Nickel and Iron Alumindes

A Case Study for the DOE/ER R&D Evaluation Workshop

Linda L. Horton
Metals and Ceramics Division
Oak Ridge National Laboratory

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Today, Nickel and Iron Aluminides are Major Areas of Research and Development

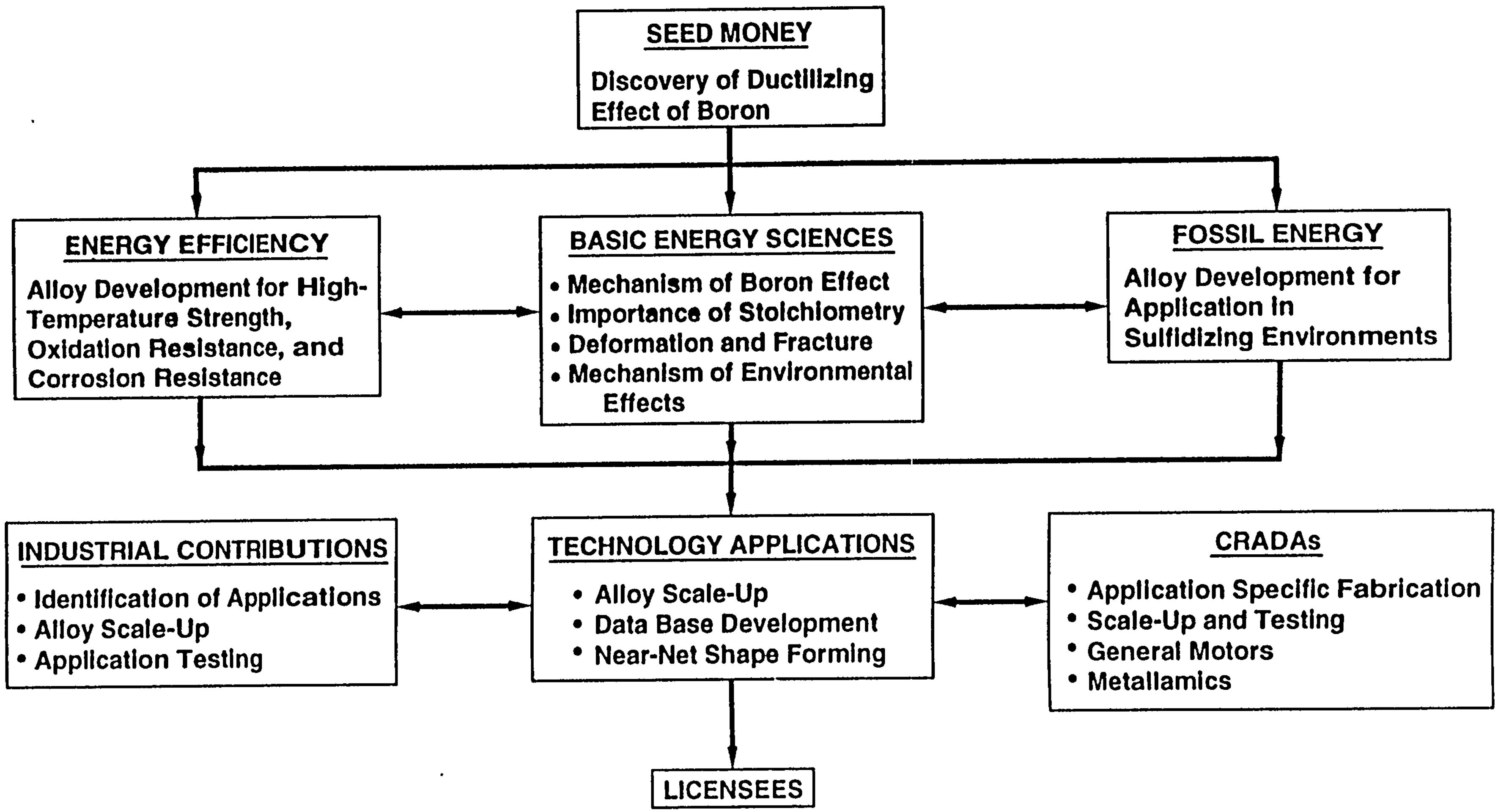
- Background
  - Not a major area of R&D in the 1970s
  - Part of an alloy class called Ordered Intermetallics
  - Good high temperature properties but poor room temperature properties
  - Intermetallic phases strengthen superalloys used in jet engines and other high temperature applications
- What caused today's interest in intermetallics as a stand-alone alloy?
  - Good scientific basis for improving properties
  - Technological advances in alloy fabrication and related technologies
  - Industrial interest and commercial products

What are the Key Elements for the Success of Nickel and Iron Aluminides?

- A good idea... and the freedom to pursue it
  - Seed Money, BES
- Partnerships in R&D
  - BES, Division of Materials Sciences
  - Fossil Energy Advanced Research and Technology Development Materials Program
  - Energy Efficiency, Advanced Industrial Materials (AIM) Program [and its predecessor Energy Conversion and Utilization Technologies (ECUT)]
  - Industrial partnerships, including CRADAs
- A multidisciplinary approach
  - Basic research on understanding properties
  - Alloy design and properties improvement
  - First principles theory through continuum mechanics
  - Advanced analytical techniques for characterization
  - Processing and fabrication research (including casting and welding)

