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Results of External Review Sandia National Laboratories Microelectronics and Photonics Program (October 2002)

David R. Myers, Paul Peercy

Prepared by
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Results of External Review
Sandia National Laboratories Microelectronics and Photonics Program (October 2002)

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Abstract

The US Department of Energy requires a periodic "self assessment" of Sandia's Microsystems Program. An external panel review of this program is held approximately every 18 months, and the report from the external review panel serves as the basis for the DOE "self assessment." The review for this fiscal year was held on September 30 – October 1, 2002 at Sandia National Laboratories, Albuquerque, NM. The panel was comprised of experts in the fields of microelectronics, photonics and microsystems from universities, industry and other Government agencies. A complete list of the panel members is shown as Appendix A to the attached report.

The review assesses four areas: relevance to national needs and agency mission; quality of science technology and engineering; performance in the operation of a major facility; and program performance management and planning.

Relevance to national needs and agency mission was rated as “outstanding.” The quality of science, technology, and engineering was rated as “outstanding.” Operation of a major facility was noted as “outstanding,” while the category of program performance, management, and planning was rated as “outstanding.” Sandia's Microsystems Program received an overall rating of "outstanding" [the highest possible rating].

The attached report was prepared by the panel in a format requested by Sandia to conform with the performance criteria for the DOE self assessment.

Contents

Executive Summary

Sandia's Microsystems program supports a very complex and unique mission. It must sustain technologies that support the enduring nuclear stockpile, whose weapons date from the 1960s, 70s and 80s while maintaining safety and reliability. Simultaneously it must develop leading-edge technologies for homeland security and future stockpile refurbishments. Sandia's microsystems program is "outstanding" by the DOE criteria.

Sandia is the world leader in radiation-hardened microelectronics. Further, Sandia is the only U.S. supplier of radiation-hardened mixed-signal integrated circuits. Sandia's radiation-hardened microelectronics is a National asset.

The panel noted excellent progress since the last review (held October 2 and 3, 2000). They noted a closer connection to customers than ever seen by the panel since this program's external reviews were initiated by the Department of Energy in 1996. At the same time, Sandia's microsystems basic science is world class and leading edge anywhere in the world. They congratulated Sandia for sustaining that research in an environment of increasing emphasis on delivering products. A very good balance has been achieved between long-term research and deliverables. However a tension exists between being successful with specific near-term deliverables against the need to continue to conduct research and to advance technologies to meet future needs. Although satisfied with the present balance between research and deliverables, committee members note that management attention will continue to be required to maintain an appropriate balance.

The program also is appropriately balanced between the commercial off-the-shelf technology solutions as well as the in-house manufactured solutions. Sandia Microsystems made substantial progress since the year 2000 review to achieve that balance.

The present review was held approximately one year after the events of September 11, 2001. The panel members admired the energy and conviction the presenters brought to the review – a passion that they were pleased to see and which they felt is very much needed.

The committee endorsed Sandia's Microsystems focus and noted the Microchem lab as a test vehicle for microsystems integration. The committee was very impressed with the Sandia's improved tech transfer model as maturing technologies from research concept to fielded products is seen as increasingly important in the post-9-11 world. Sandia has developed a robust model that specifically addresses the challenge of moving technology to products through the "valley of death."

The panel concluded by stating that with Sandia's expertise and its leading position in microelectronics, photonics, and microsystems, Sandia's Microsystems program consciously should assume the position of advising the nation in the area of microsystems for national security and for dealing with emerging threats.

I. Introductory Remarks

Sandia's Microsystems program has made excellent progress in the microelectronics, photonics, and microsystems area in the past few years. The program is appropriately balanced between the engineering deliverables and the science and technology base that will be required in order to continue to develop new deliverables. The program is also appropriately balanced between the commercial off-the-shelf technology solutions as well as the in-house manufactured solutions. The previous review noted a concern regarding the balance between externally supplied solutions and internally provided solutions. The members who were present at both the previous and the current review felt that the Microsystems Program had responded very well in resolving that concern. The panel noted that the presenters were very well prepared and the review was well organized, which enabled the panel members to understand the context as well as the materials.

[For purposes of the review, the Microsystems program consisted of elements of Center 1100 (particularly those located in the Compound Semiconductor Research Laboratory) and 8700 at the California site as well as the entire activity within Center 1700. These functional units are referred to as the "Microsystems organizations" for the remainder of this report.]

