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A Case Study in Competitive Technical and Market Intelligence Support and Lessons Learned for the *μChemLab™ LDRD Grand Challenge Project*

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Abstract

The μChemLab™ Laboratory Directed Research and Development (LDRD) Grand Challenge project began in October 1996 and ended in September 2000. The technical managers of the μChemLab™ project and the LDRD office, with the support of a consultant, conducted a competitive technical and market demand intelligence analysis of the μChemLab™. The managers used this knowledge to make project decisions and course adjustments. CTI/MDI positively impacted the project's technology development, uncovered potential technology partnerships, and supported eventual industry partner contacts. CTI/MDI analysis is now seen as due diligence and the μChemLab™ project is now the model for other Sandia LDRD Grand Challenge undertakings. This document describes the CTI/MDI analysis and captures the more important "lessons learned" of this Grand Challenge project, as reported by the project's management team.

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Executive Summary

The Sandia National Laboratories' μChemLab™ Laboratory Directed Research and Development (LDRD) Grand Challenge project began in October 1996 and ended in September 2000. With $25 million committed at Sandia, the μChemLab™ Grand Challenge represented the largest investment made by the Department of Energy (DOE) in any LDRD project. This successful intra-laboratory effort reached its technical goals and fostered significant work within Sandia in support of national security objectives. In addition, the industrial community is now making sizable investments in developing the technology into a variety of end-use applications.

From the beginning of this large project, the Sandia LDRD program manager considered the development and application of external competitive technical and market demand intelligence (CTI/MDI) a necessary cost of project support. This investment, originally considered by many to be unnecessary, proved invaluable to the success of the project. The managers of the μChemLab™ LDRD Grand Challenge project and the LDRD office, with the support of a consultant, conducted a CTI/MDI analysis of the μChemLab™.

CTI/MDI gave the managers of this project the benefit of an objective and vigilant view of the world outside Sandia. The managers used this knowledge to make project decisions and course adjustments. CTI/MDI positively impacted the project's technology development, uncovered potential technology partnerships, and supported eventual industry partner contacts. The additional investment needed to create CTI/MDI is now seen as a "due diligence" cost and the μChemLab™ project is the prototype for other Sandia LDRD "Grand Challenge" undertakings. As a result of the lessons learned from the μChemLab™ LDRD Grand Challenge project, all Sandia LDRD Grand Challenge project managers are required to obtain and apply CTI/MDI to their projects.

The first section of this report addresses "lessons learned" in the organization and management of the μChemLab™ project. The second section of this report discusses the analysis itself. The analysis had three primary goals: 1) to uncover and classify others' development efforts in microchemistry; 2) to ascertain that Sandia National Laboratories' vision for a fully integrated microchemical laboratory—with all the distinctive major features envisioned—was unique; and 3) to uncover and qualify market demand and potential applications.

To satisfy the first goal, the consultant, Perspectives, Inc., investigated other groups working with microchemistry technologies. For the second goal, they benchmarked Sandia's efforts against those of other groups working in the field. The management team then developed and tested a Value Proposition and a statement of features and benefits, partially with the support of an External Advisory Committee and a Delphi Panel. To satisfy the third goal, the consultant tested the depth of the market through research and extensive interviews with industry and other federal agency personnel knowledgeable in the fields of microchemistry R&D and applications.

A monthly *μChemLab™ Information Tracking Report* provided the team current intelligence on other organizations' efforts in microchemistry.

The findings of the analysis supported the ongoing development of μChemLab™.

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Part 1: Lessons Learned

I. Summary Overview of Lessons Learned in the μChemLab™ LDRD Grand Challenge Project

☐ ***Get the right people up front***

- Establish a management team of key technical managers and support expertise in business planning, technical and market intelligence, patents, licensing, and business development.

☐ ***Drive accountability and goals***

- Develop a full-period project plan that identifies both business and technical goals with milestones.
- Establish and maintain an External Advisory Committee (EAC).

☐ ***Define success***

- Create a "Vision of Success" that incorporates future national security work and industry partnerships, as appropriate, with technology achievement.

☐ ***Don't fly blind***

- Invest in and use technical and market intelligence to understand the business and technical environment.
- Become an expert in the patent landscape around the key technical areas of your project.

☐ ***Create value and facilitate future industry partnerships***

- Convey to your team the importance of submitting Technical Advances, prioritizing these for patent filings as possible.

☐ ***Keep talking***

- Conduct frequent, scheduled, structured team meetings to discuss milestones and goals.
- Keep your champions and their customers well informed.

Directly stated in some of the above "lessons" and implied in others is the importance of technical and market intelligence. Both sections of this report discuss the use of market and technical intelligence within the μChemLab™ LDRD Grand Challenge project. Throughout this portion of this report, the multiline sections of italic type reflect the comments of the μChemLab™ team.

II. Introduction & Background

The μChemLab™ LDRD Grand Challenge project began in October 1996 and ended in September 2000. Sandia National Laboratories invested approximately $25 million in the project during that period. This successful intra-laboratory effort reached its technical goals and fostered significant work within Sandia in support of national security objectives. In addition, the industrial community is now making sizable investments in developing the technology into a variety of end-use applications.

This document captures the more important "lessons learned" of this Grand Challenge project, as reported by the project's management team. Ed Southwell, of Perspectives, Inc., the team's competitive technical intelligence/market demand intelligence specialist, gathered this information over several months. The questions on lessons learned put to the management team cover all areas, with a focus on those that the team felt would be of most value to future Grand Challenge project managers.

This report begins with the formation of the management team and the initial concerns of the team relative to both the technical and management challenges. Each topic section provides both background and a review of the relevant lessons learned.

III. The Management Team, Operational Precepts, and Initial Concerns

A. The Management Team

Within six months of the start of the project, the key technical managers, on the advice of the LDRD Office, brought together individuals from Strategic Business Planning, Licensing/Agreements, Legal/Intellectual Property, and Competitive Technical Intelligence/Market Demand Intelligence (CTI/MDI) to assist the µChemLab™ project. These people became part of the µChemLab™ management team. This approach was rated as *invaluable* by the technical managers. This prototypical team style has, as a result, become the recommended management configuration for all Grand Challenge projects.

According to the technical managers –

> *They added expertise that we did not have and, in some cases, did not realize that we didn't have or needed. Another tangible benefit was a broader mix of internal stakeholders in the project. As management team members, they understood the context of needs. As initial presentations were made to potential major (industry) partners (PMPs), PMPs' perception of credibility with the project was enhanced because we knew our stuff in the Competitive Technology* [sic] *Intelligence (CTI) and Intellectual Property (IP) areas.*

The dynamics that made this work –

> *The Project became "their project" and they were part of the team. This is in contrast to a typical support function or "support contractor" role. They had a pride of ownership. The technical managers did not try to manage the business-side managers as a limited resource. The management team relationships and scheduled monthly and quarterly meetings became an efficient way to share information and make information available as needed. We had the right mix of challenge and trust. And finally, we liked each other and looked forward to contact.*

Was there any critical area that was missing from the team at the start?

> *In retrospect, yes. We could have used a team member—and budget—dedicated to business development. We had two people from the Business Development and Partnership Center—a business planning associate along with a licensing associate, but we needed someone who could devote time to business development, travel with the project managers, and help present the technology. We had no idea how much time this demanded. Two of the technical managers spent a significant portion of their time on development (one with the government agencies and PMP1* ["PMP1" refers to the first "potential major partner"] *and another with the petrochemical industry). A business development assistant was eventually brought on to handle all routine inquiries that come over the transom with a standard information package that he has developed. Perhaps we should have also added "technical subject matter experts" to advise the management team and help in assessing what IP might be most important for us to focus on and to give us ammunition to defend the uniqueness of our IP in meetings with PMPs. And perhaps we should have included the two key members of the technical staff. Finally, we should have assigned the role of PR to the person on the management team with the most marketing experience (or brought in a PR person), rather than treat this task as one of secondary importance.*

B. Initial and Continued Planning

The newly formed management team devoted time up front to jointly developing a three-year summary plan that identified the technical goals as well as ongoing support objectives for each of the management team areas. The area of CTI/MDI received particular focus at this time, as this was a relatively new concept for most of the team and would be supported by an external consultant. Therefore, the team developed a specific three-year outline of CTI/MDI support functions. This process helped the others on the management team understand the role of CTI/MDI within the whole of the μChemLab™ project. The team also spent significant time at this early juncture in the creation of the end-project "vision for success." This vision incorporated 1) technology achievement; 2) the ultimate acceptance of the technology in R&D projects for national security applications; and 3) the creation of industry partnerships to further development.

Concurrent with the development of the vision, the team began the iterative process of defining the Value Proposition. The team polished the Value Proposition as they learned more of other organizations' R&D efforts in this area of microchemistry, as they gathered feedback from federal agencies and industry about desired capabilities and potential applications, and as the μChemLab™ technology evolved.

The management team took care to schedule strategic planning sessions about every six months so they could all develop an understanding of the challenges the project faced and come to consensus on the major project support tasks needed to realize the success vision.

C. Operational Precepts

Key factors acted as unifying forces that contributed to the overall organizational success of the μChemLab™ technical project team.

- A compelling, shared vision of success early on. In this case, the "box," the integrated technologies in a hand-held device.
- Structured, regular meetings.
- Executive management support.
- Executive management encouragement to divest project pieces that did not fit.
- Team managers who were not overly protective of "their" budgets.
- Local DOE/AL/LDRD support and enthusiasm, including attendance at quarterly and Advisory Committee meetings—not just bureaucratic oversight.
- The External Advisory Committee (see pertinent section for more on this.)
- A top-notch team—across the board—technical, managerial, business, legal.

