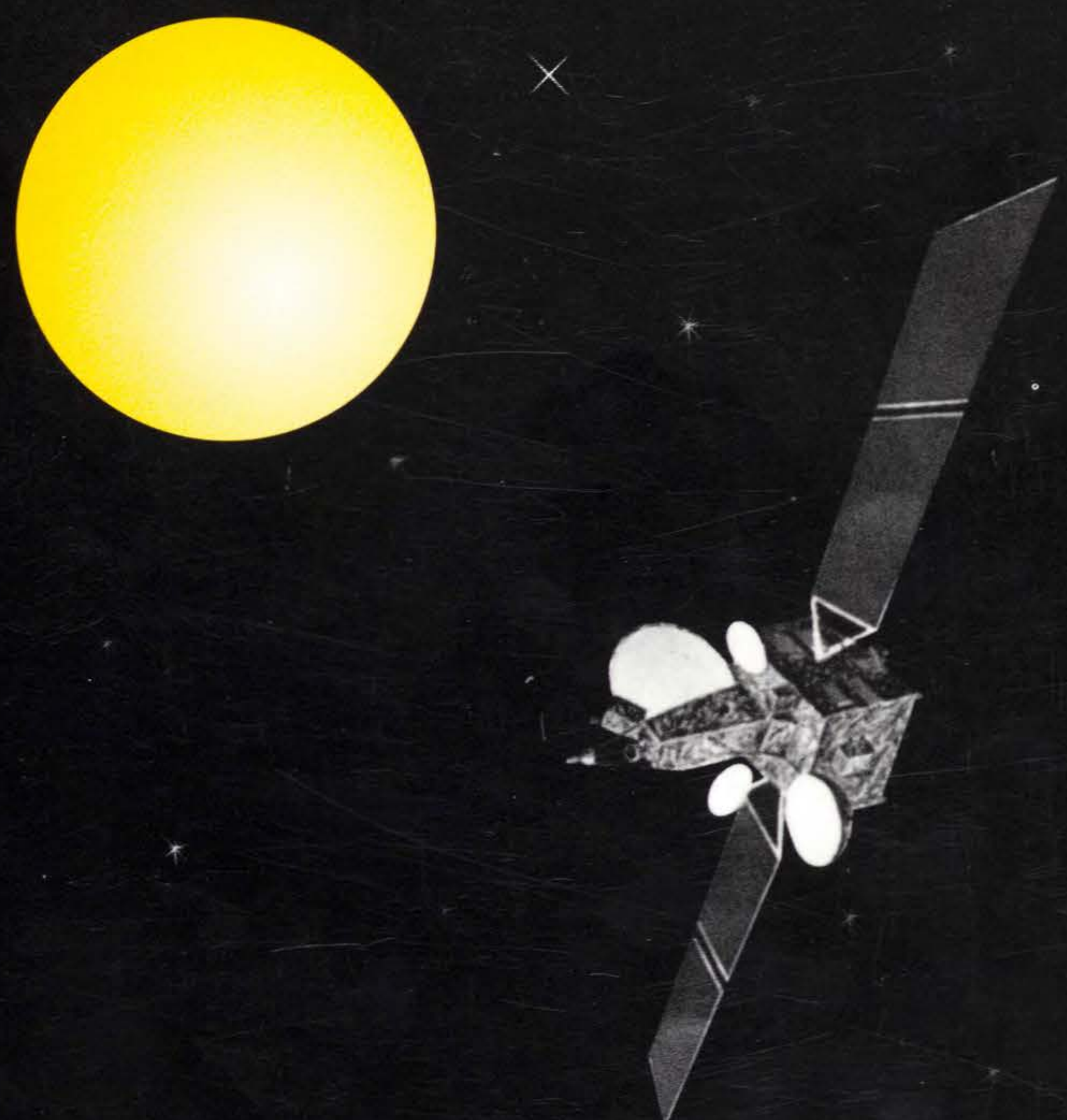

A SPACE STRATEGY FOR TEXAS FOR THE 1990s

LBJ SCHOOL OF PUBLIC AFFAIRS
THE UNIVERSITY OF TEXAS AT AUSTIN
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Foreword

The Lyndon B. Johnson School of Public Affairs has established interdisciplinary research on policy problems as the core of its educational program. A major part of this program is the nine-month policy research project, in the course of which two or three faculty members from different disciplines direct the research of ten to twenty graduate students of diverse backgrounds on a policy issue of concern to a government agency. This "client orientation" brings the students face to face with administrators, legislators, and other officials active in the policy process and demonstrates that research in a policy environment demands special talents. It also illuminates the occasional difficulties of relating research findings to the world of political realities.

This report on a space strategy for Texas for the 1990s is the result of a policy research project conducted during the 1991-92 academic year with financial support from the Center for Space Research (College of Engineering, The University of Texas at Austin), the Texas Space Grant Consortium, and the Lyndon B. Johnson Foundation. In the summer of 1991, the LBJ School and the Center for Space Research agreed to undertake the development of a long-term space strategy for the state. These two University of Texas at Austin units decided it was critically important to formulate a strategic framework to address space-related economic and business development and, in so doing, to demonstrate the breadth and depth of resources at state universities that can be brought to bear on important state policy issues. This report details this strategic framework and specifies the primary objectives that should be implemented by the state's public sector, private sector, and universities in the 1990s.

The curriculum of the LBJ School is intended not only to develop effective public servants but also to produce research that will enlighten and inform those already engaged in the policy process. The project that resulted in this report has helped to accomplish the first task; it is our hope and expectation that the report itself will contribute to the second.

Finally, it should be noted that neither the LBJ School nor The University of Texas at Austin necessarily endorses the views or findings of this study.

Max Sherman
Dean

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Executive Summary

Texas must fundamentally change its economic base to recover fully from the current recession and stabilize its economy. Diversification, with particular emphasis on developing space technology and other select high technology areas, will be the primary characteristic of the Texas economy in the 21st century.