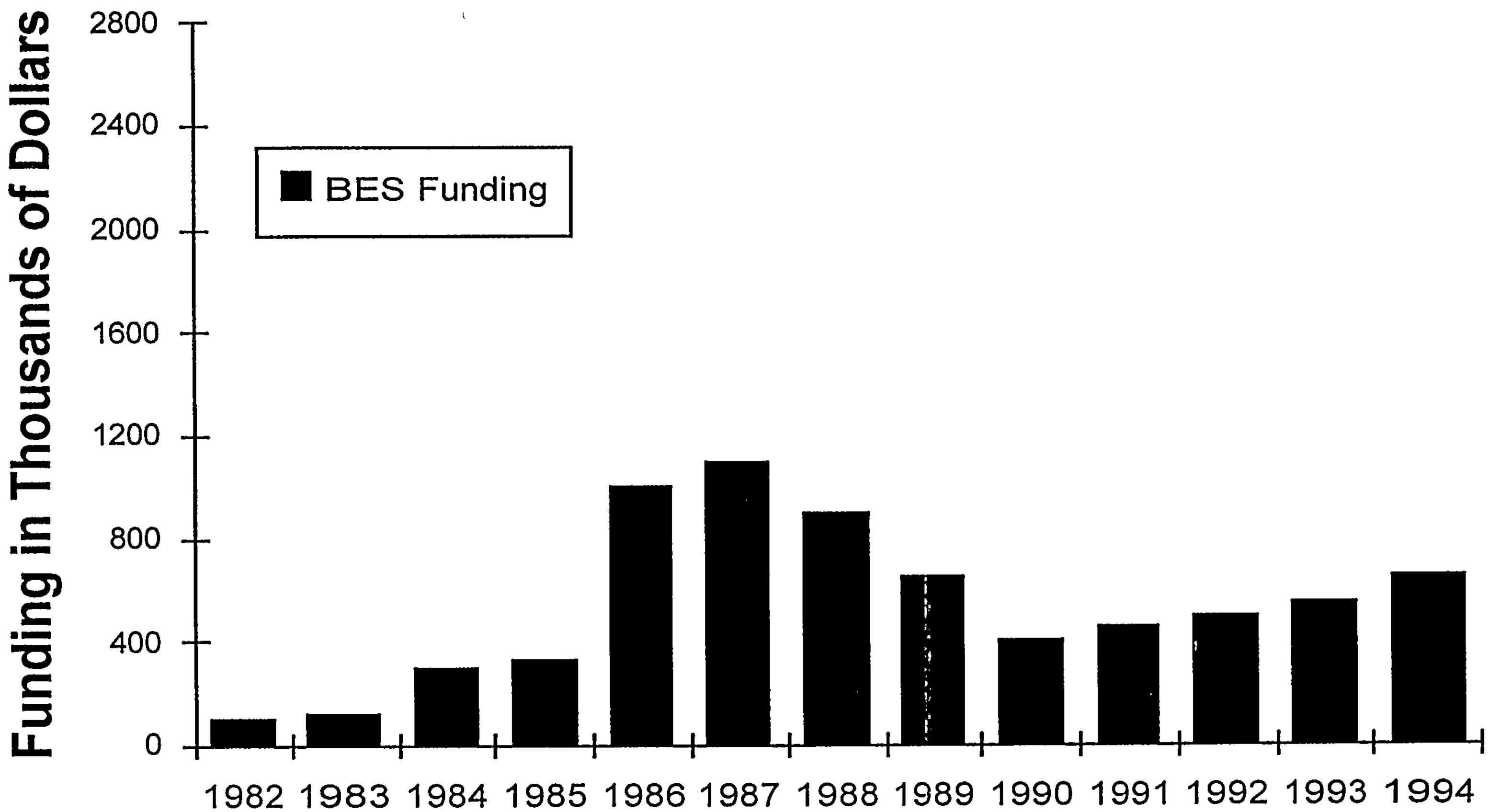
ORNL-DWG 93M-14819

DEVELOPMENT OF NICKEL AND IRON ALUMINIDES HAS REQUIRED PARTICIPATION OF SEVERAL PROGRAMS AND INDUSTRY

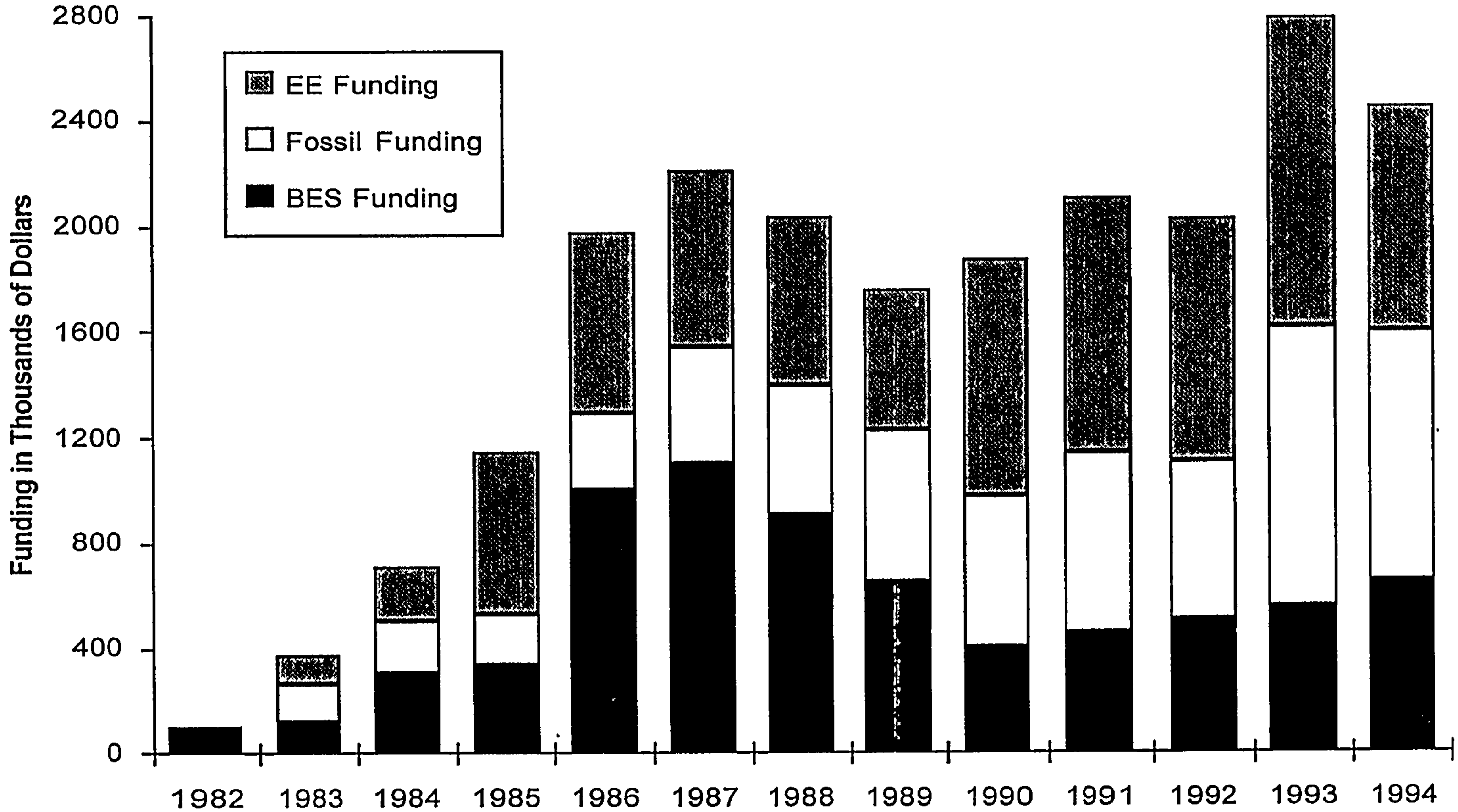


ornl

BES Funding of Nickel and Iron Aluminides Research at ORNL Began in 1982
Total: $7M to Date