Structured meetings:

- As-needed strategic planning sessions among the management team.
- Quarterly All-Hands meetings with discussion by all team members of progress and challenges.
- Monthly Management Team meetings stressing action planning, accountability, and follow-up.
- Executive quarterlies (Sandia senior management briefings on the status of all areas of the project).

D. Initial Concerns

1. Thematic Concerns

The general feelings in the room at the first All-Hands Quarterly:

- Excitement and skepticism. Some antagonism and discomfort around the "force-fit" of five projects into one. (The mix of CA and NM teams and responsibilities is sometimes an issue with Sandia, but not in this case—see the "unifying forces" in the preceding section.)

At the start of the μChemLab™ project, the greatest fears and uncertainties:

- A forced marriage between five projects.
- A very distributed management team (group of equals) with no one at the head—not typically a formula for success. This changed as the project progressed, with one manager becoming the project lead.
- Enormous technical challenges.
- Concern that the project could not realize the external revenue objectives/return on investment.

2. The Perceived Need for CTI/MDI

At the start of this project, the level of expectations around the need for—and benefit of—Competitive Technical Intelligence/Market Demand Intelligence was, at best, mixed.

> *It was obvious that there was tremendous skepticism and outright opposition from some, particularly a number of the technical people, as they felt that they knew more about the field and the players than any new outsider could learn, particularly someone without a degree in the field.*

IV. Strategy for Intellectual Property

A patent attorney from the Laboratories' legal office supported the μChemLab™ LDRD Grand Challenge project in a proactive mode, rather than one that might be called reactive or passive. The attorney became an integral member of the project's management team and subsequently attended the monthly management meetings and All-Hands Quarterlies.

This intellectual property (IP)-coordinator approach, with one person from the legal staff owning responsibility for encouragement of technical advance (TA) submissions and filing of IP, was rated "very effective" by the management team. The team recommends including this level of support at the start of the project.

A. The Need for Understanding the IP Landscape

In consideration of the potential demands on resources, the team made an early-stage decision not to make a concerted effort to continuously mine the full landscape of IP filed and held in the fields of interest. Therefore, there was late recognition that the team did not fully appreciate or understand the relevance nor the import of some of the μChemLab™ IP that was eventually filed. The following provides advice in this matter.

> *We feel that "technical subject matter experts" (beyond a legal expert in patents) should be utilized routinely to assist in assessing the potential of any particular TA and the value of the portfolio itself. Such technical subject matter experts need not (and perhaps preferably should not) exclusively consist of hired consultants. Rather, the needed function, to size up where Sandia's advances in technology stand in relation to the current advancing state of the art outside Sandia, might best be led by Grand Challenge technical team leaders or their designates. The benefit of having insiders execute this function (with assistance from outside experts) includes ensuring that the evaluator has a clear understanding both of the Sandia project and of developments outside of Sandia. If we'd had early on the perspective of a technical subject matter expert (or group of internally designated experts), as we began to meet with potential industry partners, we would have been in a better position to defend the uniqueness and breadth of the Sandia patents and potentially could have fast-tracked some of these discussions. We've realized that we need to manage IP as a portfolio, not just as individual pieces. There is a need to understand the uniqueness, the strengths, and the legitimacy of the project's IP.*

B. Defining the Scope of the Portfolio

> *There was another issue that the company [Sandia] must figure out how to deal with: Who defines the portfolio? This Grand Challenge spawned many related projects—most, but not all, funded by LDRD. We encountered (and continue to have) problems with activities that were inspired by this Grand Challenge (but not funded by it) asserting that they are outside the portfolio. Grand Challenges explicitly define business investment areas for the labs, and the entire "area" needs strategic management—not just the project!*

C. The Divisive Challenges

> *We've also come to appreciate how divisive an issue IP can be in two particular areas: first, initial attribution, and later, when PMPs are at the table, negotiating value and compensation schemes. We recommend that Sandia consider a major evaluation of how royalties are distributed and how managers can best give credit to and award the whole team*

while protecting those listed on the patent. The best approach might be in giving the project team more discretion in how royalties will be distributed and to assign a larger percentage of royalties to the team, not to the Division, as they are currently. It is our perception that the current practice is of assigning an equal share of license and royalty income to each patent, and then to each person listed on each patent. This is, in the end, not equitable.

D. Other "Lessons" Concerning IP

- Pursue aggressively international rights to seminal patents.
- Focus on key or seminal patents. Cull the portfolio, while acknowledging that "seminal" might be a shifting target and difficult to pinpoint.
- Motivate the staff from the beginning and throughout the Grand Challenge to play an active role in IP identification and harvesting.
- Improve communication to the staff on what a patent is and what makes a patent weak or strong. Although the team dedicated one quarterly meeting to patent legal issues, and IP matters came up at nearly all of the quarterly meetings, not all of the staff took a particular interest in IP.
- Identify early one or more technical staff (perhaps the technical team leaders) to partner with the patent attorney in collecting, filtering, and championing invention disclosures to ensure that the right TAs are written and the right patents are applied for.
- Encourage discussions between the Principal Investigator and the lawyer, prior to writing the TA, on the patentability of the concept and possibly which aspects should be emphasized over others.
- Make effective use of the periodic database printouts on IP status.

V. Competitive Technical Intelligence and Market Demand Intelligence: Scope, Evaluation, Advice

A. Background and Scope

The LDRD Office considered the development and application of external Competitive Technical Intelligence and Market Demand Intelligence (CTI/MDI) necessary costs of project support and expected that this input would have a positive effect on the management of the project.

As a prototype for CTI/MDI in Grand Challenge projects, CTI/MDI received funding separate from the technical funding on the μChemLab™ project. CTI/MDI accomplished the goals of giving the project managers the benefit of an objective and vigilant view of the world outside Sandia. The managers used this knowledge for thematic decisions and course adjustments that positively affected the technology development, uncovered potential technology partnerships, and supported industry and other federal agency partner contacts.

Because CTI/MDI expertise does not reside within Sandia, the μChemLab™ management team brought in an outside consultant, Perspectives, Inc. Perspectives was selected because of previous, related work for one of the μChemLab™ technical managers, as well as similar work done for other projects within Sandia.

Not surprisingly, the objectives of the CTI/MDI work evolved as needs changed and as the technical team learned of the value and the capabilities of the work and of the consultant performing the work. The flexibility of the contractual relationship was a key factor in meeting needs. "*We found that we grossly underestimated the need for [this type of support] at the beginning of the project*," said a technical manager.

Perspectives began by benchmarking the early state of the μChemLab™ technology and the vision for success against other R&D organizations' goals. External CTI/MDI also included the shaping and testing of the μChemLab™ Value Proposition with other federal agencies (OFAs) and industry, constructing profiles of enabling technologies and potential industry partners, and developing and publishing an external information synopsis, called the *μChemLab™ Information Tracking Report*. The consultant also provided assistance to the team in strategic planning and external communications.

Specifically, Perspectives performed the following tasks:

- Performed an initial benchmark of the technology and the vision for success as compared to the R&D efforts of organizations outside Sandia;
- Helped develop and continuously refined and tested the Value Proposition with both industry and OFAs;
- Established and maintained an External Advisory Committee (EAC);
- Continuously tracked and reported on others' efforts in similar fields of R&D;
- Identified alternative as well as enabling technologies;
- Provided background on potential enabling technology partners and on "Potential Major Partners" (PMPs); and
- Provided general and specific market demand information.

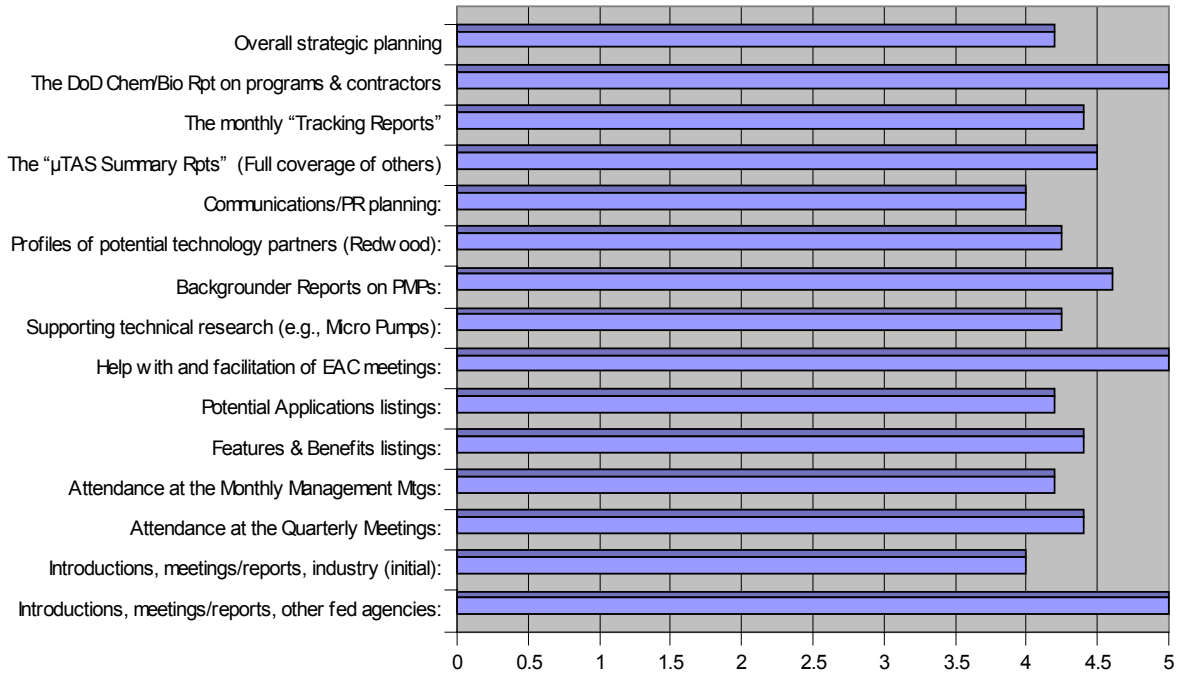
B. Evaluation of Need and Performance

As stated earlier in this report, a number of the technical managers were initially skeptical of the value of CTI/MDI and skeptical of the capabilities of the consultant to perform in this particular technical field. At the end of the project, technical managers reported the following opinions.

