target detection radar, which uses changes in Doppler returns from the moving target to track it.

Also listed under *All-Weather/Day-Night.*
ATR/Reduction of Man in the Loop.

Program title: (15) *UWB FOPEN SAR*

Synopsis: DoD has had an interest in detecting targets camouflaged or hidden by foliage since before the Vietnam War. The technology used to attempt FOPEN in this case is UWB radar, which uses low frequencies (40 to 1100 MHz) to penetrate the foliage. The wide bandwidth is used to achieve high resolution in range, while the SAR is used to achieve high resolution in azimuth. Target recognition algorithms are beginning to be developed.

Rationale: *Detection and Track.* This radar is designed to be a high-resolution radar capable of penetrating foliage to detect stationary targets. Multiple "looks" with this radar would allow for change detection indicating movement.

Also listed under *All-Weather/Day-Night.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (16) *Smart Mines Sensor System*

Synopsis: This is a development program to fulfill operational needs N063, Controllable Mine System, and N059, Robotic Smart Minefield. The program will gather target and clutter acoustic data, and develop a testbed system. The system will be able to locate, discriminate, and engage targets.

Rationale: *Detection and Track.* The intelligent minefield will be able to detect targets at relatively short ranges and report to the home controller at long range. This will allow cueing of longer range sensors or even engagement by very-long-range target-seeking or area-engagement weapons.

Also listed under *All-Weather/Day-Night.*

Program title: (17) *Information-Based Complexity ATR Algorithm*

Synopsis: This theoretical investigation may, if successful, allow ATR to be performed better than is currently possible.

Rationale: *Detection and Track.* The ATR algorithm will lend itself to sensors such as thermal imagers or radars that should enable very fast target detection timelines.

Also listed under *All-Weather/Day-Night.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (18) *Microwave Detection of Buried Mines*

Synopsis: DoD has had an interest in detecting buried mines since before WWI. The technology used to attempt ground penetration in this case is UWB radar, which uses low frequencies (40 to 1100 MHz) to penetrate the ground, wide bandwidth to achieve high resolution in range, and a SAR to achieve high resolution in azimuth. GPRs detect changes in dielectric constant, which means that metal/ground interfaces should be relatively easily detected, while plastic/ground interfaces will be much more difficult to detect. GPRs should provide usable data to depths of one to tens of meters, depending on the particular soil composition and moisture content. ATR algorithms are in their infancy.

Rationale: *Detection and Track.* This radar is designed to be a high-resolution radar capable of penetrating the ground to detect mines.

Also listed under *All-Weather/Day-Night.*
BDA.

Program title: (20) *Multi-Spectral Synthetic Scene Generation*

Synopsis: This effort is a continuation of an on-going program to emulate real scenes as viewed by different sensors, including radar, eyes, and thermal cameras. The created scenes would save time and money in developing better tracking systems.

Rationale: *Detection and Track.* The basic research tool can also be used to train gunners, pilots, and vehicle commanders on detection of new targets in new theaters before entry. The ability to predict and duplicate scene variations with change in day/night, seasons, and situation could be useful and could help avoid a potentially infinite range of field data-gathering efforts.

Not listed elsewhere.

Program title: (21) *Smart Focal Plane Algorithm Research*

Synopsis: The organic eye does a great deal of visual processing involving perception in the retinal nerve mass in the eye, largely in the region of most acute vision, the fovea. Smart focal plane arrays have the potential to embed a great deal of data processing in a decentralized way that is inherently parallel. That is, processing the data bit by bit in a single processor would take much longer than processing it in parallel where it is sensed. This also facilitates the inherent comparison provided by signal comparison from adjacent visual sensing clusters. Initially the sensor chosen would be a second-generation thermal sight.

Rationale: *Detection and Track.* The scheme is to be implemented in a day-night sensor that should aid target detection and speed up timelines greatly.

Also listed under *All-Weather/Day-Night.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (22) *Ladar Sensor and Signature Research*

Synopsis: The ladar has been a research tool for some time. Rangefinders are a ladar capable of range only, with no capability of determining what is bouncing the light back to the detector. Ladar research focuses on developing a ladar that will provide enough range resolution and angular resolution to actually image the scene. Algorithms would then compare the three-dimensional return with target profiles.

Rationale: *Detection and Track.* The high-range-resolution ladar should provide an enhanced ability to discriminate target from foliage, which would be immune to camouflage paint or to thermal crossover.

Also listed under *All-Weather/Day-Night.*

Program title: (23) *MMW Low-Angle Tracking*

Synopsis: Low-angle tracking of vehicles must overcome the effects of multipath and interference caused by ground clutter. Other obstacles are low-angle detection and identification. Targets can reduce their vulnerability by hiding in vegetation and low-lying regions. MMW radars can penetrate sparse vegetation, but cannot penetrate thick vegetation or hilly terrain.

Rationale: *Detection and Track.* MMW radars are relatively unaffected by weather effects and are not affected at all by the diurnal cycle, so they are desirable sensors. There are other effects, however, that can degrade performance. The clutter environment and effects of multipath (bounces from radar to ground to target, target to ground to receiver, etc) must be understood to be sure of detecting targets reliably and also to be confident they are where the radiation seems to originate. This program will facilitate use of the MMW technology in real terrain in geometries typical of battle.

Also listed under *All-Weather/Day-Night.*

Program title: (25) *Remote Atmospheric Sounding Research*

Synopsis: This is a multispectral approach to remote sensing of the air mass, combined with an artificial intelligence approach to diagnosis and analysis. Neural nets will be used to integrate the data and draw conclusions. Temperature and moisture content will be sensed. Sensors will include passive radiometers, radio acoustic sounders, and satellite temperature sensors.

Rationale: *Detection and Track.* Using sensors to find targets will be enhanced by the ability to tailor sensors to the weather before it happens.

Also listed under *All-Weather/Day-Night.*

Program title: (26) *Advanced ATR Processing and Algorithm Exploitation*

Synopsis: This is a synthetic environment to allow optimization of ATR algorithms and their architectures. It is a follow-on to another program ending in FY95. Once optimized for performance, algorithms are mapped into large scale, programmable image processors such as ATCURE (see program 30).

Rationale: *Detection and Track.* The software necessary for ATRs and their sensors to be optimized for target acquisition and tracking would be facilitated by this program.

