LASER AND BIOLOGICAL STAN

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LASER AND BIOLOGICAL STANDOFF DETECTION

FUTURE EXPLORATORY DEVELOPMENT NEEDS AT **EDGEWOOD CHEMICAL-BIOLOGICAL CENTER (ECBC)**

REPORT OF A PEER REVIEW BLUE-RIBBON PANEL
CONVENED AT ABERDEEN, MARYLAND
30 April – 1 May 2001

Laser and Biological Standoff Detection

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EDGEWOOD CHEMICAL-BIOLOGICAL CENTER (ECBC)

– A Panel Report –

<u>Blue-Ribbon Panel Members</u>

Dr. Adarsh Deepak, Chair
Dr. Dennis K. Killinger
Dr. Dennis J. Kozakoff
Dr. C. Russell Philbrick
Dr. Henry F. Revercomb

Report of Blue-Ribbon Panel on

Laser and Biological Standoff Detection

Convened at

Aberdeen, Maryland
30 April – 1 May 2001

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Edited by
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BLUE-RIBBON PANEL REPORT

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PREFACE

This report contains the deliberations and recommendations of the Blue-Ribbon Panel on the Laser and Biological Standoff Detection Program at Edgewood Chemical Biological Center (ECBC), convened at Aberdeen, Maryland, 30 April – 1 May 2001. The Panel consisted of the following five experts in remote sensing of aerosols and gases from universities and industry: Drs. Adarsh Deepak, President, Science and Technology Corporation (STC), Hampton, VA (Panel Chair); Dr. Dennis K. Killinger, Professor of Physics, University of South Florida, Tampa, Florida; Dr. Dennis J. Kozakoff, Professor of Electrical Engineering, DeVry Institute of Technology, Alpharetta, Georgia and Senior Scientist, Science and Technology Corporation; Dr. C. Russell Philbrick, Professor of Electrical Engineering, Director of PSU Lidar Laboratory, Pennsylvania State University, State College, Pennsylvania; and Dr. Henry E. Revercomb, Director, Space Science and Engineering Center (SSEC), University of Wisconsin, Madison, Wisconsin. Highlights of their curriculum vitae are given in Appendix A.

This effort was sponsored by William Loerop, Business Area Manager of Standoff Detection at ECBC, Aberdeen Proving Ground Edgewood Area, MD. The work was performed by Science and Technology Corporation (STC).

The general task for the Panel was to conduct a peer review of active and biological standoff detection exploratory and advanced programs for chemical and biological defense at the ECBC, except those technologies (i.e., the Hyperspectral Imaging) that were recently evaluated; and to recommend future courses of action to accomplish the program goals. The range of expertise of Panel members covered active and passive remote sensing in the various regions of electromagnetic spectrum, from UV to Microwave.

The areas of primary focus in this review were to (1) assess past performance as well as planned work as a function of mission needs and requirements; (2) identify technology gaps with respect to user requirements, and suggest possible technical solutions; (3) compare the ECBC program with other active/passive standoff detection programs in the United States, and to other standoff detectors available at other sites; and (4) make suggestions for future program plans in the active and passive standoff detection effort at ECBC. The secondary objective was to produce a Panel report containing the deliberations, conclusions, and recommendations of the Panel members.

The Panel met 30 April and 1 May (morning) 2001, at Aberdeen, Maryland, for a briefing presented by the following scientists and engineers of the ECBC Team: Kirkman Phelps, Commodity Area Manager for Contamination Avoidance; William Loerop, Business Area Manager of Standoff Detection; Cynthia R. Swim, Team Leader, Laser Standoff Detection; Ernest N. Webb, Jr., Principal Investigator, Biological Standoff Detection; Dr. James Jensen, Principal Investigator, Passive Infrared Biological Detection; Dr. Alan C. Samuels, Principal Investigator, Millimeter Wave Technology; and from Science and Technology Corporation: Dr. Avishai Ben-David, Senior Scientist. Their briefings provided the Panel with an overview of the status of the ECBC's Laser and Biological Standoff Detection program, covering both active and passive remote sensing systems for chemical and biological warfare agent defense, except the hyperspectral imaging systems since they had been reviewed by a previous Panel; and the current distribution of the manpower, funds, and other resources.

After the briefings, the panel members secluded themselves to deliberate on the tasks they were charged to address. A series of preliminary conclusions were arrived at, and a format for the Report was prepared. Each member was then asked to send written comments on the topics of their interest to the panel chair. The written comments were edited and incorporated, by the Chair, into a smooth-reading version of the draft of the report that was sent to the panel members for their final review. Although the panel did not formally meet thereafter, the panel Chair continued to hold further discussions on these topics with the panel members individually and through full-panel teleconferences.

In addition, the panel members were provided, as read-ahead material, with copies of: (1) Defense Technology Objectives (CB.07—Laser Standoff Chemical Detection Technology, and CB.35—Standoff Biological Aerosol Detection), which include the annual milestones and metrics; and, (2) a reprint of the paper entitled "WILDCAT chemical sensor development" by David B. Cohn, et al. (1995). These documents are incorporated here by reference.

The editor wishes to acknowledge the enthusiastic support and cooperation of the panel members, Technical Monitor, and the presenters from ECBC and industry, for making this a successful and stimulating Panel. My task, as Editor, was made much easier by the high quality of write-ups and the verbal comments that were received from the Panel members. It is a pleasure to acknowledge the efficient logistical support provided by Diana McQuestion, Sue Crotts, and Linda Schofield, of STC Meetings Division, in the coordination of the panel meeting and teleconferences, and preparation of the report.

It is hoped that this panel report will serve as a beneficial review of the Laser and Biological Standoff Detection Program at ECBC.

Adarsh Deepak
Panel Chair

1.0 INTRODUCTION

1.1 BACKGROUND

Edgewood Chemical Biological Center (ECBC) is the lead laboratory in the free world for the development of standoff detector systems used to protect soldiers from possible CBW attack. The main focus of the ECBC technology has been on both active and passive sensing using scattering, absorption and emission observations in the infrared where the heavy molecules applied as CW and BW agents have prominent spectral features. The current program consists of three main efforts, Laser Standoff Chemical Detection (LSCD DTO CB.07), Standoff Biological Aerosol Detection (SBAD DTO CB.35), and Chemical Imaging System (CIS DTO CB.19). There are two additional projects scheduled to begin in the next FY, Wide Spectral (WideSpec) and Joint Surface Contamination Detector (JSCD). In addition, early research and exploratory development (6.2) phase studies are being done in some areas, such as spectral properties of BW agents in millimeter wave and microwave regions. The JSWILD development is expected to transfer to a Navy managed development program, ARTEMIS, at the beginning of FY02. The SBAD effort continues with a focus of developing a useful standoff detection capability for biological agents. The Joint-Service Wide Area Detection (JSWAD) Program, which was previously evaluated, will continue to develop passive imaging technology for wide-area standoff detection.

The goal of the JSWAD Program, scheduled for 2006 with infusion of 6.4 funding, is to produce a light-weight passive wide area sensing system that maintains high chemical and biological detection sensitivity while operating at very high acquisition rates. Ideally, the goal is to develop the capability to detect "on-the-move", to "look" everywhere at once, and to do it with "no-moving part" sensors, that can detect, with high sensitivity, CW and BW agents at relatively low concentrations in the presence of interferents at distances of up to several kilometers. The user wants a wide area detection (WAD) coverage for both CW and BW agents from sensors aboard ground- and ship-based and airborne mobile platforms. Even though the WAD limits are not defined yet, they are being proposed to be: an hemisphere of 5-km radius and 60-degree scan for sensors both at fixed sites (e.g., airports and seaports) and aboard armored vehicles (moving at ~15–40 mph); an hemisphere of 20-km radius and 180-degree scan for sensors on ships; and, 20 km x 20 km for airborne sensors aboard a helicopter (~120 mph) or an unmanned aerial vehicle (~100 mph), or an aircraft (= or >100 mph).

Passive standoff detection of CW agents and simulants at moderate concentrations and close ranges has been demonstrated for some time. Sensors, such as the JSLSCAD (Joint-Service Light-weight Standoff Chemical Agent Detector) and M21 (Remote Sensing Chemical Agent Alarm), are currently being used for detecting these chemicals. Recent chamber tests, using BW simulants, suggest Passive Standoff Detection techniques in the IR can be also applied to biological detection problems. The M21 (already fielded) operates as a static sensor that detects CW at standoff distances of 5 km, whereas LSCAD (currently in development) can detect CW at 5 km from a mobile platform, such as a recon vehicle and an option to operate from an airborne platform.

Active standoff detection of CW agents and simulants at moderate concentrations and moderate ranges has also been demonstrated for sometime. Sensors, such as the Frequency Agile Lidar, are currently being used to investigate hardware and analysis issues needed for detecting these chemicals. The JSWILD (Joint-Service Warning and Identification Laser Detector), containing a more powerful CO_2 laser to increase its CW agent standoff detection range up to 20 km, is the follow-on system under development, and is a subject of the present review.

1.2 GENERAL TASK NEEDS

This effort was sponsored by the ECBC. The primary objective of this task was to conduct a technical review of the Standoff Detection Program at ECBC and recommend future courses of action, funding required and resources needed to accomplish the program goals. The two areas of primary focus in this review were to (1) examine and analyze the current laser and biological standoff detection program and its effectiveness compared to the stated goals, and (2) to make suggestions for future program plans in the active and passive standoff detection effort at ECBC. The secondary objective was to produce a panel report containing the deliberations, conclusions, and recommendations of the panel members.