> *Our [CTI/MDI] consultant did an outstanding job in providing key market research intelligence and helping define and articulate our value proposition.*
>
> *Objective and valid information about what is going on in the outside world is needed; information from the inside technical staff is not enough. For any sizable LDRD or future Grand Challenge, Sandia should invest in a CTI study to support the investment. We could have been more efficient in how we structured the technical challenges up front if we'd had better competitive intelligence at that time.*
>
> *What this also gave us was defensible data. This certainly helped with our management. Others should do this as we did—in a team relationship—with the CTI/MDI consultant and technical staff working together.*
>
> *Perspectives arranging fact-finding and presentation meetings with the right potential customers and partners was exceptional and an unexpected plus for us. It may not be intuitive to most, but Perspectives provided valuable connections into our classic customer base, other federal agencies, as well as industry. They added value to these meetings in that the "fact-finding" provided an easy way for these contacts to be open and truthful with us. They also provided us with outstanding reports on the trips that, by the way, gave a third-party view to our VPs.*
>
> *MDI also continually served us in the role of reminding us of the real-world implications of the technical features of the device we were creating.*

The management team and key members of the technical staff rated the usefulness of a number of the things that were done by the CTI/MDI consultant. The table that follows presents these findings. The survey rated "usefulness" on a scale of 1 to 5, with "5" being "extremely useful."

Table 1. Ratings of "Usefulness" of Various CTI/MDI Functions and Deliverables



The markedly high ratings given to the above functions and deliverables give clear indication that the technical project managers and other support function managers consider CTI/MDI, as provided by this consultant, to be highly useful and integral to the project.

C. Uncovering Applications and Testing the Value Proposition

The team uncovered applications and developed and tested the Value Proposition very early on with potential customers, both in other federal agencies (over 24 agencies) and industry (over 12 major corporations).

Was this a valuable exercise, and did the feedback from customers provide valuable input?

- *Absolutely valuable. It clarified for us what the unique attributes of our vision were and validated the need. The work done here helped validate the Grand Challenge project in the eyes of our customers. The results of this work were used internally with our VPs as well.*
- *We chose to ignore particular advice regarding one of the technical goals of the project and, arguably, this decision could have hurt us.*
- *And, we learned early on that the "demo" was going to be a key part of the project.*

D. Needed Attributes

The attributes other teams should look for in a competitive technical intelligence/market demand intelligence consultant:

We felt that the attributes of our [CTI/MDI] consultant are what others should look for. Strong interest in the success of the team is critical. Demonstrated ability to get the information they need to do their job—courage to ask the hard questions. Willingness to

challenge the status quo and willingness to say "no" to something that doesn't fit. Find someone who understands that their objectives are to produce useful and concise information, and to reduce the load on the team rather than add to it. And finally, get someone who can anticipate needs and fulfill them without being asked.

VI. The External Advisory Committee

An External Advisory Committee (EAC) was formed by the μChemLab™ management team. Rather than meet once a year as originally planned, the EAC, at the conclusion of its first meeting in May 1997, asked to meet every six months. The EAC met again in December 1997 and approximately every six months thereafter. The group held a commencement celebration at the last meeting in November 1999.

The μChemLab™ management team considered the membership of the EAC committee very carefully, taking into consideration many issues, including potential conflicts of interest. Importantly, the team chose a Chair who was strong, friendly to Sandia, technically competent, and very well respected by his peers. EAC members are recognized leaders in academia and government agencies. The μChemLab™ team judged the EAC an outstanding success, providing challenge and valuable insight to the entire team. In addition, friendships were forged that led to further support with personal advice and introductions to useful contacts.

According to the μChemLab™ management team, the EAC:

- *Served as a reality check. (de-gold-plated the project);*
- *Verified that we were on track (or told us when they thought we weren't);*
- *Provided a thematic focus that was good for us;*
- *Broadened our contacts and visibility;*
- *Helped validate the project in the eyes of DOE and Sandia management;* and
- *Gave us hard deadlines and held us accountable in a professional sense, rather than as employees or corporate team players*

The formation and "management" of a successful EAC is dependent upon many factors and could be the subject of a more extensive report.

VII. Licensing and Partnerships

The μChemLab™ team discovered how much effort and time building relationships with potential industry partners consumed. In addition to the obvious travel demands, the team found that the negotiations can take an inordinate amount of time and can be easily derailed by a change in corporate management and/or corporate strategy.

A. Focusing

The μChemLab™ management team began to reach out to potential industry partners in the second year of the project. The team struggled with the resource commitment this required and struggled with the question, "What has more promise, working with instrument manufacturers/OEMs or working with end-users?" Licensing to one, of course, affects—or potentially affects—the ability to license to the other. The following captures the lessons regarding this question.

> *It depends on your objectives and portfolio strategy, but we really feel the optimal is a three-way partnership between a big end-user market-maker, an instrument manufacturer (OEM), and Sandia. The OEM has generally brought more expertise to the table in terms of instrument development, but may demand more in market rights, which makes creating end-user partnerships more difficult. Importantly, we shouldn't forget the importance of alliances and partnerships with federal agencies with national security interests.*

B. The Inherent CRADA Conflict

Key technical staff members see an inherent conflict with a Cooperative Research and Development Agreement (CRADA) aimed toward "development," rather than "research."

> *The problem we see as staff is that the "win"—the big CRADA—for Sandia and the management team looks like we move from being in "research scientist mode"—with challenging research supported by LDRD—to applications engineers doing very applied work with short-term deliverables for corporate partners. The outstanding performers within the LDRD need to be rewarded for their contributions with continued discretionary research funds if goals are accomplished. Recent experience suggests that the "system" withdraws precious discretionary support from those who are able to build new science—a "penalty" for success!*

C. Internal Communications During Negotiations

> *When big dollars are on the table with PMPs, those listed on patents want to know all that is going on and can sometimes feel that the negotiating managers may not keep their best interests in the forefront. While this is a challenge that cannot be easily addressed, we feel that it is important to keep open communications with those staff listed on seminal patents during PMP negotiations.*

VIII. The "Ah-Ha's"

Finally, the μChemLab™ team presented the three or four surprises—the "ah-ha's"—to future LDRD Grand Challenge project team leaders.

A. Competitive Technical Intelligence and Market Demand Intelligence

The "ah-ha" here is finding out how critical CTI/MDI is and in how many different ways this can help the project: competitive intelligence; background intelligence on PMPs; facilitating meetings with other federal agencies; searches and reports on "enabling technologies;" collection and reporting of all the activities in the field; and, in general, being the eyes and ears to the rest of the world for an overly committed technical staff. Early on, directing the CTI/MDI deliverables to answer the question "So that what can happen?" was very enlightening.

B. Industry Partnership Development and Licensing

Big deals are very hard and involve tremendous investment from both parties. A lot can go wrong in getting commitments for large sums of money in both licensing and funds-in for R&D. In hindsight, meetings scheduled early in the process should almost always be with the PMP's senior executive/s; this would have provided more insight into whether the industrial partner has the high-level support needed, both organizationally and financially, to close the deal. Also, defining and identifying a strategic partner versus a supplier relationship is not always obvious. We should have focused some effort this past year in going for some smaller deals, not just the home runs. We grossly underestimated the amount of business development support needed. And we need to do a better job in controlling management expectations in this area.

C. Intellectual Property Development and Management

Intellectual Property strategies vary and are subject to change within and with different PMP's. IP management strategies need to be in place early in the project. IP value and attribution and royalty streams are much more internally divisive than we expected—we just don't have the internal process or systems that we need. We need a better and more comprehensive strategy here. Subject matter expertise as to the IP landscape is also needed.

IX. Management Members

Table 2. Key Management Members of the Project.

Name	*Project Role*	*Email address*
John Vitko	Lead Project Manager/ Primary OFA Contact	john_vitko@sandia.gov
Al Sylwester	Technical Manager/ Primary Industry Contact	apsylwe@sandia.gov
Terry Michalske	Technical Manager	tamicha@sandia.gov
Duane Lindner	Technical Manager	dllindn@sandia.gov
Marie Garcia	Business Planning	mgarci@sandia.gov
Ed Southwell	CTI/MDI—Perspectives, Inc.	ed@espeedaz.net
Rusty Elliott	Patents, Legal Counsel	rusty@sandia.gov
Angelo Salamone	Licensing & Partnerships	alsalam@sandia.gov
Willard Hunter	Business Development	wbhunte@sandia.gov
Greg Frye-Mason	Technical Leader—Gas Side	gcfrye@sandia.gov
Dave Rakestraw	Technical Leader—Liquid Side	info@eksigent.com
Chuck Meyers	Sandia LDRD Office	cemeyer@sandia.gov
Larry Adcock	DOE/AL/LDRD Office	ladcock@doeal.gov

X. Suggestions for Creating Successful Projects

The "lessons learned" provided in this document will help others benefit from the experiences of the μChemLab™ LDRD Grand Challenge project. The preceding sections present these lessons in the context of the project. Building on this experience, here is a summation of suggestions to jump-start a Grand Challenge project.