Five premises and assumptions serve as the departure point for strategy development in this project:

1. that the state as a whole is committed to the effort to restructure, diversify, and broaden its economic base and that this commitment will remain in place regardless of changes in the state's political climate and in the balance of political power or philosophy;

2. that the development effort to effect this economic change is long-term, at least one to two decades, and that, as a consequence, a rigorous, long-range framework is mandatory;

3. that the effort to achieve the new economic goals will proceed as rapidly as resources and circumstances allow;

4. that the long-range development effort will be economically driven (i.e., be sufficiently broad-based to accommodate all of the essential elements of the state's current space infrastructure); and

5. that space technology will remain as one of the essential, first priority sectors for development in the new economic base.

Although it is anticipated that the United States will maintain its leadership position in human space flight and that the Johnson Space Center (JSC) will remain the lead National Aeronautics and Space Administration (NASA) center for these programs, future growth of the national civil space program is likely to be restrained. New space-related technologies available to NASA will also be available to states. Moreover, commercialization of space will not occur primarily at the federal level; rather, states have a unique opportunity to foster the development of space-related industries and economies by providing the commercial and industrial framework lacking at the national level. Texas is particularly well-positioned to achieve a leadership role, given the presence of JSC, the Texas Space Grant Consortium, legislative and gubernatorial initiatives (including the Texas Space Commission), an expanding space industry, and public and private high technology business development programs.

Consistent with this Texas space infrastructure and with the diversified economic framework required by the state in the 21st century, the *long-range goal* of the project's strategic approach is as follows:

Achieve a self-sustaining space-related
economy in Texas by the year 2020.

Based on technological and market potentials, it is reasonable for Texas to expect that a space-related industrial economy in the state can achieve a self-sustaining level (i.e., be able to survive and maintain sustained growth on its own merit and economic return) by the year 2020 at a minimum, depending on the state's commitment. The year 2020 also implies that the long-range goal lies beyond the timeframe of the initial, or baseline, strategy (i.e., the 1990s) and that a series of approximately decade-long strategy/implementation periods will be necessary before achieving the long-range goal.

The space-related economy that evolves from implementing the baseline strategy and its successors will, like the strategies, be highly integrated, broad-based, and multifaceted. It will require an aggressive and efficient organization whose range of operations is statewide; a new public-private partnership and perspective that ties together the state's industrial base with its research and development base and realigns the supporting infrastructure base; and a willingness to consider nontraditional approaches to an investment base. Thus before making a decision for Texas to undertake a development period of long duration and with high stakes, as this effort requires, the state's public and private sectors must recognize and assess the risks and accept the likelihood that, to counter these risks, unconventional relationships and wide latitude in policymaking authority may become commonplace.

Commitment to this long-range economic goal, by virtue of its magnitude and the commensurate level of required effort, also will reasonably assure the state that it can aspire to a leadership role (presently vacant) among the space-faring states and that it can establish a strong competitive market position in the development and return of benefits from space-related industry and the commercialization of space. Given the high probability that new enabling technologies will also be available elsewhere, however, access to space is an essential capability for market development and a strong competitive position. This premise should be regarded as a fundamental underpinning to the initial strategy and its successors.

The state's commitment to a space strategy for the 1990s will require sustained, albeit modest, public and private support in order to move Texas space-related activity steadily toward a level of critical economic importance. This requires a (minimal) *baseline strategy* as follows:

> *Establish an organizational and operational foundation in Texas from which to address a limited number of primary and critical objectives in the 1990s that set in place the long-term direction and framework for economic development and that preserve and enhance future options to expand development, as resources and merit direct.*

Three considerations underlie the primary objectives accompanying this strategy:

1. A strategy requires an institutional base to implement it; if none exists or current organizations are not appropriately chartered, an appropriate institutional focus must be created.

2. Project findings and assessments indicate that the state's R&D base for selected technology and business development and its capability for access to and commercialization of space either do not exist or lack an adequate framework.

3. For the commercialization of space, in its broadest sense, to become a factor in the economic development of the state, a new perspective on federal-state (JSC-Texas) relations is needed.

These considerations lead in turn to the project's (required) *institutional focus* and *primary objectives*:

Institutional Focus: *Establish an independent, public-private space authority to provide the institutional focus for implementing the state's space strategy for the 1990s.*

Objective: *Establish formal relationships between Texas and the Johnson Space Center (JSC) to meet selected JSC needs for state space-related R&D, technology transfer, industry, education, and infrastructure and to access JSC technology, engineering, systems management, and business development strengths and services in the implementation of the Texas space strategy for the 1990s.*

Objective: *Establish a statewide network of space business incubators in Texas emphasizing technologies that are critical or enabling to a self-sustaining space-related economy.*

Objective: *Establish an integrated payload services capability in Texas to foster the space-related business development, investment, R&D, technology transfer, infrastructure, and human resources necessary to sustain a space-related economy.*

Objective: Establish a public-private development program for a Texas satellite system providing remote sensing, associated data management, and other communications services for industrial, commercial, scientific, educational, and governmental applications.

The institutional focus and primary objectives for this baseline strategy are an integrated set of action items that need to be addressed in Texas in the 1990s. They are intended to guide the implementation of this initial strategy and to set in place the framework leading to the long-range goal. Consequently, the degree to which they are successfully carried out will determine the base on which subsequent decadal strategies are conceived and, ultimately, the length of time necessary to achieve the long-range goal.

To achieve the self-sustaining quality of the long-range goal, the Texas space infrastructure must have an institutional focus -- a Texas space authority -- and be organized for the sole purpose of building the space-related sector of the state economy. Given the pervasive nature of the current and projected space infrastructure in Texas and the broad base of vital space interests, neither a strictly public nor a strictly private institution is adequate to encompass effectively these factors and the infrastructure. An innovative and imaginative space authority is needed to bridge these elements.