Also listed under *All-Weather/Day-Night.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (27) *Smart Focal Plane Arrays*

Synopsis: This is a basic research effort to develop the technology to implement in focal plane arrays the kind of image processing that occurs in the human retina. The new architectures and materials should allow the implementation of substantial processing of the image in the small region just behind the light-sensitive elements in a focal plane array. The light-sensitive elements must be close together in order to attain high resolution; this physical limitation on space means structures must be smaller or better packed to get the processing power necessary into the package.

Rationale: *Detection and Track.* Improving the ability of focal plane arrays to compensate for laser dazzle or to highlight/cue targets for the observer or a fire control computer, or, in the case of a munition, the guidance computer/autopilot, should improve target acquisition accuracy and decrease timelines.

Also listed under *All-Weather/Day-Night.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (28) *Advanced Optics and Display Information*

Synopsis: This is a program to exploit the possibilities in modern optics to increase the capabilities of telescopic elements and display optics. Telescopic elements are found in direct-view optics (ordinary telescopic sights), in image intensifier night vision devices, TVs, and thermal viewing systems. (Thermal devices use optical materials that do not usually transmit visible light well.) Technologies to be exploited include holographic optics, graded-index optics, and binary optics. These allow remarkable savings in weight and complexity of optical systems by using components made of light materials, and by eliminating or combining optical elements and the structures that support them. For instance, in holographic optics, a hologram acts like one or more ordinary elements—for example, acting as a laser filter and several lenses combined—and might be as light as a piece of plastic wrap. Graded-index optics varies the index of refraction (light-bending capability) of a glass optical element, so that an optical element such as a lens has the index of refraction changing in the glass, reducing image distortions (aberrations). Binary optics are otherwise conventional lenses or mirrors with tiny grooves etched in the material to diffract light, combining two or more optical functions in one element.

Rationale: *Detection and Track.* The combination of technologies should allow better, lighter weight optics for sensors. They will facilitate use of lightweight, high-performance optics on autonomous platforms or remotely emplaced sensors, proliferating battlefield coverage in both density and space, along the close battle area and well into an enemy's rear.

Also listed under *All-Weather/Day-Night.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (29) *Advanced Image Intensifiers/Optics—Aviation*

Synopsis: This is primarily a technology application effort to improve cost, weight, and performance of aviation night vision goggles (NVGs). The improved optics techniques discussed in program 28, advanced optics and display applications (above), also apply to the NVGs. Improved light-amplifying tubes and fiber optics will be used.

Rationale: *Detection and Track.* The NVGs will perform better in reduced light conditions, with improved sensitivity and resolution.

Also listed under *All-Weather/Day-Night.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (30) *Advanced Target Cueing/Recognition Engine (ATCURE)*

Synopsis: This program is intended to develop miniaturized ATR/advanced target cueing means. The architecture will be extremely compact and extremely high speed.

Rationale: *Detection and Track.* A miniature system would lead to wider deployment. Small size and high production would lower unit cost. Greater density and wider deployment would allow better coverage of an enemy's area and, potentially, better control over the U.S. logistical areas against attack and also for mundane purposes such as traffic routing. Higher performance would lead to greater probabilities of target acquisition.

Also listed under *All-Weather/Day-Night.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (31) *Precision Strike ATR*

Synopsis: This program's goal is to develop analytical modeling techniques to evaluate the effects on detection, recognition, and identification of low-observable objects using thermal imaging systems. By correcting current Army models to correctly predict target contrast, size, and background clutter simulations, we will be able to correctly predict sensor performance against "stealthy" objects.

Rationale: *Detection and Track.* This modeling will predict detection performance of sensors that are capable of operating day and night and in some limited poor weather conditions. Therefore, this model will aid in the evaluation of the ability of sensors to meet the requirements of this OCR.

Also listed under *All-Weather/Day-Night.*
ATR/Reduction of Man in the Loop.

Program title: (34) *Modular, High-Density, High-Performance Processor Technology*

Synopsis: This is a follow-on to a program ending in FY95. It is intended to develop very small, light, high-speed processors for ATR. Acquisition timelines should be shortened, and reduced size should allow proliferation of the capability into areas not exploited.

Rationale: *Detection and Track.* Proliferation of sensors onto more platforms should allow sensors to be more expendable and close the range to target, increasing the probability of successful target tracking. More sensors should allow better coverage of an enemy's area, increasing the probability of finding the enemy in the first place.

Also listed under *All-Weather/Day-Night.*
BDA.
ATR/Reduction of Man in the Loop.

Program title: (35) *Battlefield Imaging Projectile System (BIPS)*

Synopsis: The Battlefield Imaging Projectile System (BIPS) is a video imager inside a 155-mm shell that sends back video images of the target area to a ground station. The second-generation BIPS is a "sub-munition" ejected from a 155-mm shell over the target area, which floats down under a maneuverable parafoil, and contains a high-resolution color video with a GPS receiver and, in the future, an infrared (IR) sensor. The initial system is a fair weather benign environment sensor, but the addition of an IR sensor should increase its utility for night and limited adverse environment use.

Rationale: *Detection and Track.* High-resolution video images sent to a ground station in near real time will assist the commander in targeting and could be used as an adjust fire round in the absence of an observer.

Also listed under *All-Weather/Day-Night.*
ATR/Reduction of Man in the Loop.

Program title: (37) *Shared Aperture Sensor System (SASSY)*

Synopsis: This system employs three different detector arrays behind a common optical system small enough to be mounted in the nose of an attack aircraft. The three systems include high-resolution visible, medium-resolution mid-wave IR, and low-resolution long-wave IR. Minimizing the size of the sensor package by looking for alternatives to different focal lengths for each sensor is a challenge. This is a higher than normal risk employment of optimized EO/IR sensors that looks promising and could reduce costs while extending the range of the sensors by up to 40 percent.

Rationale: *Detection and Track.* The employment of two bands of second-generation FLIR with a visual system gives fairly broad area search for cueing and high resolution for target detection and ID.

Also listed under *BDA.*

Program title: (43) *Transportation Infrastructure Planning and Assessment*

Synopsis: Transportation and mobility models are used with map data to assess logistic options and capabilities and the derivative tactical options of an enemy or friendly force. This allows the commander to assess how best to hurt an enemy to prioritize attacks or to evaluate benefits after an attack. That is, BDA assesses a target; this tool allows battle damage to the entire net as a result of attacks to be assessed. The tool also allows the commander to know where to look for enemy assets, serving as cueing for reconnaissance or long-range sensors.

Rationale: *Detection and Track.* The staff can be cued where to use long-range sensors or reconnaissance.