II. Evaluation of the Microsystems Program in Each of the Performance Areas

- ### II A. Relevance to National Needs and Agency Mission

  Performance in the area of relevance to national needs and agency mission is truly outstanding. The members of the panel with experience from previous reviews feel that the relevance exhibited in this review is higher than ever before. The panel also noted a much closer connection to customers than ever before. One measure of this focus was that the presenters were all able to articulate clearly the relevance of their work to national needs. Another measure was the extent to which the customers of the Microsystems program were able to come in and submit evidence that their needs were being met. In particular, testimony from the direct customers carried a lot of weight with the evaluators.

  The Microsystems program should become actively involved in helping determine what capabilities will be needed or desired in the future of nuclear weapons. The science base and microsystems approach supported by Sandia is key to re-weaponizing existing systems to increase accuracy or broaden use conditions. The science and technology base for such a mission is already strong and needs to be maintained. Further, Sandia's Microsystem program should communicate the implication of such changes. The panel recommends that Sandia should provide capabilities for the maximum possible number of options for future nuclear weapons and let the policy makers decide which options they want to implement.

  At the time of the review (October, 2002), the panel perceived that the Nation had not developed a clear direction and an associated set of priorities for Homeland Security. Sandia was advised to take an active role in providing information, guidance, and technical insights to

people making policy decisions to help nucleate a more coherent approach rather than try to pursue all directions at once. Further, the motivation and creativity of the technical staff should be applied to identify what Sandia can do well and Sandia should make sure those options are on the table for policy makers, as the panel felt it unlikely that policy makers would be aware of Sandia's capabilities among the press of multiple conflicting demands for the time and attention of policy makers.

In the post-9-11 environment, the panel noted that the Microsystems organization is more application-driven and better focused – not just in terms of working on relevant technologies but also by making sure that the technologies support applications that would make a real difference. Quite a number of the presentations communicated a real sense of urgency for the missions supported by microsystems technologies.

Compared with two years ago, the Microsystem organizations are much more application driven and much better focused. The Microsystem organizations are not only working on technology but also making sure it supports applications that will make a difference is terrific and important.

- **II B. Quality of Science, Technology, and Engineering**

The panel assessed the quality of science, technology and engineering as "outstanding." On panel member asked: "How about 'wonderful?' Can we use 'wonderful'?" [The DOE assessment ranking are summarized in Appendix B, and "wonderful" is not an option.]

The panel noted that the presentations were uniformly impressive and the panel stated they were uniformly impressed. Members of the panel whose service extended for several of the reviews stated that technologies that have been under development for several years have shown major advances since the previous review (October 2 and 3, 2000).

Several specific examples were cited.

Sandia's support for the Extreme Ultra-Violet Lithography (EUVL) program (largely through the efforts at Sandia's California site) is very impressive. EUVL is on the critical path of an important industry (semiconductor microelectronics is a worldwide industry with $160B annual revenue). The EUVL activity defined the state of the art. It is important for Sandia as an institution to nurture such components of its research portfolio. In light of current pressures to be more applied and achieve rapid product delivery, the research element can get squeezed out. It is wholly appropriate that the Microsystems organization should always look to the future and push a technology base appropriate for all Sandia's mission needs.

The work presented by Jerry Simmons on Tunneling in Lower-Dimension Quantum Structures is world class. Sandia is to be congratulated on sustaining that type of research given the current pressures to increase emphasis on delivering products. Sandia is one of the few institutions in the world that could attempt such fundamental work, let alone deliver such

results. Such exploratory work is totally appropriate as an essential element of the Microsystems program.

The micro-chem lab is also very impressive both in the science as well as in the maturation of the technology. The microchem lab is showing the way as a test vehicle for microsystem integration to help Sandia transition the technology from research concept into fielded products. In the post 9-11 world taking technologies from concept to fielded product will be important and extremely valuable to National security. The evolution of Microchem lab and its application as a bellwether approach to pioneering mechanisms to transition research concepts into fielded systems is a very good approach and an important exercise.

Radiation-hardened CMOS is a very important mission and a critical element of Sandia's Microsystems program. Sandia's radiation-hardened microelectronics capability is a unique national asset. Sandia is a recognized leader in rad-hard microelectronics science and technology and also serves as the only U.S. supplier of radiation-hardened mixed-signal integrated circuits (i.e., chips that combine both analog and digital functions). Sandia is to be commended for stabilizing its manufacturing process to achieve the maturity and robustness needed to deliver hardened integrated-circuit products to weapon system programs and satellite customers.

The quantity and the quality of work on reliability for microsystems were impressive. If microsystems are to be inserted into high-consequence applications such as the weapons programs or into satellites, they must possess assured reliability. On the basis of mission, staff, and facilities, Sandia is the ideal place to develop microsystem reliability. Sandia is doing a very good job in the science and technology and also a very good job in balancing the tension between long-term researches against providing immediate deliverables. [This topic surfaced again in discussing performance in the operation of a major facility.]