Once the institutional focus has been established, all primary objectives are considered essential, and therefore all have equal weight and priority. The order in which the objectives are implemented is of no particular strategic importance; it is largely matters of tactical planning, priority, and timing that will determine their actual phasing over the period of the 1990s. However, full strategic importance is only realized with implementation of the entire set; a lesser effort will delay the attainment of the long-range goal. These objectives have been designed and constructed to be linked inextricably with each other; their strength and strategic importance are contained within the entire set. To perceive them separately or address them individually has virtually no larger strategic value. Taken together, the primary objectives are specific actions intended to initiate and sustain a state infrastructure to build the technology R&D base, to develop systems and capabilities to use and apply the technology, and thereby to provide the critical leverage needed to aggressively challenge and compete for a significant market share of space services.

Because a statewide constituency is vital to sustaining the growth of a space-related economy over the periods of the baseline strategy and the long-range goal, the involvement of increasing numbers of Texas citizens and organizations is an integral part of the formative planning stage of strategy implementation. Also a vital element of the preparation leading to the organization of the institutional focus and the implementation of this state space strategy for the 1990s is the completion of several studies, including:

1. the specification of models of private-public authorities having the necessary operational characteristics for an effective institutional focus;

2. the selection of critical technologies for space incubators;

3. a feasibility study of the technology base for an integrated, comprehensive payload services capability;

4. a feasibility study of a state satellite system;

5. a database of the state's space infrastructure; and

6. site studies for the location of space business incubators.

The Texas Space Grant Consortium is an appropriate institution to undertake or oversee these pre-implementation studies and to foster the development of a statewide constituency for strategy implementation.

Chapter 1.

Introduction

Rationale for a Texas Strategy

Texas must fundamentally change its economic base to recover fully from the current recession and stabilize its economy. It is unlikely the state can reacquire its former economic position through a recovery of its oil industry. Further, if the oil economy, for unforeseen reasons, recovered, the state could again find itself in the same vulnerable position (i.e., a narrow-based economy with virtually no safeguards or contingencies to offset recession effects).

Diversification, with special emphasis on developing a range of select high-technology areas to strengthen and provide new opportunities for growth and to lessen the effects of future recessions, must be the primary characteristic of the Texas economy in the 21st century. This policy of diversification, with its commensurate implications for economic policy, clearly recognizes the nature of the necessary investment and the long periods of time required to successfully reshape and redirect an already large and complex economy. Although the magnitude of the effort is sobering, the state's economic conditions and the long-term risks in maintaining a predominantly oil-based economy are unacceptable.

These economic conditions prescribe a strategic approach to lead and guide the state through an arduous and long transition period. While the conditions that characterize a strong, vital economy generally can be agreed upon, the long path, or paths, leading to a new economic base over periods of time exceeding ten or more years cannot be perceived or visualized in advance. A strategic framework which provides a basis for making prudent, rationale choices in the development of a new economic sector and which maintains the momentum toward a long-range goal is needed.

The designation of space technology as one of the priority economic sectors for development in Texas gives rise to the rationale for this project. Although the state's public and private sectors have declared their intentions to operate in this economic sector, this designation has not to date been buttressed with a level of support that matches its priority position in the new Texas economy.

With this background and rationale, the project has specified the following premises and assumptions as the initial departure point for strategy development:

1. that the state as a whole is committed to the effort to restructure, diversify, and broaden its economic base and that this commitment will remain in place regardless of changes in the state's political climate and in the balance of political power or philosophy;

2. that the development effort to effect this economic change is long-term, at least one to two decades, and that, as a consequence, a rigorous, long-range framework is mandatory if the state and its people are to realize the benefits of a new economic base within reasonable time frames;

3. that the effort to achieve the new economic goals will proceed as rapidly as resources and circumstances allow;

4. that the long-range development effort will be economically driven [i.e., be sufficiently broad-based to accommodate all of the essential elements of the state's current space infrastructure (e.g., education institutions, space industry, related nonprofit R&D institutions, federal space facilities, federal and national laboratories, and, as importantly, the agencies and institutions of the state

government)]; and

5. that space technology will remain as one of the essential, first priority sectors for development in the new economic base.

Concept and Elements of a Strategy

Generally, the use of a strategic approach is indicated (1) when the goal of a development effort is beyond the vision and ability of planners to provide, with confidence, detailed plans to reach the goal and (2) when the potential uncertainties and variables in a development effort are large and unpredictable. It is this gap between the limits of our vision and the eventual goal which drives the need for a superstructure or framework to keep a current effort connected to its long-range purpose. The analogy to a road map and its utility in the effort and experience of a traveler to undertake journeys with confidence in order to reach a predetermined, but not visible, destination is useful.

Strategies can assume several forms as they are adapted to specific situations. They can be multibranched, specifying several alternatives or paths to reach objectives and goals, or they can be multi-layered, with several substrategies undergoing concurrent implementation in advancing toward their objectives. Their application is similarly widespread, being used with equal facility in industrial, investment, political, economic, and military arenas, as well as for government planning and policy analysis and development.

The *baseline strategy* is the simplest of the forms in structure and for comprehension (but not necessarily the easiest to implement). It recommends itself when no previous experience exists or precedent strategy is in place and when availability of funds for strategic implementation is modest and dictates a gradual approach. It is construed as "baseline" for the following reasons: (1) it is the first or starting point of a series of periodic strategies (each commonly on the order of a decade in length) and (2) it is intentionally constructed as the minimal (or baseline) effort required to make major advances toward the long-range goal in the given strategy period. The corollary is also the case (i.e., if an implementation effort, over the period of the strategy, falls below the level of effort recommended, the expectations for a major advance toward the goal also need to be revised downward). The strategy developed in this report is a baseline strategy.

With this exception in the choice of form, strategies have important common elements: a long-range goal; a current base of required knowledge; a statement of the strategy for the specified period; a selective list of high priority actions that are required to address the strategy, usually called primary objectives; and a carefully developed set of considerations which guide the implementation of these primary objectives.

When the current or initial strategy is not or cannot be expected to achieve the desired results at the end of the strategy period, it is necessary to establish a *long-range goal*. More than one strategic period generally is required to achieve the long-range goal. The initial and each subsequent strategy will use the same goal as its target. While individual strategies are expected to be different, as they are shaped by short-term forces and circumstances, the long-range goal by definition is expected to remain constant. In this report, the baseline strategy will be the first of several strategies that must be implemented to attain the long-range goal.