- Organize a multidiscipline management team with key technical managers and support expertise in business planning, competitive technical intelligence/market demand intelligence, patents, licensing, and business development.
- Create a "vision of success" that incorporates future national security work and industry partnerships, as appropriate, with technology achievement.
- Create and continuously refine the Value Proposition.
- Establish success metrics and develop a full-period project plan outline. The outline should identify milestones and needs in technology achievement, business development, and competitive/market intelligence.
- Schedule appropriate resources for business development and for competitive/market intelligence.
- Establish and maintain structured team meetings and communications.
- Establish and maintain an External Advisory Committee.
- Become an expert in the patent landscape around the key technical areas of the project and convey to the team the importance of submitting Technical Advances, prioritizing these for patent filings as possible.
- Schedule regular briefings to Sandia management on the project and its progress.

Part 2: Technical and Market Intelligence Support

I. Introduction of the Competitive Technical and Market Demand Intelligence Support Role

This section will provide information about why the μChemLab™ managers and the Laboratory Directed Research and Development office dedicated resources to the tasks of gathering and communicating business and technology intelligence, the work products from that effort, and the impacts to the project.

Not surprisingly, the objectives of this work evolved as needs changed and as the management team learned of the value and the capabilities of competitive technical intelligence (CTI), market demand intelligence (MDI), and of the consultant performing the work.

Perspectives, Inc. was selected because of previous related work for one of the μChemLab™ technical managers as well as other similar work done for additional managers at Sandia National Laboratories.

Perspectives benchmarked the early state of the μChemLab™ technology and the project's vision for success against other research and development (R&D) organizations' goals. External CTI/MDI also included the shaping and testing of the μChemLab™ Value Proposition with other federal agencies (OFAs) and industry, constructing profiles of "enabling" technologies and profiles of potential industry partners, and the development and routine publication of an external information synopsis, called the *μChemLab™ Information Tracking Report*. The consultant also provided assistance to the team in strategic planning and external communications.

II. Rationale and Objectives

A. Rationale

The μChemLab™ LDRD Grand Challenge project represented the largest investment made by the Department of Energy (DOE) in any LDRD project. The Sandia LDRD project manager considered the development and application of external CTI/MDI a necessary cost of project support. CTI/MDI gave the managers of this project the benefit of an objective and vigilant view of the world outside Sandia. The managers used this knowledge to make project decisions and course adjustments. CTI/MDI positively impacts the project's technology development, uncovers potential technology partnerships, and supports eventual industry partner contacts. The additional investment needed to create CTI/MDI was seen as a "due diligence" cost.

B. Task Objectives

In order to accomplish the overall goals stated above, the μChemLab™/LDRD team established the following task objectives.

1. Perform an initial benchmark of the technology and the vision for success.
2. Test the Value Proposition with both industry and OFAs.
3. Establish and maintain an External Advisory Committee.
4. Track others' efforts that are in similar fields of R&D, identify "alternative" as well as "enabling" technologies.
5. Provide background on potential enabling technology partners and on Potential Major Partners (PMPs).

The following sections will provide more definition to these task objectives and give examples of the work product under each.

III. The Initial Benchmark of the Technology and Vision

The first CTI tasks were to: 1) uncover and classify others' development efforts in microchemistry; and 2) ascertain that the vision for a fully integrated microchemical laboratory—with all the distinctive major features envisioned—was unique.

One of the hidden challenges in this endeavor involved the creation of a taxonomy that accurately classified the developments in this field.

The chart on the following page (Figure 1) displays a brief overview of the first intelligence on other organizations working on microchemistry devices.

The tables on the next several pages present a synopsis of the principal organizations involved (as of May of 1997) in the development of a "Lab-On-A-Chip" (LOC)—the first term used to describe this work by the media. Each organization is identified, along with what the market intelligence study uncovered as their unique proposition and their collaborations and alliances.

Needless to say, in the 4½ years since this first synopsis was completed, many of these organizations have dramatically changed the direction of their R&D efforts in microchemistries. The information from May 1997 is presented here to give the reader of this SAND Report the benefit of the intelligence that was gathered at the start of this LDRD Grand Challenge project.

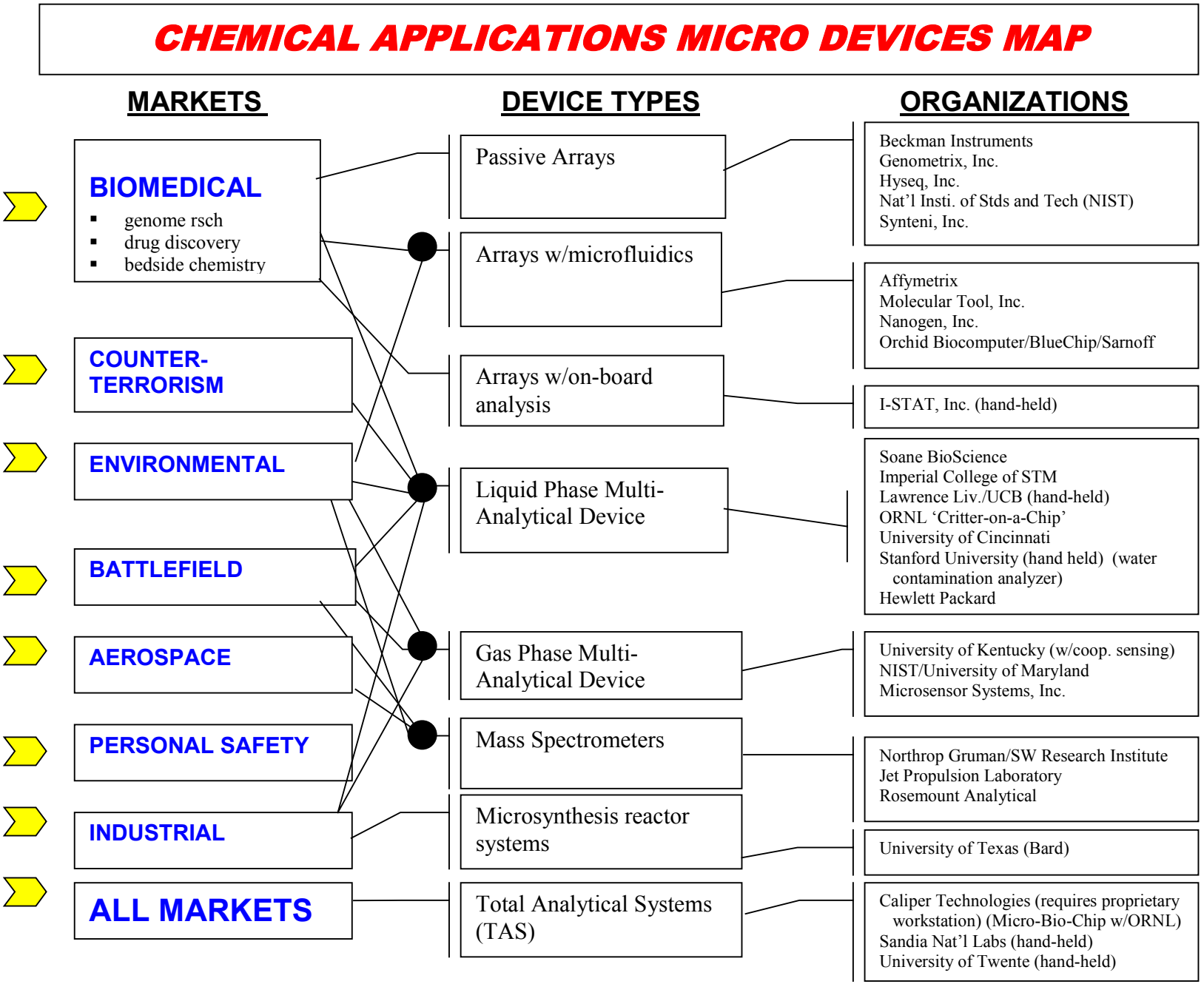


Figure 1. Chemical Application Microdevices Map

A. Passive Array Organizations

Passive arrays are LOCs that have multiple receptor elements or sensors (usually 1,000 +) and do not have any active sample handling, on-board analysis, or communications capabilities.