Col. McCasland of the panel advised the Microsystems organization to adopt formal risk management methodologies both for program management and also as a way of communicating risk to develop customer confidence.

- **II.C. Performance in the Operation of a Major Facility**

Performance in the operation of a major facility is "outstanding." However, the panel noted with concern the tension between providing short-term deliverables and continuing the research required to position the Microsystems program to support future programmatic deliverables.

The microsystems organization demonstrated a wonderful ability not only to understand what it takes to transfer research into product but also has demonstrated the ability to achieve that transition. However, such successes come with associated costs. There is a danger that, as production continues to increase in importance within the Microsystems organization, the research community at Sandia will lose their ability to access the facilities operated by the Microsystems organizations.

The MESA facility is divided into silicon microfabrication, compound semiconductors, and a transition area. Conflict and tension will naturally arise between the three different kinds of users of the same facility.

Given a fixed facility capacity, when research becomes so successful that it gets turned into a product, researchers must apply the same facility and the same equipment in which they did their research to satisfy production requirements. Sandia must determine where it will perform the long-term research that will be needed for the products ten or fifteen years from now. In particular, the Microsystems organization must develop a long-term vision and give serious thought at strategic levels as how best to assure a long-term future while achieving shorter-term product deliveries.

One facility issue is a growing demand for the Microsystems organization to manufacture specific products. MESA will update, but not enlarge the principal production resource. Sandia's Microelectronics Development Laboratory already operates three shifts, five days a week. The Microsystems organization must think through how to manage this vector of increasing demand for product, as no easy options are left for increasing capacity.

The laboratory space within the Microsystems fabrication facilities is not large. A potential conflict could arise and should be flagged for management attention between producing limited volumes of niche products versus having access to facilities that could prototype and evaluate "wild and wonderful" theoretical concepts.

Thus, the Microsystems organization must develop plans to manage and educate the research staff as to what tools and capabilities they will have available. The scientists and engineers must have a mechanism that will let them think through "How do I get to try out my idea with the tool set that I have?" Clever engineers and clever scientists will figure ways to do this but it will be an education process for management as well as staff. That some contention has already occurred between research and product development activities has helped. These comments do not reflect on the quality of the staff nor the research – both are very high. However, continued management attention will still be required.

Another issue is that the Microsystems technology roadmap for integrated circuits considers Sandia microelectronics technologies only through the 0.18-micrometer technology node. Ten years from now when the industry is projected to be at 0.02 micrometers, Sandia's program would be scheduled to be at approximately 0.2 micrometers. It is not clear whether such a technology gap will be acceptable to Sandia's leading-edge customers – or whether instead Sandia must devote additional attention and resources to narrowing the performance gap between Sandia technologies and those available through less robust and less survivable commercial technologies.

Sandia is encouraged to find a way to engineer itself out of being overloaded in the product area. In many technology areas, Sandia is the producer of last resort. For example, the 105th Congress mandated that Sandia serve as the Nation's contingent supplier of radiation-hardened microelectronics. In the radiation-hardened microelectronics, Sandia is not only the primary producer for state-of-the-art products, Sandia is the only producer for strategically

hardened mixed-signal and analog integrated circuits. Economic concerns suggest it is likely that Sandia will remain in that role. Sandia is advised, to the extent possible, to develop one or more industrial partners to let them take over some of the production load. The Microsystems organization is commended for its willingness to supply its customers with industry products provided industry's products meet customers' needs and requirements.

- **II.D. Program Performance and Management**

Performance planning and management is "outstanding" with respect to staff, facilities, and the strategic planning that had gone into positioning the Microsystems organization to meet current needs. As previously emphasized, the Microsystems organization must carefully examine possible futures and decide now what technology will be needed, what its customers will likely need, and what resources will be required to meet those needs.

Previous planning activities have proven successful in positioning the Microsystems organization to meet its present mission – even for such unexpected events as 9-11, the war in Afghanistan, and Homeland Security. It is often easier for organizational units to plan the technology than it is to decide now what its customers are actually going to need at some future time. The next few years will require additional management attention to position this organization to meet future needs in the face of extremely difficult and changing priorities in national security, especially those following 9-11 and the Nuclear Posture Review.

In that regard, more of an emphasis on scenario planning for ten or twenty years out or frankly even two and three years out is needed. The Microsystems organization should spend a fair amount of time assessing the various scenarios that it may have to address.

Still, there was good evidence that this strategic thinking has begun. The Microsystems organization has embodied its strategic thinking all the way into the business plan. The business plans were tremendously informative. They detailed in a structural sense how the program is progressing and linked the activities to the individual performing organizations. The business plans were very detailed and gave the general profile of the activity. Such plans could provide a solid basis for projecting needs out to five or ten years from now.