Strategies typically anchor their development on a *current information base* (i.e., a research effort to acquire data and knowledge on the subject to be addressed and for a subsequent assessment of the base). In this report the essential elements of the state's space-related industry are identified from the project's research base, and their roles in defining the current space infrastructure are assessed. In brief, the research base for this report's baseline strategy should address such general questions as: Who are the principal "space players" in the state? What are their individual strengths and weaknesses? What is the degree to which they collectively constitute or could constitute a state space economy? What, if any, are the relationships between them?

It is from this current knowledge base that the overall *strategy* for the decade under consideration (e.g., baseline strategy) will evolve, largely in answer to the general question: Given the present makeup and knowledge of the state's space-related activity, what can this infrastructure be expected or challenged to accomplish over a ten-year period? Each strategy period should have a succinct statement of what is, in an overall sense, expected to be accomplished by the end of the strategy period. The statement is a measure of the effort needed not only to achieve major advances on the long-range goal, but also to position the state to address subsequent strategies.

Each decadal strategy statement typically has several *primary objectives* associated with it. These are detailed, specific tasks which are required to accomplish the overall strategy for the period. Their fulfillment will achieve the required minimum level of advancement toward the long-range goal. Each primary objective is usually amplified by further criteria or considerations which guide and assess the implementation of the objective.

Not surprisingly, strategies which are developed as described above take on a highly integrated character. From the definition of the long-range goal, each strategy cascades in pyramid-like form to lower levels of detail, each level of detail being linked to adjacent levels. It is these relationships that make up the integrity of the strategy and that provide the continuity over the designated period. Because of this "wholeness" quality of the resulting strategy, it should be understood that the implementation process does not have the latitude to select only parts of the strategy to address. To do so risks the virtual loss of the strategic quality of the product. It reduces the implementation process to a series of disconnected actions whose accomplishment is likely to have little or no effect in terms of fulfilling the purpose of the strategy, positioning the state for the next period of development, or making a satisfactory advance on the long-range goal. This integrated character of a sound strategy must be clearly understood prior to beginning its implementation process.

Finally, in the formation of any strategy, care must be taken to distinguish between strategic and tactical considerations. Their employment is sequential; the strategy must first be in place, and then it provides the framework for tactical development. Tactical considerations and subsequent planning, therefore, are generally consigned to and employed in the strategy's implementation process. Unlike the long-range and constant nature of strategic planning and recommendations, tactical planning and decision-making are generally of shorter time scales and usually require a high degree of flexibility in order to address near-term actions and adapt to changing circumstances as the implementation process moves forward.

Chapter 2.

The National Context for a Texas Space Strategy

National Civil Space Program

Trends and Characteristics of Future Civil Space Programs

A number of critical factors have emerged in recent years, some with unprecedented rapidity, which seem destined to have profound effects on the directions and content of the U.S. civil space program, as well as on its relative priority and position in a national context.

1. The collapse of the Soviet Union has effectively removed a major challenger to the U.S. for world leadership in space and the national security rationale for most of the largest U.S. manned space endeavors. Further, it appears unlikely that the surviving Soviet states, especially Russia, will have the economic stature in the foreseeable future to undertake a commensurate challenge at anything near the scale of its predecessor. On the contrary, if Russia is to have any significant role in world space affairs, it will have to be achieved cooperatively or collaboratively with the remaining space-faring nations. The opportunity now for the U.S. to entertain the possibility of large endeavors in space exploration done jointly with Russia will demand careful analysis and new policy development.

2. The steady growth of the European space program and the emergence of the European Community as a viable economic power pose an entirely new challenge to the U.S. for world space leadership. While the Europeans have aspired to the goal of space autonomy vis-a-vis the U.S. and the former Soviet Union, achieving this goal, especially in manned space flight, has proved so costly to the Europeans as to provoke a new internal debate on the wisdom of their continuing to address it. Ironically, the collapse of the Soviet Union has brought about an entirely new perception to the long-range space planning and policies of Western Europe. The very technology under dispute for development within Europe now has become available at much lower cost from Russia as the major heir of the space technology capability of the former Soviet Union. The consequence of close space relations between Russia and the Europeans, especially in manned space flight and deep space exploration, will maintain a rationale for the U.S. to preserve its technological position, albeit for different reasons.

3. The cessation of the Cold War has led to a renewed national debate on the use of the so-called "peace dividend," those national resources that presumably are no longer needed for security purposes with regard to the Soviet Union. It is unclear whether any significant portion of such a "dividend" would be redirected into expansion of the civil space program; however, it is safe to assume that the host of social problems which are demanding attention at the national level will have at least equal priority for reallocation of these national resources. There is little to indicate that the national civil space program will contend and compete for these funds; on the contrary, federal government executive and legislative leaders have given clear evidence that the civil space program will likely have to retrench or maintain its present position for some indefinite period.

4. The U.S. Congress has shown increasing frustration about and resistance to the constant rise in federal expenditures for large manned space ventures (e.g., Space Station Freedom and the Space Exploration Initiative), especially in the middle of a severe, extended economic recession. The rationale and justification for increased expenditures cannot be consistently demonstrated, and performance levels have fallen short of expectations.

These factors will have significant impact on the future character of the national civil space program and will almost surely result in its reordering and restructuring. These changes, in turn, will affect the actions that individual or groups of states take in pursuing their own space interests.

Although there is little doubt that large manned programs will continue to be a major component of the U.S. civil space effort, they very likely will be forced to develop at a slower pace, under budgetary cap constraints and maintaining flexibility to reduce costs as technological opportunities become available. There will be increasing pressure to demonstrate the relevance of their objectives to other priority national goals (e.g., education, technology spin-offs, environmental applications, commercial potential). Further, manned and unmanned programs gradually will become more integrated in order to effect balance and to achieve cost management and appropriate use of new technologies (as is the case in the premises under study for the Space Exploration Initiative).

