SANDIA REPORT

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Results of External Review Sandia Microelectronics and Microsystems Program (September 2004)

P. S. Peercy, D. R. Myers

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Results of External Review Sandia Microelectronics and Microsystems Program (September 2004)

Paul S. Peercy
University of Wisconsin-Madison
Madison, Wisconsin 53706

David R. Myers
Microsystems Science, Technology and Components Center
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-1071

Abstract

The US Department of Energy requires a periodic assessment of the Microsystems Program at Sandia National Laboratories. An external review of this program is held approximately every 18 months to 24 months. The report from the External Review Panel serves as the basis for Sandia's "self assessment" and is a specific deliverable of the governance contract between Lockheed Martin and the Department of Energy.

The External Review of Microelectronics and Microsystems for Fiscal Year 2004 was held September 27 – 29, 2004 at Sandia National Laboratories, Albuquerque, NM. The external review panel consisted 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 included as Appendix A of the attached report.

The review assessed 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 rated as "outstanding," and the category of program performance, management, and planning was rated as "outstanding." Sandia's Microsystems Program thus 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 to the historic performance criteria for the DOE self assessment

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Contents

Executive Summary

Sandia's Microelectronics and Microsystems program supports a unique and very complex mission. The microelectronics and microsystems technologies developed within this activity are directly relevant to the National Nuclear Security Agency's programs in nuclear weapons and nonproliferation, to the Department of Defense, to the Nation's energy supply and critical infrastructure, to the U.S. intelligence community, and to Homeland Security. Approximately every two years, Sandia convenes a panel 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 included as Appendix A.

Among their comments, the Panel highlighted:

- a dramatic and continuing increase in the sensitivity to customers' needs,
- focused improvement of internal processes,
- expanded product range including first-time delivery of key compound-semiconductors products typified by the Photoconductive Semiconductor Switch,
- work with outside suppliers for custom weapon components and the qualification of appropriate commercial off-the shelf components (COTS) for war-reserve (WR) applications (WR COTS),
- new initiatives and developmental work in biotechnology,
- increasing relevance to non-Nuclear Weapons Strategic Management Units (SMUs) at Sandia, and
- a unique and innovative formalism for converting innovation into products for its entire customer base, and the Panel recommended this approach for submission to the Product Development Management Association's Outstanding Corporate Innovator award.

The Panel made several specific recommendations:

- Sensor technology can be a major growth platform. Sandia should continue to be concerned with getting solutions into the marketplace rapidly.
- The Panel asserts that biology-related areas have tremendous potential.
- Presenters should put the research and technology they discuss in the context of the work being done elsewhere.
- *Keep doing the good things:* (1) Expand strategic thinking and strategic alignment, (2) Continue process improvements (lean six sigma), (3) Continue to engage customer groups and future customers, (4) Maximize leverage from technology, (5) Maintain ongoing review and coordination of sensor research to ensure new sensors are compatible with a microsystem approach.
- *Sustain cultural changes:* (1) Continue use of the Balanced Scorecard, (2) Sustain strategic links to universities (MESA Institute), (3) Continue strong ties to customers through Sandia's Strategic Management Units, (4) Continue to train staff in good business practices (e.g., Counselor / Salesperson), (5) Continue implementing strategic planning teams, (6) Continue emphasizing to staff and managers the importance of having a clear notion of deliverables and of delivering on time and within budget.
- Sandia -- lab wide – must be able to react to events in the world in a future that we do not know. The Microsystems organizations should be agile and share their methodologies across

the lab because the work being done in the microelectronics and photonics, sensors and microsystems is central to Sandia's future.

- In the longer term, the Microsystems organizations must deliver product and value to a diverse customer base even if they are not able to advance the silicon integrated-circuit technology below the 0.18 micrometer node in phase with commercial suppliers. The Panel wants the Microsystems organizations to analyze the consequences of this inability to keep pace with leading-edge IC technology and report back in two years.
- For presentation at the next review, the Panel would like the Microsystems organizations to define the rigor, frequency, and methodology of reviewing its research, development, and production that sustains the activity at such a high performance level.
- The Panel recommends that Sandia increase the number of permanent staff in the microsystems area.
- With the rapid increase in biology-related activities, the Panel recommends adding someone to the Panel who has technical expertise in these areas.

The panel evaluated Sandia's microsystems program as "outstanding" in each of the evaluation 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; and (4) program performance management and planning using the historic DOE criteria (Appendix B). These ratings resulted in an overall rating of "outstanding" – the highest possible rating.