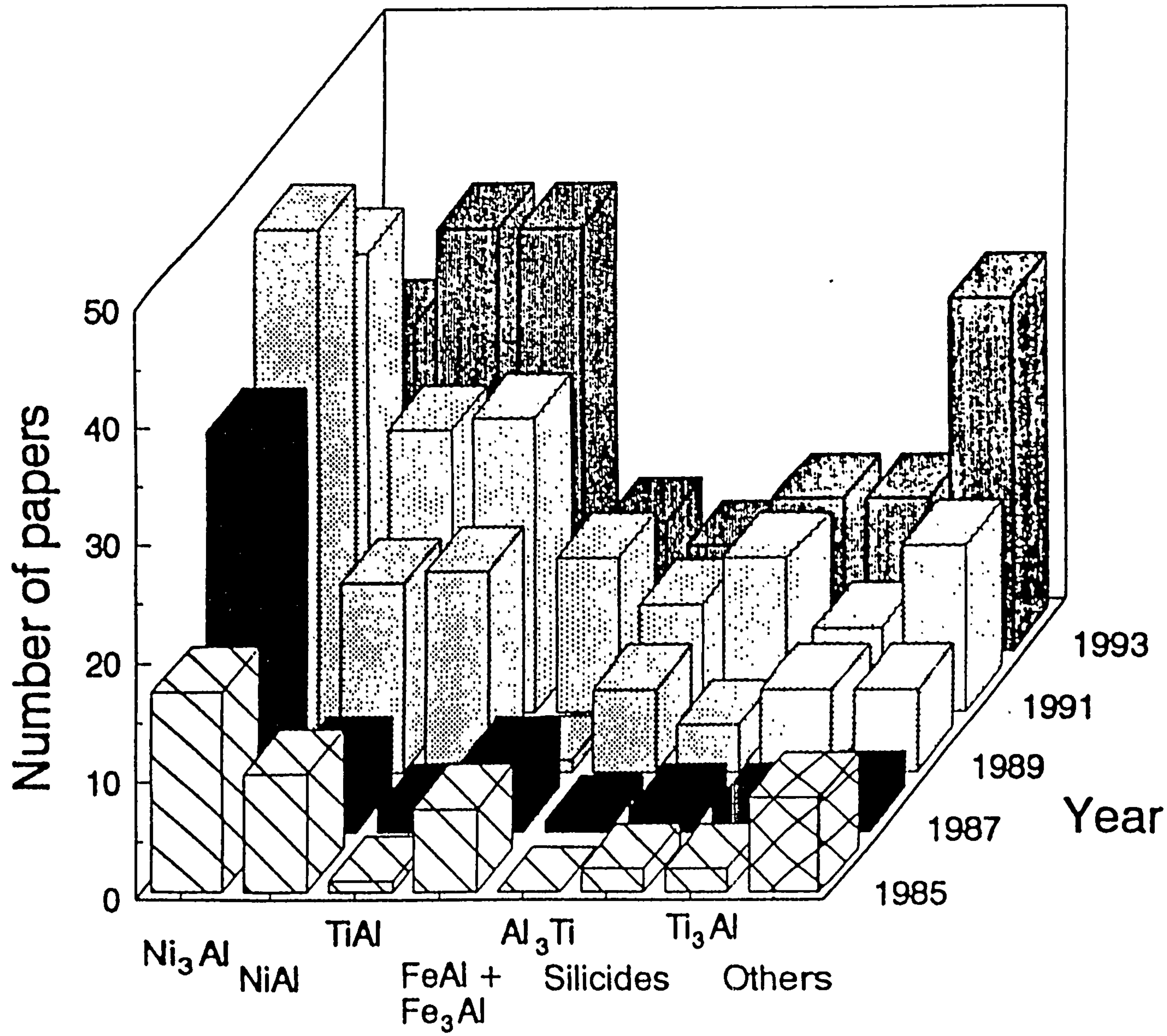


Total Funding for ORNL Nickel and Iron Aluminides Research: $21M



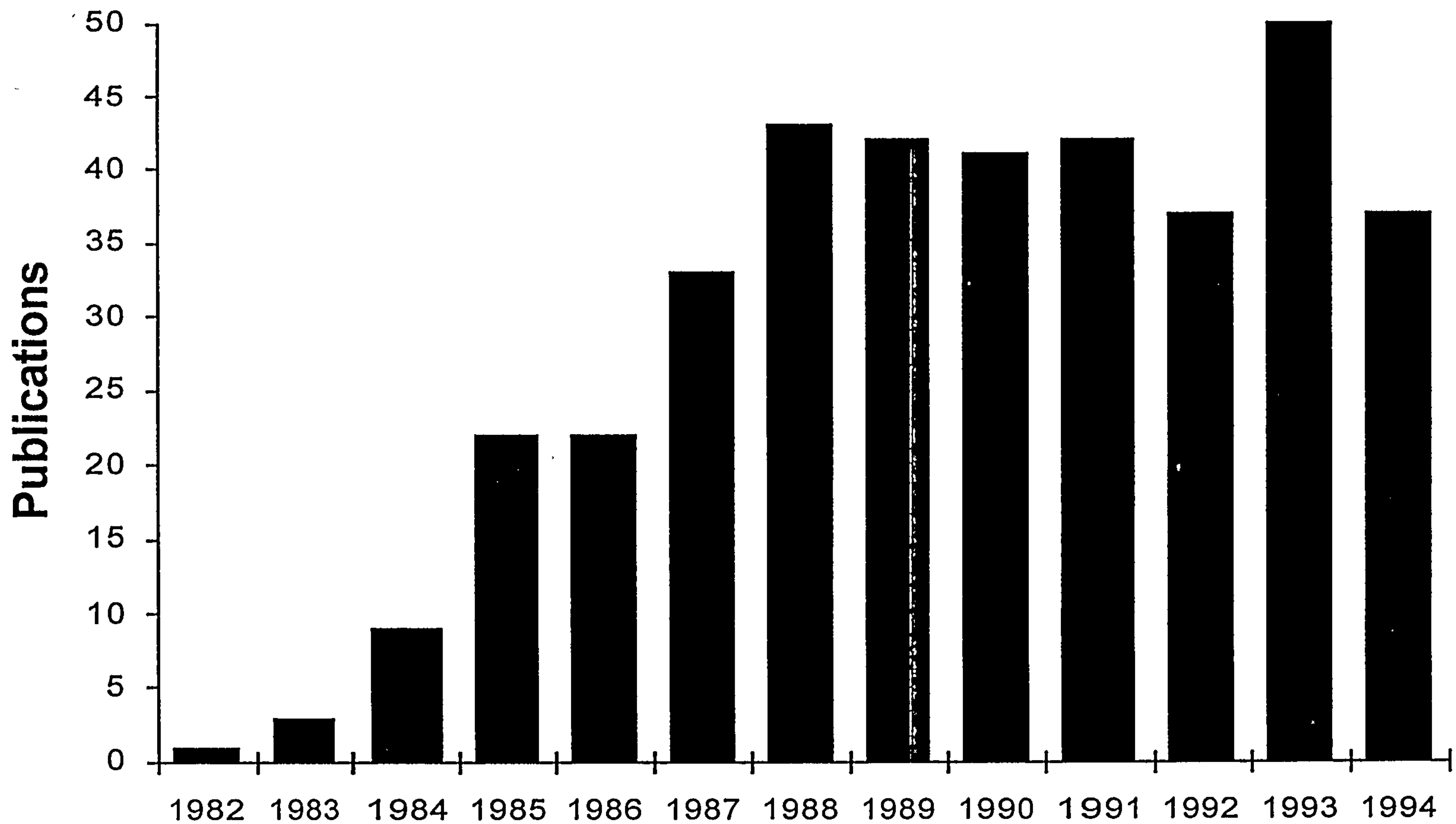
ORNL is the Key Laboratory in the International Nickel and Iron Aluminides R&D Community

- Over 200 R&D collaborations with academia, industry and other national laboratories
  - Alloy Behavior and Design
  - Theory and Modeling
  - Welding and Joining
  - Corrosion
  - Processing
- Over 100 Interactions with industries
- Organization of nearly 40 symposia and meetings
- ORNL research has involved 15 postdoctoral fellows and 25 graduate students
- Involvement in editor/editorial boards of 3 journals
  - New Journal of Intermetallics

