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# The NASA Lewis Research Center Small Business Innovation Research Program - An Assessment

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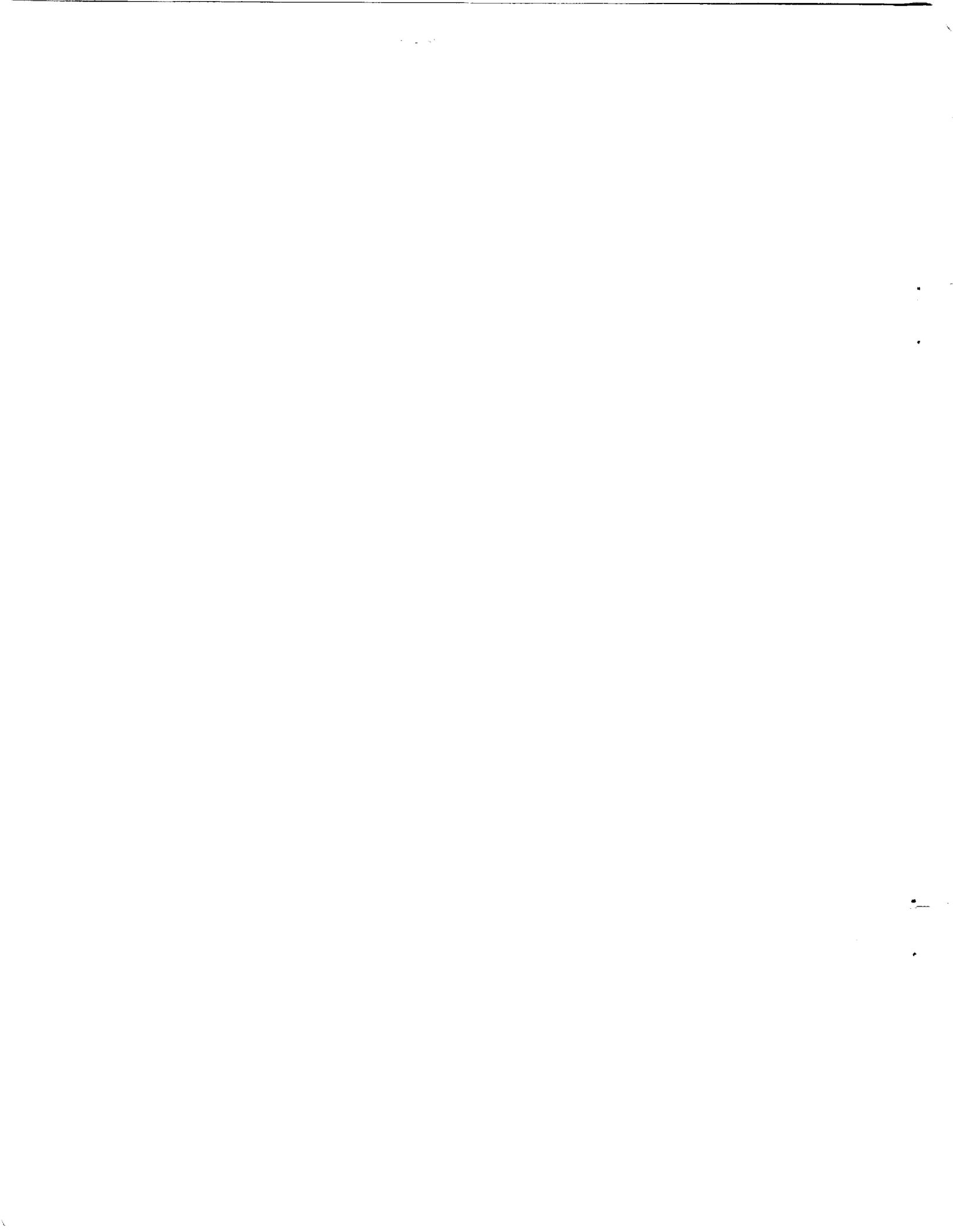
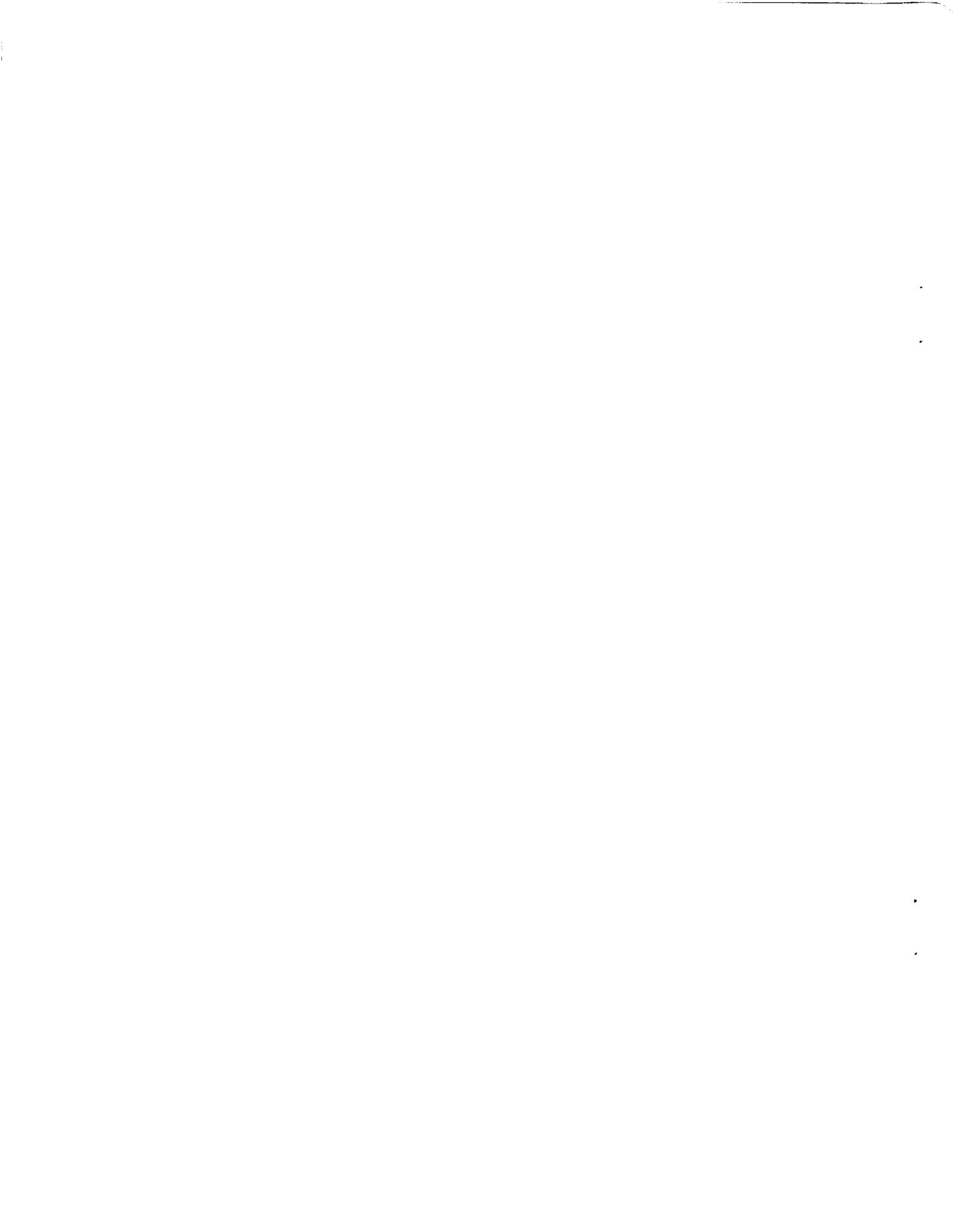