Results of External Review Sandia Microelectronics and Microsystems Program (September 2004)

I. Introduction

Sandia's Microelectronics and Microsystems program supports a unique and very complex mission. It must sustain technologies that support the enduring nuclear stockpile whose weapons date from the 1960s, 70s and 80s. Simultaneously it must develop leading-edge technologies for future stockpile refurbishments—while maintaining absolutely the highest standards of safety, security, and reliability. Sandia is the world leader in radiation-hardened microelectronics for strategic weapon systems. Further, Sandia is the only U.S. supplier of radiation-hardened mixed-signal integrated circuits. Sandia's radiation-hardened microelectronics is a National asset. In approximately one year, Sandia's Microelectronic Development Laboratory (MDL) and Compound Semiconductor Research Laboratory (CSRL) will merge in the new MESA (Microsystems and Engineering Sciences Applications) MicroFab.

Sandia's senior management team believes the linkage of microelectronics and microsystems to all of Sandia's customers through the MESA program is central to Sandia's future. Making the Nation's investment in MESA into a differentiating advantage for all of Sandia's customers is the number one priority of Sandia's Science Technology and Engineering (ST&E) Strategic Management Unit (SMU). The Microsystems organizations must achieve the agility to respond rapidly with new products when new threats emerge.

The microelectronics and microsystems technologies developed within this activity are directly relevant to the Department of Defense, the Nation's energy supply and critical infrastructure, the U.S. intelligence community, and Homeland Security.

To assess such a broad and important program area as microelectronics and microsystems, Sandia convenes an External Review Panel to evaluate the program from industry, university, and government perspectives. The technical expertise represented by the Panel ranges from silicon to compound semiconductors to micromachines to sensors to advanced packaging, and from scientific and technical expertise to management theory and practice. The majority of the panel members have supported this review for a dozen years and have developed a solid understanding of Sandia's microelectronics and microsystems program. The panel takes their service seriously and their opinion is highly informed. The Panel retains a strategic focus by sampling the program every two years, the Panel focuses on strategic

issues. Although they only see a selected sample of the activities, the members' experience allows them to see below the surface to the underlying realities.

The Panel expressed its appreciation for the well organized program and uniformly high quality of the presentations. The Panel stated they received a very good overview of the Microelectronics and Microsystems Activity and how it fits into Sandia's mission. Key customers provided a clear perspective on the role and importance of Microsystems Research, Technology and Applications.

The Panel noted the thorough response to the recommendations and questions from the previous External Review (SAND2003-3486, Printed October 2003). [See Appendix E.]

For the purposes of the review, the Microsystems program consisted of elements of Center 1100 (particularly those located in the Compound Semiconductor Research Laboratory), 8700 at Sandia's California site, and 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

The panel rated the Microelectronics and Microsystems Program as "outstanding" in all four evaluation areas for an overall rating of "outstanding" – the highest possible rating. [See Appendix B for the evaluation criteria.]

II.A Relevance to National Needs and Agency Mission

The Panel rated the Microelectronics and Microsystems program as "outstanding" in the area of relevance to national needs and agency mission. The Panel felt that Sandia's Microsystems Technology Program is very relevant to both national needs and Sandia's mission. The Panel also felt that the Microelectronics and Microsystems program is well aligned with its mission. This assessment is especially true today for the topical areas of Microelectronics, Photonics, and Microsensors. The move toward biology appears to have great potential.

The panel also recognized a dramatic increase in the sensitivity of the Microelectronics and Microsystems program to its customers and their needs. The panel noted significantly strengthened ties to customers and an improved responsiveness.

The panel favorably noted that the Microsystems organizations recognized that they must understand the needs of the customers of its immediate internal customers (their "customers' customers") to suggest effective technology solutions that will meet those larger needs.

The Panel saw satisfied customers but was unable to independently contact the entire customer set within the limited time available for the review.

The Panel felt that the scenario planning by the Microsystems organizations was excellent. The world is facing major uncertainties. The future of Sandia in those areas in which it should serve the nation is uncertain. The Microsystems organizations are challenged to prepare for a future where decisions are political and have not yet been made. Scenario planning helps the Microsystems organizations think through the possible futures and its possible roles in those futures.

The Panel believes that Stockpile Stewardship and the Stockpile Life Extension Programs are much more important to the Nation than some people in the political arena seem to recognize. The role of microsystems technology is vital to Stockpile Stewardship and the Stockpile Life Extension Program.

The Panel believes that sensor technology can be a major growth platform. Given the nature of today's uncertain threats, the Microsystems organizations should work to convert technology from design and conceptualization to being fielded on a much shorter time scale. The paradigm for this approach is the Micro Chem Lab, on which work began long before 9/11. Developing this technology base so that it is available when needed is thus a critical component to the microsystem mission.

Thus, the Microsystems organizations should consider the importance of getting solutions into the marketplace rapidly as opposed to developing a long-term program or a longer-term program to develop multiple point solutions. One option is to develop a low-cost extendible architecture that can easily be upgraded in the field. Such an approach will require industrial partners, but the benefit of this approach is that it would enable generations of compatible technologies and perhaps a succession of platforms, for example, like the Micro Chem Lab. This approach would maximize the impact of a significant amount of outstanding technology that could be used to create future sensors and sensor systems.