The plan demonstrated value in linking present planning and execution toward longer-term goals. The roadmaps for each of the constituent microsystems technologies are clear and good. However, the panel could not evaluate progress against all those roadmaps given the limited amount of time available for the review.

The Microsystem organizations presented metrics on cost, timelines and operational efficiency. However, insufficient metrics were presented to allow the panel to evaluate to what extent the products were delivered to customers on time, within cost, and on schedule. [Note added in proof: After the review was held, the Microsystem organizations were recognized by NNSA's Concurrent Design and Manufacturing (CDM) program for their second consecutive year of on-time, within-budget, mark-quality deliveries.]

As mentioned previously, the Microsystems organization is to be commended for developing a novel and robust approach to technology transfer. Sandia's Microsystem organizations have tackled the problem of how to transfer technology from concept into product – how one bring a prototype concept across the so-called "valley of death" into full-scale production.

- **II.E. Overall Asssessment**

  Sandia's Microsystems program is rated as "outstanding" overall in terms of the DOE assessment scale. [See Appendix B for the DOE rating system and associated verbal descriptors.]

III. Concluding Remarks

Sandia's Microsystems program supports a very complex and unique mission. It must sustain technologies that support the enduring nuclear stockpile, whose weapons date from the 1960s, 70s and 80s. It must simultaneously develop leading-edge technologies for homeland security and future stockpile refurbishments. The Microsystems organization must be able to provide the components required to upgrade all of the arming, firing, fusing to keep such high-consequence systems as nuclear weapons safe, secure and reliable. Meeting that mission requirement does not require tomorrow's, next generation IC technology. Instead, special rad hard capability and reliability expertise are required.

On the other hand, Sandia's Microsystem organizations must develop and field leading-edge technology for homeland security and defense systems. It is apparent that more and more customers are clamoring for components that need state-of-the-art technology. Satisfying both customer sets and achieving an appropriate a balance is an exciting but challenging assignment.

A unique combination of people, expertise, and mission qualify Sandia microsystems to advise the nation as to what it needs in the area of microsystems to support national security and to deal with emerging threats. The panel recommends that Sandia should assume the role of providing decision makers with unbiased information on microsystems technologies. The nation's policy makers need to know these technologies exist to protect the nation against threats that were just not imaginable a couple of years ago. The events of 9-11 suggest that such threats were really unimaginable by most people in this country or even by most people in the developed world. However, the panel asserts that Sandia is in the ideal place with the expertise and the leading position that you have in this micro-electronics, microfluidics, microsystems, and micro-technologies in general to be the voice for the nation in the area of microsystems for national security.

The panel noted a passion among the presenters and the whole organization that was very pleasant to see and very much needed. These technologies can make a major difference. As one example, before the war in '91, one of the comments by our adversary was we didn't believe that the United States would be able to fight a desert war because you wouldn't know where you were and so forth. But we overcame that with global positioning and achieved a truly overwhelming victory. The panel was

reassured by the initiative and passion exhibited by the Microsystems organization that the nation will have the ability to develop such technologies again. Even though the technical presentations in themselves were remarkable just for their content, the energy level of the presenters and the conviction that the organization displayed evoked the admiration of the panel.

In conclusion, the panel was very impressed with the current state of the organization and the progress that's been made. They were very impressed with the much closer tie to the customer and much more sensitivity to meeting the needs of the customer in a cost effective, timely manner. Your Microsystem's focus is excellent. I think MESA was conceived as a national resource, we as a nation need it, and the panel believes think it's well on track toward that goal. You are to be commended for a job well done here.

Appendix A: Panel Membership

•Dr. Jack Boudreaux, Program Manager, Information Technology and Applications Office, National Institute of Standards

•Dr. F. Ben Cole, Director, Research Associate Directorate, National Security Agency

•Dr. Jerry Gaspar, Vice President, Engineering and Advanced Technology, Rockwell Collins

•Dr. Ross A. Lemons, Director, Materials Science & Technology, Los Alamos National Laboratory

•Col. Niel McCasland, Director, Space Vehicle Sector, Air Force Research Laboratory

•Dr. Paul Peercy, Dean, College of Engineering, University of Wisconsin (chair)

•Dr. Tom Seidel, Executive Vice President and CTO, GENUS

•Dr. Quat Vu, Interconnect and Packaging Manager, External Programs & Technology, Intel Corporation

•Dr. Kensall Wise, Professor, Electrical Engineering and Computer Science, University of Michigan