The emergence of several critical new technologies, many from the classified development programs of the Department of Defense and Department of Energy, present very exciting opportunities for civil space applications. Offering new potential not only for the national civil program, but, as importantly, for commercial applications by industry and by individual states are the down-scaling, or miniaturization, of technologies used onboard orbiting spacecraft with virtually no loss of capability; the growing trend in the development of small launcher capability to accommodate these smaller payloads; and the proportionately lower costs associated with these reductions in size.

Given the funding problems shared by the U.S. and Western Europe space programs, together with the demise of the Soviet Union, it would appear that large exploration programs will inevitably be attracted to the economies of scale provided by cooperative programs conducted on a truly joint, equal-partner basis. This collaboration will undoubtedly require a new and innovative approach to cooperative space policy, one which will seek to redesign the interface between competition and cooperation and to redefine the terms of world leadership. It is also important to note, in looking at the change in the international sphere, that both the U.S. and Europe are keenly interested in fostering the commercialization of space.

Behind the general frustration of the Congress and some executive branch leaders with the inability of the civil space program to function and perform effectively has been the disappointment that, to date, there have been few economic or commercial benefits to the nation from the enormous investment of resources. One school of thought maintains that unless there is some beginning and growth of benefits, federal government leaders will continue to raise questions as to the real worth of the national civil space program. Some insist that, without an economic return, the program cannot survive indefinitely. To be sure, most advocates of this position have in mind the large returns that have been expected, often unreasonably so, from the commercialization of space. Although there has been a federal policy decision that the national civil program will no longer develop commercial programs, several programs and offices have been created within the National Aeronautics and Space Administration (NASA) and the U.S. Department of Transportation (DOT) to encourage and assist commercialization.

Implications for the Johnson Space Center and the State of Texas

From these critical factors and current developments, we can draw, with reasonable confidence, the following conclusions on how the perceived changes in the national and international arenas will affect NASA's Lyndon B. Johnson Space Center (JSC) and the economy of Texas.

First, in spite of the foreseeable changes in the national civil space program, there is no indication that the U.S. will soon or even gradually end its long-held leadership position in manned space flight. It is highly likely that JSC will remain the lead NASA center for large manned programs. However, the integration of manned and unmanned programs and the likely stretch-out of large manned programs imply the onset of a new set of relations for JSC with other NASA centers and with other federal agencies which now are exploring the ways and means to redirect and apply appropriate military space technology, space systems, and expertise in the civil space program. The ongoing issue of whether JSC will continue its space operations responsibilities or be reorganized into a predominantly research center for manned space flight will decide to a large extent its future direction. Whether the shift in this relative balance between operations and research produces any major or sustained economic disruption within Texas is uncertain at present. Such fundamental changes in the role and mission of the center could only be accomplished over a period of time, however, which would measurably spread and lessen any negative economic effects to the state. Nevertheless, increased JSC emphasis on R&D implies by definition the pursuit and application of new, critical space technologies. The extent that these critical technologies pursued for applications in national programs are similar to or match those selected by Texas for its own strategic purposes will determine important new market leverage, expanded opportunities, and the rationale for future relationships and business development between the state and JSC.

Second, the inability of the national economy to accommodate the cost projections of the national civil space program and the frustration of the White House and space advocates in the Congress with a lack of budget controls and program performance will drive the civil program into a period of restrained growth. To address these concerns will require new organizational and management changes in NASA and the incorporation of new technologies in NASA programs. For the large manned programs, program objectives must be able to demonstrate direct linkage and value to other national goals (e.g., how manned missions to other planetary bodies should be configured to give direct aid to teaching science, mathematics, and engineering). It is virtually certain that addressing these new education and other objectives in NASA can be done only or primarily at the NASA centers (e.g., JSC). While these centers are federal facilities and must serve the general populace, states with major NASA centers have particular advantages. Given the strong interest and encouragement expressed by NASA headquarters, state universities and university systems have opportunities to create new and innovative relations with a unique national resource for teaching science, mathematics, and engineering and for developing professional and technical skills.

Third, many of the new technologies that will be developed and enter the national civil space program will be available to individual states for the development of their own economies. Some of these technologies are available now and can be used in state programs; for the first time, states realistically can conceive of acquiring the technology to establish space programs as fundamental elements of their economies. Although the number of states with interests in developing space-related industries is growing, none has yet fully recognized or responded to the strategic importance, in economic terms, of these new technologies.

Finally, there is little doubt that the commercialization of space will not take place at the federal level. Since the decision to take the national civil program out of commercial space development, the federal government has resisted pressure to subsidize heavily the major aerospace corporations in the transition from public to private space development. Thus it is apparent that space commercialization will have to find another setting if it is to become a significant part of the overall national economy. It is conceivable that the development of space-related industries and economies at the scale of individual states provides the commercial and industrial framework that is absent in the perspective from the national level. Indeed, consistent with this development, several members and committees of Congress have begun to formulate legislation that will directly aid commercial space development in the states. For example, in November 1991 Congressman Hall (Texas) introduced the Commercial Space Competitiveness Act of 1991 (H.R. 3848).

Space Initiatives of Other States

Most state space initiatives are in an early and dynamic phase, expanding and changing as new technological and economic opportunities emerge and as business, government, and university space interests increase. These initiatives are far from uniform across the United States, given state-by-state geographic, economic, and R&D differences. Moreover, a program successful in one state may not necessarily be appropriate for development in another state. Yet an overview of selected activities in other states is useful in identifying initiatives which could create either multistate cooperation opportunities or competitive advantages for Texas as the state seeks to achieve a self-sustaining space-related economy.

Following a brief description of a multistate effort to strengthen space-related U.S. economic activity, this section highlights space developments in eight states which are generally recognized as current or potential leaders in the space industry.

Aerospace States Association, Inc.