Sandia is a neutral party and one of the largest players in microsensors, and the Panel recommended working with microsystem customers to try to develop a common, open platform for microsensor systems.

The Panel noted and endorsed the level of communication between the microsystems architectures specialists and the sensor researchers. The Panel encourages ongoing review and coordination of sensor research through this mechanism to ensure that new sensors are compatible with the microsystems approach.

The Panel also noted an untapped opportunity for microsystems to support the broader Nuclear Weapons Complex. Greater application of microsystems could make the Complex significantly more responsive to access control and materials tracking, particularly in secure environments. Sandia is particularly well positioned in this area and has the expertise to solve those problems.

II.B Quality of Science, Technology, and Engineering

The Panel rated the quality of science technology and engineering as "outstanding."

The Panel favorably noted the responsiveness of the Microsystems organizations to questions raised at the last review (see Appendix E) regarding the continuing availability of the silicon integrated-circuit capabilities and the compound semiconductor facilities to researchers to help them continue to drive the underlying science and technology despite the delivery pressures associated with the nation's response to the events of September 11, 2001. The Panel noted that the Microsystems organizations addressed these questions very thoroughly and exhibited a good balance between research, support for research, product development, and product delivery.

Presentations at this review demonstrated that Sandia has a very strong research base that will generate new knowledge and scientific understanding which will be important for future microsystems technology in even broader areas than those of today.

The approach and execution was outstanding and very well balanced.

The Panel assesses the biology-related areas as having tremendous potential. However, due to the composition of the Panel, it was difficult for the Panel to put the biology-related research in the context of similar research underway at other places. In future reviews it would be helpful for the presenters to put their research and technology in the context of work being done elsewhere.

The Panel recognizes that Sandia's Microsystems organizations are sustaining very high quality research. An ongoing self-assessment must be in place to keep it that way. The Panel would like a description of the process used by the Microsystems organizations to keep the research at such high quality.

The Panel would like the Microsystems organizations to describe the rigor, frequency, and methodology of reviewing its research, development, and production that sustains the activity at such a high level of performance at the next review.

II.C Performance in the Operation of Major Facilities

The Panel assessed the performance in the operation of major facilities as outstanding. Returning panel members were extremely impressed with the progress made during the last two years with the output of the fab and with the Microsystems organizations' ability to upgrade the facility and equipment without missing a single delivery.

Changes since the events of September 11 have been phenomenal. Microsystems organizations are producing delivered product to customers. One hundred percent of it is being delivered on time. Even while linking production to the customers, the Microsystems organizations still support research in those areas (as described in Section IIB). The Panel

was impressed that the Microsystems organizations could maintain a strong science and technology base while refocusing the fab to deliver product. The Panel recognizes the difficulty of managing such an enterprise and compliments the Microsystems organizations on the creativity that solution required.

The Panel congratulated the Microsystems organization's ability to change the culture to put in place repeatable processes that provide good yield and good emphasis on process control in the Microelectronics Development Laboratory. The panel notes that the CSRL also has become much more disciplined. Achieving low-volume, high-product-mix production in a research and development environment is exceptionally challenging, especially when delivered products are for high-consequence applications such as the nuclear stockpile.

The panel sees an upcoming challenge in managing the large growth of product deliveries between fiscal year '04 and '05. The Panel cautions the Microsystems organizations to manage this process very carefully. In the longer term, the Microsystems organizations must deliver product and value to their diverse customer base even if they are not able to advance silicon integrated-circuit technology below the 0.18 micron node in step with commercial suppliers. The Panel wants the Microsystems organizations to analyze the consequences of this constraint and report back to the Panel in two years.

Finally, the Panel commended the strategic focus on core business through outsourcing of less critical activities. The best examples were the packaging and burn-in where feasible, as well as design, in cases where that is feasible.

II.D Program Performance Management and Planning

The final area of program performance management and planning also is assessed as "outstanding."

Returning panel members noted and approved the changes in culture in the fabs, however, the Panel noted even more positive changes in the management culture.

The Panel specifically commended:

- Use of the Balanced Scorecard as a formal and disciplined management tool
- Strategic links to universities to keep ties to science outside of Sandia
- Strong couplings to customers through Sandia's Strategic Management Units
- Training staff including Counselor / Salesperson training
- Strategic planning teams for the Large Defining Programs
- A great sense of responsibility to provide solutions to customers' needs—a very good culture
- A clear notion of having a deliverable and the importance of delivering it on time
- Awareness of the importance of speeding up delivery times while maintaining 100% on-time delivery

The Panel emphasized that these are exemplary business practices, particularly strong ties to

customers to assess needs and a proactive approach to move research concepts through the 'valley of death'. The Panel emphasized that the organization needs to be funded anticipatorily to be well positioned to deal with the next attack on our nation. No one knows when nor what the next attack will be.

The Panel asserts that the Microsystems organizations require the ability to provide an even greater diversity of low-cost product to its customers to enable quicker response to changing threats. The Microsystems organizations should make this capability available to Sandia lab-wide.