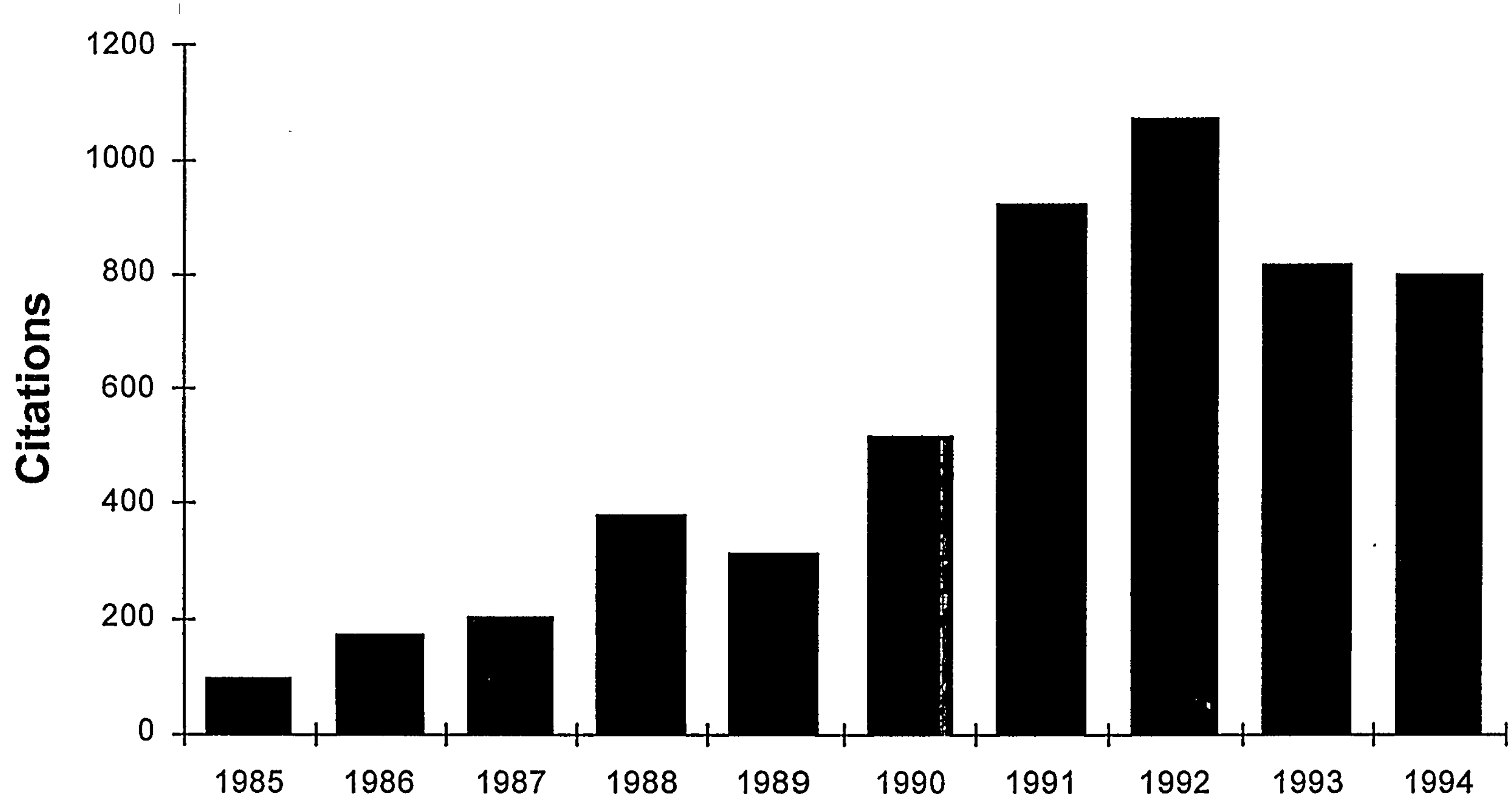


Major areas of work on intermetallics as indicated by number of papers published in the five MRS High-Temperature Ordered Intermetallic Alloys proceedings. (Courtesy of Randy Bowman and Michael Nathal of the NASA Lewis Research Center, Cleveland, Ohio.)

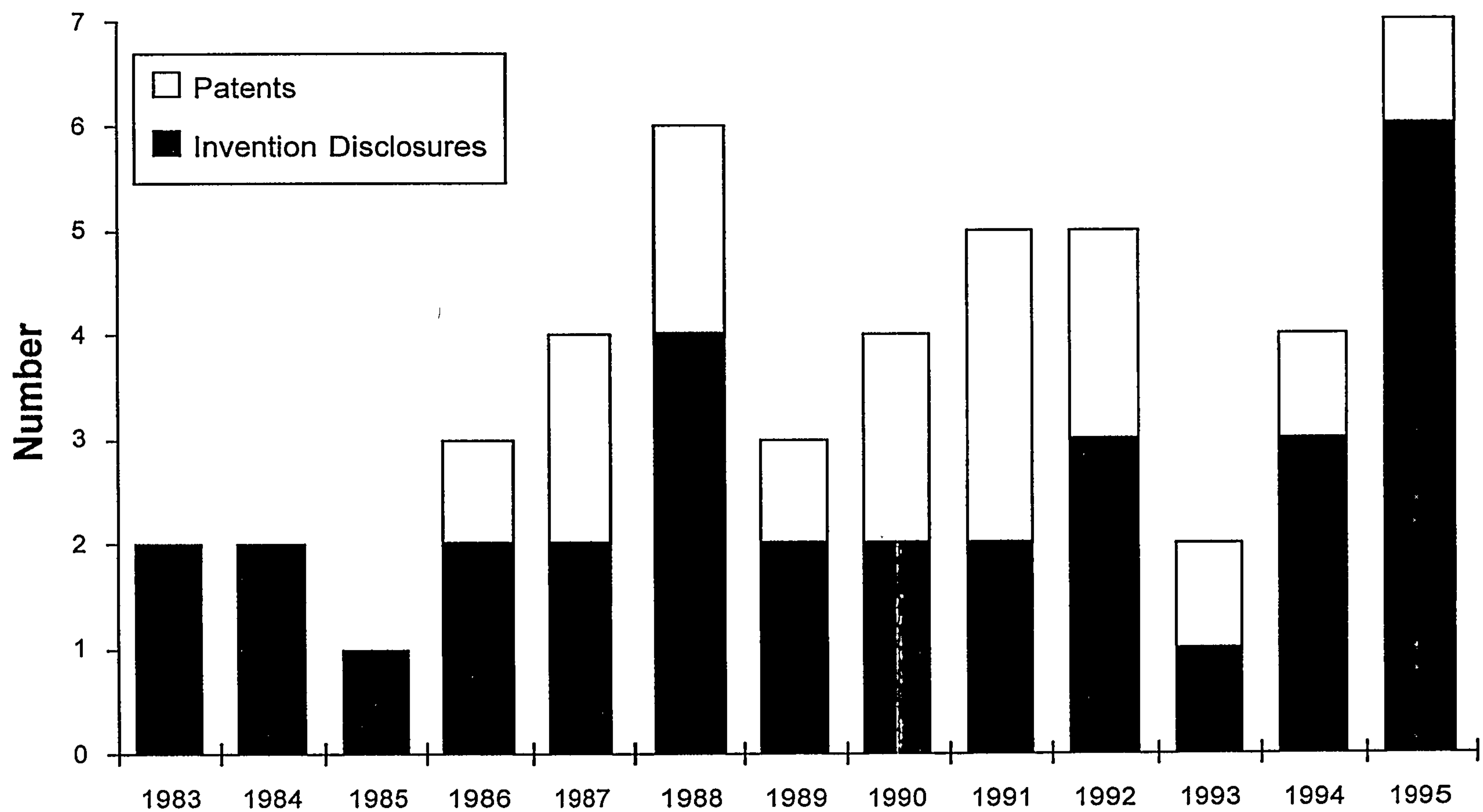
ORNL Nickel and Iron Aluminide Publications Have Averaged 40 per Year Since 1988



Since 1988, Citations to ORNL Intermetallics Publications Have Averaged Nearly 700 per Year