Appendix B. DOE Evaluation Criteria

Narrative Rating	Numerical Rating	Definition
Outstanding	90-100	Significantly exceeds the standard of performance; achieves noteworthy results; accomplishes very difficult tasks in a timely manner.
Excellent	80-89	Exceeds the standard of performance; although there may be room for improvement in some elements, better performance in all other elements more than offsets this.
Good	70-79	Meets the standard of performance; assigned tasks are carried out in an acceptable manner - timely, efficiently, and economically. Deficiencies do not substantively affect performance.
Marginal	60-69	Below the standard of performance, deficiencies are such that management attention and corrective action are required.
Unsatisfactory	Below 60	Significantly below the standard of performance; deficiencies are serious, may affect overall results, and urgently requires senior management attention. Prompt corrective action is required.

Programs are to be rated in each of four areas:

1. Relevance to national needs and agency mission

2. Quality of science, technology, and engineering

3. Performance in the operation of a major facility

4. Program performance, management, and planning

Appendix C. Final Agenda

Monday, September 30

7:00 Meet Group at Marriott..... Sandia Transportation
Sandia Escort (for all transportation)..... Carol Sumpter
Member Technical Staff (505) 284-6552, Cell (505) 235-4338

Microelectronics Development Laboratory (MDL)
Building 858, Conference Room 1004

7:30 Continental Breakfast
Attendees: Jack Boudreaux, Ben Cole, Jerry Gaspar, Ross Lemons, Neil McCasland, Paul Peercy, Tom Seidel, Quat Vu, Kensall Wise, Marion Scott, David Myers, Glenn Kubiak, Carol Sumpter

8:00 Welcome, Overview, and Business Plan.....Marion Scott
Director, Microsystems Science, Technology and Components (505) 845-8186

9:00 Nuclear Weapons.....Don Cook
Director, MESA Program Office (505) 845-7446

10:00 Non Proliferation ..... Anthony Medina
Deputy Director, Space Technology Programs (505) 845-8120

10:45 Break

11:00 Homeland Security .....Dennis Miyoshi
Director, Security Systems and Technology (505) 845-9926

12:00 Lunch
Attendees: Jack Boudreaux, Ben Cole, Jerry Gaspar, Ross Lemons, Neil McCasland, Paul Peercy, Tom Seidel, Quat Vu, Kensall Wise, Marion Scott, David Myers, Dennis Miyoshi, Paul Dodd, Glenn Kubiak, Carol Sumpter

12:50 Overview .....David Myers
Principal Deputy, Microsystems Science, Technology and Components (505) 845-9563

1:00 CMOS 7 and BUSFET .....Paul Dodd
Team Leader, Radiation Physics, Simulation and Technology (505) 844-1447

1:45 EUVL Progress and Ties to Homeland Security.....Glenn Kubiak
EUVL Program Manager, Nanoscale Science & Engineering Section Leader (925) 294-3375

2:15 Reliability of Microsystems.....Fred Sexton
Manager, Radiation and Reliability Physics (505) 844-3927

2:45 Break

3:00 MicroChemLab.....Steve Martin
Deputy Director, National Security and Sensors (505) 844-9723

3:45 Tunneling in Lower-Dimension Quantum Structure..... Jerry Simmons
Manager, Semiconductor Materials and Device Sciences (505) 844-8402

4:30 Depart for Marriott ..... Sandia Transportation

5:30 Pickup Group at Marriott and Transport to Sheraton..... Sandia Transportation

6:00 Dinner at Sheraton Old Town..... 800 Rio Grande Blvd. NW, 222-8736
Attendees: Jack Boudreaux, Ben Cole, Jerry Gaspar, Olivia Gaspar, Ross Lemons, Neil McCasland, Paul Peercy, Tom Seidel, Quat Vu, Kensall Wise, Marion Scott, David Myers, Don Cook, Mike Knoll, Thomas Zipperian, Jay Jakubczak, Dennis Miyoshi, Anthony Medina, Paul Dodd, Glenn Kubiak, Fred Sexton, Stephen Martin, Jerry Simmons, Michael Daily, Carol Sumpter, Ron Hoskie, Ron Manginell, David Fein, Greg Hassig

After Dinner Music by Cumulonimbus the Native American music group featuring Sandians Ron Hoskie, Ron Manginell, David Fein, and Greg Hassig

9:00 Pickup Group and Transport back to Marriott..... Sandia Transportation

Tuesday, October 1

7:30 Meet Group at Marriott..... Sandia Transportation

Microelectronics Development Laboratory (MDL)
Building 858, Conference Room 1004

8:00 Continental Breakfast
Attendees: Jack Boudreaux, Ben Cole, Jerry Gaspar, Ross Lemons, Neil McCasland, Paul Peercy, Tom Seidel, Quat Vu, Kensall Wise, Marion Scott, David Myers, Glenn Kubiak, Carol Sumpter, Tom Zipperian