The general task for the Panel was to conduct a peer review of all active and passive standoff detection exploratory and advanced programs for chemical and biological defense at the ECBC, except those technologies that were previously evaluated, i.e., the Hyperspectral Imaging Systems that were examined by another blue-ribbon panel in March 2001; and to recommend future courses of action to accomplish the program goals. The range of expertise of panel members covered active and passive remote sensing in the various regions of electromagnetic spectrum, from UV to Microwave.

1.3 SPECIFIC TASK NEEDS

The specific tasks for the Panel, to be performed independent of government supervision, direction or control, were to:

- Conduct a peer review of the laser and biological standoff detection program at ECBC;
- Identify technology gaps with respect to user requirements and suggest possible technical solutions;
- Assess past performance as well as planned work as a function of mission needs and requirements;
- Compare the ECBC program with other active/passive standoff detectors available at other sites;
- Evaluate future technical directions with respect to user needs;
- Make recommendations for meeting user needs; and

- Provide a panel report suggesting future directions for active/passive standoff detection in ECBC and within the entire Joint Service program.

1.4 ORGANIZATION OF THE REPORT

1.4.1 Meetings of the Panel

The Panel held a meeting at Aberdeen, Maryland, on 30 April – 1 May (morning) 2001, to receive briefings from the program managers, scientists and engineers working on ECBC's Standoff Detection Program including their invited expert from industry. The Panel meeting agenda is given in Appendix B. After the presentations, the panel members secluded themselves to conduct their deliberations, arrive at some conclusions, and receive writing assignments from the Panel Chair. The panel members conducted several teleconference sessions to arrive at the conclusions and recommendations.

1.4.2 Report Organization

This report is presented in three sections: **Section 1** presents background information, tasking to the Panel, panel agenda and activities, report organization, and scope of the review. **Section 2** provides a summary of technical review deliberations and the conclusions reached. **Section 3** contains both short- and long-term recommendations for future courses of action to be undertaken by ECBC.

1.5 SCOPE

The Panel recommended that in order to perform these tasks effectively and within the time constraints, the scope of the Panel Review should be limited to the following level of effort:

1. Focus on the laser and biological standoff detection systems.

2. Limit review to sensors operating in the spectral range of UV fluorescence, near-IR, 8-12 micrometers, millimeter waves, and microwaves.

3. Confine discussions to standoff detection systems deployable on ground-based, ship-based and airborne mobile platforms.

4. Limit the standoff range for wide area detection, in the absence of any requirements presented, for ground- and ship-based systems to a hemisphere of 5- to 20-km diameter, and for airborne systems (at speeds of 80-150 mph) looking in the nadir-viewing direction from altitudes of up to 15,000 to 25,000 ft maximum.

5. Restrict analysis scenarios, in the absence of any requirements presented, to those involving realistic battlespace, with interferents present along with CW and BW in its environment.

2.0 TECHNICAL REVIEW CONCLUSIONS

The previous work performed in the chemical/biological standoff detection area has pointed the direction toward three potentially useful topics where the present work is and should be concentrated. Most chemical agents have unique and significant spectral features in the 9-12 micron IR region due to the organophosphate bond that is common to this class of chemicals. These spectral features provide the opportunity for both passive and active sensors to be developed for standoff detection. Standoff detection of the biological agents is more challenging because these do not appear to have such unique spectral features, and they cannot be easily discriminated at the very low concentrations that are hazardous. While chemical agent detection has been demonstrated at sufficiently low concentrations to be useful, it is not clear that any reasonable investment in biological agent standoff detection can be expected to provide a useful operational system. The technical conclusions can be listed as follows:

First, the passive sensors for chemical agent standoff detection were developed and transitioned to commercially constructed hardware. The status of this development should be considered a success. However, the lesson that should be taken from that development is that an instrument development can be a very lengthy and expensive process if the administrative and technical management of the program are not focused toward a clear set of objectives. The ECBC technical support for the passive sensors should still continue activities to examine detection algorithm improvements, measure additional spectral features of agents and interferents, perform analysis to reduce the false alarm rates to make the instrument more useable, and develop analysis for useful operational scenarios. ECBC should gather information about the false alarm rates encountered by the military during the use of these units, and take the responsibility to investigate, find, and correct the problems encountered so that this investment is made useful for the future.

Second, the active sensor work with the CO_2 lidar shows a great deal of promise, however, its development has been relatively slow during the past 15 years and no prototype instrument has been tested and analyzed sufficiently to prepare an Engineering Design Model (EDM) as a 6.3B development. Continuation of the recent work on the FAL instrument and the testing of the JSWILD hardware could provide this level of development within two years if an intensive test and evaluation program is properly carried out. This activity should be the primary goal of the ECBC and must take place before a logical transition to the Navy ARTEMIS program can be effective.

Third, because the biological threat is very difficult to address and it is an extremely important concern for providing adequate detection and warning, a period of careful analysis and laboratory work should be undertaken. The goal should be to determine what path to take, if a useful approach to biological agent standoff detection can be anticipated. All of the present data from various studies needs to be synthesized to provide a summary that can be used to scale performance expectations.

While new and innovative ideas and other approaches should continue to be investigated at a modest level in 6.2 program, the primary focus of the ECBC should be to provide the basic tools at the Advanced Development prototype levels for the military to develop for personnel protection and for battle management in times of conflict. The passive instruments must be improved to reduce false alarms to a level that makes them useful devices. The active CO_2-lidar technique needs thorough testing and analysis to develop an accurate performance model for detection sensitivity versus false alarm characteristics.

To facilitate orderly presentation of the technical review, the Panel deliberations and conclusions are presented in the following two subsections: 2.1 (Chemical Sensor Development) and 2.1 (Biological Sensor Development).

2.1 CHEMICAL SENSOR DEVELOPMENT

The conclusions pertaining to chemical sensor development program are concerned with both programmatic and technical aspects, and are presented in subsections 2.1.1 and 2.1.2, respectively.

2.1.1 Programmatic Aspects

2.1.1.1 *Peer Review: Good Management Practices*

The overall impression, based on what was presented, is that the ECBC team has pursued its work effort along the guidelines of the 6.2 and 6.3 technology base, in that it has embarked on evaluating the efficacy of promising system technologies by preparing hardware and conducting field tests to detect chemical agent simulants; and analyzing the test data, using sophisticated models, algorithms, and analysis techniques. Before transitioning the lidar system from 6.3 to 6.4 phase of the development and embarking on new 6.2 studies and system testing, it was in good order to take stock of all the issues involved so as to prioritize what courses of action to pursue that clearly have the best chance of producing one or more successful instruments based on active and passive sensing. Sponsorship of the current independent peer review of the SD program at ECBC, conducted by a Blue-Ribbon Panel of remote sensing experts, was not only timely, but it was in line with good management practices.

2.1.1.2 *Prioritize Problems, Systems and Technologies*

The Panel believes that under the current limited funding constraints, ECBC would be diluting itself by pursuing so many options, without prioritizing the problems and allocating appropriate funds and resources for successful completion of the DTO(s). Before transitioning a system into 6.4 and/or undertaking new sensor development testing under conditions simulating realistic battlespace environments, a clear and realistic vision needs to be developed to prioritize which problem(s), both programmatic and technical, to concentrate on, and in what order. It is important, at this point in time, to prioritize the problems to ensure successful outcome of the program deliverables. The mission or goal for each sensor or technology presented to the Panel must be established with an appropriate priority. It seems that while each may have some useful application, but the strategy for observation, detection and discrimination of CBW in "realistic dirty" (or "dusty") environments, supporting algorithm development, and test data analysis need to be carefully defined to clarify the role of each. Then, in light of what is discussed below, the systems to utilize, the technologies to pursue, and the resources to be applied should be determined. The Panel wishes to emphasize that this is not meant to be critical of the effort being undertaken at ECBC. Clearly, there is competent engineering talent being applied to the problems, which are urgent, complex, and of vital importance. It appears that now is the time for the ECBC team to pause and review all collections of data and information from previous efforts for each sensor and technology, and for CBW agents as well as interferents, consider user requirements, set priorities, reorganize management structure, and focus efforts on the most important directions to pursue. More will be stated in Section 3.1 Short-Term Recommendations.

2.1.1.3 ***Active Sensor: JSWILD Lidar System***

a. Integration and Testing

The original plan that set up the JSWILD DTO CB07 allocated only 4 months for integration and testing of the hardware under the contract of the prime contractor (Raytheon Electronic Systems) that developed the JSWILD instrument (WILDCAT, Cohn et al., 2001). Based on the Panel's experience, it is not realistic to expect that such a system could be integrated and tested sufficiently to successfully evaluate operating performance in less than 18 to 24 months. There is actually much work remaining to be accomplished after the designed hardware is completed. In order to conduct a well-ordered program, the new hardware must be given an adequate period for test and evaluation. Often, there is a tendency among laser developers to consider the laser as the primary hurdle to be overcome, and thus the subsequent integration and testing of the complete laser remote sensing system is given a short shrift. The integration and test evaluation of the system should be the primary focus to be able to comply with the DTO. This testing should be made against actual simulant gas clouds and interfering species, and not just computer calculations or using simulated lidar signals. The Panel believes that the prior investment made in developing the instrument would justify extending the DTO schedule to include adequate testing that will allow the original questions and specifications of the DTO to be satisfactorily answered before this DTO is closed.