Table 3. Passive Arrays

Organization/ Product Description	Unique Proposition	Applications/ Key Markets	Collaborations/ Alliances
Beckman Instruments Microarray. Polypropylene substrate first used; then ethylene-methacrylic acid used.	Low-tech approach using additional bench-top–sized instruments. Simpler design considerations—no moving parts or fluidics. Low-cost disposables.	Genetic diagnosis and screening. Chip probes are read by benchtop instruments.	Member of Genosensor Consortium (which includes Genometrix, below). Collaboration with Oxford in the past (ongoing?). Joint development with MDL Information Systems.
Genometrix, Inc. Analytical workstations incorporating microarray LOCs. Silicon-based.	Market/user familiarity with format used.	High-throughput molecular analysis for genomic, pharmaceutical, and diagnostics markets. Currently genetic analysis, but going into environmental micro-organism sensors.	Part of Genosensor Consortium. Collaborating with • Beckman, • MIT, • Baylor, etc. Contracts with NASA (grant) and a "multibillion $ agribusiness company."
Genosensor Consortium Array technology, but also incorporates fluidics and electronics.	Draws on information of many institutions.	Targets DNA analysis in diagnostics, forensics, therapeutics, and agricultural research.	Beckman is most prominent member. Other members include Genometrix Houston Advanced Res. Center, Microfab Technologies, Laboratories for Genetic Studies, Genosys Biotechnologies, Triplex Pharm., Baylor College of Med., and MIT (Budget of $18.5 million, according to Beckman's Web site.) Also received grant from Advanced Technology Project (ATP) program.
Hyseq, Inc. "HyChip" Array technology.	High-throughput DNA hybridization system. Super-chip provides accurate, low-cost horizontal or vertical sequencing of more than 10k bases in a single reaction. They are marketing their product as the world's fastest gene sequencing technology.	Analyzing bacterial genome components. Super-chip does very fast gene sequencing	Funding from ATP grant. Original technology developed at Argonne NL and called SBH: Sequencing By Hybridization. • SmithKline Beecham • Molecular Informatics • Conservation Int'l
NIST Supporting technology.	Plastic microchannel technology. Liposome-based LOCs.	N/A Research project goal is to design and produce a totally integrated LOC.	Many applicable ATP grants in place.

Organization/ Product Description	Unique Proposition	Applications/ Key Markets	Collaborations/ Alliances
Synteni GEM™ Microarray. Glass substrate.	Better than oligon. arrays, works with unknown gene sequences. Also improved specificity/sensitivity.	Gene expression.	• Stanford (developer) • Expression Systems • Pharmacia • Monsanto • SmithKline • Merck • Hoffmann La Roche

B. Arrays with Microfluidics

Arrays with microfluidics are devices that have multiple receptor elements or sensors and also have the capability, or have stated development goals, to handle liquid samples. They do not have the on-board capabilities of analysis or communication.

Table 4. Arrays with Microfluidics

Organization/ Product Description	Unique Proposition	Applications/Key Markets	Collaborations/ Alliances
Affymetrix Microarray (GeneChip™) with capability to conduct sample processing and chemical transformations. Uses injection-molded plastic chip substrate (polycarbonate or polypropylene) for sample preparation. Arrays are on a silicon substrate.	Huge number of probes onto chips, and the fact that it is the only player into commercial production. Adaptation to a LOC that performs sample processing and hybridization. Uses an injection-molded plastic chip substrate using sensorless fluid positioning to simplify operations and lower cost. Have used device to perform an entire HIV polymorphism screening assay.	DNA analysis—HIV mutations and cancer.	• Hewlett-Packard • Glaxo-Wellcome • Roche Bioscience • Incyte Pharm. (LifeChip) • BioMerieux Vitek OncorMed • Genetics Institute • ATP (NIST) Grant • Merck • Mercator Genetics
Nanogen, Inc. Nanogen's APEX product (Automated Projectable Electronic Matrix). Silicon substrate.	Ability to manipulate samples electronically (move, concentrate, bind, wash, and separate charged molecules within a biological sample) as distinguished from a passive array-based LOC, and does it faster with greater sensitivity.	Molecular diagnostics, enzyme and cell assays, drug discovery, receptor assays for oncology therapy. Battlefield: casualty ID. Environmental monitoring.	• ATP • ID BioMedical, Inc. • ProLinx, Inc.
Orchid Biocomputer/ BlueChip / David Sarnoff Lab Integrated chemical analyzer utilizes probe array.	Automated DNA assays, shooting for true combinatorial organic synthesizer—100s of thousands of simultaneous reactions.	LOC performing thousands of simultaneous organic synthesis/separations and screening on single chip. BlueChip spin-off to complement efforts with microchemical analytical systems for DNA assays.	• SmithKline Beecham • NIST (grant)

C. Arrays with On-Board Analysis

Arrays with on-board analysis were defined as those LOC devices that have sample-handling capability and the ability to perform analysis and are housed in a hand-held system with communication capability. Currently, only i-STAT has such a device.

Table 5. Arrays with On-Board Analysis

Organization/ Product Description	Unique Proposition	Applications/Key Markets	Collaborations/ Alliances
i-STAT Corp.	World's only commercialized calculator-sized blood-analysis device for bedside use. Sampling is simple, results virtually instantaneous. Small disposable cartridges are plugged into the device, with each having micro-machined thin-film sensors for specific blood components.	Bedside. Emergency Medicine. (Blood components the device can measure include sodium, potassium, chloride, calcium, urea, hemocrit, hemoglobin, glucose, and pH.)	Unknown.

D. Liquid-Phase, Multianalytical Devices

Liquid-phase, multianalytical devices were defined as those LOCs that have the capability of handling liquid samples to perform separations on multiple analytes using one or more separator technologies. Some organizations that are included in this section have a stated goal of building computational analysis and reporting systems that will be portable.

Table 6. Liquid-Phase, Multianalytical

Organization/ Product Description	Unique Proposition	Applications/Key Markets	Collaborations/ Alliances
Hewlett-Packard	Patent on a "fully integrated miniaturized planar liquid sample handling and analysis device." This microsystem employs chromatographic, electrophoretic, and electrochromatograhic separation means. The microchannels are laser-ablated during fabrication.	N/A	N/A
Imperial College of Science, Technology & Materials—London Zeneca/SmithKline Beecham Centre for Analytical Science.	One focus area is on integrated microanalyzers using external flow and sensing control.	On-line process control, medical applications, and environmental sensing.	• Ciba-Geigy • Caliper Technologies
Lawrence Livermore National Laboratory Combines PCR and CE. The chip consists of a PCR reactor, an electrophoretic valve, and a CE system that is etched in glass. Silicon-housed.	The researchers say that the integrated chip reduces the time required for analyzing DNA and other gene targets. The device has a miniature thermal cooling system that can achieve rates of 10–20 C/s, ten times that of commercially available benchtop devices. A portable prototype has been produced.	DNA analysis—*in situ*.	• UC Berkeley • Others, TBD

Organization/ Product Description	Unique Proposition	Applications/Key Markets	Collaborations/ Alliances
Oak Ridge National Laboratory (#1) Critter-on-a-Chip (Mike Simpson)	A half-living/half-silicon chip. The bioluminescent bioreporter integrated circuit consists of living sensors (such as bioluminescent bacteria) placed on a standard integrated circuit. Small, low-power, rugged. Projected @ <$1.	Environmental and battlefield detection of pollutants, explosives, and a number of chemicals in soil and water.	• U of Tennessee Center for Environmental Biotechnology
Oak Ridge National Laboratory (#2) MicroBioChip (Mike Ramsey)	Based on electrophoresis. Plans are to have a portable system ready for the market by year-end 1997 at a cost of around $5,000. DNA mapping can be done in minutes *in situ*.	DNA-mapping in the field.	• Caliper Technologies • Others, TBD
Soane Biosciences "LabCard" Integrated analyzer. Plastic for microfluidics.	Chemical detection through microfluidics in a plastic substrate. Electrophoretic valve connects reactor to analyzer but keeps reagents segregated. Can check PCR reaction as it runs to see if enough amplification has occurred.	Performs multiple lab operations on single LabCard (reagent mixing, incubation, separation) for DNA analysis.	• Hitachi • Grant from Human Genome Project • CuraGen Corp • NIH grant
Stanford University A mercury/iridium microsensor and an electrochemical oxidation/reduction system.	Unambiguous detection of heavy metals in water. Hand-held device.	Environmental purity testing. May also be applicable in testing water purity in the fab.	TBD
Univ. of Cincinnati "Chemist on a Chip" (under development) Platform unknown.	Scope of project is to design a "wearable chemical biological sensor" of specified biological compounds.	"Chemist on a Chip" to be designed for battlefield use. Other applications possible, including environmental pollutants, drug delivery, monitoring vital signs and even medical implants.	$2.8 million from DARPA, 4/14/97

E. Gas-Phase, Multianalytical Devices

Gas-phase, multianalytical devices are LOCs that can handle gas samples to perform separations on multiple analytes using one or more separator technologies. Some organizations that are included in this section have a stated goal of building computational analysis and reporting systems that will be portable.

Table 7. Gas-Phase, Multianalytical

Organization/ Product Description	Unique Proposition	Applications/Key Markets	Collaborations/ Alliances
Microsensor Systems, Inc. 4 SAW sensor units.	Portable prototype for field use. Analysis requires personal computer.	Industrial—measures exposure to toxic chemicals.	Unknown.
NIST/University of Maryland	An array of four specific gas microsensors that allows detection of gas concentrations in mixtures.	Battlefield. Environmental.	• DoD • American Industry/Gov't Emissions Research Consortium
University of Kentucky With cooperative sensing.	Distributed chemical sensing systems. Proposed systems designed within standard batrication processes, based on MEMS. Will use large numbers of chemical sensors arranged in novel architectures to detect and locate gases of interest in uncontrolled sensing environments.	MEMS-based distributed chemical sensing systems for monitoring battlefield and weapons storage sites.	TBD

F. Mass Spectrometers

Mass spectrometers analyze ions of liquids and gases in simple mixtures in a controlled environment.