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# THE NASA LEWIS RESEARCH CENTER SMALL BUSINESS INNOVATION

## RESEARCH PROGRAM—AN ASSESSMENT

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### SUMMARY

An assessment was made of the NASA Lewis Small Business Innovation Research (SBIR) Program for the years 1983 to 1989. The assessment was based on the study of 99 Phase I contracts and 39 Phase II contracts. The overall impact of SBIR has been found to be very positive, contributing strongly to many NASA programs. In addition, many successful efforts have been commercialized benefiting the small business, federal agencies, and the aerospace industry. The program was evaluated in terms of contract quality, innovativeness, comparison to the state-of-the-art, achievement of goals, difficulty, and impact. Program difficulties were also identified, which could suggest possible program improvements.

Much of the information gained in this assessment provided a basis for a SBIR data base which will be updated every year. This data base is computerized and will provide an excellent source of information about past SBIR efforts and company capabilities.

### I. INTRODUCTION

#### Description of the SBIR Program

The NASA Small Business Innovation Research (SBIR) Program was initiated in 1983 with the purpose of stimulating innovative aerospace research and development in the small business community. This program has the multipurpose of strengthening the role of small business in meeting national R&D needs while encouraging commercial application of their results and fostering participation by minority and disadvantaged enterprises.

SBIR funding by NASA from 1986 was set at 1.25 percent of the agency's extramural R&D budget, in accordance with the minimum guidelines set by public law (P.L. 97-219). However, this represents a significant fraction of the agency's discretionary research effort. The total program funding for the NASA Lewis Research Center from 1983 to 1990 was \$63.2 M. This number reflects an allowable participation lower than 1.25 percent for the 1983, 1984, and 1985 program years.

The SBIR program employs a three-phase approach, of which only the first two phases are funded by the program. The Phase I objective is to determine the feasibility of an innovative concept or approach to a problem which is defined by the agency in its announcement of subtopics. Phase I contracts are

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\* During the final preparation of this assessment, the SBIR Program was reauthorized by public law (S.2941, 10/30/92) to gradually increase the minimum funding level from 1.25 percent to 2.50 percent by FY97. Phase I funding would increase from \$50 K to \$100 K and Phase II funding from \$500 K to \$750 K. Commercialization of successful contract efforts is also emphasized, and small business participation in non-SBIR federal R&D encouraged through a Small Business Technology Transfer Program.

generally limited to a six month duration and \$50 K, \* as recommended by the Small Business Administration.

A Phase II contract may be awarded, following a successful Phase I effort, to further develop the proposed idea. Phase II contracts normally extend over a 2 year period and are limited to \$500 K.

Phase III is not funded by the SBIR program, and therefore, is not subject to SBIR review. In Phase III, the small business pursues further development of Phases I and II achievements through private funding or follow-on contracts with federal agencies who will use the R&D product.

The Lewis Research Center has, in the period from 1983 to 1990, funded 230 Phase I contracts and 110 Phase II contracts. A listing of the numbers and total dollar value of Phase I and Phase II contracts for program years 1983 through 1990 is given in Table I.

TABLE I.

Year	Phase I		Phase II	
	Number	\$ (Millions)	Number	\$ (Millions)
1983	19	0.9	8	3.5
1984	19	.9	12	5.5
1985	22	1.1	11	5.2
1986	26	1.3	10	5.0
1987	30	1.5	16	7.2
1988	34	1.7	15	7.0
1989	37	1.8	17	8.5
1990	<u>43</u>	<u>2.1</u>	<u>21</u>	<u>10.0</u>
	230	11.3	110	51.9
<b>Grand Totals</b>				
	Number		\$ (Millions)	
	340		63.2	

### Rationale for Assessment/Data Base

This assessment has been conducted to determine the impact of the SBIR Program and its value to LeRC since its beginning in 1983, and to provide an easily retrievable data base of information on the completed contracts since that date. To accomplish this, feedback has been obtained primarily from Lewis SBIR technical monitors (TM), NASA persons most closely connected with the contract work. For purposes of assessment, this proved to be a more reliable source than that from the principle investigator (PI), who tends to rationalize failure.

Information gained included the nature and objective of the project, its expected NASA application, the achievement of its goals, its potential for NASA or other follow-on support and application (Phase III), and various other factors relating to the quality of the work. Information about company plans to continue the work into Phase III through follow-on contracts or other marketing of their product, however, usually came from company sources. It should be noted, though, that these plans often involve projections several years into the future which can be expected to change somewhat. Details of the assessment process will be given in Section II.

The information obtained from the technical monitors, principle investigators, and contract reports was summarized and put into a computerized data base. This fulfills our second objective, to make useful to NASA the experience of past SBIR contracts. As such, this data base should provide a source of new R&D ideas, devices, computer codes, and company resources. The data base will be discussed in greater detail in Section III.

## II. ASSESSMENT PROCESS

As indicated earlier, the assessment process drew on information from the Lewis technical monitors, contract reports and, for Phase III activity, the stated intentions of the companies. A questionnaire was sent to the technical monitors for Phase I and Phase II contracts through the 1989 program year. The technical monitors of some 1983 and 1984 contracts could not be found, so these contracts were not assessed. For Phase I contracts, a total of 12 questions were asked. For Phase II contracts, an additional seven questions were added. The questionnaire is shown in the Appendix. It was designed to minimize the burden on the respondent and to facilitate incorporation of the responses into a computerized data base. However, the respondent was encouraged to expand on any reply. If still lengthier discussion was desired, a telephone or personal interview was arranged.

As was expected, not all of the questionnaires were returned completed. Various reasons for this included:

- Technical monitor was no longer available.
- Phase I questionnaire was not completed if a follow-on Phase II contract was assessed.
- Many 1987, 1988, and all of 1989 Phase II contracts were not completed at the time.

Nevertheless, about 58 percent of the questionnaires were completed (99 of 173 Phase I's sent and 39 of 66 Phase II's sent). We believe that this represents a statistically significant response to evaluate the LeRC SBIR program.

Additional information about the contracts was obtained from contractor reports, where available. However, these were never used alone to evaluate the work since we have often found significant disparity between the degree of success given by the principle investigator and by the LeRC technical monitor. These reports were most useful in providing details of the programs and in providing the companies' plans for Phase III activity.

The information obtained from the questionnaires and reports was summarized onto special forms for input into the data base and for program assessment purposes.

## III. SBIR DATA BASE

From the inception of the SBIR program at NASA in 1983 until 1990, Lewis has funded 230 Phase I contracts and 110 Phase II contracts. This represents a significant source of R&D ideas and company capabilities. To fully utilize this knowledge, it should be readily available to NASA's staff. The Lewis SBIR data base is designed to facilitate systematic retrieval of important aspects of these contracts.

For example, a researcher might wish to know what new devices, instruments, or ideas were developed under the SBIR program in a specific topic or subtopic area. Another may want a list of companies with certain R&D capabilities. A manager may wish to know which contracts relate to a specific NASA program. Still another may ask what new computer codes have been developed.