Clearly, the stated objective of the DTO CB.07 (namely, "Demonstrate capability to detect agents at a distance of 20 km and evaluate sensitivity for 'dusty' chemical agent detection") has not yet been achieved to date, because the new WILDCAT Lidar system has not yet been delivered, let alone tested. The hardware is expected at ECBC a few weeks after this Panel review. The Panel believes that the status of the sensor system should be reviewed again after sufficient field tests demonstrating the performance of the brass-board system have been completed. At this point in time, however, as stated above, the current development phase will need to be extended to adequately accomplish this objective.

b. Test Data Documentation

The Panel did not learn if the contractor (Raytheon) was required by the hardware contract to measure or meet any specific technical performance specifications. Assuming that there are specifications that they are required to demonstrate, then those data should be carefully and fully documented so that the information will be available for further evaluations in the future. It is very important that the actual test data be gathered and documented for the laser provided with the instrument as well as for other lasers of similar types manufactured by the same company. In order to carry out a successful testing period, it is important the technical support be available from the hardware contractors. While it is preferred that the testing of the delivered system be carried out independently, it could be important for the contractor (Raytheon) to feel an incentive to remain onboard (or on-call) during the period of integration and performance testing.

c. Prior Similar Instrument Development and Test Results

Between 1978 and 1985, the USAF prepared a warning and detection system for chemical agents called Area Detection System (ADS) that had nearly identical performance standards and requirements to those of JSWILD (see ADS Contract Reports, Leonard et al., 1982, 1985, 1987; and scientific report, Leonard et al., 1996). The ADS system used the Spectral Pattern Recognition Differential Absorption Lidar (SPR-DIAL) technique that is the basis for the FAL and JSWILD instruments. The ADS developed from two parallel efforts by competing technical approaches that the USAF funded at GTE Sylvania and at SRI. Both contractors made contributions that are important and significant for the JSWILD sensor development activity. The GTE approach was selected as the more successful design and it was carried through a series of successful tests with chemical agent stimulants in several field programs, and, in addition, with actual chemical agents inside a chamber with an optical window at the Battelle Columbus facility. Also, several interferents were measured and the relative importance of interfering materials was evaluated. The data, performance evaluations, and field test results from the ADS program should be reviewed and incorporated as appropriate into the current program, and these results should be made available to the current team for use in planning and developing their test program.

d. Spectral Characteristics of Agents, Simulants and Interferents as an On-going Activity

The primary spectral data on agents, simulants and interferent species provide the key data base on which the designs of standoff detection techniques, both active and passive, are based. Some of these data were collected prior to modern digital techniques being available. A small but critical part of the Chemical Defense Program should include archiving and updating the database that supports the Chemical Defense community's work. This function should be an on-going effort that supports all of the programs with a line item funding that does not depend on any specific project. Some of these data are sufficiently old that modern tests should verify that those results are still valid. It would be unconscionable to let these data, on which immense time and funds have been expended, be lost by deterioration on old media. The cost-effective efforts needed to save, validate, and store these results in electronic databases should be a high priority. These data could be stored in user-friendly retrieval formats to easily use them in development and testing of models and instruments.

e. System Development to Stated Goals Versus Next Generation Research

It is often difficult to achieve stated system development goals when the system development activities are mixed with research investigations focused upon future ideas. For example, the report on the WILDCAT development places significant emphasis upon the use of CO_2 laser frequency doubling into an optical parametric oscillator (OPO). This research topic is potentially very important for the next generation of transmitter sources, however, the power output efficiency does not lend itself to current systems. The organophosphate bond characteristic of chemical agents has been demonstrated to have sufficient overlap with the available CO_2 laser lines that detections can be made. The OPO activity is a "research activity" which would expand future capability, rather than a "system development activity" and both activities should not be part of the same contract. The OPO CO_2-laser development was carried out several years ago at Westinghouse Laboratory (Taylor and Suhre) and significant progress was made toward use of that type of instrument for monitoring of vapors from chemical waste tanks. That effort and the general progress in OPO technology should be reviewed before expending additional resources on this topic. The questions arise: Was the topic to examine the OPO in the original contract? Are the contract monitors keeping the contractor activity focused?

2.1.1.4 ***Program Planning, Coordination and Oversight***

Overall, technical and programmatic aspects of program are good considering the limited resources and budget. However, the manpower and budget should be significantly increased to accelerate the program and ensure success. Specific test milestones must be enhanced and documented. Continuity and overlap of program transition phases from 6.3 to 6.4 (such as, JSWILD to ARTEMIS) should be coordinated in a timely manner. Also, as mentioned earlier, there is a need for longer transition stages and detailed acceptance testing of the JSWILD system.

The Panel believes that program peer reviews of imaging, standoff, and point sensors should be coordinated together, and possibly be held with the same review panel, to enhance achieving insights and synergies from common technical aspects of spectra, lethal concentrations, particles/cm^3, etc.

Notwithstanding the good overall business area management, there appears to be some lack of overall technical oversight and coordination at very detailed level between different programs. To ensure an efficient coordination, there is a need for a single person overseeing the technical aspects of the overall CB standoff detection program, to better coordinate and allocate resources among the different phases of technical work, ranging from early 6.2 to advanced 6.3. Questions that need to be adequately addressed include: Are the technical areas possibly too ambitious, with extraneous portions involving new 6.2 work: for example, the initiation of the 8.3-micron laser development before the high-power 10-micron laser has been tested, notwithstanding the fact it shows some promise (as indicated in section 2.1.2.6)? There is a need to focus better on clear specific goals for each project, and to better coordinate initiation of new projects with timely completion (including documentation) and transitioning of ongoing work.

The JORD (Joint Operational Requirements Document) requirement of general threat specifications tends to lead to a wider range of technical solutions that may not be technically feasible. There is a need to better coordinate and focus the JORD specifications, and perhaps rewrite, interpret, and document them in terms of technical specifications: for example, instead of stating 'threat' out to 20 km, specify a specific threat, such as GB, at range of 5 km and concentration of, say, 20 ppl. Without technical specifications, it is too easy to just say that a system will detect the threat as opposed to quantifying the probability of detection (in a radar detection sense) of a specific agent, and at a selected probability of false alarm.

2.1.1.5 *Technology Oversight Team*

There is a need for a Technology Oversight Team, composed of experts in active and passive remote sensing of aerosols, from universities, non-profits, and industry, to review the active and passive standoff systems and technologies being considered within the DTOs. For details, see the Recommendations section 3.1.1.1.

2.1.1.6 *Operations Research Project Methodology: Sensor Suites*

ECBC has effectively been moving toward (active and passive) detection of chemical and biological agents at distances to 20 km. The FAL system had demonstrated great promise in moving toward this goal. It now appears that ECBC has invested significant funds to scale upwards the power level of this laser in the new WILDCAT design hoping to demonstrate detection capability at the 20 km. In addition, several complex problems, such as agent detection and discrimination in the presence of interferents, remain to be addressed and demonstrated.

Borrowing from the idea of "operations research," one solves difficult research projects by initially drawing on a very wide range of disciplines. It would be productive to broaden the thinking and technology scope of the research project participants to link optical or IR to other chemical and acoustical technologies. It is quite likely that this problem can only be solved effectively by a multi-sensor suite and by a computer analysis approach based on expert systems/artificial intelligence to allow rapid, real-time, data interpretation. For example, this has been the bottom line conclusion in other defense-related remote sensing programs, such as buried mine detection, and automated target recognition algorithms for smart weapons.

2.1.2 Technical Aspects

2.1.2.1 *Sealed High-Power CO_2-Laser Concerns*

The CO_2 DIAL system offers excellent potential for standoff detection of CB. The efforts here need to be focused to testing that will provide a useful performance model. The previous 0.1 J/pulse CO_2 FAL system was well designed and had undergone excellent initial field studies showing 100 million shots and being sealed with no outside gas replenishment. However, the JSWILD laser has only operated less than 10 hours (1 M shots at 30 Hz) and so there is concern about the sealed laser. More DIAL measurements need to be done with different hard targets (10 or so), different dust (i.e., interferent) clouds, and CB agents in cells; these DIAL tests need to be done simultaneously to measure detection probability in the presence of different target backscatter reflectivity (differential albedo) and interfering spectral shapes from dust, etc., that will mimic the agent spectra. Such testing usually requires about 18 to 24 months to conduct, so that hardware and software modifications can be made as the data are collected. Computer simulations are only made useful by the process of validation during extensive field tests.

The fact that the high-pulse energy CO_2-laser is a sealed system is a matter of concern, because such systems have historically had short-performance lifetimes. The low power versions (typically ~100mJ) have demonstrated long life, but the higher-power lasers (>1 J) suffer from poisoning of the gas supply. The ECBC Lidar group certainly appreciates the problems associated with the sealed CO_2-laser systems, based upon the research papers presented (Fox et al., 1988 and Cohn et al., 1995), however, the Panel is still concerned about this approach for a laser system which is expecting to output > 1 J per pulse for multi-line operation at 100-Hz rate. Most of the higher-power CO_2-lasers use a flowing gas system to obtain a reasonably long operating life. The laser should be tested for MTBF (mean-time between failures) and laser lifetime degradation rate, and those results assembled with available results from the manufacturer. If it turns out that there is indeed a problem with the laser lifetime, how difficult would it be to convert the laser to a flowing system? This question should be evaluated to develop mitigation strategies.

Lifetime of 1 J/pulse WILDCAT Tunable CO_2-laser not yet demonstrated:

As stated earlier, the operational life-time of the high-power tunable CO_2-laser (1J, 100-Hz at 9P44, 9.77μm) was of major concern to the panel members. Apparently 50-Hz operation has been demonstrated, but little detailed performance data was presented to the Panel. To allay this concern, a brief summary was provided to the Panel, which stated that 1 million shots had been shown (that is less than 10 hours), but not as a closed/sealed (no outside gas) laser, without incurring discharge-module or high-voltage failures, catalyst-activity degradation, or optical damage. The Panel believes that extensive laser tests need to be performed to demonstrate 100 million shots during closed, hands-off, laser operation. Extensive system testing will need to be performed in the field against interference and agent clouds. Such tests will probably require 18–24 months to be effective.

Personnel working on DIAL and passive systems are knowledgeable. However, the program needs to have additional people working on the activity of test and evaluation to insure success.