ORNL Nickel and Iron Aluminides Research Has Generated over 30 Invention Disclosures and 16 Patents Since 1983



Since 1985, There Have Been 12 Licenses for Nickel and Iron Aluminides Technology

Iron Aluminides

- Ametek, Inc. (1990)
- Cast Masters Division, CT Manufacturing Corp. (1992-93)
- Harrison Alloys, Inc. (1990-94)
- Hoskins Manufacturing (1991)

Nickel Aluminides

- Hoskins Manufacturing (Armada Corp.) (1987)
- Armco, Inc. (1987)
- Ametek, Inc. (sub-license under Armco)
- Cummins Engine Co. (1985-94)
- Harrison Alloys, Inc. (1990-94)
- Metallamics, Inc. (1987)
- Rapid Technologies (1994)
- Valley Todeco Division, Lamson and Sessions Co. (1988)

Six CRADAs Involve Nickel or Iron Aluminides
Total Value of Over $3M

Development of Ni_3Al Heat-Resistant Assemblies for Heat-Treating Furnaces
General Motors - Saginaw; EE/AIM-support; 1992-96; $1.9M

Ni_3Al for Use as Transfer Rolls in the Hot Processing of Steel
Metallamics; EE/AIM-support; 1992-95; $400K

Use of Ni_3Al-Based Alloys for Walking Beam Furnaces
Rapid Technologies; ERLTA-support; 1993-95; $100K

Development of Corrosion-Resistant Surface Protection for Fossil Power Systems
ABB Combustion Engineering; Fossil Energy-support; 1994-97; $360K

Development of Filler Metals for Welding of Iron Aluminide Alloys
Devasco International; Defense Programs-support; 1993-95; $100K

Development of Commercial Applications of FAPY Alloy
Hoskins Manufacturing; Fossil Energy-support; 1994-97; $200K

Four CRADAs Represent Spin Off Work From the Base Aluminides Program

Shape Memory Application Material
- Eaton & Johnson Controls; EE/AIM-support; 1991-92; $1.0M

Development of a High Temperature Shape Memory Alloy
- Teledyne Wah Chang; ERLTA-support; 1994-95; $100K

Alloy Design of $Nd_2Fe_{14}B$ Permanent Magnets
- Delco Remy, GM, ERLTA-support; 1995-97; $1.2M

Development of Isotropic, Micro-Toughened Titanium-Base Intermetallics for High Temperature Service
- United Technologies, Pratt & Whitney Div., Defense Programs -support; 1993-95; $4.5M

Several Commercial Nickel and Iron Aluminide Products are in Use and Under Development

- Dies
  - glass manufacture
  - fabrication of “super” magnets
- Furnace trays
- Transfer rolls for re-heat furnaces in steel manufacture
- Furnace rails
- Filters for fossil energy applications
- Turbochargers for diesel engines
- Pressure reduction valves (petroleum applications)

Nickel and Iron Aluminide Research Has Received Significant Recognition

- 3 R&D 100 Awards
- E. O. Lawrence Award
- Humboldt Award (Germany)
- Professional Society Fellows: TMS; ASM (4)
- Buehler Technical Paper Merit Award (Best paper of the year)
- Scripta Metallurgica Outstanding Paper of the Year
- Jennings Memorial Award, American Welding Society
- 3 Federal Laboratory Consortium Special Awards for Technology Transfer
- 3 DOE/BES Materials Sciences Awards
- 2 Martin Marietta Jefferson Cups (Inventor and Scientist of the Year)

New Areas of Research Have Opened or are Opening

- Magnetic materials
  - $Nd_2Fe_{14}B$ “super” magnets
  - FeCo
- Nickel and iron aluminide ceramic composites
- Titanium aluminides,silicides, . . .
- Hydrogen storage materials
- Back to superalloys
  - apply alloy design principles

"Metrics" of Importance in Evolution of Nickel and Iron Aluminides Research

- Scientific and technological progress
  - Advances in understanding
    - » Hard to measure
  - Invention disclosures and patents

- Creativity
  - Recognition of new, important needs and opportunities
  - Redirection of research to tackle scientifically important problems
  - Requires "freedom"

- R&D Partnerships
  - Among research supported by BES and Applied DOE Programs
  - Among national laboratories, universities and industry
    - » Postdoctoral fellows and students

“Metrics” of Importance in Evolution of Nickel and Iron Aluminides Research

- Scientific leadership
  - Awards
  - Journal editorships
  - Symposium organization
- Collaborations
  - Throughout the technical community
- Publications and presentations
  - Peer review
  - Peer recognition
- Industrial interactions
  - Collaborations, licenses, subcontracts, CRADAs, industrial fellowships, etc.
- Multidisciplinary research
- Utilization of user facilities

R&D Evaluation Workshop

R&D Measures - *Getting it Right*

Dr. Martha Krebs
Director, Office of Energy Research

September 7, 1995

Why Are We Here?

- BESAC Review of Laboratory Research and Technology Transfer
- BESAC Review of Economic Value of BES Research
- Secretarial Review of Energy Research Goals and Measures

Other Drivers

- Government Performance and Results Act of 1993
- Clinton Administration - *Reinventing Government*
- DOE Commitments:
  - Performance Based Contracts
  - Strategic Alignment
  - Process Re-engineering
  - Continuous Improvement

Expectations for the Workshop

- Identify Effective Evaluation Methods
  - Scientific Quality
  - Success of Collaboration
- Identify Predictors of Success

Lessons Learned - *Opportunity for Improvement*

- What satisfied the industrial collaborators?
- How do we measure the economic value of collaborations?
- What can this mean:
  - *for improving BES program?*
  - *for improving other ER programs?*
  - *for integrating basic research and technology programs?*

OAK RIDGE NATIONAL LABORATORY
MANAGED BY LOCKHEED MARTIN ENERGY SYSTEMS
FOR THE U. S. DEPARTMENT OF ENERGY

POST OFFICE BOX 2008
OAK RIDGE, TENNESSEE 37831-6132

TELEPHONE: (615) 574-5081
FACSIMILE: (615) 574-4066
E-MAIL: hortonll@ornl.gov

Date: September 1, 1995

To: Participants in the DOE OER R&D Evaluation Workshop

From: Linda L. Horton *Linda*
Associate Director, Metals and Ceramics Division

Subject: Background Information on Intermetallics

In the package that you recently received from the DOE R&D Evaluation Workshop, there was some information on intermetallics research. Unfortunately, some of this was outdated and inaccurate information. We have compiled the enclosed information on the nickel and iron aluminides subset of the overall intermetallics research effort. We hope that this provides a focused summary of the history of this research as background reading for the workshop.

I look forward to seeing you in Washington.

NICKEL AND IRON ALUMINIDES

The continuing quest for more efficient, environmentally-friendly processes and technologies often requires the use of materials at high temperatures in hostile environments. In theory, higher operating temperatures make possible higher efficiencies and lower pollution. In practice, the physical limitations of materials call for moderation to ensure reliability and longevity of the equipment.

Basic Energy Sciences researchers have contributed significantly to the emergence of new metallurgical alloys, called nickel and iron aluminides, that have great commercial promise. These alloys are made of nickel or iron and aluminum, with trace amounts of boron and other alloying additions. When properly prepared, these alloys exhibit extraordinary properties. For example, nickel aluminide is much stronger than stainless steel at elevated temperatures. In contrast to most other materials, it actually increases in strength with increasing temperature, up to about 1300°F. It then maintains this strength to more than 1600°F. Iron aluminides have tremendous resistance to oxidation and sulfidation, important properties for applications involving fossil fuels.