Table 8. Mass Spectrometers

Organization/ Product Description	Unique Proposition	Applications/Key Markets	Collaborations/ Alliances
Northrop Grumman Science Technology Center (formerly Westinghouse Electric Systems)	Mass spectrometer on a chip under development; prototype developed. Goal is hand-held unit.	Environmental toxin detection. Aerospace (as part of a gas handler).	• Southwest Research Institute • Funding by DARPA.
Jet Propulsion Laboratory	A 4-W quadrupole array project.	Aerospace: soil samples in alien environments.	TBD
Rosemount Analytical	Has patented a MS the size of a toothpick. Company is designing a complete system around this.	TBD	TBD

G. Microsynthesis Reactor Systems

Microsynthesis chemical reactor systems control temperature under a constant pressure state to allow for separations and analysis.

Table 9. Microsynthesis Reactor Systems

Organization/ Product Description	Unique Proposition	Applications/Key Markets	Collaborations/ Alliances
University of Texas (Allen Bard) Integrated chemical synthesizer.	Controls compounds through temperature and continuous high pressure. Modular reactor chambers use electrophoretic, photochemical, chromatographic, thermal, and pressurized reaction chambers processes. Analyzers are electrochemical, spectroscopic, and fluorescence.	TBD	TBD

H. Micro Total Analysis Systems

Total analysis systems will incorporate gas and liquid sampling, separations, analysis, information processing, and communications capabilities.

Table 10. Micro Total Analysis Systems

Organization/ Product Description	Unique Proposition	Applications/Key Markets	Collaborations/ Alliances
Caliper Technologies "LabChip." Integrated chemical analysis/synthesis. Requires proprietary analytical benchtop station to compute and display results. Plastics under development (with Dow) for microfluidics. Also uses glass, silicon, quartz.	Probably closest to commercialization of this type of LOC. Developing disposable polymer chips. Dedicated analysis of a wide variety of chemical/biochemical analytes.	Initially targeting the analytic R&D market and high-throughput experimentation in the areas of drug screening, genomics, and combinatorial chemistry.	• Dow Chemical • Hoffman LaRoche • Licensing agreements with Harvard, Northwestern, Princeton, University of Pennsylvania, and Oak Ridge NL. • Board membership includes Manz, Ramsey, Harrison. Abbott Labs (David Milligan – Sr. VP Abbott Research – also on Board)
Sandia National Labs	All capabilities. Very broad spectrum. Autonomous. Hand-held.	Crosses all applications and markets.	TBD
Twente, University of Mesa Research Institute (Albert van den Berg) Integrated total analysis system.	Concept is a self-contained instrument with electronics, sample handling, and multiple analytic capabilities on a chip.	Crosses all applications and markets.	Unknown.

I. Summary

As can be seen from the above tables, the μChemLab™ LDRD Grand Challenge project team finished their first six months of this four-year project with their current state of R&D in a leading position and their vision for a completed μChemLab™ unique.

IV. Testing the Value Proposition

The creation and testing of the Value Proposition of the μChemLab™ was an ongoing process throughout the project. The team first developed a list of proposed features for both their accompanying benefits and the optimism that they were achievable. From these features naturally came the Value Proposition. Following the development of the Value Proposition, the team tested it within the national security community, a broader range of federal agencies, and, of course, with industry. The team felt strongly that the technology would be compelling, but wanted confirmation from potential users. They also needed to hear what proposed features and performance levels would be the most beneficial. This information influenced the R&D process.

Presented in this section are recent snapshots of the elements of developing and testing the Value Proposition as they reached maturity, not a detailing of this process as it unfolded. As needed for understanding, these snapshots are placed in their historical context.

A. Features and Benefits

The following table presents those features and benefits discussed with the External Advisory Committee in November 1999. These have no nondisclosure conflict with any outside agency. The features of the μChemLab™ have evolved since that time.

An abbreviated listing of potential features and benefits proposed to date by industry and government agency contacts, the μChemLab™ team, and others is shown in the following table.

Table 11. μChemLab™ Features and Benefits

μCHEMLAB™

Feature	Benefits
Small self-contained package: 3.98"W x 8.785"L x 2.75"H	❑ Hand-carryable ❑ Easily portable into field ❑ Provides information at site ❑ Operable without access to electricity
Multiple gas and liquid analyte chromatographic separation channels with multiple detection schemes	❑ Highly reliable, with low false positives and negatives ❑ High sensitivities in the ppb range for target analytes ❑ Broad spectrum capabilities, versatile ❑ Outstanding efficacy in presence of complex backgrounds ❑ Can identify a "fingerprint" of a target mixture of analytes ❑ Compensates for false readings from channel and/or detector ❑ Applicable to both gas and liquid sample situations
Simple display and four--button operation	❑ Easy to use and read top-line information ❑ Can be operated by field personnel ❑ Operable in extreme anxiety situations ❑ Operable in full HazMat protection gear
~ 1-minute cycle times for gas analysis, ~ 3 minutes for liquid	❑ Very rapid identification of substances ❑ Preventative, safety, or curative actions can be taken quickly ❑ Relatively rapid environmental changes can be measured
Full down-load and up-load communications capabilities	❑ Full chromatographs can be uploaded remotely for study ❑ Results can be archived ❑ Operable remotely for personnel safety or clandestine needs

μChemLab™

Feature	Benefits
Modular design	❑ Spent resources (e.g., batteries, reagents) can be replaced ❑ Contaminated parts can be replaced ❑ Family-specific preconcentrators, separation channels, and detectors can be swapped out to maximize sensitivity to different families of analytes
Small sample and reagent requirements	❑ Contributes to rapid analysis time ❑ Relatively inexpensive to operate, even with high-cost reagents ❑ Relatively noninvasive for medical diagnostics
Low costs of components, with total unit cost expected to be less than $5,000 and gas or liquid-only systems at $2,500 or less	❑ Very affordable ❑ Multiple units may be cost-effectively deployed for cooperative sensing ❑ Replacement modules are inexpensive

B. Creating the Value Proposition

Upon learning that the μChemLab™ was at the forefront of the technology and that the vision for success was unique, the team needed to determine if that vision was compelling. To put this vision in terms that could be readily understood by industry and OFAs, the team developed an initial Value Proposition that included a list of the key attributes for incorporation in a hand-held μChemLab™. Those attributes have changed somewhat over the period of R&D, with the most significant change being the separation of the "cooperative and distributed" technology from the project. (This was done partially as a result of advice given us by the External Advisory Committee.) The Value Proposition, as it currently stands, follows. This text is taken from the μChemLab™ video.

> Under development at Sandia National Laboratories, the μChemLab™ is a hand-held, integrated chemical sampling and analysis instrument with many advantages over current systems.
>
> This new technology—currently at the prototype stage—will allow the identification of a broad range of compounds and their concentration levels—very quickly—with results displayed in less than two minutes.
>
> Its design doesn't require any knowledge of the chemical analysis process, making it easy to use with a simple push button control.
>
> Even in the presence of interfering compounds, it provides reliability and accuracy and an extremely low false alarm rate.
>
> Since it relies on the same batch microfabrication processes that continue to make computers less expensive, it will be relatively inexpensive to produce—with units tailored for individual applications estimated to cost less than $5,000.
>
> Never before has it been possible to take the equivalent of a full-sized chemical analysis lab

into the field and have it fit in the palm of your hand….

But with its compact size and ability to run on batteries—the μChemLab™ promises new detection and analysis opportunities.

C. Testing Demand

Testing demand means testing the Value Proposition, developed as a result of stating the features and benefits of the technology, in the context of existing user alternatives. Implied in this statement is an understanding of the *applications* for which the technology will be used. As the μChemLab™ is really a "market-making" technology, the team needed to hear some good, objective thinking on possible future applications. This need led to the development of a Delphi Panel.

1. The Delphi Panel

The outstanding panel included subject-matter experts who are broad vision thinkers from:

- Analytical Instrument Companies (4)
- Academia (2)
- Futures Studies Institutions (2)
- Venture Capital Companies (1)

Table 12. The Delphi Panel

Affiliation	Title	Company/Org.
Analytical Instruments	Director of Research Measurements Laboratory	Varian Instruments
Analytical Instruments	Site Manager Cambridge Manufacturing	Analog Devices
Analytical Instruments	Director of Chemistry Development	Beckman Instruments
Analytical Instruments	Chief Technology Officer and Senior Vice President of Corporate Development	Perkin Elmer Corporation
Academia	Professor of Chemistry	California Institute of Technology
Academia	Professor, Director of Center for Mechanics and Control	Texas A&M University
Future Studies	President	Coates & Jarratt, Inc.
Future Studies	Director	Institute for the Future
Venture Capitalists	Director, Project Funding	Technology Venture Corporation

This panel, which met over approximately a six-month period, provided confirmation of the applications already brainstormed by the μChemLab™ team, along with a few new ideas. The panel also provided an important ancillary benefit of creating awareness of the DOE investment and Sandia technology and establishing future useful contacts.

2. Existing Markets

The consultant completed an analysis of the existing analytical instruments marketplace in October 1998. This was done at this time to provide the team with current sales and markets for laboratory and field instruments and to identify the leaders in each of several market segments. The report included profiles of these leaders showing market shares, sales trends, and unique selling points. A table from this report follows.