8:30 Heavy Labs, Impact of MESA, Technology Migration ..... Tom Zipperian
Unit Director, MESA Fabrication (505) 844-6407

9:00 Product Deliveries and Commitments..... Mike Knoll
Unit Director, Design and Products (505) 844-6735

9:45 Microsystem Deliveries..... Mike Daily
Manager, Integrated Microsystems (505) 844-3145

10:15 Planning Process and Wrap Up .....David Myers

10:30 Break

10:45 Panel Deliberations

12:00 Working Lunch for Panel

1:00 Panel Outbrief to Sandia Management
Attendees: Al Romig, Vice President, Science and Technology and Partnerships; John Stichman, Vice President, Weapon Systems; David Nokes, Vice President, National Security and Arms Control; Marjorie Tatro, Director, Energy and Transportation Security; Carolyne Hart, Director, Nuclear Weapons Science and Technology Programs; Julia Phillips, Director, Physical and Chemical Sciences; Marion Scott, Don Cook, David Myers, Carol Sumpter, Glenn Kubiak

2:00 Transportation Available to Marriott and Airport ..... Sandia Transportation

Appendix D: Abstracts

(shown in order of presentation)

- **Welcome and Overview - Marion Scott**

  Sandia's Microsystems activity exists to provide National Security Solutions through Sandia's Strategic Business Units (SBUs) and Strategic Management Unit (SMU). The work content spans the capabilities represented by several Centers within the laboratories. Microsystems activities are coordinated through the Electronic Science and Technology Council, which consists of representatives of the SBUs and SMU from centers that have substantial electronics capability and are critical to accomplishing SNL's fundamental mission. The council includes organizations across the labs that have system, component, and technology development responsibilities. Through these council members and their internal and external partnerships, we have identified the attributes of the products and services needed by Sandia to supply security solutions to the Nation. We execute this activity through research, development, and engineering, by operating facilities for prototyping and low-volume production, and through partnerships with universities, other government agencies, and external suppliers.

  As the National Research Council's Report on the War on Terrorism (Chapter 12) noted: " Research performed but not exploited, and technologies invented but not manufactured and deployed, do not help the nation protect itself from the threat of catastrophic terrorism." To meet National Security needs, we must be able to move our research results into microsystem products while meeting customer expectations for performance, cost, and schedule. We have analyzed the requirements for moving research and development into fielded systems and will demonstrate the applicability of this approach through specific examples throughout the review program.

- **Nuclear Weapons - Don Cook**

  The interplay of four factors help shape the future of the nation's nuclear deterrent. Fact 1: The US nuclear stockpile contains the most powerful explosive devices in the US arsenal that are on "alert" status. Fact 2: The effectiveness of modern technologies applied to targeting, delivery, and fusing of conventional munitions, demonstrated in the 1991 Gulf War, created a very capable class of advanced conventional munitions. Fact 3: In 1993, the US made a decision to extend for an indefinite period of time the moratorium on underground nuclear testing that began in 1992. It was argued that new nuclear explosive package development (the role of LANL and LLNL) is constrained by the cessation of underground nuclear testing, but that confidence in the readiness of the existing stockpile could be achieved through a program of science-based stockpile stewardship. Fact 4: In the case of Sandia's mission responsibilities, no limitations were put in place that either precluded or hindered the objective of keeping nuclear weapons safe, secure, and reliable. These four facts are related to each

other, at least indirectly. The 2001 Nuclear Posture Review (NPR) called for integrated planning of both nuclear and non-nuclear forces. NNSA is charged with maintaining the capabilities of the nuclear stockpile under the guidance of the NPR. The associated work scope includes not only extending the life of existing weapons, but also weapon system improvements and modernizations, and new weaponizations of existing explosives where required by mission need. This talk will cover the NW SBU requirements and expectations for weapon microtechnologies for the next 1-2 decades.

- **A New Microsystem Sensor for Nuclear Explosion Monitoring - Anthony Medina**

  The mission of the NNSA Nuclear Explosion Monitoring Program is to develop, demonstrate, and deliver advanced technologies and systems to operational monitoring agencies to support US monitoring requirements for detecting and characterizing nuclear explosions.

  As a key NNSA Laboratory in executing this mission, Sandia National Laboratories is charged with maintaining and developing new sensor and electronics technologies to meet growing monitoring requirements. A fundamental component of this capability is Sandia's ability to design, manufacture, and integrate advanced microsystems for spaceflight applications. The latest microsystem sensor under development will be described to demonstrate how this capability is leveraged to provide new capabilities for monitoring systems.