Technically, nickel and iron aluminides are part of a larger family of materials known as "ordered" intermetallic alloys, so named because of the precise ordering and interweaving of the atomic structures or lattices of the two metals. This particular situation, called a low "free energy" condition, makes it difficult to remove an atom from its position in the lattice, which gives the material its strength and chemical stability.

Intermetallic alloys were well known in the 1950s and 1960s for their extraordinary strength. Unfortunately, the problem with them at that time was that they were too brittle for most practical applications, especially at room temperature. Although single crystals of some of these alloys were known to be ductile, bulk quantities in polycrystalline form fractured like glass.

The basic problem was with the microscopic interfaces, called grain boundaries, where the crystals which constitute the bulk material join together. It was at these interfaces where the crystals tended to pull apart under stress, causing the material to break. This problem could be solved, it was hypothesized, if means were found for increasing the adhesiveness of these surfaces. Perhaps the addition of small amounts of alloying elements, to be used in the larger matrix of nickel/iron and aluminum, could somehow cause a strengthening of metal-to-metal bonding at these surfaces. Little knowledge was available to guide this search, however, and progress in solving the brittleness problem slowed.

In 1980, researchers at Oak Ridge National Laboratory (ORNL), using Laboratory Directed Research and Development and Basic Energy Sciences/Materials Sciences funds, began work to understand grain boundary brittleness and to find metallurgical ways to solve this critical problem. In 1981, the ORNL researchers found that Japanese researchers had reported a remarkable discovery in the Japanese journal "Nippon Kinzozu Gakkaishi," published in 1979 and written in Japanese. This publication reported that addition of small amounts of boron to nickel aluminide increased its ductility. However, the mechanism underlying this increase was not understood at all. Detailed BES studies of the boron effect revealed strong boron segregation to grain boundaries that enhanced grain boundary cohesion. Most importantly, the ORNL researchers discovered that the ductilizing phenomenon only worked under a highly specific condition. This was when the total number of aluminum atoms, compared to the total number of nickel atoms, was just slightly less than that dictated by its natural or stoichiometric ratio. In nickel aluminide (Ni_3Al), the natural atom ratio of nickel to aluminum is 3 to 1, or in other terms, 75 to 25 atom percents.

In a series of papers first published in 1982, Basic Energy Sciences researchers presented their findings and offered an explanation of the ductility phenomenon. Under conditions where the relative abundance of aluminum, compared to nickel, was slightly less than the natural ratio in pure Ni_3Al, say 24 atom percent rather than 25, boron atoms migrated to the grain boundaries. They accumulated there in the top two or three atom layers of the surface. They concentrated themselves in numbers far outweighing, by 60 times or more, their bulk proportion of, say, 0.1 percent. Under these circumstances, boron acts as an electron donor in the lattice structure. This is believed to add to the electron bonding potentials of nickel atoms between the intergranular surfaces. This makes the surfaces adhesive, lending ductility to the polycrystalline bulk material.

Other elements, by contrast, such as sulfur or phosphorous, were found to migrate strongly to open cavities and voids, and to a much lesser degree to the grain boundaries. This was fortunate, because these elements act as electron captors, believed to diminish the bonding strength between the intergranular surfaces, encouraging fracture and adding to embrittlement. Specifically, Basic Energy Sciences researchers showed that the solubility limit of boron in Ni_3Al was about 0.3 weight percent; that ductility of Ni_3Al increased dramatically from near zero to over 50 percent elongation with the addition of up to about 0.1 weight percent boron; that boron migration to the grain boundaries was highly dependent on the existence of slight deficiencies in the relative abundances of aluminum atoms compared to nickel; and that grain boundary boron segregation strongly affected grain boundary cohesion and related atomic arrangements, which affected ductility.

All of this led to a much clearer understanding of the boron-ductility phenomenon which, in turn, led to more broadly-based research on other members of the family of ordered intermetallic alloys. It also provided much needed specificity to guide theoretical work on the role of atomic arrangements and electron structures in metal-to-metal bonding at grain boundaries. Finally, it encouraged engineers to pursue practical applications by lending predictability to various metallurgical procedures.

The discovery of the boron-stoichiometry effect on the ductility of aluminides has been pivotal in the development of a whole new field of research. It precipitated much follow-on and continuing research by both Government and industry on nickel aluminide. Beginning as early as 1983, following the initial discovery of ductile nickel aluminides at Oak Ridge, research funded by Energy Efficiency (Advanced Industrial Materials) and Fossil Energy (Advanced Research and Technology Development Materials) Programs has focused on development of intermetallic alloys for multiple applications, as well as addressing a host of issues in casting, welding, and related fabrication technologies. A number of companies have been involved in the commercialization of nickel and iron aluminides through licenses, cooperative research and development agreements, and other collaborations. These include Metallamics, Rapid Technologies, Valley Todeco Division of Lamson and Sessions Co., Hoskins Manufacturing Co., Ametek, Armco, Cummins Engine Co., Cast Masters Division of CT Manufacturing Corp., Pall Corp., General Motors, and ABB Combustion Engineering. In 1983, the research earned an IR-100 award from *Research & Development* (formerly *Industrial Research*) magazine .

Important in the success of the nickel and iron aluminides has been ongoing R&D from both the basic and applied perspectives. Ongoing fundamental studies of atom ratios, boron segregation and environmental embrittlement have provided information critical to understanding the mechanisms governing brittle fracture in nickel and iron aluminides and other ordered intermetallic alloys. Perhaps the best example is the resolution of the reasons for persistent embrittlement problems in iron aluminides. The discovery of "environmental embrittlement" in iron aluminides sparked a new direction in basic research that has led to the startling conclusion that iron and nickel aluminides are not "inherently" brittle as suspected for decades. Instead, these alloys are brittle due to interactions with the hydrogen in the moisture found in air. Arriving at this understanding involved an in-depth investigation of the mechanisms behind the mechanical failure of the alloys, atomic imaging of the structure, first principles theoretical calculations, use of ion implantation and characterization to determine "where is the hydrogen?", and a host of well-defined experiments correlating environment and fracture. In addition to providing basic scientific insights that are being applied to other intermetallic alloys, the knowledge of the mechanisms of environmental embrittlement has been used to guide alloy development for application of these alloys.

Today, commercial applications of nickel aluminides include industrial products and dies supplied by Metallamics for the production of magnets. These dies are used to hot press magnets into the desired shape in air at high temperatures. At one factory where these new dies are used, General Motors Company (GM) - Magnequench, over 1,000,000 magnets are produced each month. The lifetime of the nickel aluminide intermetallic die is about 100,000 magnets, a 5- to 10- times increase compared to earlier components composed of Inconel 718, a strong nickel-based superalloy.

Nickel aluminides have proven to be an effective material for furnace applications. Three major furnace components (large rolls, trays, and rails) are currently in full-scale testing at industrial manufacturing facilities. Major users include steel mills, automotive heat-treating facilities, and preheating furnaces for near-net shape forgings. GM - Saginaw Division and ORNL are working cooperatively to develop improved, longer life, heat-resistant assemblies made from nickel aluminides for heat-treating furnaces that have a carbon-bearing atmosphere. These assemblies contain the parts to be heat-treated and consist of trays, support posts, and fixtures. This work is under a Cooperative Research and Development Agreement (CRADA) funded by the Energy Efficiency Advanced Industrial Materials Program. These components, which are currently under testing at GM, will enable a more energy-efficient manufacturing process for producing automotive parts and an increase in throughput from the improved lifetimes.