2.1.2.2 *Test Plan for WILDCAT*

No detailed test plan for the WILDCAT system has yet been written or approved, thereby making it very premature to consider the transfer of the as-of-yet undelivered system toward the ARTEMIS program.

2.1.2.3 *False Alarm Rate*

One of the most important performance parameters for a chemical agent detector is its false alarm rate. The false alarm rate discrimination is as important as the ability for the instrument to remotely detect concentrations sufficiently low to provide effective warning and useful information for battle management. The test program should include various industrial and battlefield interferents in pure and mixed phases to test the actual sensor performance in a simulated realistic battlespace environment against that predicted from the spectral data.

2.1.2.4 *Testing of an Appropriate "Dusty" Simulant*

The test plan was not presented, and has apparently not yet been prepared. Although the summary claims that the DTO is "On schedule for FY01 milestone completion" with "technology ready for transition" it seems to be impossible to expect adequate testing of the new lidar system and the discrimination algorithms to be conducted in the 4-5 months remaining in this fiscal year.

2.1.2.5 *Real-Time Discrimination Algorithm Issue*

Nothing was presented before the Panel to demonstrate the status of the work on development of a real-time discrimination algorithm, although papers were distributed that show significant progress had been achieved in algorithm development. Real data will be required to test the performance of discrimination algorithms, especially under conditions of realistic battlespace environment, with significant interferents such as heavy dust, burning fires, smokes/ obscurants or partial cloudiness. This should be part of the recommended review following the successful conclusion of field tests. The algorithms should be used with real SPR-DIAL field measurements of actual simulant and interfering gas clouds in order to accurately assess the sensitivity of the system and related accuracy.

2.1.2.6 *The 8.3-Micron Laser for Enhanced Mustard Detection*

The brief, preliminary results presented on this topic show promise, but little detailed information was presented to the Panel. Apparently, the technique is still some distance from being mature enough for demonstration in the field; but might have potential to warrant early 6.2 technology exploration.

2.1.2.7 *System Performance Metrics*

There is need for the development and use of a Feature Vector parameter or easily visible parameter to measure and quantify the chemical detection performance of a DIAL or Passive detection system. This could possibly be a 3-D visualization of a detection probability cloud for each CB agent and how it changes with range or interferent. Such a parameter is essential to show and quantify how each new discrimination technique (UV Fluorescence, etc.) increases the density of the probability cloud and improves the detection probability. Without such a Performance Parameter, it is hard to compare and quantify different sensors and techniques.

2.1.2.8 *End-to-End System Performance Analysis*

It is important to conduct end-to-end system performance analyses for the CB sensor systems under consideration. These analyses should include the presence of various interferents mixed with CW and BW in the simulated battle environment. The Panel suggests that such an analysis be carried out for the JSWILD and other systems, in case it had not been done for them.

2.1.2.9 *Knowledge Gaps*

To date, return polarization has not been studied as a potential chemical or biological discrimination methodology. Perhaps, relative to quantifying particle shape, this should be considered a priority. This is an example of technology gap that could be considered for further investigation.

2.2 BIOLOGICAL SENSOR DEVELOPMENT

The Joint Services Standoff Biological Aerosol Detection (DTO CB.35) was a new start in FY2000. The programmatic aspects and technical aspects are discussed in subsections 2.2.1 and 2.2.2, respectively.

2.2.1 Programmatic Aspects

The standoff detection of biological agents is a most difficult problem, and it should be a very high priority in our national program, if there is a reasonable chance of success. The probability of success in this area should be carefully reviewed. The fact that significant funds were spent to attempt detection of a potential release by identifying "unnatural" clouds, tacitly admits to the difficulty of directly detecting the biological agent by either fluorescence or by IR signature. There are several general claims about fluorescent detection of biological agents, but these results need to be summarized and put into some perspective that allows scaling of performance. The same type of detailed analysis of results needs to be prepared on the IR signature.

It is extremely important to place the biological agent detection problem into proper perspective, which logically connects the measurement capability with the hazard concentrations. When we relate the requirement to measure 15 ACPLA at 25 km to a useful comparison with air pollution aerosols (mg/m3 for 1–10 micron particles), there appears to be a great disconnect. For example, if we consider 1-micron particles, then 15 ACPLA = 7.8×10^{-6} mg/m^3, and for 10 micron particles, 15 ACPLA = 7.8×10^{-3} mg/m^3. The program approach should be to try to accurately present the relationships between the needs and the technical capabilities. What are the real possibilities? Can the detection be made when the concentrations are high at the release point? What dispersal time is available for realistically making the detection? What is the minimum detectable concentration when hard target returns are used?

2.2.1.1 *UV Fluorescence Data Base Development and Evaluation*

The Panel concludes that at the onset of the Standoff Biological Aerosol Detection (SBAD) Program all of the past data should be surveyed and a summary of all valid data sets which show fluorescence detection of biological simulant be prepared, documented and stored in a computerized format in a relational database management system for user-friendly retrievals. The results from all valid tests could probably fit onto a single figure to show the range, concentration, and signal-to-noise ratio (SNR) achieved for fluorescent detection. These data should be separated into tests using vapor stimulants in air and those using materials deposited onto a hard surface. With a summary of the past results, scaling arguments for potential system performance can be developed. The second part of the argument for performance of future systems must be based upon the concentration dilution rate after dispersal to include early detection of delivery. The problem with the present plans is the disconnect between the apparent fluorescent signal level and the hazardous concentration levels.

2.2.1.2 *Passive FTS discrimination*

Importance of observing geometry:

The sensitivity of passive observations viewing upward (zenith-viewing) with the sky background is much higher than that viewing downward (nadir-viewing) with the warm surface background. This statement is a key distinction in deciding how to make the best use of passive techniques. It is supported by information presented to the Panel showing the radiance signal of emission from a biological agent cloud and an additional calculation (Ben-David, et al., 2000) showing signal estimates when viewing downwards. The minimum detectable signals, for upward viewing observations, are also largely independent of the detailed temperature structure of the atmosphere and surface. By comparison, the down-viewing sensor sensitivity can change radically with diurnal variations of temperature structure, actually approaching zero for some conditions.

Detection conditions:

Certainly for the down-viewing geometry, FTS discrimination requires a dense cloud of biological agent for detection (10^4 particles/cm^3 or 10^7/liter for a 10 m thick cloud and a surface-cloud temperature difference of 5°C results in about a spectral brightness temperature signature with an amplitude of about 1°C). While useful sensitively might be achieved under the right conditions in the down-viewing mode, a sensitivity of anywhere near 15 particles/liter will not be possible. It seems that an up-viewing mode has substantially more promise.

For both modes, careful spectroscopy of possible sources of false alarms is important. The results for aerosols presented by ECBC showed at least on dust aerosol (Cab-O-Sil:01) that has a very similar spectrum to BG.

FTS Measurement Noise:

It was pointed out that the spectrum-to-spectrum noise is large, much larger than the random detector noise on each spectrum. This excessive noise is clearly a problem for the sensitive detection required for this application. It is probably caused by interferometric tilt-noise induced by vibrations from the mechanical detector cooler. If the mechanical cooler is a two-part design, it might be possible to substantially reduce the large tilt-noise by providing mechanical isolation for the cooler compressor. If not, this vibration-induced noise can be eliminated through the use of a cryogenic dewar in place of the mechanical cooler.

2.2.1.3 *Measurements of IR signature*

The recent IR spectral measurements have shown some characteristic features in the "finger print" region. While the spectral features are not as rich as those of the chemical agents, it may be that they offer better detection possibilities for standoff techniques than the fluorescent measurements. Before additional hardware development is undertaken in SBADP, a careful trade analysis study should be completed to compare predicted performance of biological detection with UV fluorescence and with IR fingerprint. Results of this study should be used to select path to best system approach.

2.2.1.4 *Far IR Discrimination*

All weather advantage:

The potential advantage of the Far IR for being able to operate in the presence of clouds and smoke warrants investigation.

Water Vapor:

However, water vapor is very absorbing in the sub-millimeter region of the spectrum and may blind this technique. Detection interference from water vapor needs to be evaluated.

Spectroscopy and observing techniques:

The broadband observations of laboratory FTS spectra in this spectral region are very useful for assessing the potential utility of this approach. However, a detailed sensitivity analysis is needed to assess the feasibility of a useful observing technique in this spectral region. A millimeter wave, microwave or Far-IR radiometer approach should be investigated for fundamental feasibility along the lines of the passive FTS studies presented.

2.2.2 Technical Aspects

2.2.2.1 *Biological Lidar System*

The current Biological Lidar system only detects the spatial presence of a cloud and cannot identify the composition of the cloud. The presence of a biological agent is inferred from the size and temporal movement of the cloud. The potential use of a fluorescence lidar to help augment this classification has not yet shown the sensitivity as far as discrimination and classification is concerned. Data shown to the Panel indicated the detection of a biological cloud, but the cloud was not differentiated from that of a dust cloud. Further work is required in this area in order to determine if such a lidar or Fluorescence lidar technique can detect a biological agent cloud with sufficiently low false alarm rate and high probability of discrimination between biological agent clouds and natural dust clouds.

2.2.2.2 *Knowledge Gaps*

Because of the relatively low level of data available on BW agents and simulants in several frequency ranges, there are knowledge gaps in technology to develop standoff detection systems. These technology gaps along with proposed ways of rectifying the knowledge gaps are briefly described in subsections 2.2.2.3 – 2.2.2.5.