The Panel commended the leadership in the Microelectronics organizations in five critical areas:

- expansion of the strategic thinking and strategic alignment,
- orientation to process and process improvement, which naturally led into the Lean-Six-Sigma initiative,
- engagement with its customer groups and those perceived as future customers,
- relevance of the work, and
- getting leverage out of the technology -- one of the truly the outstanding parts. The change in this area over that of the previous review period was really pronounced.

[Comments refer to the method developed by Mike Daily of Sandia was presented to the Panel as described in the abstract contained in Appendix D as abstract 15.]

The Panel noted an international organization called the Product Development and Management Association, PDMA, which excels at assessing the quality of a firm or an activity in the above five areas. The PDMA annual award is the "Outstanding Corporate Innovator." The 2004 award winner was the Air Force Research Lab. The Panel recommends that the Microsystems organizations apply to PDMA for the 2005 Outstanding Corporate Innovator award based the Microsystems organizations' formalized approach to innovation to make the process part of the routine operation of the enterprise.

The techniques used to identify potential products and associate them with a specific customer are wonderful. The panel noted that it is such a clean process that any organization would benefit from examining and perhaps extending it to its own environment.

III. Additional Remarks

In addition to assessing the Microelectronics and Microsystems program relative to the four mandated activity areas the Panel had several additional observations.

The Microsystems organizations exhibit an enthusiasm that can carry an organization a long way. The Microsystems organizations retain their customer focus at all organizational levels, yet align their processes to the granularity of the deliverables.

The program and projects in the microelectronics and photonics, sensors and microsystems are central to Sandia's future. The Panel feels that Sandia should determine how to increase the permanent staff in this area. The Panel emphasizes permanent staff because staff turnover represents a real cost which leads to lost opportunities. The Panel also recognizes that if the Microsystems organizations cannot grow their staff they can focus only on a limited set of the most strategic programs and opportunities.

The Panel would also like for the Microsystems organizations to update scenario planning and its implications for microsystems area for the next external review. As noted earlier, the Panel was impressed with the scenario planning.

With the rapid increase in biology-related activities, the Panel recommends adding someone to the Panel who has technical expertise in these areas.

IV. Summary of Recommendations for the Next External Review

The Panel made several specific recommendations, which are summarized below.

- Sensor technology can be a major growth platform. Sandia should remain concerned with getting solutions into the marketplace rapidly (as opposed to a longer-term program to develop multiple point solutions).
- The Panel asserts that biology-related areas have tremendous potential.
- Presenters should put the research and technology they discuss in the context of the work being done elsewhere.
- *Keep doing the good things:* (1) Expand strategic thinking and strategic alignment, (2) Continue process improvements (lean six sigma), (3) Continue to engage customer groups and future customers, (4) Maximize leverage from technology, (5) Maintain ongoing review and coordination of sensor research to ensure new sensors are compatible with microsystem approach.
- *Sustain cultural changes:* (1) Continue using the Balanced Scorecard, (2) Sustain strategic links to universities (MESA Institute), (3) Continue strong ties to customers through Sandia's Strategic Management Units, (4) Continue to train staff in good business practices (e.g., Counselor / Salesperson), (5) Continue implementing strategic planning teams, (6) Continue emphasizing to staff and managers the importance of having a clear notion of deliverables and the importance of delivering on time and within budget.
- Sandia -- lab wide – must be able to react to events in the world in a future that we do not know. The Microsystems organizations should be agile and share their methodologies across the lab because the work being done in the microelectronics and photonics, sensors and microsystems is central to Sandia's future.
- In the longer term, the Microsystems organizations must deliver product and value to

a diverse customer base even if they are not able to advance the silicon integrated-circuit technology below the 0.18 micrometer node in step with commercial suppliers. The Panel wants the Microsystems organizations to analyze the consequences of this and report back to it in two years.

- The Panel would like the Microsystems organizations to define the rigor, frequency, and methodology of reviewing its research, development, and production that sustains the activity at such a high level of performance for presentation at the next review.
- The Panel recommends that Sandia increase the number of permanent staff in the microsystems area.
- With the rapid increase in biology-related activities, the Panel recommends adding someone to the Panel who has technical expertise in these areas.

Appendix A: Panel Membership

Dr. John M. Aitken, Manager, Advanced Technology Reliability Engineering, IBM Microelectronics

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

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

Mr. David Emily, Program Manager, Rad-Hard Parts, Navy Strategic Systems Program Office, SP23, Naval Surface Warfare Center, Crane, IN.

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

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

Dr. Paul Peercy, Dean, College of Engineering, University of Wisconsin

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

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

Note: All but Dr. Aitken and Mr. Emily were returning members from previous Panels.