Under another Energy Efficiency Advanced Industrial Materials CRADA, Metallamics and ORNL are evaluating the potential of nickel aluminide alloys for transfer rolls in heat-treating furnaces and slab reheating furnaces used during the normal hot processing of steel ingots into rolled products. The use of nickel aluminide may lead to rolls with longer operational life, improved high temperature oxidation resistance and mechanical properties, higher quality rolled steel products, and improved energy and operational efficiencies in the hot processing of steel. The goal of this CRADA is to successfully test the nickel aluminide transfer rolls in order to improve process efficiency, minimize waste by virtue of producing rolled steel of higher quality and to enhance the competitiveness of U.S. based steel producers. Nickel aluminide rolls are currently being tested at a major steel manufacturing plant in the United States.

Rapid Technologies, Inc. is now using nickel aluminide technology for walking beam furnace components. Walking beam furnaces are used to convey parts through several heat-treating steps. These furnaces require materials with a high melting point, resistance to oxidation and carburization, high-temperature strength, and ease of castability. Prior to the use of nickel aluminides, the rails at the entrance to the furnace had to be replaced at an unacceptable rate. Under a CRADA funded by the Energy Research Laboratory Technology Transfer Program and cooperation with the Energy Efficiency Advanced Industrial Materials Program, the application of nickel aluminides was evaluated and this technology was subsequently adopted by the company. Today, nickel aluminide components are listed in the Rapid Technologies catalogue under the alloy trade name of RTI-2000™.

Several energy-related commercial applications of iron aluminides are being pursued. In a Fossil Energy CRADA, ORNL and Hoskins Manufacturing Company are developing iron aluminide alloys for industrial and domestic heating element applications. ABB Combustion Engineering and ORNL are working on another Fossil Energy CRADA that will demonstrate the use of iron aluminide alloys as a protective weld overlay in fossil energy power systems. The first large-scale use of iron aluminides is for porous hot-gas filters in coal gasification power plants. This is a collaborative development between ORNL, Ametek Specialty Metals Division (a licensee for iron aluminides alloy powders) and Pall Corporation for filter manufacture.

Beyond the commercial and economic implications, this joint research by Basic Energy Sciences Division of Materials Sciences, Energy Efficiency Advanced Industrial Materials, and Fossil Energy Advanced Research and Technology Development Materials programs has set into motion a resurgence of research activity on ordered intermetallic alloys. Today, attendance at intermetallic alloy symposia at major scientific meetings is typically in the hundreds. The number of publications in this field has grown to the point that a successful international journal entitled "Intermetallics" was established in 1993. Support for intermetallics research has grown on an international scale with major R&D programs in place in Japan, Europe, and a growing program in China. Within the United States, research for specific intermetallics alloys is now funded for defense as well as energy applications. This worldwide effort is focused on further development of intermetallic alloys for structural use at elevated temperatures in hostile environments. The emphasis on intermetallics can be illustrated by the observation that one out of four of the papers presented at the Japanese Institute for Metals meetings (>2,000 papers) are related to intermetallic alloys. In addition, the 1994 Intermetallics Symposium at the Materials Research Society Meeting had the largest number of proceedings papers in the history of the meeting. Intermetallics have been clearly established as a major new area of alloy research and are evolving as a major commercial material.

Attachment

Implementation Plan
1995 Performance Measurement Pilot

Center of Excellence for Synthesis and Processing of Advanced Materials

Background
The 1995 Performance Measurement Pilot is a research project sponsored by the U. S. DOE Office of Basic Energy Sciences (OBES) for the purpose of testing an approach for ongoing performance measurement of basic research that supports future assessment of the impacts on industry and DOE technology programs. A model will be documented for possible transfer to other OBES programs.

With increasing competition for a smaller pool of basic research funds, and increasing opportunities for basic research and R&D to impact U. S. global competitiveness, measuring the economic performance and progress of basic research has become essential. There are requirements for performance measurement from the National Performance Review, the Government Performance and Results Act of 1993, the Office of Management and Budget, the DOE Secretary's Performance Agreement, and from the Assistant Secretary for Energy Research.

Expected Outcomes
Outcomes of this research are (1) compliance with current and future DOE, White House and Congressional measurement requirements, (2) improved understanding of techniques for measurement of OBES R&D, (3) development of useful decision-making infirmation for internal and external stakeholders, and (4) cost-effective data collection.

Description of the Objectives and Approach of the S&P Center
The DOE Office of Basic Research formed the Center of Excellence for Synthesis and Processing of Advanced Materials in 1993. The Center is a collaboration of a dozen DOE and university laboratories, the objective of which is to support quality, multi-disciplinary, multi-laboratory, basic research with a clear relationship to DOE and industry technology applications.

The Center forms partnerships with industry and with DOE technology program offices. With existing and potential partners, the Center promotes collaboration in research, exploring and sharing information on new avenues with persons from other research fields, laboratories and industry. Exploration leads to selection of those collaborative research projects that meet Center criteria for funding and support. The Center's research projects result in peer reviewed publications exchange visits, among others. In the short term, the quality and relevance of research can be measured. Only in the longer term are potential or actual economic impacts measurable. Center collaboration activities add value that can be measured by increased interaction among the partners, formal agreements, effective use of teams, and value as reported by partners in a survey.

A diagram of the activities, related representative outputs, and expected outcomes of the Center's performance shown in "Performance Map for an Energy Research Collaborative" attached.

S&P Center 1995 Performance Measures

Center Research Project coordinators have chosen a small set of 1995 performance measures that address the quality of their research, the value-added of Center activities, and the impact of research on industry and DOE technology office partners. Recognizing that results may not be forthcoming in all areas because Center activities are just beginning, the criteria for evaluating the success of 1995 Center performance are (1) Scientific and technical excellence, (2) Effective Collaboration among the laboratories, (3) Increasing partnerships with industry and DOE technology programs, and (4) Positive impact on industry and DOE technology programs.

Performance measures and evaluation questions have been identified, along with sources of data and evaluation methods, for each of these 1995 performance measures. A table is attached which summarizes the measures and data sources.

Data Collection Plan

Data collection will take three forms, (1) expert panel reviews of each project every three years, (2) tracking selected common performance indicators, and (3) a Center user survey.

Expert Panel Review Protocol

The primary purpose of project expert panel reviews is to examine research quality. However, relevance to mission, economic and technology goals, and technical risk may also be considered. Project coordinators will agree on a recommended protocol for the reviews, with the intention that projects will be reviewed similarly. The protocol will cover selection of panelists, issues to be addressed and rating schemes, if any, based upon best practice and current reporting requirements.

Tracking Common Performance Indicators and Attendance at Events

Tracking common performance indicators will be incorporated into routine Center communication. For example, the annual Field Work Proposal Executive Summaries produced in December each year contain accomplishments, publications, invited presentations, and cooperative agreements. These will be collected as they are prepared for other reporting purposes, at least annually. Preliminary data collection forms have been developed and are attached.

As they occur, projects will provide attendance and invitation lists from Center events, and information on informal interactions, visits and assignments. This information will be summarized at least semi-annually, and the names will be compiled for the Center User Survey.

Simple Information System

The measurement pilot will develop a temporary, simple tracking and information reporting system for the Center's 1995 performance measures. The information and reporting system will be accessible to all project coordinators, capture common performance measurement data and generate summary statistics and graphics for Center performance reports. It will be user-friendly and run through common windows-based software.