The Aerospace States Association, Inc. (ASA), organized by six states in 1990 at a meeting convened by the State of Florida, is a coalition of states committed to ensuring that the United States maintains a strong and competitive presence in space commerce. As its bylaws state,

> ASA recognizes the importance of aerospace commerce to the economies of its member states, and it is bound by strong state government commitment to broad-based educational efforts in support of aerospace industry and research. ASA members are further committed to seek the enhancement of U.S. competitiveness in aerospace through commercial innovation, joint programs, cooperation in space-related commerce and space-related advanced technology endeavors, technology transfer, and . . . information exchange on these topics.[1]

ASA state representatives are appointed by their respective governors. The Colorado lieutenant governor was elected the initial ASA chairman in January 1991, at which time ASA comprised 15 states: Alabama, Alaska, Arkansas, California, Colorado, Florida, Hawaii, Kentucky, Michigan, Mississippi, New Mexico, Ohio, Texas, Utah, and Virginia.[2] As of July 1992, ASA membership had increased to 31 states.[3]

Comparison of State Initiatives

Comparative information about other key states' space plans, programs, and progress is important to the formulation of a Texas space strategy for the 1990s. Summarized below, in four categories, is selected information from eight states (all of which are ASA members): Alabama, Alaska, California, Colorado, Florida, Hawaii, New Mexico, and Virginia.[4]

State Space Organization(s).

Actions taken to develop an organizational framework for space-related activity vary widely among the eight states. For example, the Alabama Legislature created the Alabama Commission on Aerospace, Science and Industry, a public-private organization charged with developing and implementing a long-range plan to expand and achieve international recognition for the state's space industry and science. In Alaska, the legislature created in 1991 the Alaska Aerospace Development Corporation (AADC), which is managed by a public-private board and responsible for attracting commercial space firms to Alaska. The Alaska Science & Technology Foundation, established in 1988 as a public corporation in the Alaska Department of Revenue, complements AADC through its general support for basic and applied research. In 1989, as a result of the Florida Governor's Commission on Space, the Florida governor and legislature created the Spaceport Florida Authority to coordinate and stimulate statewide efforts to improve space launch facilities and associated transportation and support infrastructure. It is the nation's first commercial space transportation authority and is able to issue up to $500 million in revenue bonds. The Hawaii Office of Space Industry (OSI) was created by the legislature in 1988 in the Department of Business, Economic Development & Tourism (DBED) to support a broad range of space activities, including the development of a commercial launch facility. Also in DBED is the Hawaii Space Development Authority (HSDA), created in 1989 to promote space industry and international space cooperation among universities, government, and business. Space New Mexico, while not created by the legislature, links the state's national laboratories (Los Alamos, Sandia, Phillips), universities, and other space-related groups to promote land-based satellite recovery and other space business opportunities. Virginia's Center for Innovative Technology (CIT) is a nonprofit organization created by the state to support the state's space industry through research and development. Among its initiatives have been the establishment of the Virginia Space Development Consortium, ten technology development centers, a network of enterprise centers and business incubators, and the Commercial Space Archives (jointly with the Space Foundation), as well as participation in the launch of VaStar, a small experimental satellite (jointly with Orbital Sciences Corporation). Virginia also was the first state to employ a full-time space business advocate in the governor's office. California, on the other hand, while fully recognizing the importance of space-related manufacturing, business, research, and other activity in the state, has neither adopted an explicit state space policy nor created a state space authority.

Characterization of Space Industry.

There is no broad agreement among states as to which firms and industrial sectors constitute the space industry. Some states include anything related to aerospace activity; others limit it more narrowly to specific sectors. For Alabama, the space industry includes not only its aircraft, missile, space, and information systems industries, but also its research universities and institutions. For California, the space industry is composed of firms that provide space-related products and services to the government and other paying companies; these products and services include, for example, space transportation, communications satellites, remote sensing, and materials processed in space. Hawaii takes yet another approach, separating its space industry into two segments: (1) commercial space activities, including Hawaii companies in space R&D, manufacturing, and related technologies and non-Hawaii companies having Hawaii offices servicing local space-related contracts, and (2) related activities, including university research and education programs, government programs, and nonprofit public service corporation activity.

NASA and Other Federal Facilities.

Most of the eight key states have significant NASA or other federal facilities within their borders. Huntsville, Alabama, is the site of NASA's George C. Marshall Space Flight Center, which provides the shuttle orbiter's engines and boosters and plays a key role in shuttle payload development. Even more important to the Huntsville (and Alabama) economy is the U.S. Army, whose Redstone Arsenal, Missile Command, and Strategic Defense Command all are located there. California, Florida, and Virginia each has a particularly significant NASA presence as well. In northern California, NASA's Ames Research Center specializes in scientific research and new technology applications and also operates the Dryden Research Facility in the Mojave Desert; in southern California, NASA's Jet Propulsion Laboratory focuses on unmanned deep space scientific missions. Florida's John F. Kennedy Space Center is NASA's primary center for testing, checking out, and launching space vehicles at the Kennedy Center and Cape Canaveral. In Virginia, NASA's Langley Research Center's projects include technology development for the National Aero-Space Plane, while NASA's Wallops Flight Facility (operated by the Goddard Space Flight Center) manages and implements NASA's scientific balloon and sounding rocket projects. NASA's Space Station Freedom program office also is located in Virginia. While Colorado has no NASA center, it is the primary site of the National Center for Atmospheric Research (NCAR) and the National Oceanic and Atmospheric Administration (NOAA), as well as major U.S. Department of Defense facilities, including the U.S. Space Command, the Air Force Space Command, and numerous Air Force bases. New Mexico likewise has no major NASA center, but it is the site of NASA's White Sands Test Facility (operated by the Johnson Space Center), two U.S. Department of Energy national laboratories (Sandia and Los Alamos), the Air Force's Phillips Lab (a space or missile "superlab"), and the Army's White Sands Missile Range. Although Hawaii and Alaska have no major federal space centers, Alaska's state-owned Poker Flat rocket range/launch facility receives significant federal funding, while Hawaii's Pacific Space (PacSpace) links technical expertise in Hawaii and the Pacific Basin with space R&D opportunities worldwide and also works with NASA's Ames Research Center (California) to transfer space technology into Hawaii's private sector. (See appendix A for an overview of the nine NASA centers.)