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: Schedule of Events

Sunday, September 26

6:30 Reception at Marriott..... 2101 Louisiana Blvd. NE, 881-6800
Attendees: John Aitken, Jack Boudreaux, Ben Cole, David Emily, Jerry Gaspar, Ross Lemons, Paul Peercy, Tom Seidel, Quat Vu, Kensall Wise, Pace Vandevender, Marion Scott, David Myers, Don Cook, Mike Knoll, Thomas Zipperian, Jay Jakubczak, Stephen Martin, Carol Sumpter, Amy Faucett

Monday, September 27

7:00 Meet Group at Marriott..... Sandia Transportation
Sandia Escort (for all transportation)..... *Anna C. Garcia*
Office Administrative Assistant (505) 845-7683

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

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

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

9:00 Military Technology and Applications perspective.....David Keese
Deputy Director, Strike Systems, DoD Systems Analysis and Concepts Center (505) 844-1899

9:50 Nuclear Weapons perspective .....Henry Abeyta
Deputy Director, Stockpile Systems, NM Weapon Systems Engineering (505) 844-8280

10:45 Break

11:00 Nonproliferation and Assessments perspective .....John M. Taylor
Manager, Systems Assessment & Research Center (505) 844-8207

12:00 Lunch
Attendees: John Aitken, Jack Boudreaux, Ben Cole, David Emily, Jerry Gaspar, Ross Lemons, Paul Peercy, Tom Seidel, Quat Vu, Kensall Wise, Marion Scott, David Myers, Carol Sumpter

12:50 S&T Session Overview .....David Myers
Principal Deputy Director, Microsystems Science, Technology, and Components Center (505) 845-9563

1:00 Science and Technology Overview .....Julia Phillips
Director, Physical and Chemical Sciences Center (505) 844-1071

2:00 Implementing THZ/IR/PBG/QCL .....Jim Hudgens
Manager, Photonic Microsystems Technology Department (505) 845-0671

2:30 Molecular Electronics..... David Wheeler
Micro-Total-Analytical Systems Department (505) 844-6631

3:00 Break

3:15 Biotechnology..... Susan Brozik
Microsensor Science and Technology Department (505) 844-5105

3:45 Gallium Nitride.....Andy Allerman
Chemical Processing Science Department (505) 845-3697

4:15 Reliability and Failure Analysis .....Ed Cole
Failure Analysis Department (505) 844-1421

5:00 Depart for Marriott ..... Sandia Transportation
Anna Garcia, Microsystems Science, Technology, and Components, Sandia escort for all transportation

6:00 Pickup Group at Marriott & Transport to Atomic Museum.. Sandia Transportation
Anna Garcia, Microsystems Science, Technology, and Components, Sandia escort for all transportation

6:30 Dinner at National Atomic Museum .... 1905 Mountain Road NW, (505)245-2137
Attendees: John Aitken, Jack Boudreaux, Ben Cole, Jerry Gaspar, Ross Lemons, Paul Peercy, Tom Seidel, Quat Vu, Kensall Wise, David Emily, Pace Vandevender, Marion Scott, David Myers, Julia Phillips, Don Cook, Mike Knoll, Thomas Zipperian, Jay Jakubczak, Stephen Martin, Michael Daily, David Wheeler, Andy Allerman, Carol Sumpter

After Dinner Music by Millenium Trio music group featuring Sandians Barney Doyle, Gordon Osbourn, and Marcelino Armendariz

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

Tuesday, September 28, 2004

7:00 Meet Group at Marriott..... Sandia Transportation
Anna Garcia, Microsystems Science, Technology, and Components, Sandia escort for all transportation

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

7:30 Continental Breakfast
Attendees: John Aitken, Jack Boudreau, Ben Cole, David Emily, Jerry Gaspar, Ross Lemons, Paul Peercy, Tom Seidel, Quat Vu, Kensall Wise, Marion Scott, David Myers, Tom Zipperian, Carol Sumpter

8:00 Planning and Operations.....David Myers
Principal Deputy Director, Microsystems Science, Technology, and Components Center

8:30 MESA Operations and Technologies ..... Tom Zipperian
Deputy Director, Microsystems and Engineering Sciences Microfabrication Unit (505) 844-6407

9:00 Product Deliveries and Commitments.....Mike Knoll
Deputy Director, Design & Product Unit

9:45 Break

10:00 Research and Production Mix in a Silicon Fabrication Facility.....Linda Cecchi
Manager, Microelectronics Development Laboratory Operations Department

10:30 Crossing the Valley of Death Update.....Mike Daily
Manager, Integrated Microsystems Department

11:00 Panel Deliberations

12:00 Working Lunch for Panel

1:00 Panel Outbrief to Sandia Management
Invitees: Panelists, Sandia Executives

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

Appendix D: Abstracts of Presentations

(In order of presentation)

1. Welcome and Introduction

Marion W. Scott

The Microsystems organizations at Sandia deliver research, technology, and products for national security applications. As the Microsystems and Engineering Sciences Application (MESA) program nears completion, we have been given unrivalled capabilities to convert microsystem innovation into revolutionary new ways to advance our nation's security. Our challenge is to obtain the people, space, and programs to deliver on our potential and to sustain them throughout the years.