2.2.2.3 *Information Contained in Complex Refractive Index*

The data shown on the complex index of refraction for biological agents should be carefully examined to determine whether useful spectral features exist in the IR and other regions. Since the biological materials do not have such unique features as those exhibited by the chemical agents, it will be necessary to obtain high signal to noise measurements to effectively discriminate the presence of agents. One of the ways to gain large SNR is to use differential signals from hard targets, and accept that the instrument only works on certain radials and that the results are integrated over a long path. However, the rather large complex index of refraction measured for the biological agents indicates that this approach could be only one, which will result in useful identification and discrimination against interferents.

2.2.2.4 *Spectroscopic Measurement of Biological Agents*

Measurements of spectroscopy of biological spores over the frequency range of 75 to 110 GHz were presented to the Panel. Even though this effort was at a relatively low level compared to the research at IR, the Panel believes it to be of value as a stepping stone to empirically investigate spectral signatures over the full 1 to 10 cm^{-1} range.

It is understood that these measurements were obtained by packing a waveguide flange section with analyte and that measurements were made through the sample (i.e., transmission measurement), and also with the waveguide section terminated in a short circuit (i.e., reflection measurement). The complex permittivity of biological spore particles in suspension should follow the model developed by Sihvola and Kong (1988).

The measurement method should be evaluated because when making transmission measurements through the sample, it may be difficult to interpret the data and spectral lines could be masked, because of data contamination by both front and rear face Fresnel reflection coefficients of the sample. Alternate methods of characterizing the complex permittivity of samples inserted into a waveguide were reported in Kozakoff (1980) and Moore (1987). In addition to waveguide measurements, alternate methods include the Fabry-Perot interferometer and the free space bridge. But all these methods are best performed at a single frequency, and are not efficient for wide frequency scanned data analysis.

2.2.2.5 *Millimeter Wave Detection of Aerosol Cloud*

Aerosol cloud formation and history were presented to the Panel as another potential identifier for attack by a chemical or biological weapon. This can be remotely sensed and imaged by a passive millimeter wave passive radiometer or active radar, and this is a candidate for further study. Millimeter wave radiometry between the wavelengths of 1 and 30 cm has been used in a significant number of remote sensing applications over the past twenty years. But, very recently, the component cost and performance have improved to make these systems practical for many new commercial and military applications.

Millimeter waves can penetrate many types of inclement weather and offer good image contrast. Even with rather high values of biological mass (up to 3 kg/m^2), plant canopies are relatively transparent to these types of sensors operating in the decimeter wavelength range. Initially, passive imaging equipment was bulky, but now millimeter waves integrated circuits (MMIC) technology has resulted in single-element scanners and imagers commercially available for 35, 94, 140 and 220 Ghz. For passive imaging, the pixel size at a range of 4 km is estimated at about 20 meters.

If absorption spectra can be identified within the 1 to 10 cm^{-1} band, a dry powder or an aerosol cloud would appear radiometrically very hot to this type of sensor. A dual-channel radiometer (one channel on an absorption line and one off the absorption line) might provide the desired discriminant to be exploited. As an example, a strong absorption line around 100 GHz would produce the one-way absorption of approximately -9.07 dB, -0.91 dB, -0.09 dB and -0.01 dB through a 100-m thick cloud with particle volumetric ratios of 10–6, 10–7, 10–8 and 10–9, respectively.

A discriminant of the aerosol cloud might be the particle shape and measureable by a coherent millimeter wave radar. Recent analysis published by Han and Wu (2001) studied the expansion of the Gaussian beam in terms of a prolate spheroidal vector wavefunction. The expansion coefficients were determined as well as the numerical values of the spheroidal eigenvalues. The results are applicable to the interaction of a focused laser beam or millimeter wave beam with various particles in suspension. Analysis of electromagnetic wave scattering is particularly applicable to aerosols in the atmosphere, to determine radiative transfer, particle shape and size, beam/aerosol cloud penetration and so on. Another method investigated by Osterwalder and Nyland (1993) studied the phase of an active systems penetration through the cloud. Clearly, they found that for low densities, changes in the phase function were seen long before changes in amplitude were seen. These should both be considered in analytical studies.

A hybrid method investigated in recent years by the Georgia Institute of Technology was coined an "active radiometer." This approach did in fact illuminate the area under surveillance with high-power noise energy to study energy absorbed. This should also be considered as an alternative.

3.0 RECOMMENDATIONS

The Panel's recommendations are divided into two categories, namely, Short-term (0 – 2 years) and Long-term (3 – 5 years), and are discussed in sections 3.1 and 3.2, respectively. Under each, they are further subdivided into General Recommendations and Specific Recommendations.

3.1 SHORT-TERM (0–2 YEARS) RECOMMENDATIONS

3.1.1 General Recommendations

The thrust of the program to develop useful standoff detection capabilities for the military must be kept in focus. The overall program should be viewed with regard to what hardware can be readied for deployment and used by the military in various battlespace scenarios. There is a responsibility to prepare new systems, evaluate and improve prior developments, and carefully invest resources to prepare the new technologies for future applications. The hardware previously developed for passive detection of CB agents was used in the Gulf conflicts and ECBC should conduct a critical review of its field performance. The current developments should focus on the CO_2-lidar (not OPO, which is a next generation technology) application to standoff detection for chemical-agents. However, the development of OPO and other technologies for future standoff detection applications should be encouraged as part of the 6.2 phase. The review of future technology should focus on summarizing the results from UV fluorescence and IR absorption to analyze expected performance for a system to detect and identify BW agents.

In general, the Panel recommends that more resources be allocated to the test and evaluation phases of programs to demonstrate performance. The test and evaluation phase of the program should receive about the same emphasis in resources (time and funding), as is spent on the design, fabrication and integration of the hardware system. Significant progress is not made in a technical area when the hardware fabrication exclusively receives most of the attention. If the hardware portion of a program has been successful, then the hardware must be used to define a performance capability, which should be evaluated to determine the detection probabilities for various concentrations versus expected false alarm rates. **More emphasis should be given to reduction of false alarm rates from a CB standoff detection system, as stated in Section 2.0 and 2.1.2.3. The full process of system development and testing is required to prepare equipment that can be considered for effective transition to operational hardware.**

3.1.1.1 *Support of Active and Passive Sensors*

The Panel strongly supports the fullest exploitation of active and passive remote sensing sensors and methods, operating in the spectral ranges of UV fluorescence (200 nm), visible, IR and millimeter and micro waves, and encourages continued pursuit of research and exploratory developments to address remote sensing needs for CB detection.

3.1.1.2 *Maintain and Enhance Core Capabilities*

Based on the ECBC presentations and the Defense Technology Objectives (DTO), the Panel makes a general recommendation that the ECBC Standoff Detection Team should continue to concentrate on the modeling, algorithm development, data collection and processing, false alarm rate minimization, field testing, and analysis aspects of the CB sensors, and become the center of excellence in this area. To achieve such a goal, the Panel recommends that the in-place overall good business area management covering both active and passive system programs, should be complemented by an overall technical area manager overseeing both programs to provide technical oversight and coordination at very detailed level among the different projects in 6.2 and 6.3 areas. In addition, a vision and road map should be developed to achieve such a goal by prioritizing and focusing on fewer specific goals, but ensuring that those undertaken are given the full resources to completely accomplish the DTOs, including testing in realistic environments, data processing and evaluation, and documentation of the results and lessons learned.

3.1.1.3 *Enhance Resources and Funding to Accelerate the Testing Program*

The overall technical and programmatic aspects of program are good considering the limited resources and budget. However, the number of people and budget need to be significantly increased to accelerate the program and ensure success. Specific test milestones must be enhanced and documented. There is a need for longer transition stages and detailed acceptance testing of the JSWILD system.

3.1.1.4 *Conduct Peer Reviews*

The Panel recommends that the same Panel be convened in 12 months or later to review the status of field testing of the lidar system performance in simulated "realistic" battlespace environment in the presence of interferents.

In addition, the Panel recommends that program peer reviews of imaging, standoff, and point sensors should be coordinated together, and possibly be held with the same review Panel, to enhance achieving insights and synergies from common technical aspects of spectra, lethal concentrations, particles/cm^3, etc.

3.1.1.5 *Form a Technical Oversight Team*

The Panel recommends the formation of a Technical Oversight Team, composed of experts from university and industry, which meets periodically (half-yearly for instance) to reduce program risks and provide cost-effective technical advice for ECBC. Such an oversight team should represent a range of applicable technologies and experience. The Technical Oversight Team might identify problems before they occur, avoid technical impasses, and project new or emerging technology to the Project. Members of the team could also be a resource as specific needs occur and they would assist in establishing long-range program goals.

3.1.1.6 *Form a Team to Develop Operational Scenarios and Translate into Specifications*

The Panel recommends that an internal team be established to develop a set of realistic operational scenarios that can be useful for guidance and direction for setting goals for the performance of instruments and equipment by the ECBC program. These descriptions could be used to prepare an operational philosophy and determine the minimum performance specification for a useful standoff detection system. For example, is the sensor unit to be used only for detection alarm or does it have a role in battle management to describe when battle units must take certain actions for protection and for carrying out their mission. The analysis should help define the operational philosophy and establish hardware requirements for such parameters as the time period for a hemisphere scan, and the data refresh rate. The potential value of hard target returns in establishing the hazard levels on certain radials should be included in operational planning because of the huge gain in sensitivity to low vapor concentrations. Advantages for detection of CB attack could be had from use of other data products to allow the active/passive sensors to be more effective in measurements of the agents. For example, acoustic sensor could be used to determine the direction and distance to potential CB attack volume by providing alert to detonation of a munition, rocket impact, or low-altitude aircraft. Similarly, visible and IR imagery could locate suspicious volumes of the atmosphere that the CB sensor could probe. Another useful activity would be to prepare an optical performance model for detection and discrimination, using the tri-service MOTRAN model as the starting point. Such a CB standoff detection aid would provide a basis for arguing performance expectations that would be most valuable in making decisions on resource allocations. The operational scenarios developed by the internal team should be later considered by an outside team to add other scenarios and to evaluate/order the importance of them for developing the system specifications.