- **Physical Security Systems for Homeland Security - Dennis Miyoshi**

  The tragic events of September 11, 2001, highlighted the need to improve the protection of our nation's critical infrastructure. Like most Americans, the people of Sandia National Laboratories responded to the atrocities of September 11, 2001, with newfound resolve on both a personal and professional level. As the lead laboratory for physical security research and development for DOE's Office of Safeguards and Security, Sandia has a rich history providing security solutions for high-consequence facilities. Over the past 25 years, DOE has invested over $500 million in Sandia's security programs. The results of this investment include unique sensor-testing facilities, advanced security systems, a wealth of system-testing experience and capabilities, and a large, multidisciplinary technical base. This talk will highlight key issues in assuring the protection of high-value assets and identify the drivers for the development and deployment of microsystems technologies.

- **CMOS 7 and BUSFET - Paul Dodd**

  Radiation-hardened microelectronics remains a critical need for a number of Sandia's SBUs. We must refurbish and migrate the nuclear weapons stockpile, as well as ICs flown in space on Sandia satellite payloads. Sandia's radiation-hardened microelectronics strategy continues

to be to buy parts from commercial suppliers where products meet customer requirements, while simultaneously developing, producing, and delivering radiation-hardened ICs from the MDL where we are uniquely qualified. Meeting our customers' challenging needs and enabling new system applications requires a continually evolving rad-hard IC process technology.

The science and technology of radiation-hardened microelectronics requires an appropriate mixture of IC fabrication technology, design, simulation, radiation physics, and hardness assurance. Our science-based approach to developing new rad-hard IC processes will be illustrated by our migration to a 0.35-μm silicon-on-insulator process. This experience highlights the importance of three-dimensional simulations in guiding early process and design decisions. The successful application of this technology to memories and custom processors was awarded a DOE Weapon Award of Excellence in 2002. We will conclude by summarizing the issues in the further migration of rad-hard technologies and direction for future research based on our experience in the radiation assurance of advanced commercial technologies even for terrestrial applications.

- **Progress in the Extreme Ultraviolet Lithography Program - Glenn D. Kubiak**

Sandia is working jointly with Lawrence Berkeley and Lawrence Livermore National Laboratories and a consortium of semiconductor manufacturers to develop Extreme Ultraviolet Lithography (EUVL) for the commercial production of integrated microelectronics. EUVL is the industry consensus choice for supporting high-volume integrated circuit lithography needs for CD's below 65 nm. This technology builds on conventional optical lithography experience and infrastructure, uses 13.5 nm photon illumination, and is expected to support multiple technology generations down to 22 nm. The EUVL development program is sponsored by a consortium of semiconductor manufacturers, the EUV Limited Liability Company (LLC), composed of Advanced Micro Devices, Intel, Motorola, Micron, Infineon and IBM. The program goals include: (1) facilitating the research, development and engineering to enable lithography equipment manufacturers to provide beta and early production exposure tools to support ≤65-nm IC manufacturing by 2005, (2) development, integration, and testing of an "alpha"-class exposure tool to provide EUV learning and early process development, and (3) assisting in the development of the supplier and process infrastructure to assure the availability of masks, optics, coatings, photoresists, EUV sources, and metrology for successful technology implementation in manufacturing. This presentation will summarize recent progress in the development and testing of the alpha-class EUVL exposure tool located at Sandia/CA. We conclude by briefly discussing applications and extensions of the resulting EUVL patterning capability for Sandia microsystems applications.

- **Microsystem Reliability - Fred Sexton**

  Sandia's National Security mission solutions require high reliability and predictable behavior for high consequence applications. Sandia achieves high reliability and war reserve quality product for its stockpile deliveries through a physics of failure based understanding. The introduction of a new technology, such as MEMS or other microsystems, requires the development of a similar fundamental understanding of physics of failure – for different technologies and new materials with different failure mechanisms – so that robust qualification and assurance methodologies can be validated. Research suggests that a robust solution to meet this need is by assembling microsystems into a controlled microenvironment. Science of aging to determine how to control and where to control the internal environment forms the basis for this approach.

Electronic Interactions in Lower Dimensional Semiconductor Structures - Jerry Simmons

This talk will give an overview of Sandia's work on lower dimensional semiconductor structures which interact with one another. After reviewing earlier work on Tunable Fermi surfaces in coupled double quantum wells, I will describe more recent work on a quantum tunneling transistor operating at 77K, and on coupled ballistic double 1D quantum wires. Finally, I will describe our current efforts to produce Bose condensation in Coulomb-coupled electron-hole bilayers.