We have developed a strategy for realizing the promise inherent in the MESA vision. By working with Sandia's Strategic Management Units, our goal is to become indispensable to our customers and stakeholders by combining bottom-up innovation with top-down guidance and support. A key element of our strategy is to develop Large Defining Programs, which generate millions of dollars of annual revenue, develop synergy across the laboratories. Large Defining Programs help us maintain leadership in our focus areas and provide multi-year funding stability and support a common infrastructure for multiple departments to draw on and which enables us to reach out to a larger customer base than the initial target market segment.

2. Military Technology and Applications Perspective

David Keese

The increasing complexity of urban warfare and the increasing complexity of urban warfare and the dangers posed by asymmetric threats have led the Department of Defense to develop eight major initiatives which require varying degrees of innovation. These initiatives are:

- Missile Defense
- Strike Systems
- Homeland Defense
- Surveillance& Reconnaissance
- Military Space
- Minimally Manned Warfare
- Directed Energy
- Modeling & Simulation

This talk will describe to what extent microelectronics and microsystems can support Sandia's programmatic activities in support of these identified needs.

3. Nuclear Weapons Perspective on Microsystems at Sandia

Henry Abeyta

The Nuclear Weapon Program is focused on balancing Science and Technology exploration and maturation with direct application of products to support on-going nuclear weapon related projects. Success of our nuclear weapon system responsibilities is dependent on product delivered from the Microelectronics and Microsystems program. Examples of these products and current status will be provided.

Preparing for future military needs is an important element of our stockpile stewardship responsibilities. Anticipating these future needs requires investments in technologies today that will allow us to meet emerging requirements. Projected needs will also be summarized.

The ability to qualify future systems for War Reserve is dependent on physical and computational simulation in addition to the ability to prototype potential designs rapidly. Constraints driven by evolving security requirements, pressures on budget, and the need to assure a responsive infrastructure will drive alternative approaches to system qualification. An example of an emerging need affecting Microelectronics and Microsystems will be described.

4. Nonproliferation and Assessment Strategic Management Unit: A Microelectronics Partner

John M. Taylor

For Sandia to realize its vision of "helping our nation secure a peaceful and free world through technology" in a time of proliferation and use of weapons of mass effects, the Laboratories must expand its business associated with nonproliferation and assessments. The technological innovation that will enable us to deter, detect, defend against, and defeat our nation's enemies strongly depends upon advances in microelectronics and microsystems.

The Nonproliferation and Assessments (NP&A) Strategic Management Unit (SMU) and the Microsystems organizations must be dependent on each other for mission success. For that reason, the Programs and Initiatives with NP&A are current and future users of the Microelectronics capability. As part of its strategic planning, NP&A includes key members of the Microsystems organizations. As one metric, synergies between the two program areas have led to nearly a doubling of the funds that flow from NP&A to Microelectronics in the last four years.

The Microelectronics and Microsystems organizations are valued partners of NP&A.

5. Seed Corn for the Future: Science for Future Microelectronics and Microsystems Needs

Julia M. Phillips

Identifying and investing in the science that will enable Sandia to meet future microelectronics and microsystems needs is an essential part of Sandia's microelectronics and microsystems strategy. This presentation will set the context for identifying our science investments and give examples of ongoing work that is expected to pay off on various time scales. Examples will include:

- Nitride-based Compound Semiconductors: This is an example of the unique multi-pronged approach we can bring to bear on complex problems, resulting from our infrastructure (built up over decades), breadth of capabilities, and team approach.
- Radiation Effects Microscopy: Our invention of these microscopies is based on our historic strength in applied nuclear science and is already being applied to Sandia-specific problems.
- Low Dimensional Quantum Transport and Terahertz Detection: This panel heard about some of our quantum transport research at the last review. Some aspects of that work are now being extended to the extremely high frequency regime, which may have national security implications.
- Dynamic Adaptive Assembly: In recent years, we have looked to biological systems for insights (and perhaps materials) that may enable us to incorporate unheard-of functionality into microsystems that are fabricated using bottom-up assembly processes.
- Center for Integrated NanoTechnologies (CINT): Sandia's microelectronics and microsystems capabilities were a strong drawing card when the Office of Basic Energy Sciences decided to place one of its five nanoscience centers at Sandia/Los Alamos. In return, the science and capabilities of CINT (to become fully operational in FY06) are likely to provide new insights and advances that will contribute to future microsystems.

6. Implementing THz/IR/PBG/QCL

James J. Hudgens

Sandia National Laboratories has developed a number of breakthrough technologies including THz detectors, three-dimensional metallic photonic crystals and quantum cascade lasers. These developments have aided in cementing Sandia's reputation as a premier research and development facility. After 9/11 it is apparent that we cannot let the marketplace discover and apply this science, insertion cannot be left to chance. To be successful in our mission Sandia must be proactive in maturing and implementing these technologies for National Security applications.