Also listed under *BDA.*

OCR: **Battle Damage Assessment (BDA)**

Program title: (2) *Microwave and Millimeter-Wave Circuits*

Synopsis: The advantages of MMW include the ability to generate narrow beams of radiation with physically small and hence light antennae and transceivers, and the ability to resolve small objects, which also allows discrimination of targets based on internal detail better than with longer wavelength radars.

Rationale: *BDA*. The ability to discriminate between the configuration of a target with or without damage depends on the amount of information in the returned signal. MMW radars can resolve tremendous detail and, due to their small physical size, can be put on platforms and hence proliferated in ways not previously possible. Frequency agile systems can generate high-resolution downrange profiles with low susceptibility to jamming and SAR techniques can be used to generate high-resolution crossrange information. These images can be used to detect, identify, and assess damage to targets. Stumbling blocks include the interpretation of that detail; a system that shows entrance holes a decimeter across also should resolve every rock in the field of view that size, as well. Cueing, in order to sort out where to look with very-high-resolution sensors, is a difficult and related problem, as is processing and interpretation of the immensity of raw data to find the desired information.

Also listed under *All-Weather/Day-Night.*
ATR/Reduce Man in the Loop.

Program title: (3) *Millimeter-Wave Polarimetric Clutter Program*

Synopsis: This program is directed toward the measurement of the polarization characteristics of a variety of background clutter. The key to distinguishing a target from its background is to know the properties both of the background and of the target. A knowledge of the background can allow selection of distinguishing target characteristics. A reflected radar pulse from a surface can experience a change in its polarization. These changes in polarization depend on the surface material, the geometry of the surface, and the wavelength and polarization of the incident radar wave. Different types of vegetation or terrain can have different surface geometries, characteristic lengths (related to, for instance, leaf size and grouping, rock size and type, etc), or composition. These change with seasons, and may even change with diurnal cycle (mimosa foliage, for example). Measurements of the mixture of polarizations from real objects or terrain allow selection of polarizations, wavelengths, or discrimination algorithms that can tell targets from background.

Rationale: *BDA*. The use of MMW allows the sensor to pick up physically smaller objects in a target that may allow better target analysis (presence or absence of holes in armor, damage to external panels, etc).

Also listed under *Detection and Track.*
All-Weather/Day-Night.
ATR/Reduce Man in the Loop.

Program title: (4) *Fusion of Multiple Sensing Modalities for Machine Vision*

Synopsis: Machine vision is a means of not only ATR, but also analysis of the perceived target to extract key characteristics. In industry, these characteristics allow quality control inspection (decision: yes—release to packaging; no—scrap; no—rework, etc) or positioning of tools. The military analog is target classification and prioritization and engagement planning.

Rationale: *BDA*. ATD and tracking are related to industrial processes involving machine vision. Machine functions could range from simple cueing to full ATR. Analysis of the visual or thermal target signature could be speeded up dramatically by machine processing. Other signatures such as a complicated radar signature with only subtle differences in factors not easily displayed or trained to, such as polarization ratio, would be better done by machine. In particular, BDA requires analysis of complicated signatures to find relatively subtle clues, such as relatively small holes, missing or disarrayed external panels, and so forth. Further, these analyses must be done for many objects in extended areas, in real time.

Also listed under *Detection and Track.*
ATR/Reduction of Man in the Loop.

Program title: (5) *Study of Photorefractive Fibers for Optical Interconnects, Switches, and Massive Memories*

Synopsis: These are the nuts and bolts (enabling technologies) of the next really big advance in computer speed and capacity. Target analysis will require enormous memories and very high speed to process the available data in real time. Computers presently are limited by, among other things, the speed at which charges drift through the semiconductors. This is far short of the speed of light. Some semiconductors, such as gallium arsenide, have higher charge velocities than silicon, which is presently the mainstay of computing and memories.

Rationale: *BDA*. Replacing the analytical powers of a human observer and processing signals representing swathes of terrain kilometers wide and hundreds of kilometers per hour in real time will require very large computing speed and memory capacity. Additionally, the extraction of subtle differences in target signature in real time will demand fast processing.

Also listed under *Detection and Track.*
ATR/Reduction of Man in the Loop.

Program title: (8) *Non-Cooperative Target Recognition*

Synopsis: High-range-resolution radar has the potential to provide maps of scattering intensity versus range that may be characteristic of different targets. This program is directed toward air and reentry vehicles, and is intended to develop algorithms and target response databases for use with a ground-based radar. The technique may be applicable to ground targets as well or to air vehicles on or near the ground.

Rationale: *BDA.* If the library of targets included damaged targets, the algorithm would characterize the target as damaged, and, if damaged, how severely damaged. The damage would have to be severe in order to change the radar pulse in a substantial way, and the damage would have to be predictable. That is, if a target blew off a turret often—as tanks with autoloaders (such as the T-72) or caseless charges (such as the M551A1 Sheridan) are apt to do—that damage profile might be cataloged. Interpreting an unknown or damage mode would probably not be feasible, nor would damage that either did not radically alter the vehicle profile (a burned-out tank), or blow it to tiny pieces.

Also listed under *Detection and Track.*
ATR/Reduction of Man in the Loop.

Program title: (9) *MMW Anti-Armor Target Detector*

Synopsis: Relatively simple MMW monopulse radar algorithms can be used to track military vehicles at medium ranges. At closer ranges (100 to 250 m), the guidance system is more sensitive to radar aimpoint errors caused by target inference effects. At near-field ranges only a portion of the target is illuminated; therefore different guidance techniques are required. Analysis of monopulse radar tracking data should indicate how well various tracking algorithms perform.

Rationale: *BDA.* Battle damage assessment should be possible using MMW technology. In theory, if you can identify a target, you can identify a damaged target. Damaged targets may have a characteristic signature that can be distinguished from an undamaged target using high-resolution, multipolarization techniques.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
ATR/Reduction of Man in the Loop.

Program title: (11) *Remote Sensing Research*

Synopsis: This project is an investigation into the nature of radar clutter and improved techniques for finding military targets in natural backgrounds. The focus is on SAR.

Rationale: *BDA.* These radars are relatively unaffected by the diurnal cycle and by weather. A better understanding of clutter will allow improved capability under those conditions.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
ATR/Reduction of Man in the Loop.

Program title: (15) *Ultra Wideband FOPEN SAR*

Synopsis: DoD has had an interest in detecting targets camouflaged/hidden by foliage since before the Vietnam War. The technology used to attempt FOPEN in this case is the use of a UWB radar, which uses low frequencies (40 to 1100 MHz) to penetrate the foliage. The wide bandwidth is used to achieve high resolution in range, while the SAR is used to achieve high resolution in azimuth. Target recognition algorithms are beginning to be developed.