Space Business and Technology Development.

Approaches by these eight states to space business and technology development are substantial but vary significantly. Florida, for example, links numerous projects through the Spaceport Florida Authority to create a comprehensive space infrastructure. These initiatives include the Florida High Technology and Industry Council, the Technological Research and Development Authority, the Foreign Trade Zone at Port Canaveral, the Florida/NASA Technology Transfer Agreement, the Spacecraft Florida Labs, the Florida Space Business Roundtable, and the Commercial Space Transportation Infrastructure and Systems Modernization Program. Likewise, Virginia's Center for Innovative Technology actively coordinates and supports the development of the five-university Virginia Space Development Consortium, four special university research institutes focusing on R&D projects with strong commercial application potential, ten technology development centers, the Virginia Community College System-based Technology Transfer Program, a network of seven innovation centers (i.e., combinations of enterprise centers and business incubators), and the Commercial Space Archives; it also develops interstate agreements with space authorities in other states (e.g., Florida's Technological Research and Development Authority). The State of Alaska, through its Alaska Aerospace Development Corporation and Alaska Science & Technology Foundation, has aggressively sought to enhance space business and technology through the expansion of its Poker Flat rocket launch range into a major commercial facility for microsatellite launches into polar orbits. Hawaii, through its Office of Space Industry and its Space Development Authority, also is aggressively seeking to establish a commercial launch facility, since it is the only land-based U.S. site capable of launching payloads into both equatorial and polar orbits. With less of a state government role, Space New Mexico has focused on development linked to distinctive in-state technologies and resources, including land recovery of satellites. The Alabama Commission on Aerospace, Science and Industry offers the potential to provide the focus for designing and implementing a comprehensive space strategy focusing on business and technology development. For example, it is preparing plans to use an oil drilling rig in the Gulf of Mexico as a commercial rocket launch site, with associated prelaunch preparation services in Mobile. An initial test launch is scheduled for fall 1993. As for California and Colorado, both states clearly recognize the importance of space-related development to their respective state economies, even though neither state has yet adopted a formal statewide plan or strategy to achieve this result.

Findings

Based on these eight-state comparisons, it is clear that the states which have been most successful in moving toward a space-related economy have had an institutional focus through which objectives are formulated and implemented. Most of the states surveyed have major NASA or other federal facilities and incorporate new initiatives involving these facilities in their long-range business and technology development plans. Other noteworthy activities in the more forward-looking states include the development of commercial launch facilities for microsatellites (but minimal attention, except for New Mexico, to land-based satellite recovery and other payload services); technology-based innovation center networks; opportunities for and interest in space collaboration among states; and the launch of a state satellite. The above comparisons also clearly demonstrate that there is no generally accepted definition, or characterization, of the space industry in a state.

The importance of an institutional focus, relationships with NASA facilities, payload services, a technology-based innovation center network, a state satellite, and other elements in one or more of these eight states as they seek to achieve a space-related economy suggests strongly that these elements also should be considered in the formulation of a Texas space strategy for the 1990s. Following an overview of the space infrastructure in Texas in chapter 3, chapter 4 provides the strategic framework for this baseline strategy, with chapters 5 through 9 addressing its essential elements.

Notes

1. Aerospace States Association, Inc., "Bylaws," March 12, 1992, p. 1.

2. Renee Saunders, "States Unite to Further Space Industry Involvement," *Space News*, February 11-17, 1991, p. 6.

3. Telephone interview with Lieutenant Governor Callahan, State of Colorado, Denver, Colorado, July 20, 1992.

4. Throughout the remainder of this chapter, information regarding these states' space activities is found in the following sources:

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<u>Alabama</u>

Debra Polsky, "Alabama Considers Polar Launches From Gulf Platform," *Space News*, July 6-19, 1992, p. 11.

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<u>Colorado</u>

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Chapter 3.

Space Infrastructure in Texas

NASA and JSC

Any discussion of a Texas space strategy must take into account the National Aeronautics and Space Administration (NASA) civil space programs and NASA's presence in Texas. This section reviews the strategic plans and economic impact of both NASA generally and the Johnson Space Center (JSC) specifically.

National Aeronautics and Space Administration

The original objectives of NASA, as specified in the National Aeronautics and Space Act of 1958 (P.L. 85-568), were the

> expansion of human knowledge; improvement of space vehicles; development and operation of space transportation systems; establishment of long-range studies of space activities for peaceful and scientific purposes; preservation of the United States as a leader in space science and technology and in their application for peaceful purposes; transfer of information to other agencies; and international cooperation.[1]

In response to these objectives, primary program activity has been in the areas of human space flight (e.g., Apollo, Space Shuttle, Space Station Freedom), space science and applications (e.g., robotics, planetary exploration, astronomy, meteorology, communications, remote sensing), and associated technology development (e.g., launch vehicles, spacecraft, tracking networks, and data acquisition and management).

NASA's appropriation for fiscal year (FY) 1992 was $14.4 billion, slightly more than its FY 1991 appropriation ($13.9 billion) but less than NASA had requested to fund its increasingly more costly human space flight programs as well as its ongoing space science and technology development activities. NASA's FY 1992 appropriation was about two-thirds of that year's U.S. Department of Defense (DOD) space appropriation, which for the past decade has annually surpassed and grown more rapidly than NASA's.[2]

The current framework for NASA program activity in the 21st century in *Vision 21*, its strategic plan for the 1990s which was released in January 1992.[3] Developed in response to evolving national civil space priorities and resources, this plan seeks to inspire and better the lives of all Americans by focusing NASA activity on the following four goals:

1. "advance scientific knowledge of the planet Earth, the sun, the solar system, the universe, and fundamental physical and biological processes";

2. "expand human activity beyond Earth orbit into the solar system";

3. "strengthen the competitive posture of the United States in the fields of space and aeronautics"; and

4. "attract young people to the wonders of mathematics, science and technology and ensure a more technically literate society equipped for the world of tomorrow."[4]