Even before completion of the data base, the data collected for entry into the data base has been put to several uses. Examples include compilation of a set of success stories used in testimony at the 1991 Congressional budget hearings on SBIR program renewal, and identification of SBIR projects to be highlighted in Lewis displays and in Technology 2001 displays.

The information entered into the data base includes the following:

For All Contracts:

- Title of contract
- Proposal number, year, phase, set, step
- Contract number
- PR number
- Proposed value, contract value
- Award date
- Scheduled completion date
- Final close date
- Company name
- Address, city, state, zip
- Principal investigator, phone number
- Technical monitor
- Subtopic manager
- Contracting officer
- Task number
- Organization code
- Phase II award (Y-N) (Phase I only)
- Objective category
- Objective
- NASA application
- Achievement of goals
- Outcome (Abstract)
- NASA impact
- Technical difficulty

For Phase II Contracts Only:

- Impact statement
- Phase III application
- Innovativeness
- Cost effectiveness
- Quality versus other contracts
- Comparison to the state of the art

In addition, for Phase II contracts, a short narrative describing the achievement (or failures) of the contract and any plans for follow-on (Phase III) activity can be retrieved from the data base.

The data base has been proved very useful in assessing the Lewis SBIR Program, both in providing statistical data which will be discussed in the next section, and in development of the narrative summaries of the Phase II projects found in Section VI.

The software used for this data base, Paradox, was chosen for compatibility with NASA Headquarters files. Paradox is IBM compatible and permits easy creation of a variety of reports from the stored data.

#### IV. STATISTICAL FINDINGS

##### Phase I

Questionnaires were sent to the technical monitors regarding Phase I contracts from 1983 through 1989. As indicated earlier, 99 of 173 questionnaires for Phase I contracts were completed. Of these 99 contracts, 48 were described as having fully achieved their goals, 32 partially achieved them, and 19 failed to achieve their goals. It should be noted, however, that appraisal of successful achievement is somewhat subjective and technical monitor review represents a severe critique. This was evident by the relatively large number of Phase I projects called "partially completed" which were submitted and subsequently awarded Phase II contracts. Also, it should be noted that half of the "partially completed" projects were for the last two reviewed years and some of these contracts were not completed at the time of the questionnaire interview.

There seemed to be no correlation between the achievement of goals and technical difficulty. Seventy percent of the completed projects were considered by the technical monitors to be above average in difficulty, 25 percent of average difficulty, and only 5 percent below average.

It is difficult to assess the value of Phase I contracts on their own merit since most companies regard Phase I as a stepping stone to the larger Phase II contract. Nor does the failure to acquire Phase II funding for the project speak harshly of Phase I achievement since the number of Phase II contracts awarded are limited by funds available and some otherwise good efforts are left unfunded.

However, the technical monitors were asked about the specific impacts of the projects on NASA, and the results were found to be very positive. Nineteen percent of the respondents said the work solved a particular NASA problem, 38 percent said the work brought out new ideas, 33 percent said the work expanded the scope of NASA's programs, 17 percent said a known concept was developed sooner, and 19 percent said that the work solved a particular problem. (The percentages exceed 100 percent because multiple answers were allowed.)

In addition, 17 percent of the respondents commented that the SBIR program introduced them to a new company. This knowledge should prove useful in future R&D contracting.

Although not normally expected for Phase I, a number of the contractors expressed intentions or plans to continue development of their ideas under non-SBIR funding including NASA, other agencies, private capital and company funds.

In some cases, sufficient progress was made under Phase I that the company chose to market their findings immediately. This was true of a number of contracts which developed new computer codes where further development was neither necessary nor justified. Generally, however, success in Phase I was followed by application for Phase II funding. The next section gives an assessment of Phase II contracts.

## Phase II

Phase II assessment includes the SBIR program years of 1983 through 1988. Sixty-six questionnaires were sent and 39 were returned. Again, many of the contracts from the later years were not completed at this writing. However, the 59 percent response was considered significant for defining statistical trends. The assessed projects were distributed over 9 SBIR topics with Aeronautical Propulsion and Power, and Space Power contributing over half. The number of assessed projects in each topic is given in Table II.

TABLE II.—NUMBER OF ASSESSED PHASE II PROJECTS  
BY SUBTOPIC

Title	Assessed projects
Aeronautic Propulsion and Power	12
Aerodynamics and Acoustics	2
Aircraft Systems, Subsystems and Operations	2
Materials and Structures	6
Spacecraft Systems	1
Space Power	9
Satellite and Space System Communication	4
Material Processing, Microgravity and Commercial Applications in Space	1
Communications Satellite	2

Of the 39 Phase II contracts evaluated, all but two were considered by the technical monitors to have fully or largely achieved the contract goals. This high rate of success underlines the value of the Phase I "screening" phase of the SBIR program.

The impacts of the SBIR contracts on NASA were also categorized for the Phase II efforts. Nearly one-half of the technical monitors said that the SBIR contract brought a new idea to NASA's attention. Thirteen percent said the work solved a NASA problem. Thirty-one percent mentioned that the SBIR effort expanded their program scope, and thirteen percent said that it developed a known concept sooner.

Phase I "screening" also may have contributed to the higher percentage of Phase II respondents who felt that their SBIR contract brought a new idea to NASA's attention (50 versus 38 percent for Phase I). This would result if the Phase II reviewers favored proposals with new ideas.

On the other hand, only 17 percent of the Phase II technical monitors listed the introduction of a new company to NASA as a SBIR impact versus 28 percent for Phase I contracts. This difference may not be significant, however, since once the company receives a Phase I contract, the respondent may not regard it as a "new" company in Phase II. Nevertheless, the important thing to note is that a significant number of new companies are being introduced to NASA staff through the SBIR program. (Again, the percentages given for all NASA impacts do not add to 100 percent since multiple answers were permitted.)

The technical monitors were further asked to assess an overall quality of their SBIR contract compared to other non-SBIR contracts in their experience. Thirty-one contracts were able to be evaluated in this way, based on the respondents contract experience. Of these 31, 23 were judged above average in overall quality, 6 were average quality, and only 2 below average quality.

The technical monitors were also asked to evaluate the projects on innovativeness and status with respect to the state-of-the-art (SOA). Eight of 31 were judged to be major innovations and 10 others were



Since the companies were responding to NASA subtopics, it is not surprising that 18 of these 27 projects have been listed as candidates for NASA applications within 5-10 years. Nine of these have already been the basis for additional R&D under NASA funding or are currently being used in NASA's programs.

Other government agencies have expressed interest in continuing research on 10 of these 27 projects. Further development of the ideas through private industry funding by other companies is indicated for 13 of the projects. And of the 27 SBIR contractors, 12 have stated the intention to either continue work with internal funding or to market their achievements through commercial sales. Note that these categories are not exclusive: a number of the contractors plan using several or even all four Phase III modes.

This Phase III activity is shown graphically in figure 2. The number of contracts planning Phase III activity is plotted against the overall quality of the Phase II effort; and again, we see a strong correlation, with the preponderance of Phase III candidates judged high or above average in quality. Figure 2 also shows the distribution of activity among the four Phase III modes.