- **MicroChemLab Program - Steve Martin**

  The terrorist attacks of September 2001 revealed a critical need for technologies that can rapidly identify threats to the United States. These threats included explosives, chemical and biological warfare agents, and radiological materials. Systems to identify these threats are needed for a number of applications, including portal screening, facility protection, first responders, unmanned aerial vehicles, and intelligence collection for non-proliferation.

  Traditionally, bench-top laboratory instrumentation has been required to characterize chemical, biological, or radiological threats. Many of the applications, however, require systems that are hand-held or smaller and must be fairly low cost for widespread deployment. Analytical instrumentation can be dramatically reduced in size and cost by using microfabrication techniques to produce the analytical components in the system.

  Sandia is applying microsystems technology to miniaturize a number of analytical systems, including the gas chromatograph, mass spectrometer, ion mobility spectrometer, and optical correlation spectrometer. Microfabrication of analytical components reduces the size, weight, and power requirement, enabling the system to be battery powered and contained within a hand-held unit. In many cases, the scaling down of component size also leads to significant performance advantages such as decreased analysis time. In addition, the batch fabrication of

analytical components can lead to significant cost reduction (analogous to integrated circuits) enabling widespread deployment of detectors and improved coverage.

This talk will focus on the development of MicroChemLab, a hand-held chemical analysis system that collects an air sample and can detect a wide range of chemical warfare (CW) agents in about two minutes. The system uses microfabricated analysis stages to achieve small size, rapid analysis, and low operating power. Prototype systems have successfully detected CW simulants in atmospheric tests and actual CW agents in laboratory tests. MicroChemLab is being developed for a number of government agencies for facility protection, first responders, and micro UAV applications. In addition, several companies are partnering with Sandia to develop the technology for commercial applications.

- **Heavy Labs, Impact of MESA, Technology Migration - Tom Zipperian**

In support of our mission to deliver microsystems technologies to Sandia's Strategic Business Units, Center 1700 operates two heavy laboratories (cleanrooms). The Microelectronics Development Laboratory (MDL) is a 33,000 net sq. ft., class 1, cleanroom, operating in a near-production mode, which specializes in radiation-hardened microelectronics and polysilicon-based, micro-electro-mechanical systems (MEMS). The Compound Semiconductor Research Laboratory (CSRL) is an 8000 net sq. ft., class 100, research facility specializing in compound semiconductor-based RF microsystems technologies, sensors and sensored systems, and micro-power. RF microsystems include high-frequency electronic, optoelectronic, and photonic component technologies. Significant work in both the hybrid and monolithic integration of these various components into microsystems is performed in both laboratories. Applications-driven, technology migration strategies have been developed for all of these research areas.

MESA (Microsystems and Engineering Sciences Applications) is a $450M capital improvement project, which will have significant effect on these facilities over the next few years. MESA will merge the MDL and CSRL into a single facility dedicated to microsystems technologies at the same time that it completely recapitalizes the microfabrication infrastructure at Sandia. It also brings three distinct communities (weapons systems engineering, microfabrication, and computational science and engineering) together in one complex.

This talk will describe the operation of the two heavy laboratories, our roadmaps for technology support and migration, and will detail the impact of the MESA program on these capabilities.

- **Product Deliveries and Commitments - Mike Knoll**

The Microsystems Center designs, develops, and delivers microelectronics integrated circuits (ICs), electronic components, and microsystems products to our Strategic Business Unit

customers, which are Nuclear Weapons, Nonproliferation and Materials Control, Energy and Critical Infrastructure, and Emerging Threats. These products are provided to our customers through both "Make" and "Buy" methodologies. Our strategy is to buy commercial products where they meet our mission needs and to maintain in-house research, technology, and product capabilities where industry capabilities either do not exist or are at risk of continuing to exist. Lack of industry capability to meet our hostile environments is especially true of Microsystems and Radiation Hardened Microelectronics.

This briefing will describe Sandia's: 1) radiation hardened CMOS IC product development & deliveries, and 2) approach to selecting and qualifying COTS components for hostile environment applications.

- **Microsystems Products - Mike Daily**

To meet the needs of our SBU customers we must be able to move our research results into microsystem products while meeting customer expectations for performance, cost, and schedule. Taking new technologies from the laboratory to fieldable product has been compared by some to crossing a "Valley of Death". We will discuss the methodology used to approach this challenge in order to maximize delivery of high value products. We will discuss specific examples of current and past projects.

- **Planning and Operations - David Myers**

Sandia's Microsystems Science, Technology, and Components Center 1700 is a key element in Sandia's Microsystems Activity. This talk will briefly summarize key financial and staffing aspects in the context of our formalized planning, and restate the charge to the review panel.

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