Rationale: *BDA.* This radar is designed to be a high-resolution radar capable of penetrating foliage to detect stationary targets. Since a high-resolution radar has many pixels on each target, it is possible that a difference between a damaged and undamaged vehicle could be detected.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
ATR/Reduction of Man in the Loop.

Program title: (17) *Information-Based Complexity ATR Algorithm*

Synopsis: This theoretical investigation may, if successful, allow ATR to be performed better than currently possible.

Rationale: *BDA.* The ATR algorithm will lend itself to sensors such as thermal imagers or radars that should enable very fast target detection and characterization timelines. Target characterization may help the operator eliminate possibilities.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
ATR/Reduction of Man in the Loop.

Program title: (18) *Microwave Detection of Buried Mines*

Synopsis: DoD has had an interest in detecting buried mines since before WWI. The technology used to attempt ground penetration in this case is the use of a UWB radar, which uses low frequencies (40 to 1100 MHz) to penetrate the ground, wide bandwidth to achieve high resolution in range, and a SAR to achieve high resolution in azimuth. GPRs detect changes in dielectric constant, which means that metal/ground interfaces should be relatively easily detected, while plastic/ground interfaces will be much more difficult to detect. GPRs should provide usable data to depths of one to tens of meters, depending on the particular soil composition and moisture content. ATR algorithms are in their infancy.

Rationale: *BDA*. Since this radar is designed to be a high-resolution radar capable of penetrating the ground to detect mines, it could also be used to determine if mines have been cleared from an area, and could be used to determine if attacked bunkers have been penetrated by munitions.

Also listed under *All-Weather/Day-Night.*
Detection and Track.

Program title: (21) *Smart Focal Plane Algorithm Research*

Synopsis: The organic eye does a great deal of visual processing involving perception in the retinal nerve mass in the eye, largely in the region of most acute vision, the fovea. Smart focal plane arrays have the potential to embed a great deal of data processing in a decentralized way that is inherently parallel. That is, processing the data bit by bit in a single processor would take much longer than processing it in parallel where it is sensed. This also facilitates the inherent comparison provided by signal comparison from adjacent visual sensing clusters. Initially the sensor chosen would be a second-generation thermal sight.

Rationale: *BDA*. By facilitating the perception of differences, the system may aid target detection and the highlighting of differences—damage—that the observer might miss under stress.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
ATR/Reduction of Man in the Loop.

Program title: (26) *Advanced ATR Processing and Algorithm Exploitation*

Synopsis: This is a synthetic environment to allow optimization of ATR algorithms and their architectures. It is a follow-on to another program ending in FY95. Once optimized for performance, algorithms are mapped into large-scale, programmable image processors such as ATCURE (see project 30).

Rationale: *BDA*. The software necessary for ATRs and their sensors to be optimized for target acquisition and tracking would be facilitated by this program. Depending on the sensor, if the necessary resolution were present, the algorithms necessary to detect and highlight the changes in the target occurring from battle damage could be developed or refined.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
ATR/Reduction of Man in the Loop.

Program title: (27) *Smart Focal Plane Arrays*

Synopsis: This is a basic research effort to develop the technology to implement in focal plane arrays the kind of image processing that occurs in the human retina. The new architectures and materials should allow the implementation of substantial processing of the image in the small region just behind the light-sensitive elements in a focal plane array. The light-sensitive elements must be close together in order to attain high resolution; this physical limitation on space means structures must be smaller or better packed to get the necessary processing power into the package.

Rationale: *BDA*. If the sensor has sufficient resolution to detect the battle damage, improving the ability of the sensor (through the massively parallel computing approach inherent in this technology) to highlight damage for the observer or a guidance computer should allow better target prioritization.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
ATR/Reduction of Man in the Loop.

Program title: (28) *Advanced Optics and Display Information*

Synopsis: This is a program to exploit the possibilities in modern optics to increase the capabilities of telescopic elements and display optics. Telescopic elements are found in direct-view optics (ordinary telescopic sights), in image-intensifier night vision devices, TVs, and thermal viewing systems. (Thermal devices use optical materials that do not usually transmit visible light well.) Technologies to be exploited include holographic optics, graded-index optics, and binary optics. These allow remarkable savings in weight and complexity of optical systems by using components made of light materials, and by eliminating or combining optical elements and the structures that support them. For instance, in holographic optics, a hologram acts like one or more ordinary elements—for example, acting as a laser filter and several lenses combined—and might be as light as a piece of plastic wrap. Graded-index optics varies the index of refraction (light-bending capability) of a glass optical element, so that an optical element such as a lens has the index of refraction changing in the glass, reducing image distortions (aberrations). Binary optics are otherwise conventional lenses or mirrors with tiny grooves etched in the material to diffract light, combining two or more optical functions in one element.

Rationale: *BDA*. The combination of technologies should allow better, lighter weight optics for sensors. They should also be less expensive due to fewer elements, less complicated structures, and, for some technologies, less expensive mass production. They will facilitate use of lightweight, high-performance optics on autonomous platforms or remotely emplaced sensors, proliferating battlefield coverage in both density and space, along the close battle area and well into an enemy's rear. This should enhance ability to get close to and to image well battle damage wherever a strike occurs.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
ATR/Reduction of Man in the Loop.

Program title: (29) *Advanced Image Intensifiers/Optics—Aviation*

Synopsis: This is primarily a technology application effort to improve cost, weight, and performance of aviation NVGs. The improved optics techniques discussed in project 28, advanced optics and display applications, also apply to the NVGs. Improved light-amplifying tubes and fiber optics will be used.

Rationale: *BDA*. The NVGs will perform better in reduced light conditions, with improved sensitivity and resolution. This may allow the pilot to assess damage better, especially if the aircraft does not have stabilized thermal systems with high magnification.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
ATR/Reduction of Man in the Loop.

Program title: (30) *Advanced Target Cueing/Recognition Engine (ATCURE)*

Synopsis: This program is intended to develop miniaturized ATR/ advanced target cueing means. The architecture will be extremely compact and extremely high speed.

Rationale: *BDA*. A miniature system would lead to wider deployment. Small size and high production would lower unit cost. Greater density and wider deployment would allow better coverage of an enemy's area, and increase the probability of a sensor being near the damaged area. Higher performance would lead to greater probabilities of detecting damage where it occurs.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
ATR/Reduction of Man in the Loop.

Program title: (31) *Precision Strike ATR*

Synopsis: This program is a DA-mandated increase to a program for the integration and assessment of fusion algorithms into a specific processor. It is primarily focused on radar/thermal sight.