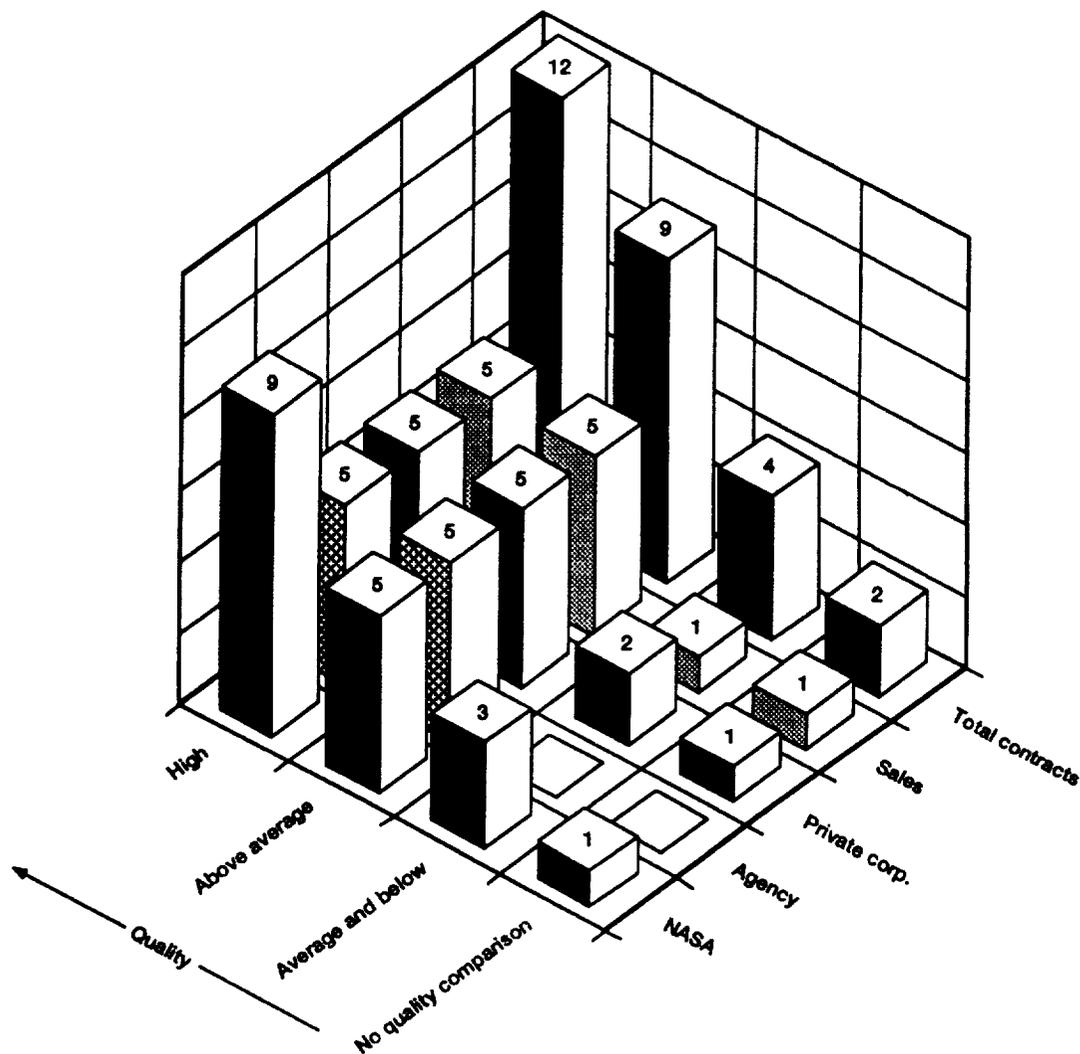


Figure 2.—Phase III activity.

In contrast, for the group of 12 projects which are not expected to go to Phase III, only two were rated better than average quality.

The correlation seen between quality and Phase III activity indicates that the technical monitor's judgement of the quality of the projects is mirrored by the companies appraisals of the success of their efforts and their commitment to the development of them.

A word of caution is required here, however, regarding the use of a single criterion to predict future success of SBIR contract efforts. Two of the 39 Phase II contracts reviewed were considered unsuccessful since they failed to achieve the contract goals. In both cases, however, the company has expressed plans to continue the work into Phase III. This would indicate that the company feels that the ideas are good but they need more time to develop them. Delays can be devastating to the short term contractor and reasonable patience could prevent the loss of valuable research and development ideas.

Project summaries for all Phase II contracts in the following section are presented under the SBIR Topic headings presented in Table II.

Although Phase III activity was not anticipated following the Phase I feasibility studies, several (6) companies expressed plans to market their Phase I products immediately or solicit non-SBIR support for additional R&D. Two of these companies did not apply for SBIR-Phase II support. But this was not because of failure to reach their contract goal, as all six were fully successful. Although not stated, it would seem that these two companies were eager to commercialize their product as soon as possible.

## V. NARRATIVE SUMMARIES

Thirty-nine Phase II contracts have been surveyed in this assessment. This section presents a brief summary of these projects, and for 27 of them, the companies' plans for Phase III activity. Those with planned Phase III activity are printed in italics. Since it is particularly useful to know which projects may be candidates for NASA application, these are identified with an asterisk.

### Phase II

#### Aeronautic Propulsion and Power

Title: Computations of Tip Flow Fluid in Advanced Propellers  
Company: Scientific Research Assoc., Inc.  
Proposal No.: 84-1-01.01-0511A  
Contract No.: NAS3-24881

A Navier-Stokes code was modified to investigate the development of the tip vortex on a propeller. The tip vortex influences propeller efficiency, off-design performance, and acoustics. This code, which was to provide a tool to investigate parameters affecting the tip vortex, was only partly successful because the calculations were done on a non-rotating analogy to the rotating propeller and could not correctly model the boundary layer and downstream wake.

Title: Optimization Procedure for Aerodynamic Design for Advanced Turboprop  
Company: Flow Industries, Inc.  
Proposal No.: 84-1-01.01-8500  
Contract No.: NAS3-24855

An attempt to develop an optimization scheme to aid in the design of advanced turboprops was partly successful. For simple cases, the geometry could be modified while the flow solution converged. For complex cases, the noise in the solution convergence prevented the optimization.

Title: Adaptive Computational Methods for Fluid Structure Interaction in Internal Flows  
Company: Computational Mechanics Company, Inc.  
Proposal No.: 85-1-01.01-0618  
Contract No.: NAS3-25196

A 2-D and a 3-D computer code were developed to study turbomachinery flows with moving boundaries. No immediate NASA use is expected.

Title: \*Fuel Atomization and Air/Fuel Interactions in a Turbulent Environment  
Company: Aerometrics, Inc.  
Proposal No.: 85-1-01.01-8887  
Contract No.: NAS3-25204

An instrument, the phase doppler anemometer, was developed to provide simultaneous measurement of fuel particle velocity and size in fuel injection systems. This innovative, non-intrusive device is being applied by NASA to characterize complex, turbulent fuel flow in gas turbine and rocket engines. In addition, it has created great interest in the commercial sector attested to by its selection for an international award by Toyota, and by commercial sales of the product in excess of \$20 M.