3.1.1.7 *Establish Data Repository*

The Panel recommends that a program element responsibility be established for preparing, maintaining, documenting (including assigning error bars, which is a must, and details of collection method), and archiving the characteristics of all known chemical agents, simulants, carcinogens, and a wide assortment of interferents encountered in battlespace. These interferents include background environments, dusts, battlefield munitions, fires, burning fuels and, especially, military smokes and obscurants, for the spectral regions ranging from ultraviolet (200 nm) through microwave. This does not mean that ECBC mount a major new measurement program—but, rather, collect all previous data, analyze it, prepare and archive it in user-friendly relational database management system(s) so they are useful for evaluation—taking care to account for differences between high-resolution spectral data from dry, mono-dispersions versus data from mixed particulate size distributions (or, poly-dispersions), wet material, and liquid. The past activities in the area of spectral analysis of the agents, simulants and interferents have provided the foundation on which all of the current programs rest. The prior work of individuals (for example, that of Dennis Flanigan, 1985) has resulted in the present database that is widely used in the community. Quality data products are critical in order to make successful decisions, evaluate trade-off issues, model the performance predictions for detection and false alarm rates, and field testing and evaluation. The data that remain from the earlier investigations should be transferred to modern storage media for longer archiving. It appears that some of the original data may already be lost and/or corrupted by age of the data tapes. Much of the early data on chemical agents (for example Barrett and Dismukes, 1969) is still a reference source for current work but the archive has not been updated to modern media. This activity should be established in the near-term and continued as a long-term part of the Chemical Defense Program.

3.1.1.8 *Fund an Extensive Test and Evaluation Program*

The Panel recommends that a **well-planned** and **intensive** system performance test plan be developed and carried out as part of the R&D process for evaluation of the development of new systems. For example, extensive testing of FAL and JSWILD should be undertaken to complete the DTO CB.07. It would seem appropriate to consider delaying or minimizing the start of new tasks in order to complete the present work and validate the full system development. The overall program should be viewed with regard to what hardware can be readied for deployment and used, with confidence, by the user in realistic battlespace. The plans for the Navy to take on the development of the ARTEMIS as a follow-on to the JSWILD project does not make sense without the proper completion of the work through extensive integration, testing and evaluation, to ensure that the system is capable of detection and discrimination of CB in the presence of interferents within a prescribed level of certainty. Such measurements are not a small add-on to a major laser development program, but should be considered to take longer and be a major part of the lidar system development program.

3.1.1.9 *System Performance Metrics*

The Panel recommends that ECBC group develop and use a Feature Vector parameter (or an easily visible parameter) to measure and quantify the chemical detection performance of a DIAL or Passive detection system. For example, this could be a 3-D visualization of a detection probability cloud for each CB agent and how it changes with range or interferent. Such a parameter is essential to show and quantify how each new discrimination technique increases the density of the probability cloud and improves the detection probability. Without such a Performance Parameter, it would be hard to compare and quantify different sensors and techniques.

3.1.1.10 *End-to-End System Performance Analysis*

The Panel recommends that ECBC conduct end-to-end system performance analyses for the CB sensor systems under consideration. These analyses must include the presence of various interferents mixed with CW and BW in the simulated battle environment. Such an analysis should be carried out for the JSWILD and other systems, in case it had not been done for them.

3.1.2 Specific Recommendations

3.1.2.1 *Conduct Additional Testing for the Lidar Systems*

The Panel recommends delaying transition of JSWILD to ARTEMIS for 18–24 months to allow for WILDCAT Lidar system field tests to complete the DTO CB.07 objective; that is, to "demonstrate capability to detect agents at a distance of 20 km and evaluate sensitivity for 'dusty' chemical agent detection." The FAL system should be used to better test more targets, clouds, and interferents. The WILDCAT system is not yet ready for testing and will require 18 to 24 months of field measurements to ascertain its performance and clarify sensitivity and lifetime issues. This suggestion will cause a delay in the Navy effort on the formal development of ARTEMIS for up to 24 months to conduct a sufficient testing period for the WILDCAT Lidar (JSWILD DTO) system to obtain measurements and prepare a performance analysis. It would make sense for the WILDCAT hardware to transfer to the Navy program at some point, to serve as their test bed and evaluation tool during the initial phase of ARTEMIS.

3.1.2.2 *Addition of UV Fluorescence Lidar for Biological Detection*

The Panel recommends that the ECBC group optimize the wavelength to be used and show lidar signal-to-noise, and how it adds in discrimination and changes the Performance Parameter compared with the spatial cloud mapping lidar already used. The available data on fluorescence should be summarized and used in simulations to estimate expected performance for a standoff detection system.

3.1.2.3 *Investigate Use of Hard Target Differential Absorption for Biological Agents*

The Panel recommends that the measurements of the complex index of refraction data be reviewed and interesting regions be investigated to determine standoff detection capability when the backscatter signals from hard targets are used to measure the long path differential absorption. The CO_2 laser lines should be examined first and then other spectral regions considered. The advantages offered by long path SNR may well off set the limitations of poor spatial resolution (long path on few radials) in obtaining detection of low concentrations of biological agents with weak spectral features.

3.1.2.4 *Extend Frequency Range of Spectral Signature Measurements over 1 to 10 cm^{-1}*

To date, testing within the millimeter wave region, as presented to the Panel, encompassed the spectral range from 75 Ghz to 110 Ghz, and was based on use of the Hewlett Packard HP8510 Network Analyzer. This equipment, as configured, only covered a very small range of the frequencies of interest (30 to 300 Ghz, corresponding to 1 to 10 cm^{-1}, respectively).

The Panel recommends that this frequency range be extended by use of millimeter wave up and down converters (mixers) driven by a stable oscillator (STALO). By using full waveguide band mixers, we can accomplish this with two up/down converter assemblies configured around the following two waveguide bands: WR-7 (110-170 Ghz), and WR-4 (170-260 Ghz). Or, alternatively, around the following three waveguide bands: WR-8 (90 – 140 Ghz), WR-5 (140 – 220 Ghz) and WR-3 (220 – 325 Ghz).

A design and cost tradeoff should be performed before proceeding further. It would be most cost- effective for ECBC to purchase the parts and assemble this system in-house.

3.1.2.5 *Continue Investigation of Performance of M21 and LSCAD*

Although no discussions were presented, the follow-up and evaluation of performance of the fielded M21 system and the LSCAD system (under development) should be regarded as the responsibility of the developer organization. Certainly, after field use of M21 by the services, the performance evaluations and critique of the sensor algorithms should be continued in order to consider additional interferents, increase sensor responsiveness, and reduce false alarms.

The Panel recommends that ECBC form an internal team to perform an investigation of the operational performance and testing of the fielded M21 system. The investigation should include interviews of soldiers that have used the sensor and officers that have had experience with it. Based on experience gained in the field, are there improvements to be made in the hardware or software to increase the sensor utility? What is the proposed plan to implement any needed changes? Investigation of similar questions regarding performance evaluation of LSCAD should be considered.

3.1.2.6 *Investigate Knowledge Gaps for Potential CB Standoff Detection Applications*

The Panel recommends that in the near future, as part of the early 6.2 phase, investigations be initiated to investigate the feasibility of utilizing the special features of the research areas, identified as knowledge or technology gaps in sections 2.1.2.9 and 2.2.2.2 – 2.2.2.5, for CB standoff detection applications in the future. These areas include studying how to use measurement of polarization of return laser signal to quantify shape and complex refractive index of scattering particles.

3.2 LONG-TERM (3 – 5 YEARS) RECOMMENDATIONS

3.2.1 General Recommendations

3.2.1.1 *Continue the Data Archival and Preparation of Relational Database*

The Panel recommends continuing the activity (as proposed in section 3.1.1.7) of preparing, maintaining, documenting (including assigning error bars and details of collection method), and archiving the characteristics of all known chemical agents, simulants, carcinogens, and a wide assortment of interferents encountered in battlespace. After the archive is established and computerized in an advanced relational database management system in a user-friendly format for ease of data retrieval, carry out simulations of operational performance versus test results.

3.2.2 Specific Recommendations

3.2.2.1 *Conduct External Panel Study to Evaluate Operational Scenarios*

As a follow-on to the internal study in subsection 3.1.1.2, the Panel recommends the standoff detection program could benefit by having a panel of outside experts conduct a study and an external review of the operational scenarios report prepared. The external panel would be charged to critically evaluate the major operational scenarios and suggest the influence they have upon the future hardware development issues, including translation of user requirements and operational scenarios into environmental characteristics and hardware specifications.

3.2.2.2 *Convene Panel to Review and Evaluate the Performance for Bio Standoff Detection*

Based upon the analysis and investigations carried out on the biological standoff detection expected performance, make recommendation on technical approach which can result in a useful sensor, or recommend that resources be invested elsewhere if the sensitivity and discrimination expectations do not warrant further system development.

3.2.2.3 *Conduct a Study of Millimeter Wave Detection of Aerosol Cloud*

The panel recommends that an analytical study be conducted to determine if aerosol cloud formation and history can be remotely sensed and imaged by a coherent millimeter wave radar or a passive millimeter wave radiometer. If so, this can be used as another potential identifier for attack by a chemical or biological weapon.

3.2.2.4 *Investigate Dual Use of Millimeter Wave Detection Information for Decontamination*

The Panel recommends that on the basis of the information gained during investigation of millimeter wave detection of BW agents, a study be conducted to explore the potential of high-power millimeter waves (HPM) as a method of decontamination of biological spores. Potential sources include pulsed gyrotrons and backward wave oscillators (BWOs), for instance, which can produce very intense electromagnetic fields. The kill mechanism might be other than just heating alone, perhaps breaking of the protein or DNA bond, and particularly effective if the illumination source operated at a respective absorption line.