Rationale: *BDA*. The thermal sight should have the resolution to detect changes in the target not apparent to the radar's lower resolution.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
ATR/Reduction of Man in the Loop.

Program title: (34) *Modular, High-Density, High-Performance Processor Technology*

Synopsis: This is a follow-on to a program ending in FY95. It is intended to develop very small, light, high-speed processors for ATR. Acquisition timelines should be shortened, and reduced size should allow proliferation of the capability into areas not exploited.

Rationale: *BDA*. Proliferation of sensors onto more platforms should allow sensors to be more expendable and close the range to target, increasing the probability of successful damage assessment.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
ATR/Reduction of Man in the Loop.

Program title: (35) *Battlefield Imaging Projectile System (BIPS)*

Synopsis: The Battlefield Imaging Projectile System (BIPS) is a video imager inside a 155-mm shell that sends video images of the target area back to a ground station. The second-generation BIPS is a "sub-munition" ejected from a 155-mm shell over the target area, which floats down under a maneuverable parafoil, and contains a high-resolution color video with a GPS receiver and, in the future, an IR sensor. The initial system is a fair-weather benign environment sensor, but the addition of an IR sensor should increase its utility for night and limited adverse environment use.

Rationale: *BDA*. High-resolution video images sent to a ground station in near real time will assist the commander in BDA if fired after the smoke and dust from an attack has settled.

Also listed under *Detection and Track.*
ATR/Reduction of Man in the Loop.

Program title: (37) *Shared Aperture Sensor System (SASSY)*

Synopsis: This system employs three different detector arrays behind a common optical system small enough to be mounted in the nose of an attack aircraft. The three systems include high-resolution visible, medium-resolution mid-wave IR, and low-resolution long wave IR. Minimizing the size of the sensor package by looking for alternatives to different focal lengths for each sensor is a challenge. This is a higher than normal risk employment of optimized EO/IR sensors that looks promising and could reduce costs while extending the range of the sensors by up to 40 percent.

Rationale: *BDA*. Being able to observe targets at three different wavelength bands, one a high-resolution visible band, provides a good source of data for making determinations about damage to targets.

Also listed under *Detection and Track.*

Program title: (43) *Transportation Infrastructure Planning and Assessment*

Synopsis: Transportation and mobility models are used with map data to assess logistic options and capabilities and the derivative tactical options of an enemy or friendly force. This allows the commander to assess how best to hurt an enemy to prioritize attacks or to evaluate benefits after an attack. That is, BDA assesses a target; this tool allows battle damage to the entire net as a result of attacks to be assessed. The tool also allows the commander to know where to look for enemy assets, serving as cueing for reconnaissance or long-range sensors.

Rationale: *BDA*. The staff can assess the damage to enemy capability, not just an enemy installation. Traffic analysis can also be used to estimate the level of damage sustained.

Also listed under *Detection and Track*.

Program title: (44) *Hardened Structures—Survivability/Vulnerability Analyses of Critical Facilities Response to Conventional Weapon Threats*

Synopsis: This is an automated method for estimating probable damage from a given munition and location of impact for hardened structures.

Rationale: *BDA*. If the point of impact is known but visible damage is limited or unknown, the probability of levels of damage can be estimated.

OCR: **ATR/Reduction of Man in the Loop**

Program title: (1) *Automatic Target Recognition and Information Fusion*

Synopsis: This project is exploratory basic research in ATR. The focus will be to explore fundamental improvements in ATR. The means will be information exchange within the community, with the Army Science Board to provide direction.

Rationale: *ATR/Reduction of Man in the Loop*. This project may uncover fundamental phenomena or techniques.

Program title: (2) *Microwave and Millimeter-Wave Circuits*

Synopsis: The advantages of MMW include the ability to generate narrow beams of radiation with physically small and hence light antennae and transceivers, and the ability to resolve small objects, which also allows discrimination of targets based on internal detail better than with longer wavelength radars.

Rationale: *ATR/Reduction of Man in the Loop*. The ability to discriminate between the configuration of a target with or without damage depends on the amount of information in the returned signal. MMW radars can resolve tremendous detail and, due to their physically small size, can be put on platforms and hence proliferated in ways not previously possible. For instance, MMW active systems should be able to resolve much finer detail than available previously. Stumbling blocks include the interpretation of that detail; a system that shows entrance holes a decimeter across should also resolve every rock in the field of view that size, as well. Cueing, in order to sort out where to look with very-high-resolution sensors, is a difficult and related problem, as is processing and interpretation of the immensity of raw data to find the desired information.

Also listed under *Detection and Track.*
BDA.

Program title: (3) *Millimeter-Wave Polarimetric Clutter Program*

Synopsis: This program is directed toward the measurement of the polarization characteristics of a variety of background clutter. The key to distinguishing a target from its background is to know the properties both of the background and of the target. A knowledge of the background can allow selection of distinguishing target characteristics. A reflected radar pulse from a surface can experience a change in its polarization. These changes in polarization depend on the surface material, the geometry of the surface, and the wavelength and polarization of the incident radar wave. Different types of vegetation or terrain can have different surface geometries, characteristic lengths (related to, for instance, leaf size and grouping, rock size and type, etc), or composition. These change with seasons, and may even change with diurnal cycle (mimosa foliage, for example). Measurements of the mixture of polarizations from real objects or terrain allow selection of polarizations, wavelengths, or discrimination algorithms that can tell targets from background.

Rationale: *ATR/Reduction of Man in the Loop.* The use of MMW allows the sensor to pick up physically smaller objects in a target and better measure their configuration. Cues such as the presence or absence of and number of roadwheels or tires, cab or turret configuration, etc, are easily determined by the location and number of reflecting single and multiple surfaces.

Also listed under *Detection and Track.*
All-Weather/Day-Night.
BDA.

Program title: (4) *Fusion of Multiple Sensing Modalities for Machine Vision*

Synopsis: Machine vision is a means of not only automatic target recognition, but also of the analysis of the perceived target to extract key characteristics. In industry these characteristics allow quality control inspection (decision: yes—release to packaging; no—scrap; no—rework, etc) or positioning of tools. The military analog is target classification and prioritization and engagement planning.

Rationale: *ATR/Reduction of Man in the Loop.* The machine can analyze and discover targets, prioritize them, and present a list of targets with proposed engagement parameters. This is especially important with wide-area surveillance systems, such as satellites and SAR.

Also listed under *Detection and Track.*
BDA.