The first rounds of data collection will be on paper forms. To the extent they can be anticipated, the temporary information system will be designed with consideration for future modifications.

Center User Survey

The measurement pilot will design, complete, and report findings from, a Center User Survey. The Center pilot User Survey will assess the impact of the Center research on DOE technology partners and industry partners including the value of the collaboration to the next stage user, perception of relevance to industry or DOE technology research, effectiveness in forming and using interdisciplinary teams, effectiveness in setting and changing milestones, research direction or funding, and spin off projects, if any.

The User Survey will be conducted from a representative sample of those attending or invited to Center events during FY 1995. Interviews with project coordinators and a few users will provide direction for survey design, such that the survey will measure what is important to users.

Analyzing Data and Reporting Performance

The measurement pilot will draft, for thorough review by Center coordinators, a strawman FY 1995 Center Performance Report based upon chosen measures. DOE and Center project coordinators will clearly determine the uses and distribution of the FY 1995 pilot Performance Report, but it is anticipated that the 1995 report will be for internal use only. The intention is that the Center Performance Report will synthesize and summarize performance measures, along with results of the User Survey and any Expert Panel Reviews. A final version of the performance report will be written after project coordinators and DOE managers have commented on a December 1995 draft report.

Preliminary briefing slides for a Center Performance Report are attached.

Documenting Lessons Learned and a OBES Model

The measurement pilot will document the Center pilot as a possible model for DOE Office of Basic Energy Research. This documentation will consider the findings of an independent review of the 1995 process. Further review of the model will be solicited from R&D evaluation experts. Lessons learned specific to the S&P Center will be shared with the Center in time for improvements for FY 1996 Center performance measurement.

Provide an R&D Evaluation Workshop

Sandia proposes to plan and implement an OBES (co-sponsored) R&D Evaluation Workshop. At this one day workshop R&D evaluation experts and practitioners, including OBES research program management, will meet to discuss current R&D performance measurement and evaluation issues. The workshop will be held Summer 1995, in Washington, DC or at Georgia Tech.

Peer
eviewed
(Joint)
ublications

Research
relevant to
Industry
and
DOE
Technology
Offices

Impact on
Industry
and
DOE
'echnology
Offices

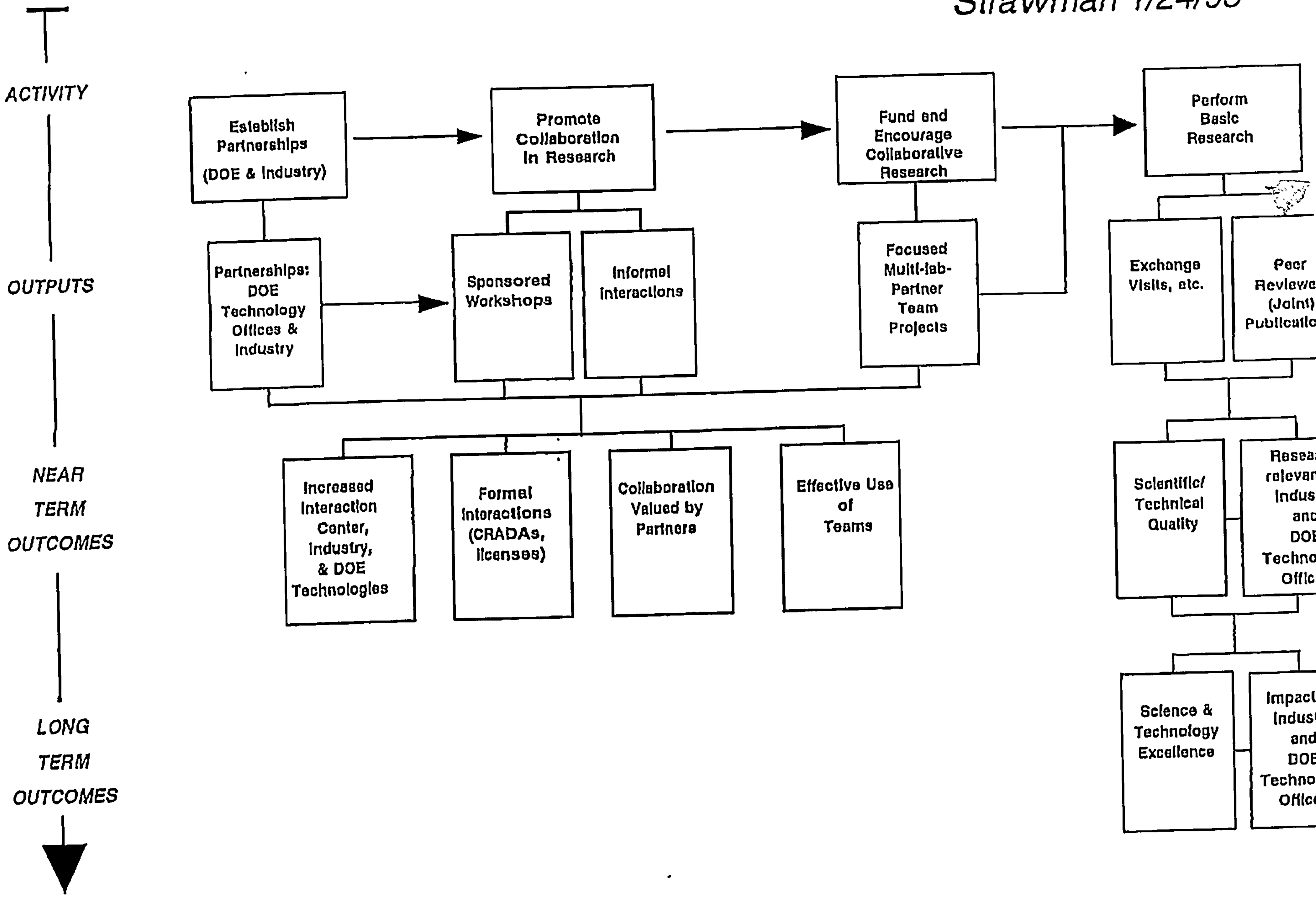
1995 performance measures have been drafted and sources of data and evaluations identified.

uccess Criteria and Performance Indicators	Data Source(s)
cientific/Technical Excellence	
• Number of peer reviewed publications	– Center tracking from lab reports
• Number of patent disclosures/applications	– "
• Number of invited presentations	– "
• Report of expert panels (each project every 3 years)	– Expert Panel Reviews
• Reports of Industrial Steering Group, DOE technology managers	– Center User Survey
ollaboration Among the Laboratories	
– Number of joint publications, patents	– Center tracking from lab reports
– Number of exchange visits and assignments	– "
– Effectiveness in forming and using interdisciplinary teams	– Center User Survey
ncreasing Partnerships with Industry/DOE Technology Offices	
– Number and total funds of joint projects, CRADAs, and other formal interactions	– Center tracking from lab reports
– Workshops: % attending that are DOE and Industry	– Event Attendance Lists
– Number of informal interactions/collaborations	– Center tracking from lab reports
– Number of lab visits and assignments by industry and DOE technology representatives	– "
Positive Impact on Industry and DOE Technologies	
– Feedback from these customers (next stage and potential)	– Center User Survey
– Number of licenses	– Center tracking from lab reports

Vorking Draft 3/3/95

Performance Map for an Energy Research Collaborative

Strawman 1/24/95



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