Investigations of this possibility should be made via laboratory bench tests to confirm the potential for decontamination by this method. This ECBC team could provide assistance to the appropriate CB Decontamination Group at ECBC, and thus achieve dual-use applicability. If this is successful, the next recommended step would be computer modeling based on the state-of-the-art components and devices, followed by scaled-up outdoor testing.

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5.0 APPENDICES

5.1 APPENDIX A. BLUE RIBBON PANEL MEMBERS' VITAE

Dr. ADARSH DEEPAK

EDUCATION

Ph. D. (Aerospace Eng.)	1969	University of Florida, Gainesville, FL, USA
M.S. (Physics)	1959	University of Delhi, Delhi, India
B.S.Honors (Physics)	1956	University of Delhi, Delhi, India

PROFESSIONAL EXPERIENCE

1979–Present	Founder and President of Science and Technology Corporation
1979–1980	Adjunct Professor of Physics, College of William and Mary, Williamsburg, VA
1974–1977	Adjunct Research Associate Professor of Physics and Geophysical Sciences, Old Dominion University, Norfolk, VA; and Principal Investigator for ANSA research grants.
1972–1974	NRC Postdoctoral Resident Research Associate, NASA-Marshall Space Flight Center (MSFC), Huntsville, AL
1971–1972	Consultant and Research Associate, Research Institute for Engineering Sciences (RIES), Wayne State University, Detroit, MI, under NASA-MSFC contract.
1970–1971	Joint Research Associate at Wayne State University (RIES) and University of Florida (Physics Department)
1970–1971	Postdoctoral Research Associate in Physics with Professor A.E.S. Green, University of Florida, Gainesville, FL
1968–1969	Research Assistant in Physics, University of Florida.
1965-1968	Instructor, Physical Sciences Dept., University of Florida

Research interests include:

- Remote Sensing of Aerosols and other Atmospheric Constituents;
- Remote Sensing of Aerosol Motions using Laser Doppler velocimetry, laser, solar radiation, photometer, optical scattering, and photographic techniques from space, airborne, and ground platforms;
- Theoretical and Computer Modeling of the single and multiple scattering phenomena; the characteristics of particulates, fogs, clouds, and snow; aerosols and their impact on global climate;
- Parametric analysis of laser beam propagation, lidars and laser Doppler velocimeter (LDV) systems.

Chair and Co-Chair of 31 workshops, symposia, and conferences; and 2 International Working Groups on Global Aerosols
Chair of 8 "Blue-Ribbon" Panels for Army and NASA program reviews
Director of 10 Short Courses

PUBLICATIONS
Author/coauthor of 100 papers and technical reports
Editor/Coeditor of 31 Workshop and Symposium proceedings, 7 Blue-Ribbon Panel Reports, and 2 International Working Group Reports (on Global Aerosols)

Dr. DENNIS KILLINGER

EDUCATION

Ph.D (1978) – Physics – University of Michigan
M.A. (1969) – Physics – DePauw University
B.A. (1967) – Physics – University of Iowa

PROFESSIONAL EXPERIENCE

Dr. Dennis K. Killinger is a Professor of Physics at the University of South Florida and is an expert in laser and optical remote sensing/Lidar, applied laser spectroscopy and laser physics. He received the BA degree from the University of Iowa, MA degree from De Pauw University, and Ph.D. degree in Physics from the University of Michigan. He has conducted research on radar analysis and microwave atmospheric propagation while employed as a research physicist at the Naval Avionics Facility, and was on the research staff in Quantum Electronics at Lincoln Laboratory, Massachusetts Institute of Technology conducting research in the development of new solid state lasers and their application as spectroscopic Lidar probes of the atmosphere. In 1987, he joined the Physics faculty at the University of South Florida and is director of the Center for Laser Atmospheric Studies and Technical Director of the Technology Deployment Center working on technology transfer for the University and regional industries.

Dr. Killinger is a Fellow of the Optical Society of America, Senior Member of the IEEE, past associate editor of Applied Optics and Optics Letters, past member of the NAS/NRC Committee on Optical Science and Engineering, and has served as chairman of several international conferences on lasers and applied spectroscopy.

EXTESIVE PUBLICATIONS
He has published over 200 technical papers, reports, and conference papers, and three books or book chapters.

Dr. DENNIS J. KOZAKOFF

EDUCATION

Ph.D Eng. (1992) – Engineering - Southeastern Institute of Technology
M.S.E. (1969) – Engineering - University of Florida
B.S. (1962) – Engineering - Polytechnic Institute of Brooklyn

PROFESSIONAL EXPERIENCE

2001 – Present *Senior Scientist/Principal Investigator, Science and Technology Corporation*

1999 – 2001 *Professor, DeVry Institute of Technology, Alpharetta, Georgia*

Teaching courses in wireless, wire communications and networking encompassing antenna and transmission lines, microwave systems, propagation, digital signal transforms, modulation and demodulation methodology (AM, FM, ASK, PSK, QPSK), noise analysis and signal budget calculations, bit error rates (BER), fiber optic distribution systems and computer networking, and calculus (differential and integral).

1999 – 2000 *Consultant, Millennium Electronics,. Marietta, Georgia*

Designed a Ku band FMCW fire control radar front end including system analysis, signal and error budgets, transmitter and receiver hardware design. Performed hardware selection and performance/cost tradeoffs, design of ultra-low sidelobe antennas, and packaging concepts. On another project, designed a low power FMCW radar front end for a petrochemical tank liquid level measuring radar. The design was totally on microstrip using low cost surface mount components, and included a prescalar channel for instrumentation calibration.

1982 – 1999 *Chief Engineer, Millimeter Wave Technology Inc, Marietta, Georgia*

Functioned as Chief Engineer of a small R&D company with extensive hands-on experience in microwave and millimeter wave instrumentation, communications systems development and electromagnetics analysis. Designed QPSK millimeter wave data links at 38 Ghz and 61 Ghz, K/Ka/W band FMCW radar front ends using Fresnel zoned lens antenna approaches, and broadband ridged horn antennas used in the test instrument products. Dr. Kozakoff's work included the development of a shaped beam Ku band antenna and electromagnetic window for a hypersonic missile application.

In consulting efforts, he designed numerous radomes for SATCOM, aircraft communications and radar applications. For the office of naval research (ONR). He developed multi-functional broadband antenna concepts for naval applications. Led the design of microwave and millimeter wave portable reflectometer instruments for point inspection of low observable (LO) surfaces on aircraft, naval vessels or ground vehicles.

Antenna design experience included Ultra-wide band (UWB) antennas for fixed, mobile, naval and airborne (UAV) applications. Also worked on multifunctional, multi-band and dielectric embedded apertures and simultaneous multibeam antennas. Performed research in low cost phased array antennas, ultra-broadband fractal antennas and artificial dielectric research (including electro-rheological materials). Extensive experience in the modeling and design of absorbing materials for low observables applications at frequencies from L-band through W-band. This included coatings and multiplayer absorber types.

Dr. Kozakoff served as Program Manager on over twenty-five R&D programs, with extensive hands on experience in performance of tasks and also directing subordinates. Prepared documentation, made presentations and interfaced with customers.

1980 – 1982 *Principal Research Engineer, Georgia Institute of Technology, Atlanta, Georgia*

Performed designs for microwave and millimeter wave hardware-in-the-loop (HWIL) test systems, including system budgets and tradeoffs. Performed radar instrumentation design studies for MICOM and development of computer codes for analysis of radome effects on missile radar guidance. Performed space research studies for NASA Marshall SFC. Served as Project Manager on over ten programs, with extensive hands on experience, guiding tasks of other project team members.

1962 – 1979 *Senior Engineer, Martin Marietta Corporation, Orlando, Florida*

Designed and developed numerous production missile antennas and radomes, and terrestrial SATCOM antennas. Did significant work in computational electromagnetics and computer modeling. Performed modeling of airframe infrared signatures, including hot body and plume. Performed propagation analysis and RF system budgets for space and terrestrial communications systems and radar projects. Performed radar (RCS) signature reduction studies for cruise missile systems.

OTHER

Member of the Technical Program Committee - International Conference on Antenna Theory and Techniques (ICATT99), Member of Steering Committee - IEEE International Symposium on Antennas and Propagation (AP-S), Atlanta, GA 1998, Session Chairman at the International Infrared and Millimeter Symposium, Orlando, Florida (1996), Session Co-Chairman of the International Society for Optical Engineering (SPIE) OE LASE '93 Symposium, Los Angeles, CA (1993), Past Vice Chairman, IEEE Professional Group on Microwave Theory and Techniques (MTT), Atlanta, GA (1983) and General Chairman of the 15th International Symposium on Electromagnetic Windows, Georgia Institute of Technology, Atlanta, GA (1980). Received several awards from NASA MSFC for space research and was invited panel member representing the US in antenna technology at the International Symposium on Solar Power Satellites, Toulouse, France, 1980.

PUBLICATIONS

Dr. Kozakoff has authored or coauthored four books and published over 150 papers, articles or other technical publications.