Title: Numerical Modeling of Turbulence and Combustion Processes  
Company: Cambridge Hydrodynamics  
Proposal No.: 88-1-01.01-1515  
Contract No.: NAS3-25942

A new computer code was developed to model turbulence and chemical reactions in complex engine flows. Additional NASA support is not expected, but the company intends commercial sales of the product.

Title: Cast SiC/Al Technology with Direct Application to Rotary Engines  
Company: PDA Engineering, Inc.  
Proposal No.: 85-1-01.02-8402  
Contract No.: NAS3-25201

Mechanical properties of discontinuously reinforced SiC/Al composites were measured including tensile, fatigue, stress rupture, creep, and wear tests. Thermal analyses of the rotor were conducted and a structural analyses at high creep rate were made to determine structural stability.

Title: Fiber-Optic, Photoelastic Pressure Sensor for High Temperature Gases  
Company: Strainoptic Technology, Inc.  
Proposal No.: 86-1-01.03-3383A  
Contract No.: NAS3-25419

A pressure sensor for measurement of gas pressures at high temperatures has been developed and a prototype has been successfully tested in the laboratory.  
The ultimate use intended for this device is a propulsion control sensor.

Title: \* Durable, Fast Response, Optical-Fiber Temperature Sensor Useable from 600-1900C  
Company: Conax Corporation  
Proposal No.: 86-1-01.03-4500  
Contract No.: NAS3-25451

An optical fiber sensor has been developed which is capable of making accurate temperature measurements of turbine inlet gases in gas turbine engines. This sensor is a candidate for use in NASA's Fiber Optic Control Sensor Integration Program. The company also plans to market the product through commercial sales for a broader range of applications.

Title: \* Rayleigh Scattering as a High Temperature Combustion Diagnostic Method  
Company: Aerodyne Research, Inc.  
Proposal No.: 83-1-01.04-9500  
Contract No.: NAS3-24613

A diagnostic temperature measuring system using Rayleigh scattering was developed. This system is ideal for measuring average and dynamic gas temperatures in the exhaust of combustors. The PI has left the company so no further R&D is expected by them. The continuing work at LeRC, however, has quite successfully employed this instrument in the study of H<sub>2</sub>-O<sub>2</sub> rocket plumes, which has contributed to the acquisition of two Lewis awards by the researchers.

Title: Supersonic Turbulent Reacting Flow Modeling and Calculation  
Company: Nielson Engineering and Research  
Proposal No.: 87-1-01.04-9457  
Contract No.: NAS3-25633

A CFD code was modified to provide analysis of high speed chemically reacting flows. This program supports the National Aerospace Plane effort at NASA Lewis. The code developed was tested for a variety of flows. Some numerical problems were encountered.

Title: Detonation Duct Gas Generator Development  
Company: Istar, Inc.  
Proposal No.: 86-1-01.06-7332A  
Contract No.: NAS3-25453

The feasibility of the generation of detonation waves in gas turbine engine ducts by dynamic compression of the gas was demonstrated. Critical problems identified were fuel injection and mixing. The implication of this work to more efficient and simpler gas turbine engines has aroused interest for additional R&D support by private capital.

Title: An Investigation of the Properties of Cooled Supersonic Flows  
Company: Fleckaerospace Ltd. Partnership  
Proposal No.: 86-1-01.06-4490  
Contract No.: NAS3-25461

Experiments were conducted to determine the changes in the properties of supersonic gas streams subjected to cooling by latent heat effects. This work contributed to the understanding of the physics of hypersonic engine cycles. While NASA plans no immediate extension of the work, further R&D is likely through private capital funding.

#### Aerodynamics and Acoustics

Title: Unsteady Compressible Flows in Intakes and Nozzles  
Company: GMAF, Inc.  
Proposal No.: 83-1-02.01-8450  
Contract No.: NAS3-24540

Progress was made toward applying numerical techniques to predict complex turbomachinery flows containing shocks. Although this project demonstrated new solution methods for complex flow problems, more work is needed to automate this procedure for general flow situations containing more than one high-gradient region.

Title: \*High Speed Helical Gear Power Transmissions  
Company: Transmission Technology Company, Inc.  
Proposal No.: 83-1-02.09-0418  
Contract No.: NAS3-24539

A new type helicopter transmission was developed which uses high contact ratio helical gears. This is a high reduction ratio transmission which will reduce weight, size, and cooling complexity. It is being evaluated by NASA for possible application within 5 to 10 years.

### Aircraft Systems, Subsystems, and Operations

Title: Icing Sensor and Ice Protection System  
Company: Innovation Dynamics  
Proposal No.: 85-1-03.01-4846  
Contract No.: NAS3-25200

A closed-loop system was developed and tested which used a piezoelectric film as an ice detector and an electroimpulse coil for deicing. An ice thickness threshold could be set, which when reached, triggered the deicing mode. Although no additional NASA support is expected, this major innovation will be further developed by private capital.

Title: Advanced Instrumentation for Aircraft Icing Research  
Company: Aerometrics, Inc.  
Proposal No.: 87-1-03.01-8887  
Contract No.: NAS3-25635

To improve general aviation safety through better understanding of aircraft icing, a prototype droplet sizing instrument was developed for use in ground icing test facilities and on icing research aircraft. The company anticipates private support of additional R&D and plans commercial sales of the product.

### Materials and Structures

Title: \*New Perfluoroether Fluids with Excellent Oxidative and Thermal Stabilities  
Company: Exfluor Research Corporation  
Proposal No.: 84-1-01.05-3812  
Contract No.: NAS3-24856

Four new fluids have been synthesized which are candidates for high temperature lubricants for satellite and gas turbine engine bearings. They are based on perfluoroethers which have excellent oxidative and thermal stabilities to 700F (370C). The innovative process to synthesize these ethers by direct fluorination has reduced their cost by about a factor of 100. Besides NASA interest, this product has potential for further development by Air Force and private funding. The company also plans commercial sales of the products.

Title: Embedded Fiber Optic Sensors for Polymer-Matrix Composite Process Monitoring  
Company: Geo Centers, Inc.  
Proposal No.: 87-1-04.01-7070  
Contract No.: NAS3-25817

Sensors embedded in the composite is the feature of a system developed to monitor the state of cure of polymer composite matrices. These sensors, which measure temperature (to 315C) and pressure, are expected to reduce the rejection rate of polymer composite components. In addition, interest from another agency, Sandia has planned further support of this work.

Title: \* An Expert System for Finite Element Modeling  
Company: Autodesk, Inc.  
Proposal No.: 85-1-04.02-8095  
Contract No.: NAS3-25150

A working structural analysis and modeling capability was developed. An expert system was incorporated to guide automation. NASA plans additional R&D support for development of this program which is designed to be used by non-experts. Private capital plans further support.

Title: An Expert System for Integrated Analysis and Optimization of Aerospace Structures  
Company: Structure Analysis Technology  
Proposal No.: 87-1-04.04-1319  
Contract No.: NAS3-25642

An innovative computer program was developed for structural analyses which featured an optimization capability provided by an internal expert system. Although potentially useful for design of structural components for NASA missions, NASA plans no further funding. The company, however, expects to market the product.

Title: \* Improved Perfluoroalkylether Fluid Development  
Company: Exflur Research Corporation  
Proposal No.: 83-1-08.05-2670  
Contract No.: NAS3-24632

To obtain an advanced gas turbine engine lubricant, a commercially available high temperature fluid was modified to improve its stability. The goal was partly achieved with a product whose use temperature in pure oxygen was increased from 280C to 360C. However, in air, the product loses its properties due to hydrolysis. Therefore, it may be useful as a lubricant only in space.