Table 13. Market Share Strength in Selected Lab and R&D Instrument Categories

Company	LC	HPLC	Ion C	LC-MS	CE	CE-MS	GC	GC-MS	MS	Quad /IT	MALDI TOF	Mol. Spec
P-E	◉	○	○	●	○	○	●	○	◉	○	●	●
Thermo	●	●	○	●	○	○	●	●	●	●	●	●
H-P	●	●	○	●	●	●	●	●	●	●	◉	○
Shimadzu	◉	●	●	◉	○	◉	●	●	◉	○	●	◉
Hitachi	○	●	◉	◉	○	◉	◉	●	○	○	○	◉
Varian	◉	○	○	○	○	○	●	●	○	○	○	●

● Top 5 position ◉ Top 10 position ○ Little to no market share

3. Industry

Industry visits to verify potential applications and to determine potential demand began as the Delphi Panel concluded its study. These visits continued throughout the remainder of the project. By year-end 1998, the team had briefed more than 16 companies and industry associations on the Grand Challenge. Representatives from these companies and industry associations provided feedback regarding the most needed features, potential applications, and future demand. Exposure to several of these early industry contacts later benefited new discussions concerning partnership opportunities.

The companies, company divisions, and trade associations whose feedback the team received represented a diverse set of industries including commodity chemicals, petroleum processing, oil and gas exploration, pharmaceuticals, analytical instruments for process control, analytical instruments for medical laboratory analysis, *in situ* medical diagnostics, and environmental site analysis. Below is a partial listing of companies and divisions that the team visited by year-end 1998.

Table 14. Companies Visited by μChemLab™ Team

Title and Department	Company
Director of Chemistry Development	Beckman Instruments
Senior Staff Engineer, Advanced Technology Center	Beckman Instruments
Strategic Marketing Manager, Diagnostics Development Center	Beckman Instruments
Director, Advanced Instrumentation	Beckman Instruments
Vice President, Director, Advanced Chemistry Biotechnology Development Center	Beckman Instruments
Vice President, Advanced Technology Center	Beckman Instruments
Assistant Vice President, Environmental & Policy Analysis	Chemical Manufacturers Association
Director, Advanced Materials Development	DuPont
Business Manager, Biotechnology Group	DuPont
Business Development Manager	DuPont
Director, Biotechnology Business Development	DuPont
Director, Corporate Technology Transfer	DuPont
General Manager	Fluid Data Corporation
Director of Technology	Fluid Data Corporation
General Manager	Galaxy Instruments
Senior Research Scientist, Geotechnology Research Institute	Houston Advanced Research Center
Associate Director, Environmental Information Systems Laboratory	Houston Advanced Research Center
President and Chief Executive Officer	Onix Systems, Inc.
Chief Technical Officer and Senior Vice President of Corporate Research	Perkin-Elmer Corporation
Senior Research Chemist, Molecular Structure Safety & Scientific Services Division	Phillips Petroleum Company

Title and Department	Company
Environmental Technology Manager, Analytical Sciences Groups	Phillips Petroleum Company
Manager, Technical Resources Division	Phillips Petroleum Company
Director of Biotechnology Research Applications Division	SAIC
Integrated Technology Manager	Searle Chemical Sciences
Chemist—Optical and Microscopy	Shell Chemical
Research Chemist, Exploration and Production Technology Department	Texaco
Project Scientist, Exploration and Production Technology Department	Texaco
Scientist, External Technology	The Dow Chemical Company
Research Associate, Process Analytical R&D	The Dow Chemical Company
Biotech Business Manager, Advanced Materials—Electronics	The Dow Chemical Company
Scientist, Sensor Systems Group Leader	The Dow Chemical Company
Intellectual Asset Manager, Central Research and Development	The Dow Chemical Company
Technology Project Director Central and New Business R&D	The Dow Chemical Company
Research Associate and Scientist, Separations Sciences	The Dow Chemical Company
Research Leader Process, Analytical R&D	The Dow Chemical Company
Associate Director, Corporate Research Division	The Procter & Gamble Company
Section Head, Analytical Chemistry, Corporate Research Division	The Procter & Gamble Company
Research Fellow, Corporate Professional and Regulatory Services	The Procter & Gamble Company
Research Fellow, Corporate Research Division	The Procter & Gamble Company
Research Fellow, Corporate Research	The Procter & Gamble Company
Senior Scientist	The Procter & Gamble Company
Technology Leader, Global Product Supply Engineering	The Procter & Gamble Company
Section Head (and Collaborative Research) CRD	The Procter & Gamble Company
Associate Director, P&G Pharmaceuticals	The Procter & Gamble Company
President	Thermo Environmental Instruments
Director of Measurements Laboratory, E.L. Ginzton Research Center	Varian Associates, Inc.
Executive Vice President	Varian Instruments, Inc.

4. Other Federal Agencies

The team completed a review of OFA publicly available activities and funding in June 2000. The Chem/Bio Report provided the team with:

- Identities and profiles of the major commercial manufacturers of chem/bio equipment.
- Confirmation that the μChemLab™ technology bundle was unique.
- Intelligence on the μChemLab™ capabilities' alignment, by needs and by agency.

Concurrent with visits to industry, the team implemented a thorough set of briefing/feedback targets within OFAs. By year-end 1998, more than 24 OFAs had been briefed for market intelligence feedback on the μChemLab™.

Table 15. A Partial Listing of Other Federal Agencies Briefed

Title and Department	Organization
Deputy Director	Army Center Environmental Health Research
Director, Research Division	Customs Service
Chief, Technology Development and Acquisition Branch	Customs Service
Project Manager (Microfluidics and Chemical Systems), DSO	DARPA
Director, ETO	DARPA
Specialist for Sensors	Director, Defense Research & Engineering, Office of the Secretary of Defense
Associate Deputy Administrator	Drug Enforcement Agency, Department of Justice
Chief, Laboratory Operations Section, Office of Science and Technology	Drug Enforcement Agency, Department of Justice

Title and Department	Organization
Laboratory Director	Drug Enforcement Agency, Department of Justice
Associate Director for Security Policy Office of Intelligence and Security, Office of the Secretary	Department of Transportation (S-60)
Director of Biological Warfare and Chemical Warfare Project	Defense Intelligence Agency/Central Measurement & Signature Intelligence Office
Director, Sensors and Electronics Technology	Department of Defense/ Director, Defense Research & Engineering
Assistant Chief Patrol Agent, Senior Project Analyst	Department of Justice—U.S. Border Patrol Headquarters
Deputy Director, Office of Criminal Enforcement, Forensics and Training	Environmental Protection Agency
Director, Technology Innovation Office, Solid Waste and Emergency Response Office	Environmental Protection Agency
Director, Technology Users Support Project	Environmental Protection Agency
Project Manager, Remedial Site Management	Environmental Protection Agency
Supervisory Special Agent, Hazardous Materials Response Unit	Federal Bureau of Investigation
Research Chemist, Laboratory Division, Forensic Science Research	Federal Bureau of Investigation
Assistant Director, Laboratory Division	Federal Bureau of Investigation
Technology Development Coordinator	Food and Drug Administration
Director, Combat Developments	Joint Service Integration Group— U.S. Army Chemical School
Branch Chief, Division of Pathology	National Cancer Institute
Assistant to the Director, Strategic Technologies	National Cancer Institute
Chief, Technology Development Branch, Cancer Diagnosis Project	National Cancer Institute
Chief, Natural Products Branch	National Cancer Institute
Natural Products Branch	National Cancer Institute
Deputy Director, Advanced Technology Group	National Earthquake Information Center
Director of Immunoassay Lab	National Institutes of Health
Director of Urinalysis Lab and Acting Director of Clinical Chemistry	National Institutes of Health
Director of Special Chemistry	National Institutes of Health
Director of General Chemistry and Statistics Lab	National Institutes of Health
Acting Director of Technical Development	National Institutes of Health /National Cancer Institute
Chief, Section Medical Biophysics	National Institutes of Health /NICHD
Director, Border Research and Technology Center	National Institutes of Justice
Director of Office of Science and Technology	National Institutes of Justice
Director, Research and Technology Development Division	National Institutes of Justice
Assistant for Science and Technology, Special Operations and Low-Intensity Conflict	Office of the Assistant Secretary of Defense, Special Operations & Low-Intensity Conflict
Director, Counter Drug Technology Assessment Center	Office of National Drug Control Policy
Director, Medical Research; Research, Development and Acquisition	Office of the Assistant Secretary of the Army
Special Assistant, Office of Chemical/Biological Matters	Office of the Secretary of Defense
Special Assistant, Chemical/Biological Matters	Office of the Under Secretary of Defense
Scientist	Public Health Service
Director, Technology Assessment Branch	Department of Agriculture Food Safety Inspection Service

V. The External Advisory Committee

The μChemLab™ External Advisory Committee held its first meeting in May 1997. Its Charter follows.