Dr. C. RUSSELL PHILBRICK

EDUCATION

Ph.D. (1966); M.S. (1964); B.S. (1962) – Physics North Carolina State University, Raleigh, NC

PROFESSIONAL EXPERIENCE

1988 – Present Professor of Electrical Engineering, Pennsylvania State University, University Park, PA, Remote Sensing Department Head (1993-1998), Senior Scientist at the Applied Research Laboratory

1980 – 1988 Supervisory Physicist – Air Force Geophysics Laboratory, Hanscom AFB, MA

1969 – 1980 Research Physicist – Air Force Cambridge Research Laboratory (now AFGL)

1966 – 1969 Research Physicist – 1st Lieutenant and Captain, USAF, AFCRL

TECHNICAL ACTIVITIES AND RESPONSIBILITIES

1988 – Present Professor of Electrical Engineering, lectures on remote sensing, electro-optics, space physics, upper atmosphere/ionosphere. Applied Research Laboratory Senior Scientist for optical communications, EO applications, development of lidar techniques. Developed four lidar systems at PSU and used them for many investigations, the effort included the first prototype of an operational lidar instrument, which was demonstrated on a Navy ship in 1996. The PSU lidar instruments have been used for shipboard measurements of the marine environment, for arctic and Antarctic atmospheric investigations, and for studies of air pollution episodes in Los Angles and Philadelphia. Educational accomplishments include advising 35 students through their graduate degrees, and development of graduate and advanced undergraduate courses in areas of remote sensing, optical engineering, laser remote sensing and space physics. Adjunct Professor in Department of Marine, Earth and Atmospheric Sciences, NC State University, 1998-present.

1978 – 1988 Program Scientist responsible for all aspects of development of lidar capabilities for atmospheric sounding at AFGL. The effort included the conception, design development, safety analysis, calibration, field test, data collection and interpretation of results of two advanced lidar sounders. The capability of lidar to replace meteorological rockets for atmospheric data between 10 and 80 km was demonstrated. Advisor and technical monitor for AF program office that developed the ADS system for remote detection of chemical agents. Served on committees that prepared the Air Force Roadmap for Chemical Agent Detection and the Tri-Service Plan for Chemical Agent Detection.

1976 – 1984 Program scientist responsible for developed a high spatial resolution accelerometer for atmospheric investigations. The instrument provided the most detail measurements to date on gravity waves, atmospheric structure and dynamical properties. Measurements were obtained in several international scientific investigations and during testing for the atmospheric effects on ballistic reentry vehicles. Techniques were prepared and demonstrated to permit validation of reentry vehicles and a model was prepared for the atmospheric conditions at Kwajalein Missile Range.

1966 – 1978 PI for a series of eight satellite mass spectrometer experiment investigations of the composition and structure properties of the upper atmosphere and ionosphere which are important basis for several atmospheric and ionospheric models. Responsible for fabrication, integration and operation of two scientific research satellites.

1966 –1975 PI for development of liquid nitrogen and liquid helium cryo-pumped mass spectrometers (NACS) for the first direct measurements of mesosphere composition on rocket payloads between 60 and 140 km and responsible for several major international rocket payload investigations of the atmosphere and ionosphere including the largest ones conducted by the US. These investigations provided the data and results the have formed the basis of our understanding of the physics of the middle atmosphere and of the D- and E-regions of the ionosphere.

PROFESSIONAL HONORS AND ACTIVITIES

10 Awards and Citations by Air Force for Technical Achievement (1968 to 1987); US Air Force Research and Development Award, 1968; USAF Safety Award, 1986; Sr. Research Fellow, Max-Plank-Institute (1981); Representative to North American Research Strategy for Tropospheric Ozone (NARSTO), 1997 – present.

PROFESSIONAL COMMITTEE ACTIVITY

Member of the COSPAR Panel C.2. on "Earth's Middle Atmosphere and Ionosphere" (1972–Present, Vice-Chairman 1980–1986); Session Chairman and organizer for several AGU, SPIE and COSPAR sessions and symposia; author of more than 100 scientific papers and reports; NSF – CEDAR Short Course on "LIDAR Techniques" June 1991, Boulder Co.

TECHNICAL ADVISOR

1966 – 1982	Atmospheric Nuclear Effects
1968 – 1979	Upper Atmospheric Model Development
1970 – 1976	Satellite Orbit Determination
1974 – 1979	Ballistic Vehicle Reentry Effects
1974 – 1985	Ionospheric Model Development
1978 – 1985	Chemical Agent Remote Detection (ADS)
1984 – 1985	Roadmap for Chemical Defense
1986 – 1994	National Aerospace Plane (NASP)
1988 – 1992	Long Range Under Water Detection
1988 – 1993	Satellite Laser Communications (SLC)
1989 – 1992	Photonics Mast
1989 – 1992	Underwater Lidar
1996 – present	MORIAH Committee on Environmental Measurements
1993 – present	National Polar Orbiting Environmental Satellite System (NPOESS)

PUBLICATIONS

Author/coauthor of over 200 papers and reports.

Dr. HENRY E. REVERCOMB

EDUCATION

Ph.D (1972) – Theoretical Physics University of Wisconsin-Madison

PROFESSIONAL EXPERIENCE

As Director of SSEC (Space Science and Engineering Center), Dr. Revercomb is involved in radiation measurements of the earth and in studies of planetary atmospheres. Recently, he has been the Principal Investigator (PI) for several projects related to radiometrically accurate, high spectral resolution observations of the atmosphere, including (1) UW participation in the development of the GIFTS (Geosynchronous Imaging Fourier Transform Spectrometer) for the 3rd earth orbiting mission of the NASA New Millennium Program, (2) Design, fabrication, and field deployment of the new Scanning High-resolution Interferometer Sounder (Scanning HIS) aircraft instrument, (3) High Spectral Resolution FTS Observations for the DOE Atmospheric Radiation Measurement (ARM) Program, (4) Atmospheric Emitted Radiance Interferometer (AERI) fabrication and test (9 units) for the ARM program, (5) Marine AERI fabrication and test (3 units) for a University of Miami NASA EOS project, (6) NASA AIRS Science Team Membership, and (7) Analysis of IMG data from the ADEOS spacecraft. He is a Co-Investigator on a UW Planetary Imaging FTS (PIFTS) development project that has already contributed directly to the GIFTS interferometer design and holds promise for future planetary missions. From 1983 to about 1995, he also served as the SSEC Program Scientist for the original HIS aircraft instrument program, which demonstrated the radiometric performance needed to provide higher vertical resolution temperature and water vapor soundings from space. In 1991, as part of his work toward improving atmospheric sounding and emission measurements, Dr. Revercomb was also the Principal Investigator for a project to design the ITS, an advanced FTS operational sounder for EUMETSAT that has evolved into the NPOESS Cross-track Infrared Sounder (CrIS) planned for flight starting 2004.

Earlier involvement with remote sensing of the earth from satellite included development work on the VISSR Atmospheric Sounder (VAS) and its ground processing system, and instrument problem solving on the current geostationary sounder. In 1981, he was awarded the NASA Group Achievement Award for his role in VAS. At SSEC, Dr. Revercomb has also contributed to the design of satellite systems for monitoring the earth's radiative energy budget and was a Co-Investigator for the ERBE program.

As a member of the planetary group at SSEC, Dr. Revercomb has studied the atmospheric circulation of Venus, Jupiter, and Saturn. Dr. Revercomb also participated in investigations of the radiative properties of the atmospheres of Venus and Jupiter for which he was awarded NASA Group Achievement awards: in 1980, for participation in the Small Probe Net Flux Radiometer development at SSEC, and in 1992, for participation as Co-Investigator in the Galileo Net Flux Radiometer project.

EXTENSIVE PUBLICATIONS

5.2 APPENDIX B. BLUE RIBBON PANEL AGENDA

BLUE-RIBBON PANEL REVIEW
of
LASER AND BIOLOGICAL STANDOFF DETECTION PROGRAM AT ECBC
Sheraton Four-Points Hotel, Aberdeen
980 Hospitality Way, Aberdeen, MD 21001
30 April – 1 May (a.m.) 2001

MEETING AGENDA

Monday, 30 April 2001

7:30 AM Continental Breakfast

8:00 AM WELCOME REMARKS
- *Kirkman Phelps*, Commodity Area Manager for Contamination Avoidance (ECBC)

8:05 AM OBJECTIVES AND TASKING
William Loerop, Business Area Manager for Standoff Detection (ECBC)

8:15 AM BUSINESS AREA REVIEW
- Laser Standoff Detection, *Ms. Cynthia R. Swim,* Team Leader, Laser Standoff Detection (ECBC)

8:40 AM TECHNICAL REVIEW
- Laser Standoff Chemical Detection Technology (DTO CB.07)
  Ms. Cynthia R. Swim
  - User Requirements
  - Technical Brief

10:10 AM BREAK

10:20 AM – Standoff Biological Aerosol Detection (DTO CB.35)
Ernest Webb Jr., PI, Biological Standoff Detection Program (ECBC)

11:45 AM WORKING BUFFET LUNCH w/Briefers and Panel Members

12:45 PM TECHNICAL REVIEW (Cont'd)
-- User Requirements
-- Technical Briefings
- *Ernest Webb, Jr.* PI, Biological Standoff Detection Program (ECBC)
- *Dr. Avishai Ben David*, PI, Signal Processing (STC)
- *Dr. James Jensen*, PI Passive Infrared Biological Detection (ECBC)
- *Dr. Alan Samuels*, PI, Millimeter Wave Technology (ECBC)

4:00 PM -- Panel Q&A Session with Briefers

5:00 PM PANEL DELIBERATIONS [Members Only; with ECBC Presenters on-call]

– *Dr. Adarsh Deepak*, Panel Chair (Science and Technology Corporation)

- Review and Discussions; Detailed Outline of Report; Member write-ups; Writing Assignments. (Members to bring their relevant papers/reports.)

6:30 PM WORKING DINNER (at The Crazy Swede)

Tuesday, 1 May 2001

7:30 AM Continental Breakfast

8:00 AM PANEL DELIBERATIONS -- Continued

– *Dr. Adarsh Deepak*, Panel Chair (Science and Technology Corporation)

11:00 AM ADJOURN