This talk will outline an approach to maturing such technologies to deliver value to National Security customers. We will give a technology developers viewpoint on the steps necessary to successfully implement product driven technology maturation. Steps include: 1) Identification of National Security opportunities; 2) Discovery of strategic customers, value proposition, customer need, technology gaps etc.; 3) Formation of a multidisciniplinary team to execute the product driven maturation. Our work with three-dimensional metallic

photonic crystals will be used as a case-study. Additionally, we will overview our THz and diffractive optics programs.

7. Molecular Electronics

David Wheeler

Our approach to developing a molecular electronics, polymer electronics capability has centered on new approaches to nanosensors. Sensor development is a core business of Sandia and thus serves as an excellent business platform on which to develop the infrastructure to explore nanotechnology. Our approach to nanosensors relies on fundamentally new approaches to electrical transduction of analyte substrate interactions. To achieve our goals of a new nanosensor based on molecular electronics we have developed critical enabling technologies, chemistries and methodologies that will serve well for expanded forays into nanotechnology.

Our new molecular sensor approach relies on the assembly of a matrix of nanoparticles and conducting (pi conjugated) sensor molecules between nanoelectrodes. To achieve our new sensor, we have made significant advances in three distinct areas. First, we have developed methodologies and fabrication techniques that allow us to create reproducible nanogap electrodes in metal and silicon using standard lithographic techniques. The nanogaps are achieved be using a sacrificial oxide layer between two conductors. Thorough characterization of the devices has allowed us to begin to separate the effects of substrates from overall nanodevice performance. Second, we have developed new nanoparticle chemistry that allows us to rapidly replace the ligands that surround a nanoparticle with other ligands. This allows for the stepwise assembly of nanoparticle structures. Thirdly, we have developed an incredibly powerful method to functionalize semiconducting surfaces and conducting surfaces via bias directed assembly of monolayers. We have developed two groups of molecules; one group self assembles spontaneously, but can be blocked by positive bias. The other group does not assemble spontaneously, but will assemble with negative bias. Together these two classes of molecules forms and orthogonal capability that allows us to functionalize surfaces in a directed fashion using electrical bias. The films assembled using this bias directed approach are robust enough to allow subsequent chemistry and forms the foundation on which we have built nanoparticle organic molecule architectures for molecular sensing.

8. Integrated Biological Microsystems

Susan Brozik

Sandia's national security missions depend upon state-of-the-art capabilities in biotechnology. Our biological and chemical detection and security programs extend the nation's capabilities via the integration of biology with novel microtransducers, microelectronics and MEMS to yield innovative biological microsystems. As an example, by designing biomimetic transducers that mimic the molecular machinery of the cell, we can make highly "flexible" biological and chemical microsensor systems. Our research is

working to combine chemistry, materials science, cell biology, genomics, advanced engineering and systems analysis for rapid identification of toxins, pathogens, viruses, and DNA. Current biosensor technologies include electrochemical, optical, and acoustic transducer systems as a basis for the design of immuno-based and DNA sensors. In addition to developing sensor systems, we design new tools and instrumentation to detect and manipulate single molecules and to address cell membrane signaling.

9. Gallium Nitride Materials: Science Advancing Applications

Andy Allerman

The aluminum gallium nitride system represents a challenging material system with important applications in both light-emitting diodes as well as high-frequency, high-power transistors. We will describe the basic science of the nucleation and growth of wide bandgap, nitride materials and the tools we developed tools to monitor growth and characterize materials. These advances result in increased performance in deep UV-LEDs and RF electronics by improving material properties.

10. Reliability and Failure Analysis

Ed Cole

In support of Sandia's national security mission a number of IC failure analysis capabilities have been developed to address critical needs and unique situations. These technologies have become valuable enablers for Sandia and have also found wide industry application. In particular, defects such as open/shorted conductors, resistive interconnections, parametric failures, and critical timing paths have been successfully targeted. Several of the developments to localize these defects will be described in terms of their physics and application examples. The impact these techniques have had on mission success will be described as well as their applications beyond conventional failure analysis.

11. Planning and Operations Overview

David R. Myers

The Microsystems Science, Technology, and Components Center is the steward of the MESA microfabrication technology. To sustain these capabilities, we have applied the strategy map formalism as adapted to non-profit organizations by the Balanced Scorecard Institute.

This talk will focus on the financial statistics and our processes to improve internal operations. Subsequent talks will describe specific implementations in greater detail.

12. MESA Operations and Technologies: The MDL and CSRL Merging into the MESA MicroFab

Thomas E. Zipperian

In approximately one year, Sandia's Microelectronic Development Laboratory (MDL) and Compound Semiconductor Research Laboratory (CSRL) will come together as the new MESA MicroFab. In the past, these two laboratories developed much different technologies, operated in qualitatively different ways, served different customers with significantly different expectations, and operated with dissimilar business models. The future will be different. In a Center business strategy where we seek to have impact to the NW, NP&A, MT&A, and E&IA Strategic Management Units at Sandia, placing fieldable microsystems components *of every type* in the hands of real National Security applications is crucial. This must be done at the same time that we continue to develop and nurture a vibrant microsystems science and technology base as "seedcorn" for the future. To succeed at this complex mission both the MDL and the CSRL must change.