CHARTER
for
THE μCHEMLAB EXTERNAL ADVISORY COMMITTEE (EAC)

Background

In October 1996, Sandia National Laboratories began a major multimillion dollar initiative to develop a fully self-contained microchemistry laboratory that is pocket calculator size or smaller. Such an instrument is expected to make major contributions to Sandia missions ranging from detection and deterrence of the proliferation of weapons of mass destruction to the characterization and monitoring of environmental waste sites. The μChemLab initiative will both develop a prototype of an autonomous μChemLab and develop the enabling technologies for future generations of ChemLabs. Specifically, during the course of the next three years we will concurrently:

- *develop a fully self-contained pocket calculator-size device capable of analyzing both gas-phase and liquid-phase samples at the ppb to ppt level and in the presence of large backgrounds;*
- *develop the necessary technology—microfluidics, integrated microoptics, and multivariate data analysis—to enable the next generation ChemLab, which will be credit card size or smaller and have increased number of parallel analyses paths to give it even more analytical capability; and*
- *develop the architectures and control algorithms to use 10s to 100s of these sensors in a cooperative manner to solve complex detection problems.*

The External Advisory Committee

To help guide the μChemLab project, we have formed a committee of some dozen nationally recognized technical and applications experts drawn largely from government and universities. This External Advisory Committee (EAC) will meet annually to perform a top-level review of the project: its vision, strategy, and implementation. The resulting recommendations will be used by the μChemLab management team in formulating directions for the following year and in refining the longer-term vision. Because of the natural course of the development of the project, it is expected that each year's review would have a somewhat different focus, i.e.,

- *Spring 1997: because the project is still in its first year, this review will concentrate on the vision and on the implementation strategy of the overall project.*
- *Spring 1998: at this time, the preliminary design of the first-generation ChemLab will be complete and we will be well on the way to optimizing its components in preparation for a final engineering design in Fall 1999. Therefore, this review will spend a proportionately larger amount of time on the design and implementation of the first-generation instrument.*
- *Spring 1999: since the first-generation ChemLab will be nearing completion, this review will spend proportionately more time on the status of the technology for the next generation ChemLab and the architectures and controls for using them in a cooperative manner to address complex detection problems.*

Key Questions for the Spring 1997 Review

In particular, for the Spring 1997 Review, we would like the External Advisory Committee to address the following aspects of the project:

1. Is the vision of an autonomous hand-held instrument, with the capabilities of quickly and inexpensively analyzing a very broad range of chemical substances *in situ*, compelling? Why?

2. Is it advantageous to be able to perform ultrasensitive analyses of a broad range of chemicals in a single instrument, or is it sufficient for a particular instrument to target a few selected chemicals? Why? (This impacts the number of parallel channels and their design.)

3. Will using multiple ChemLab sensors in a cooperative manner enable addressing still more complex chemical detection problems? Which ones?

4. What specific features and capabilities of ChemLab are most important? Why? Which, if any, features would you change, and why?

5. What are the additional benefits and applications implications of moving from pocket size to credit card size or smaller? Are there other directions you would like to see emphasized in the next-generation ChemLab?

6. Is the project design—top-level goals/deliverables, approach and implementation strategy—appropriate to the tasks? If not, why?

7. Is the chromatographic approach a reasonable one?

8. What do you see as the biggest challenges to overcome during the next 12 months and how would you approach them?

9. Are you aware of mature efforts in any of the enabling technologies? Where/who?

Rather than meet once a year as planned, the EAC, at the conclusion of its first meeting in May 1997, asked that they meet every six months. The EAC met again in December 1997 and approximately every six months thereafter. A commencement celebration was held as part of the last meeting in November 1999.

Membership of the EAC consisted of leaders in academia and government agencies. The titles and organizations of those who participated follow.

Table 16. Members of the External Advisory Committee

Title	Organization
Professor of Chemistry	Stanford University
Associate Director, Microfluidics Laboratory, Department of Engineering	University of Illinois
Professor, Associate Director, Center for Process Analytical Chemistry	University of Washington
Professor, School of Applied and Engineering Physics	Cornell University
Project Manager, Chemical/Biological Warfare Group	Battelle
Chemical Projects Manager	Defense Intelligence Agency
Director, Border Research and Technology Center	NIJ/Sandia
Special Assistant, Chemical & Biological Matters	Office of Undersecretary of Defense
Director of Biotechnology Research	SAIC
Director of Compliance and Technology, Regional Office	Environmental Protection Agency
Acting Director, Office of Technical Development	National Cancer Institute

The EAC was an outstanding success, providing both challenge and valuable insight to the entire team. In addition, the team forged friendships with the EAC members that led to further support with personal advice and introductions to useful contacts.

VI. Tracking Other Organizations' R&D

After the initial Benchmark Report was completed in May 1997, the team had an ongoing need to track others' developments in this exploding field to ensure that the μChemLab™ technology bundle remained unique or at the forefront of the field; to identify others' technologies that could be "enabling" to the μChemLab™ effort; and to identify any alternative technologies that would lessen the Value Proposition for the μChemLab™.

Immediately following the Benchmark Report, the team established a passive system to notify them when other organizations made important announcements. When warranted, as it often was, further work would be done and a brief paper prepared providing more detail on an advancement or a new entry. This seemed adequate for a time, but it became clear that the team needed a new summary look, particularly at the new entrant organizations. The team issued a thorough Delta Report in April 1999 that identified several new developments and served as a wake-up call that the "passive" system of looking at press releases and relying on team members to spot new technologies was not adequate.

The team developed the *μChemLab™ Information Tracking Report* and active intelligence system to meet this need. The first Information Tracking Report followed the Delta Report by three months, and the second was completed two months later. The new intelligence system worked well, and the results of five or six months of implementation led to the need for another summary report, a Conspectus, issued in July 1999. The team issued another summary report in January 2000.

Beginning in January 2000, the Tracking Report's frequency increased to every month. This supported the increasing needs of the team for intelligence as "demo" opportunities became a reality and as talks with PMPs increased in number and intensity. Issue 16 of the *μChemLab™ Information Tracking Report* was released at the end of October 2000.

The first page of the first report follows. The 16-page report is issued in electronic format. Users may click on any subject heading on the first page (or on the pdf table of contents that shows on the electronic version) and go immediately to the detail on that subject. Links are also provided to relevant Web pages.

Information Tracking Report

A Service of Business Intelligence & Analysis, Org. 4315

μChemLab™

Issue 1: April/May 1999

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Summary (headlines here – detail follows)

Press Coverage of μChemLab™

Sandia issued a press release, "Sandia's tiny acoustic wave sensors will detect minute traces of dangerous chemicals," on March 29th. Our search through late May indicated the item was picked up in six publications: *Emerging Food R&D Report*, the *Daily Telegraph* (UK), *BMD Monitor*, *Electronic Engineering Times*, *Electronic Times*, and *Pesticide & Toxic Chemical News*. In addition, it was mentioned by Bill Richardson during the DOE Medical Technology Expo (reported in the *Federal Technology Rep*ort).

Other News

- **Caliper** completes new California facility (HQ and manufacturing) and names new VP of Operations.
- **Caliper** and **ACLARA Biosciences** (AKA Soane) are suing each other over IP.
- ***Ciphergen*** *launches ProteinChip product.*
- **Ciphergen, Clinical Micro Sensors, Cepheid** and others participate in 1st Annual BioPartnering Ventures forum.
- **Cyrano** and **H-P** intend to launch a hand-held industrial e-nose later this year.
- **DARPA "Dog-Nose" contractor (Texas A&M)** gets press on technology under development.
- ***DRDE (India Defense Estab.)*** *develops a portable IMS-based chemical warfare agents detector.*
- ***Drew Scientific*** *targets point-of-care blood analysis application for electrochemical analyzer.*
- ***DuPont*** *and* ***U of Del*** *have devised a bioluminescent biosensor.*
- **EG&G** completes acquisition of PE Analytical Instruments division.
- **INEEL** designates $1.7 million for new Center for Ion Mobility Spectrometry – may
- **InVision** gets $2.125 million more from DARPA for QR landmine detector device.
- **Motorola and DuPont** possibly collaborating with VCU on biosensors; Motorola granted exclusive license from Xenometrix for gene expression profiling.
- **Naval Research Lab** (McGill) papers from 1998 conference on SAW device posted.
- **Northrop Grumman** author publishes on micro-machined vacuum pump.
- ***Orchid*** *launches new SNP-related website; collaboration with GenoVision, a Norwegian gene test company, disclosed.*
- ***PE Biosystems, ACLARA*** *and* ***J&J*** *announce agreement to develop instruments for rapid drug screening.*
- **RMV Scientific** (startup firm) has portable GC under development.
- *Chemical Engineering* magazine had a brief mention of **Sawtek's VaporLab.**
- **U of Michigan's** DNA LOC costs $6.

FYI … news on some gas detectors for the petroleum industry; analysis of "The Ultimate Terrorists;" Jane's March Chem-Bio Conference; and articles on proteomics and MEMS.

lead to better hand-held chemical detectors.

VII. Providing Background Profiles

The team frequently needed background profiles in two distinct areas: 1) enabling technologies; and 2) company profiles.

A. Enabling Technologies Profiles

The team commissioned profiles, or technology surveys, on a wide variety of topics, including: 1) ultrathin insulation materials; 2) micropumps; 3) microhumidity sensors; 4) micro CO/CO_2 sensors; and 5) microtemperature sensors.

These reports varied in length from 15 to 60 pages and included 1) dimensions; 2) operating characteristics and limitations; 3) detail on the developers and manufacturers; and 4) contact information. The consultant also collected technical conference papers, pictures of the devices, and literature when available.

B. Company Profiles

The team received more than a dozen profiles of companies that they used to prepare for meetings with companies interested in a partnering relationship or to provide background on companies that had an enabling technology that was potentially useful.

These profiles could contain 1) financial analysis; 2) markets and market shares; 3) company strengths and weaknesses by markets or products; 4) major competitors; 5) corporate goals and strategies; 6) identities of the decision-makers; and 7) contact information.

VIII. Conclusion

The technical and market intelligence analysis of the μChemLab™ satisfied the goals of 1) uncovering and classifying others' development efforts in microchemistry; 2) ascertaining that Sandia National Laboratories' vision for a fully integrated microchemical laboratory—with all the distinctive major features envisioned—was unique; and 3) uncovering and qualifying market demand and potential applications.

While Sandia remains at the forefront of R&D in microchemistry, ongoing intelligence collection and analysis of other organizations' efforts in this field, as well as continued excellent technical work, are vital to maintain Sandia's position.

Contact Marie Garcia, 505-844-7661, email mgarci@sandia.gov for advice and suggestions.

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