Program title: (5) *Study of Photorefractive Fibers for Optical Interconnects, Switches, Massive Memories*

Synopsis: These are the nuts and bolts (enabling technologies) of the next big advance in computer speed and capacity. Target analysis will require enormous memories and very high speed to process the available data in real time. Computers are presently limited by, among other things, the speed at which charges drift through the semiconductors. This is far short of the speed of light. Some semiconductors, such as gallium arsenide, have higher charge velocities than silicon, which is presently the mainstay of computing and memories.

Rationale: *ATR/Reduction of Man in the Loop*. Replacing the analytical powers of a human observer and processing signals representing swathes of terrain kilometers wide and hundreds of kilometers per hour in real time will require very large computing speed and memory capacity.

Also listed under *Detection and Track.*
BDA.

Program title: (7) *Signals Intelligence/Moving Target Indicator (SIGINT/MTI) Correlation*

Synopsis: This technique will exploit the disparate capabilities in MTI radar and signal intelligence by combining them to cue each other and provide a target detection with greater speed and confidence. The project will develop a database and sensor fusion algorithms. Both communications intelligence and electronic intelligence will be used. The types of—and, if not encrypted, the content of—radio signals will also aid target characterization and, possibly, identification. Signal types may also aid in target characterization and prioritization.

Rationale: *ATR/Reduction of Man in the Loop*. This technique enhances sensor capabilities by combining the information obtained by each. This is inherently multisensor fusion and should greatly reduce the manpower-intensive nature of such correlation as it is presently done. Additionally, the types of signals combined with tactical configuration should aid greatly in target recognition.

Also listed under *All-Weather/Day-Night.*
Detection and Track.

Program title: (8) *Noncooperative Target Recognition*

Synopsis: High-range resolution radar has the potential to provide maps of scattering intensity versus range that may be characteristic of different targets. This program is directed toward air and reentry vehicles, and is intended to develop algorithms and a target response database for use with a ground-based radar. The technique may be applicable to ground targets as well, or to air vehicles on or near the ground. The technique is inherently an ATR scheme.

Rationale: *ATR/Reduction of Man in the Loop.* This algorithm would characterize targets within its database automatically and in real time.

Also listed under *Detection and Track.*
BDA.

Program title: (9) *MMW Anti-Armor Target Detector*

Synopsis: Relatively simple MMW monopulse radar algorithms can be used to track military vehicles at medium ranges. At closer ranges (100 to 250 m) the guidance system is more sensitive to radar aimpoint errors caused by target inference effects. At near-field ranges only a portion of the target is illuminated, so different guidance techniques are required. Analysis of monopulse radar tracking data should indicate how well various tracking algorithms perform.

Rationale: *ATR/Reduction of Man in the Loop.* MMW technology is well suited for automatic target detection, tracking, and discrimination.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
BDA.

Program title: (11) *Remote Sensing Research*

Synopsis: This project is an investigation into the nature of radar clutter and improved techniques for finding military targets in natural backgrounds. The focus is on SAR.

Rationale: *ATR/Reduction of Man in the Loop.* An understanding of clutter is basic to improving the ability to interpret complicated radar returns. That is, a change in a target return may be noise added to the signal or the result of a change in the target itself.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
BDA.

Program title: (13) *Real Aperture Stationary Target Radar*

Synopsis: The key to achieving high target detection probabilities with low false alarm rates for stationary targets is the development of enhanced ATR algorithms. These algorithms must be trained on extensive databases of targets and clutter to look for the most effective discriminants between the targets and clutter. These ATR algorithms are being applied to MMW radar data for target acquisition for airborne and ground-based weapon systems.

Rationale: *ATR/Reduction of Man in the Loop.* This program is using large quantities of data to train target discriminating algorithms to correctly identify targets in a variety of different clutter conditions. The achievement of probabilities of detection of above 80 percent with false alarms below one every 10 km^2 significantly reduces the operator's efforts in target ID.

Also listed under *Detection and Track.*
All-Weather/Day-Night.

Program title: (14) *Affordable Lightweight Enabling Radar Technology*

Synopsis: Today's and tomorrow's radars will need frequency agility to operate in the battlefield ECM environment, as well as faster data acquisition, digitization, and processing in ever smaller packages to meet the user requirements. This project concentrates on state-of-the-art direct digital synthesis of wideband novel waveforms, high-speed A/D converters, and the creation of open architecture processor systems that use advanced rapid software prototyping tools. These radar components would support MTI radars, UWB radars, short-range UAV, and corps SAM.

Rationale: *ATR/Reduction of Man in the Loop.* One of the underlying principles of this program is the introduction of high-speed digital signal processors capable of processing large volumes of data to detect targets in near real time.

Also listed under *All-Weather/Day-Night.*
Detection and Track.

Program title: (15) *Ultra Wideband Foliage-Penetrating Synthetic Aperture Radar*

Synopsis: DoD has had an interest in detecting targets camouflaged/hidden by foliage since before the Vietnam War. The technology used to attempt FOPEN in this case is the use of a UWB radar that uses low frequencies (40 to 1100 MHz) to penetrate the foliage. The wide bandwidth is used to achieve high resolution in range, while the SAR is used to achieve high resolution in azimuth. Target recognition algorithms are beginning to be developed.

Rationale: *ATR/Reduction of Man in the Loop.* Discrimination of targets in a high clutter background of foliage is a difficult problem, and one that requires the use of ATR algorithms. The characteristics that discriminate targets from clutter may not be visible in magnitude imagery shown to radar operators, but may be in the raw radar data that only ATR algorithms could effectively and efficiently evaluate.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
BDA.

Program title: (17) *Information-Based Complexity ATR Algorithm*

Synopsis: This theoretical investigation may, if successful, allow ATR to be performed better than currently possible.

Rationale: *ATR/Reduction of Man in the Loop*. This is basic research into ATR algorithms.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
BDA.

Program title: (18) *Microwave Detection of Buried Mines*

Synopsis: DoD has had an interest in detecting buried mines since before WWI. The technology used to attempt ground penetration in this case is the use of a UWB radar that uses low frequencies (40 to 1100 MHz) to penetrate the ground, wide bandwidth to achieve high resolution in range, and a SAR to achieve high resolution in azimuth. GPRs detect changes in dielectric constant, which means that metal/ground interfaces should be relatively easily detected, while plastic/ground interfaces will be much more difficult to detect. GPRs should provide usable data to depths of one to tens of meters, depending on the particular soil composition and moisture content. ATR algorithms are in their infancy.