Title: \* Optimization of Silicon Carbide Production  
Company: Aerodyne Research Inc.  
Proposal No.: 84-1-08.09-6500  
Contract No.: NAS3-24891

A 2-D predictive model of -SiC growth in a chemical vapor deposition reactor was delivered to NASA. The model includes a mass transport code coupled with finite rate chemistry. Surface studies by the contractor provided the necessary code input. The results of this program are currently used at LeRC to better understand transport during SiC growth to guide experimental work.

### Spacecraft Systems

Title: \* Electronic Component Temperature Control Using Metal-Matrix Composites  
Company: DWA Composite Specialties, Inc.  
Proposal No.: 84-1-09.05-1504  
Contract No.: NAS3-24896

Very high thermal conductivity composite materials of graphite reinforced metals were developed and tested. The primary application of these materials is thermal management in electronic devices. Also researched were leads compatible with these materials. Graphite reinforced metals are of interest for future NASA missions, the company also plans commercial sales of the product. In fact, over 50 percent of the company's business is now devoted to high thermal conductivity materials.

### Space Power

Title: Novel Electrodes for Hydrogen-Bromine Battery  
Company: Giner, Inc.  
Proposal No.: 84-1-10.01-7270  
Contract No.: NAS3-24878

Catalysts of improved stability to Br<sub>2</sub> and Br were developed and incorporated into electrodes for fuel cell testing. The application of this work is an improved rechargeable battery for Space Station. However, to date, cell performance was modest compared with competing technologies.

Title: \* Dual Function Perovskite Catalyst and Supports for Alkaline Regenerative and Pressurized Fuel Cells  
Company: Physical Sciences, Inc.  
Proposal No.: 85-1-10.01-9030  
Contract No.: NAS3-25199

Oxide catalysts for use in fuel cell electrodes were prepared and tested for long term stability. Pyrochlore oxides of lead and rubidium of very high surface area proved satisfactory on cathode catalysts in alkali of O<sub>2</sub> for reduction. Additional R&D funding is planned by NASA, and the company expects funding from private capital as well.

Title: \* Indium Phosphide Solar Cells on Silicon Substrate  
Company: Spire Corporation  
Proposal No.: 87-1-10.01-6000A  
Contract No.: NAS3-25798

Indium phosphide solar cells are candidates for use in severely degrading radiation environments. To reduce their cost and increase their strength, cells were epitaxially deposited on silicon substrates. Their efficiencies (10.6 percent) were the highest achieved for cells produced in this way. With additional effort, however, higher efficiencies were deemed achievable, and NASA, Navy, private companies and Spire Corporation all plan additional effort or support. The company also anticipates commercial sales of the product.

Title: \* Improved Mirror Facet for Space Applications  
Company: Solar Kinetics  
Proposal No.: 87-1-10.01-2376  
Contract No.: NAS3-25632

Panels were developed to be used in a solar concentrator for the solar dynamic power system. The goal was a highly reflective, low-weight solar reflector that can survive the hostile space environment for more than 10 years. Spin coating was used to produce a very smooth doubly curved surface on which is deposited the reflecting aluminum layer. This major innovation is a candidate for future NASA missions and is of interest for further support by DOD.

Title: \* A Fresnel Lens Gallium Arsenide Photovoltaic Concentrator for Space Applications  
Company: Entech, Inc.  
Proposal No.: 85-1-10.02-0900  
Contract No.: NAS3-25192

The performance of a mini-dome, Fresnel lens photovoltaic concentrator was demonstrated. This high efficiency, lightweight power system was tested in flight experiments. The concept makes use of recent advances in refractive concentrator lenses and tandem photovoltaic cell technology to significantly improve the power to area ratio of solar arrays and reduce the cost of a variety of space power systems. Boeing Aerospace, working in conjunction with Entech, is scaling up this major innovation to provide a second generation replacement upgrade of the silicon array solar power system for Space Station.

Title: \* High Efficiency, Radiation Resistant Indium Phosphide Solar Cells  
Company: Spire Corporation  
Proposal No.: 84-1-10.03-6000  
Contract No.: NAS3-24857

Radiation resistant InP solar cells were prepared by a vapor phase epitaxial deposition process. This resulted in production of the world's highest efficiency (18.8 percent) InP solar cell. NASA plans possible application in future space power systems and the Navy has contracted to have cells produced in quantity. The company expects further R&D support by private capital and plans commercial sales of this product.

Title: \* Lightweight Mirror Structures  
Company: Ultramet, Inc.  
Proposal No.: 86-1-10.03-0236B  
Contract No.: NAS3-25418

An environmentally immune, highly reflective, lightweight mirror was developed for possible use in a space solar concentrator. The slightly dished, 6 inch mirror met contour and smoothness goals, but weighed 2.2 kg/m<sup>2</sup> (over 2x the planned specific weight). It is also uncertain whether this mirror concept can be scaled up. However, its high quality makes it of interest to NASA for future space missions and of interest to another agency.

Title: \* A Deployable 1MW Solar Concentrator with Receiver with Heat Storage  
Company: Energy Science Laboratories, Inc.  
Proposal No.: 84-1-10.04-7039  
Contract No.: NAS3-24882

A prototype deployable solar concentrator was constructed for use in a solar dynamic energy conversion system. However, the optical performance did not meet expectations. A second goal of the contract was to determine the feasibility of using beryllium for sensible heat storage in a solar receiver. NASA plans no further funding, but additional R&D support is expected through private capital.

Title: \* Measuring Reversing Flow Pressure Drop in Stirling Engine Heat Exchangers  
Company: Sunpower, Inc.  
Proposal No.: 84-1-10.04-2221A  
Contract No.: NAS3-24879

A unique flexible rig for measuring pressure drop in oscillating flows was constructed, tests were run on a variety of tube and regenerator test samples over a wide range of Stirling engine parameters. This rig provided some of the first insights into oscillating flow effects in Stirling heat exchangers which are leading to improved Stirling engine design. The rig has been loaned to Ohio University for additional research. Additional NASA R&D is anticipated.

#### Satellite and Space System Communication

Title: Advanced Low-Cost Universal 20 GHz Monolithic Receiver Front-End  
Company: Microwave Monolithics  
Proposal No.: 84-1-14.01-6642  
Contract No.: NAS3-24894

A low-noise amplifier and local oscillator were developed. But fabrication difficulties resulted in a mixer which did not perform as expected. Thus, while some components were successful, the overall receiver was inoperable.

Title: \* Investigation of Textured Oxide Cathode Substrate  
Company: Star Microwave, Inc.  
Proposal No.: 86-1-14.01-6868A  
Contract No.: NAS3-25452

In a program to develop techniques to enhance emission current capability and reliability of oxide-type thermionic cathodes, an improvement was demonstrated from the addition of scandium oxide to the cathode oxide coating. This technique, used in Japan in high resolution large area CRT's, has seen little exploitation in the U.S. However, NASA is considering possible future mission applications.