In this talk, the author will discuss some of the operational changes occurring in compound semiconductor and sensored systems technologies within the CSRL and in MEMS technologies within the MDL. Some of the "large defining programs" being developed and executed in both areas will also be described. Important operational metrics for both facilities will be detailed. A crucial operational challenge (the final conversion of the Si IC production toolset from 6" to 8" wafers), and the strategy for addressing it, will also be described.

13. Microsystems 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 Management Unit customers, which are Nuclear Weapons, Nonproliferation and Assessments, Military Technology and Applications, Homeland Security, and Energy and Infrastructure Assurance. 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, design custom products for industry manufacture, 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 the Microsystems Center's Product Development and Deliveries. Our product development and delivery scope includes: 1) microsystems, 2) custom microelectronics ICs, 3) custom magnetic, high energy density capacitor, interconnect, radio frequency, and optical components, and 4) qualified COTS electronic components for hostile environment applications.

14. Research and Production Mix in a Silicon Fabrication Facility

Linda Cecchi

There was a concern expressed by this panel at the review in 2002 that the production we anticipated for stockpile refurbishments would consume MDL resources at the expense of R&D that could lead to future product offerings. We shared that concern and, over the past two years, have developed management practices specifically to ensure that R&D continues and even flourishes in our limited production environment.

In this presentation, I will capture key attributes of the MDL fab as it operates today and describe our progress in meeting the commitments to NW and satellite customers that were projected two years ago. The number of R&D projects supported by the MDL has actually increased in the same time period and has grown in scope. Projects include derivatives of the now mature CMOS and MEMs process recipes as well as projects that have required development of new capabilities to support sensors and other devices for homeland defense.

Finally, I'll describe the management methodology that guides the day-to-day operations to support our broad range of activities. Our experience to date gives me confidence that we can continue to support an increasing number of R&D initiatives with a tool set and process engineering staff that also supports production.

15. Update on Crossing the "Valley of Death"

Michael R. Daily

The Valley of Death is a term coined to describe the gap between basic research / demonstrated feasibility of a new idea and production of a product based on the idea. This gap is characterized by a lack of available funding - symptomatic of the simultaneous existence of high technical risk and high business risk. In order to be relevant to our SMU customers and the Nation we have developed a methodology for managing the technical and business risks so that crossing this "Valley of Death" can be accomplished and complex microsystem products can be delivered to the operational environment when required. This talk will discuss the 3-step Stage-Gate process used to manage the complex microsystem product business. A discussion of Phase 0 will cover how we use sales training, customer qualification, and value analysis to maximize customer satisfaction and repeat business while minimizing the starting of projects that are inappropriate to the customer's business situation. Some metrics will be provided. A discussion of Phase 1 will cover our process for maximizing knowledge of what to expect and to quantify the difficulties and risk issues most likely to cause product development problems before product development is attempted. Some examples from the MESASAR project will be provided. Phase 2, implementation of the product development effort, will be referred to only briefly.

Appendix E: Recommendations from the Previous External Review and Sandia Responses

The previous review listed six specific concerns in its report (SAND2003-3486).

1. Balance research and deliverables.

2. Need for metrics.

3. (Sandia has unique combination of people, expertise, and mission.) Sandia should assume the position of advising the Nation in the area of Microsystems for national security and for dealing with emerging threats (focus the activity rather than pursue all opportunities at once).

4. Formal risk management method for program management and as a way to communicate risk to develop customer confidence (TRLs).

5. Need for scenario planning for 10 to 15 years out.

6. Tech migration for integrated circuits.

Sandia response to these specific concerns was described by the following speakers:

1. Phillips, Hudgens, and Cecchi discussed achieving an appropriate balance between deliveries and R&D.
2. Myers, Knoll, and Zipperian presented metrics associated with value-stream analysis, deliverables and operations.
3. Gosler, Scott, and Zipperian serve on the NSA study for sustainability. Gosler and Scott support Defense Science Board on High-Performance Microchip Supply. Myers summarized other areas where relevant staff and managers support government-level boards and decisional panels.
4. Myers summarized a formal risk-management system based on 9-level technology readiness scales. The Microsystems organizations are assisting its implementation throughout Sandia.
5. The Microsystems organizations support Nonproliferation Assessments strategic planning. Post-SLEP Nuclear Weapons strategic planning will begin early in 2005.
6. Zipperian presented our plans for technology and capability migration.

In addition to these presentations, Sandia's response was codified in the Center 1700 Business Plan (Internal Distribution Only) – which was shared under non-disclosure with the Panel Members.

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