Rationale: *ATR/Reduction of Man in the Loop*. Discrimination of targets in a high clutter background of foliage, a difficult problem, requires the use of ATR algorithms. The characteristics that discriminate targets from clutter may not be visible in magnitude imagery shown to radar operators, but may be in the raw radar data that only ATR algorithms could effectively and efficiently evaluate.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
BDA.

Program title: (19) *Second-Generation Model Based Multi-Sensor Fusion*

Synopsis: A thermal sight-ladar ATR algorithm will enable fast detection timelines using two sensors insensitive to diurnal cycles. The increased thermal clutter during the day can be reduced in effect by the ladar, which is unaffected by thermal clutter. The combination is, however, sensitive to weather extremes (obscuration).

Rationale: *ATR/Reduction of Man in the Loop*. The sensor fusion effort will allow operation of ladar with a thermal system. This will ease crew workload in acquiring targets. ATR is a part of the program.

Also listed under *All-Weather/Day-Night.*

Program title: (21) *Smart Focal Plane Algorithm Research*

Synopsis: The organic eye does a great deal of visual processing involving perception in the retinal nerve mass in the eye, largely in the region of the most acute vision, the fovea. Smart focal plane arrays have the potential to embed a great deal of data processing in a decentralized way that is inherently parallel. That is, processing the data bit by bit in a single processor would take much longer than processing it in parallel where it is sensed. This also facilitates the inherent comparison provided by signal comparison from adjacent visual sensing clusters. Initially the sensor chosen would be a second-generation thermal sight.

Rationale: *ATR/Reduction of Man in the Loop*. This is an ATR program.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
BDA.

Program title: (26) *Advanced ATR Processing and Algorithm Exploitation*

Synopsis: This is a synthetic environment to allow optimization of ATR algorithms and their architectures. It is a follow-on to another program ending in FY95. Once optimized for performance, algorithms are mapped into large-scale, programmable image processors such as ATCURE (see project 30).

Rationale: *ATR/Reduction of Man in the Loop*. This is an ATR development tool.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
BDA.

Program title: (27) *Smart Focal Plane Arrays*

Synopsis: This is a basic research effort to develop the technology to implement in focal plane arrays the kind of image processing that occurs in the human retina. The new architectures and materials should allow the implementation of substantial processing of the image in the small region just behind the light-sensitive elements in a focal plane array. The light-sensitive elements must be close together in order to attain high resolution; this physical limitation on space means structures must be smaller or better packed to get the processing power necessary into the package.

Rationale: *ATR/Reduction of Man in the Loop*. The massively parallel computing approach inherent in this technology should allow ATR functions to be improved directly or by deriving image-based cues.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
BDA.

Program title: (28) *Advanced Optics and Display Information*

Synopsis: This is a program to exploit the possibilities in modern optics to increase the capabilities of telescopic elements and display optics. Telescopic elements are found in direct-view optics (ordinary telescopic sights), in image-intensifier night-vision devices, TVs, and thermal viewing systems. (Thermal devices use optical materials that do not usually transmit visible light well.) Technologies to be exploited include holographic optics, graded index optics, and binary optics. These allow remarkable savings in weight and complexity of optical systems by using components made of light materials, and by eliminating or combining optical elements and the structures that support them. For instance, in holographic optics, a hologram acts like one or more ordinary elements—for example, acting as a laser filter and several lenses combined—and might be as light as a piece of plastic wrap. Graded-index optics varies the index of refraction (light-bending capability) of a glass optical element, so that an optical element such as a lens has the index of refraction changing in the glass, reducing image distortions (aberrations). Binary optics are otherwise conventional lenses or mirrors with tiny grooves etched in the material to diffract light, combining two or more optical functions in one element.

Rationale: *ATR/Reduction of Man in the Loop.* The combination of technologies should allow better, lighter weight optics for sensors and displays.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
BDA.

Program title: (29) *Advanced Image Intensifiers/Optics—Aviation*

Synopsis: This is primarily a technology application effort to improve cost, weight, and performance of aviation NVGs. The improved optics techniques discussed in project 28, advanced optics and display applications (above), also apply to the NVGs. Improved light-amplifying tubes and fiber optics will be used.

Rationale: *ATR/Reduction of Man in the Loop.* The NVGs will perform better in reduced light conditions, with improved sensitivity and resolution.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
BDA.

Program title: (30) *Advanced Target Cueing/Recognition Engine (ATCURE)*

Synopsis: This program is intended to develop miniaturized ATR/ advanced target cueing means. The architecture will be extremely compact and extremely high speed.

Rationale: *ATR/Reduction of Man in the Loop.* This is an ATR program.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
BDA.

Program title: (31) *Precision Strike ATR*

Synopsis: This program is a DA-mandated increase to a program for the integration and assessment of fusion algorithms into a specific processor. It is primarily focused on radar/thermal sight.

Rationale: *ATR/Reduction of Man in the Loop.* This is a sensor fusion program.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
BDA.

Program title: (33) *Low-Cost, Low-Observable Multi-Spectral Technology*

Synopsis: This program's goal is to develop analytical modeling techniques to evaluate the effects on detection, recognition, and identification of low-observable objects using thermal imaging systems. By correcting current Army models to correctly predict target contrast, size, and background clutter simulations, we will be able to correctly predict sensor performance against "stealthy" objects.

Rationale: *ATR/Reduction of Man in the Loop.* This modeling will look at factors such as target contrast, size, and background clutter on standard and low-observable targets, which will lead to the identification of features that discriminate the targets from the clutter for ATR algorithms.

Also listed under *All-Weather/Day-Night.*
Detection and Track.

Program title: (34) *Modular, High-Density, High-Performance Processor Technology*

Synopsis: This is a follow-on to a program ending in FY95. It is intended to develop very small, light, high-speed processors for ATR. Acquisition timelines should be shortened, and reduced size should allow proliferation of the capability into areas not exploited.

Rationale: *ATR/Reduction of Man in the Loop.* Proliferation of sensors onto more platforms should allow sensors to be more expendable and close the range to target, increasing the probability of successful damage assessment.

Also listed under *All-Weather/Day-Night.*
Detection and Track.
BDA.

Program title: (38) *Multi-Source Aircraft Classification*

Synopsis: Target detection, classification, and identification algorithms are being developed to incorporate data input from a variety of sensors (radar, IR, visual, etc) to improve the performance over single-sensor discriminants. A large aircraft database has been compiled and development is underway for a method to combine the possibly contradictory data from various sensors to achieve better detection versus false alarm rates.