Title: Advanced GaAs Monolithic 20 GHz RF Switch Matrix  
Company: Microwave Monolithics  
Proposal No.: 84-1-14.02-6642  
Contract No.: NAS3-24895

A 20 GHz switch matrix was delivered to NASA for possible use in 30/20 GHz satellite. The planned 0 dB insertion loss and 60 dB isolation goals were partially met, requiring auxiliary buffer amplifiers to be fabricated to meet the 0dB loss requirement.

Title: Multi-user, Receiver Demodulator Satellite Communication System  
Company: Amerasia Technologies, Inc.  
Proposal No.: 88-1-14.05-9388  
Contract No.: NAS3-25862

A device was built and demonstrated to simultaneously demodulate hundreds of signals in a commercial satellite communication system for low cost, low data-rate service. A unique feature was the use of surface acoustic wave devices in a reflective array compressor configuration. Although the primary goals were only partly achieved, a spin-off was an arbitrary wave form generator, developed for testing the system, which the company marketed. DOD has also shown interest.

#### Material Processing, Microgravity, and Commercial Applications in Space

Title: \*Digital Active Materials Processing Platform Effort  
Company: Applied Technology Assoc.  
Proposal No.: 87-1-15.01-8371  
Contract No.: NAS3-25806

A multi-degree-of-freedom inertial actuator has been developed and demonstrated. This actuator can isolate sensitive microgravity science packages from spacecraft generated disturbances due to crew movement, machinery thruster firings, etc. It is particularly useful to isolate difficult low frequency motions which include many space structure natural modes. Both NASA and other agencies have expressed interest in further R&D support and the company plans commercial sales of the product.

#### Communications Satellite

Title: \*Advanced Monolithic Switch Matrix  
Company: Microwave Monolithics  
Proposal No.: 83-1-26.02-6642  
Contract No.: NAS3-24252

A 3 x 3 MMIC intermediate frequency (3.0 - 6.0 GHz) switch matrix was developed and delivered to NASA. Not all design goals were achieved due to fabrication difficulties, but the concept was proven. A follow-on NASA contract to develop a fully integrated 6 x 6 switch matrix was completed, contributing to the post-ACTS technology by reducing weight, complexity, and power use.

Title: \*High Frequency (30 GHz) Gallium Arsenide Materials and Devices  
Company: LNR Communications, Inc.  
Proposal No.: 83-1-26.03-7112  
Contract No.: NAS3-24251

The development of gallium arsenide RF devices for K-band communication systems and a 30 GHz up-link transmitter for ACTS were not fully achieved. The measured diode power output fell considerably short of the anticipated 2-3 watts rf. Additional R&D support was obtained, however, through other government contracts.

Summaries were also prepared for the six Phase I contracts for which immediate Phase III activity was indicated. More commonly, however, Phase III activity was initiated after the work went to Phase II and the investigator had more opportunity to test his idea.

### Phase I

#### Aeronautic Propulsion and Power

Title: Non-Contact, High Temperature Strain Gage  
Company: Optra, Inc.  
Proposal No.: 85-1-01.03-7670  
Contract No.: NAS3-24848

A high temperature, high frequency non-contacting extensometer system was developed. The project was not continued in Phase II, but a commercial product did result.

Title: Laser Induced Fluorescence Measurements of Velocity in Supersonic Reacting Flow Fields  
Company: Physical Sciences, Inc.  
Proposal No.: 89-1-01.03-0003  
Contract No.: NAS3-25840

The feasibility was established to use laser induced fluorescence as a non-intrusive velocity measurement tool in supersonic reacting flows. In addition to expected NASA support for Phase II, further R&D support is expected with private capital.

#### Aircraft Systems, Subsystems, and Operations

Title: Eddy Current Repulsion Deicing Strip  
Company: Electroimpact, Inc.  
Proposal No.: 89-1-03.01-2403  
Contract No.: NAS3-25836

A prototype eddy current strip was developed to remove ice from aircraft. The technique was found to be successful in removing several kinds of ice and may be particularly useful for helicopter rotors. The company is in the process of further development for commercial sales.

Title: A Transputer Based Finite Element Solver  
Company: Sparta, Inc.  
Proposal No.: 86-1-04.04-5200  
Contract No.: NAS3-25126

A parallel processing finite element analysis capability for a desk-top computer was demonstrated. Analysis of a Shuttle main engine turbine blade was made at only 3X the CPU time of a Cray XMP (\$7M computer) in a \$70K class workstation. Negotiations are underway with major workstation vendors to market a completed system as an 'attached' processor.

#### Space Power

Title: Flexible, Lightweight, Amorphous Silicon Solar Cells Tuned for AMO Spectrum  
Company: Iowa Thin Film Technologies, Inc.  
Proposal No.: 89-1-10.01-3203  
Contract No.: NAS3-25825

Studies were made to determine the feasibility of preparing thin film amorphous silicon solar cells on Kapton by a process which yields continuous, fully interconnected ribbon. It is planned to use these ribbons as ultralight solar power arrays for both orbiting and planetary surface power systems. This was a fully successful project which will serve as a basis for further NASA funded R&D and application. The company also anticipates state venture funding and commercial sales of the product.

#### Satellite and Space System Communication

Title: High Accuracy Characterization of Monolithic Millimeter Wave Devices  
Company: Cascade Microtech, Inc.  
Proposal No.: 86-1-14.01-8245  
Contract No.: NAS3-25122

A prototype coplanar waveguide probe was developed which enabled on-wafer device characterization up to 50 GHz. The company has a very successful business based on a product line derived directly from this work. They did not continue the work into Phase II.

## VI. SELECTED COMMENTS AND RECOMMENDATIONS

To aid in this assessment of the Lewis SBIR Program, the technical monitors were asked to share any noteworthy comments, results, and experiences that could contribute to the overall evaluation of the program. These could be based on their own experience or on the experiences of the small business investigators. They were also asked to comment on any technical and administrative difficulties they may have encountered with their SBIR contracts.

Noteworthy results were generally positive and have been included in the narrative write-ups of Section IV. Comments and experiences of the SBIR program ranged from "fantastic" to "worthwhile." The greater enthusiasm was from the small businesses who cited their opportunity to do innovative research not possible without SBIR funding. Good ideas are not the exclusive property of big industry;

individual minds create them. But individuals in a small business may lack the financial backing required to develop their ideas.

Negative experiences or difficulties, especially when accompanied by suggestions for improvement, can also prove useful for future program management.

A major concern mentioned by both the companies and the TM's was the delay between the completion of Phase I and the beginning of Phase II. These delays, which could be as long as a year, often result in a loss of interest for the company, the pertinent NASA office, and even the potential Phase III investor. Perhaps interim funding, such as that provided by the states, and streamlining the contracting procedures can alleviate this problem.

Several TM's mentioned difficulties arising from their disagreement with their selection of contracts which they were asked to monitor. It is important that the TM should be selected based on his expertise and his approval of the proposed research.

Delays in the program are another source of concern. While some delays are uncontrollable, such as those due to the PI's illness, mentioned in two cases, and the termination of the PI in one case, it was felt that other company problems could have been avoided by better planning. Examples include; a contractor who experienced delays resulting from procurement of equipment from the USSR, and another whose program had to be drastically altered when their planned use of a Battelle facility was cancelled.

Attention should also be given to the size of the small business. Two Lewis TM's expressed the opinion that their contractors were too large to pay serious attention to this type of contract. Still another said the small size of his company limited its ability to perform the work.