Rationale: *ATR/Reduction of Man in the Loop*. Combining multiple inputs rather than relying on a single sensor for target ID certainly promises to at least lower false alarms and probably will improve detection as well.

Distribution

Admnstr
Defns Techl Info Ctr
Attn DTIC-DDA (2 copies)
Cameron Sta Bldg 5
Alexandria VA 22304-6145

Hdqrts 2nd Bn 1st Spc Warfare Tng Grp (Abn)
USAJFKSWC
Attn AOJK-CD-CS COL Pulley
Attn AOJK-CD-CS LTC C A Vanek
FT Bragg NC 28307-5200

Hdqtrs Dept of the Army
Attn SARD-DO COL Huff
Attn SARD-DO S Diaz
103 Army Pentagon
Washington DC 20310-0103

Louisiana Maneuvers Task Frc
Attn DACS-LMO P Cherry
FT Monroe VA 23651-5000

Prgm Exec OfcrMis Dfns
Attn SFAE-MD-TMD-SI-P B Nichols
Attn SFAE-MD-TMD-SI-P R Strider
PO Box 1500
Huntsville AL 35807-3806

Prgm Exec Ofcr Tactical Mis
Attn SFAE-TM N Fritchie
Redstone Arsenal AL 35898-7998

Prgm Exec Ofcr Tactical Mis
Attn SFAE-MSL
Bldg 4488
Redstone Arsenal AL 35898-8000

US Army Comb Arms Ctr
Attn ATZL-CDC C Johnson
Attn ATZL-CDC-B
FT Leavenworth KS 66027-5000

US Army Air Dfns Ctr & Schl
Attn ATSA-ADL J Hendley
Attn ATSA-ADL MAJ T Doyle
FT Bliss TX 79916-5000

US Army ARDEC
Attn AMSA-AR-FSP-A D Troast
Attn AMSA-AR-FSP-A V Ilardi
Attn SMCAR-CC
Picatinny Arsenal NJ 07806-5000

US Army ARMC
Attn ATZK-MW
FT Knox KY 40121

US Army Army Armor Ctr
Attn ATZK-MW W Ball
FT Knox KY 40121-5000

US Army Aviation Ctr & Schl
Attn ATZQ-CDB K Kiger
FT Rucker AL 36362-5000

US Army CASCOM
Attn ATCL-B
FT Lee VA 23801

US Army Cheml Schl
Attn ATZN-CM-CS LTC P Musgrove
FT McClellan AL 36205-5000

US Army Commctn & Elect Cmnd
Intllgnc & Elect Warfare Dirctrt
Attn AMSEL-RD-IEW-TSA-M B Chernick
FT Monmouth NJ 07703

US Army Commctn & Elect RDEC
Attn AMSEL-RD-AS
FT Monmouth NJ 07703-5201

US Army Edgewood RDEC
Attn SCBRD-ASP
Attn SCBRD-RTE B Compton
Aberdeen Proving Ground MD 21010-5423

US Army Engr Schl
Attn ATSE-CDB LTC S Fernald
FT Leonard Wood MO 65473-5000

US Army Field Artillery Ctr & Schl
Attn ATSF-CBL W Millspaugh
Attn ATSF-CDC Mr Bailey

Distribution

US Army Field Artillery Ctr & Schl (cont'd)
Attn ATSF-CDC T D Mooney
FT Sill OK 73503-5600

US Army Infantry Ctr &Schl
Attn ATSH-WC
Attn ATSN-WC-BL-C
FT Benning GA 31905-5000

US Army Intllgnc Ctr & Schl
Attn ATZS-CTD
Attn ATZS-CDT R Bolling
FT Huachuca AZ 84613-5000

US Army Mis RDEC
Attn AMSMI-RD
Redstone Arsenal AL 35898-5242

US Army Mis Syst
Attn SARD-SM J Bass
103 Army Pentagon
Washington DC 20310-0103

US Army Natick RDEC
Attn STRNC-Z
Natick MA 01760-5000

US Army Rsrch Lab
Attn AMSRL-WT-WF S Wansack
Attn AMSRL-WT
Aberdeen Proving Ground MD 21005-5067

US Army Rsrch Lab
Attn AMSRL-CI
Aberdeen Proving Ground MD 21005-5068

US Army Rsrch Lab
Attn AMSRL-HR J Nickel
Aberdeen Proving Ground MD 21005-5425

US Army Rsrch Lab
Attn AMSRL-HR-MF L Pierce
Bldg 700 Rm 112A
FT Sill OK 73503-5600

US Army Rsrch Lab
Attn ATSF-ARL T Kinney
FT Sill OK 73503-5600

US Army Rsrch Lab
Attn AMSRL-BE
White Sands Missile Range NM 88002-5501

US Army Signal Ctr
Attn ATZH-BL
FT Gordon GA 30905

US Army Tank-Automtv RDEC
Attn AMSTA-ZA
Warren MI 48397-5000

US Army Train & Doctr Cmnd
Attn ATCD-B LTC Mazzanti
Attn ATCD-B
FT Monroe VA 23651-5000

US Army Waterways Exprmnt Sta
Attn CEWES-GM B Willoughby
Attn CEWES-S K Hall
3909 Halls Ferry Rd
Vicksburg MS 39180-6199

US Navy AWC
Attn Code 104 M Mele
Warminster PA 18974

US Air Force OCD Rome Lab
Attn Wide Area Surveillance Branch
26 Electronic Parkway Bldg 106
Griffiss AFB NY 13440-4514

US Air Force Wright Lab
Attn WL-AARI Bldg 22 T Porubcansky
2690 C Stret Ste 1
Wright Patterson AFB OH 45433-7408

US Army Rsrch Lab
Attn AMSRL-SL
Aberdeen Proving Ground MD 21005

US Army Rsrch Lab
Attn AMSRL-OP-SD-TA Mail & Records Mgmt
Attn AMSRL-OP-SD-TL Tech Library (3 copies)
Attn AMSRL-OP-SD-TP Tech Pub

Distribution

US Army Rsrch Lab (cont'd)
Attn AMSRL-SS-IB E Adler
Attn AMSRL-SS-M S Kovel
Attn AMSRL-SS-P J Owens
Attn AMSRL-SS-S E Burke
Attn AMSRL-SS-SC J Brand
Attn AMSRL-SS-SD G Goldman

US Army Rsrch Lab (cont'd)
Attn AMSRL-SS-SG K Sturgess
Attn AMSRL-SS-SH B Stann
Attn AMSRL-SS-SK G Jones
Attn AMSRL-SS-SM J Eicke
Attn AMSRL-MO