Despite some negative comments, the consensus of both the Lewis TM's and the small business contractors is that the SBIR program is an excellent approach to R&D. The two-phase funding approach is useful in reducing many potential problems. The emphasis on innovation and commercialization insures unique and useful R&D products which benefit both NASA and the small business contractor. The small business gains access to the government and major industry's research needs, and they, in turn, become aware of the small business' capabilities. In the words of one small business PI, "SBIR is the most productive R&D program run by the Federal Government."

## VII. SUMMARY OF RESULTS

The NASA LeRC SBIR Program was assessed covering the period from its beginning in 1983 through the contract year 1989, the latest year to obtain information on completed Phase I contracts. The information used was obtained mainly from questionnaire interviews with the NASA technical monitors; however, for completeness additional, input was also obtained from company sources and reports. A total of 99 Phase I contracts and 39 Phase II contracts were studied of the total Lewis SBIR contracts for that period.

The impact of the SBIR program on NASA has been very positive. About half of the projects either solved a particular NASA problem or expanded the scope of NASA's program directly. Still, others brought out new ideas which may have use in future programs. The overall quality of the SBIR contracts was judged to be better than comparable non-SBIR contracts. This was not at the expense of innovativeness as nearly 60 percent of the Phase II contracts were called either major innovations or significant advancements.

In addition, of the 39 Phase II projects studied, 27 were planned for continuation into the Phase III or commercialization mode. Eighteen of these have been listed as candidates for NASA application within 5 to 10 years. Nine have already been slated for further NASA funding or are currently being used in NASA programs. Other government agencies, industry, and internal funding accounts for other commercialization sources. Thus, the program has been seen to be mutually beneficial to both NASA and the small businesses.

Some difficulties mentioned proposal reviewing, contracting procedures, funding lapses and program delays, suggest certain programmatic improvements could be made. Since the start of this assessment, new legislation has been passed by Congress which will alleviate some of the funding problems. Other improvements are being made through an evolutionary process and as a result of a total quality management evaluation of the program at both the NASA Center and NASA Headquarters level.

One of the more subtle, yet not insignificant, values of the SBIR program is the identification of R&D resource companies which could be called upon in the future to help solve NASA's problems. This information, and much more, now can be provided from the SBIR Data Base. This data base lists all Lewis SBIR contracts awarded since 1983. In addition to the usual routine contract data and vitae, it contains program objectives, outcome, and NASA impact where assessed. Also included are contract evaluation factors, a short narrative description of the contract achievements, and where relevant, plans for follow-on (Phase III) activity. The data base is computerized for easy access to NASA staff.

The SBIR Program has proved to be an important stimulus for small businesses both to contribute to national R&D goals and to develop their ideas into commercial products. It will be the purpose of a follow-on report to update the successes of SBIR at the NASA Lewis Research Center in more detail, primarily as they apply to NASA programs and to commercialization of their products.

## VIII. CONCLUSIONS

The LeRC SBIR Program has been found to be a useful tool to meet the R&D program needs of the agency while enhancing the role of small business in this effort. The small businesses have also benefited from the opportunity to translate their ideas into commercial products.

Since a significant number of small businesses are minority, women, or disadvantaged person owned, the SBIR program provides opportunities for their identification and participation in NASA research and development.

The need to better disseminate the results of the LeRC SBIR contract efforts has led to the creation of a computerized data base of SBIR findings and company capabilities. This data base will be kept up-to-date and will serve as an important reference source of SBIR results.

## APPENDIX

SBIR ASSESSMENT

INTERVIEW FORM: NASA PERSONNEL

1. Project Identification

1.1 Title: \_\_\_\_\_

1.2 Project No., Phase: \_\_\_\_\_ Contract No: \_\_\_\_\_

1.3 Principle Investigator: \_\_\_\_\_

2. What was the objective of this project?

3. How do you categorize the objective of this project?

3.1 To develop a device or component (prototype)

3.2 To develop a new process or technique

3.3 To develop a new computer program

3.4 To develop or prove a new concept

3.5 To provide a research aid or instrument

3.6 Other (specify\*)

4. What was the intended NASA mission or application for this project at the time of award?

5. Technical discipline(s)—Related RTOP, if any.

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\* Feel free to comment or expand on any answer given. If you wish to discuss your answers at still greater length, please indicate this in question number 20, and we will contact you.

6. Have the goals of the contract been achieved for this project?
  - 6.1 No
  - 6.2 Partly
  - 6.3 Fully
  
7. What was the outcome of the project?
  
  
  
  
  
  
  
  
  
  
8. What were the specific impacts of this project on NASA?
  - 8.1 None
  - 8.2 Bring a new idea to NASA's attention
  - 8.3 Develop a known concept sooner
  - 8.4 Introduce a new R&D company to NASA
  - 8.5 Expand the scope of your program
  - 8.6 Solve a particular problem
  - 8.7 Others
  
  
  
  
  
  
  
  
  
  
9. What is your opinion of the degree of technical risk or difficulty of this project?
  - 9.1 Low
  - 9.2 Moderately Low
  - 9.3 Average
  - 9.4 Moderately High
  - 9.5 High
  
  
  
  
  
  
  
  
  
  
10. If this was a Phase I project, was a Phase II project submitted?
  - Yes
  - No

The following questions (11 through 17) only apply to Phase II projects.

11. What are the expected applications of the results of this project by NASA (Phase III)?
  - 11.1 No knowledge
  - 11.2 No NASA use expected; however, project provided useful technical information for NASA
  - 11.3 Enhance research and development capabilities
  - 11.4 Candidate for mission or application within 5 (10) years
  - 11.5 Selected for specific mission or application
  - 11.6 Basis for additional R&D and/or study funded by NASA

12. Are there non-NASA applications of the projects results (Phase III)?
  - 12.1 Unknown
  - 12.2 Commercial sales of the product(s)
  - 12.3 Interest and support by another agency
  - 12.4 Further R&D support by private capital
  - 12.5 Other
  
13. Innovativeness of this project compared to other similar efforts.
  - 13.1 A major innovation
  - 13.2 A significant advancement
  - 13.3 A step forward
  - 13.4 Useful information provided
  
14. Status of this project with respect to current technology.
  - 14.1 Leading edge of current technology
  - 14.2 Moving into a new direction
  - 14.3 In the mainstream
  - 14.4 Of questionable relevance
  
15. How do you rate the quality of the research conducted in this project with other non-SBIR contracts you may have monitored?
  - 15.1 Cannot make a valid comparison
  - 15.2 High quality research effort
  - 15.3 Better than average quality
  - 15.4 Average quality
  - 15.5 Below average quality
  
16. Please cite project(s) used as a basis of comparison.
  
17. What is your estimate of the cost effectiveness of this project compared to other contracted work?
  - 17.1 No opinion
  - 17.2 Poor
  - 17.3 Average
  - 17.4 Good
  - 17.5 Excellent

18. Have you had technical/administrative difficulties with this project?
- Yes
  - No
19. Did you have any noteworthy results or experiences that should be considered in the assessment of this project?
20. Do you want me to contact you for additional information?
- Yes
  - No
21. If you have a SBIR Final Report Project Summary Sheet for this project, we would greatly appreciate it if you would send a copy along with the completed questionnaire.
22. LeRC Assessment Respondent:

Org. Code:

Phone:

Mail Stop:

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

# REPORT DOCUMENTATION PAGE

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