To implement its goals, NASA has identified four primary missions for the 1990s, as follows:

1. "Space Science -- the pursuit of basic discovery and understanding to advance the study of the universe, to solve practical problems on Earth, and to provide the scientific foundation for expanding the human presence in space";

2. "Mission to Planet Earth -- the use of the unique perspective of and conditions in space to understand global changes on Earth and how humans are affecting our planet";

3. "Mission from Planet Earth -- the exploration of space and the expansion of human presence and activity beyond Earth orbit into the solar system through Space Station Freedom, lunar base development, and exploration of Mars"; and

4. "Aeronautics Research -- vehicular technology and disciplinary research to sustain U.S. leadership in the increasingly competitive field of aviation (e.g., the National Aero-Space Plane program)."[5]

To carry out these missions, NASA in turn has identified five essential enabling capabilities: human resources (in the aerospace industry and universities as well as in the NASA centers); physical resources (including launch pads, computational centers, research laboratories, and management systems); space technology (the development of technology as well as its active transfer to industrial and commercial applications); Space Station Freedom; and space transportation and communications (launch services as well as a command, control, and communications infrastructure).[6]

Central to NASA's successful development and application of these capabilities to carry out its missions are its nine centers, one of which is the Lyndon B. Johnson Space Center. Appendix A includes brief descriptions of these NASA centers.

Johnson Space Center

The Lyndon B. Johnson Space Center (JSC), located near Houston, is one of four NASA centers with major space flight responsibilities. (The other three are the Kennedy Space Center, the Marshall Space Flight Center, and the Stennis Space Center.) It is the focal point of space activity in Texas and the means through which NASA most directly affects the Texas economy.

JSC's January 1992 strategic plan sets forth the foundation for carrying out its program responsibilities in the overall framework of NASA's January 1992 statement of goals, missions, and enabling capabilities.[7] JSC's strategic plan builds on its experience and expertise as the lead NASA center for human flight activity; its refocused mission is in turn "the expansion of human presence in space through exploration and utilization for the benefit of all." The JSC strategy formulated within this framework now states that

1. "JSC is the lead center for human spaceflight, exploration, and utilization";

2. "JSC will concentrate on piloted vehicles, human systems, life sciences and related technology development"; and

3. "JSC will participate in selected precursor activities that will develop our expertise and experience required for human space exploration."[8]

Noteworthy about the JSC strategic plan is its emphasis on "doing business differently" -- finding synergies in current programs; implementing new approaches to major programs; keeping its workforce up-to-date technologically; cultivating partnerships with the contractor community; building in safety, reliability, and quality assurance; and improving its service base.[9] Also encouraging from the perspective of Texas are the plan's statements that JSC will "[w]ork closely with the Mid-Continent Regional Technology Transfer Center and state agencies to facilitate access by the private sector to technologies from NASA, our aerospace contractors, and other Federal laboratories"; "[m]ake optimal use of our existing facilities by allowing contractors access to them"; "[e]xpand the creative application of space-related knowledge and techniques to the classroom and campus environments"; "[r]each beyond traditional aerospace industry and technical fields of study to establish partnerships in support of educational programs"; and "[f]ind ways for government, academic, or private sector users to take advantage of our assets in space and improve the methods we use to accommodate their specific requirements."[10] These written statements, reinforced orally by JSC officials, suggest that NASA and JSC will be increasingly amenable to innovative joint initiatives with business, state government, and universities in Texas as the state implements its space strategy for the 1990s.

Economic Impact

As its annual appropriations approach $15 billion and its civilian workforce continues to exceed 20,000, NASA has assumed an increasingly major role in the space-related economies of several states, including Texas. In FY 1990, for example, firms operating in Texas received NASA funds totalling $1.25 billion, third behind California ($3.15 billion) and Florida ($1.34 billion) and ahead of Alabama ($1.12 billion) and Maryland ($0.8 billion).[11] Of the top 100 education and nonprofit institutions receiving NASA research funding in 1990, 10 were in Texas; their awards exceeded $101 million.

In FY 1990, NASA procurement expenditures of $11.3 billion nationally were estimated to create, directly or indirectly, 237,000 jobs, $23.2 billion in industry sales, $2.4 billion in corporate profits, and $7.4 billion in federal, state, and local tax revenues.[12] The Texas Comptroller's Office has stated that NASA and its contractors generate about $4 billion in total economic activity annually in Texas through procurements, operations, and wage payments, supporting about 30,000 public and private sector jobs.[13] While the precise economic multiplier for NASA procurement expenditures in Texas is difficult to ascertain, it is clear that the state's total benefits, direct and indirect, from NASA procurements are significant.

Other national NASA initiatives, namely, the Centers for the Commercial Development of Space (CCDS) program and the Regional Technology Transfer Center (RTTC) program, also have enhanced state economies. The CCDS program, established in 1985, seeks to encourage private sector interest and investment in space-related technology that has commercial potential. Two of the 16 CCDS centers are in Texas: the Space Vacuum Epitaxy Center at the University of Houston and the Center for Space Power at Texas A&M University. The RTTC initiative, established by NASA's Technology Utilization program, funded six new regional nonprofit centers in late 1991 to promote access to and use of technology from NASA and from federal laboratories and agencies and to foster the commercial application of this technology. One of the six RTTCs, the 16-state Mid-Continent RTTC, is located in Houston. Services include access to data bases, seminars, product development and technical assistance, and regional networks. Primary sponsors of the successful Texas application leading to the creation of this center were Texas A&M University, the University of Houston-Clear Lake, Southwest Research Institute, UT San Antonio, and the Midwest Research Institute, assisted by the Texas Department of Commerce's Office of Advanced Technology.[14]

To understand more clearly and fully NASA's economic impact in Texas, it is useful to focus specifically on JSC. It is one of the three largest employers among the NASA centers, accounting for approximately 15 percent of NASA's personnel strength, about the same as the Marshall Space Flight Center and slightly less than the Goddard Space Flight Center. In FY 1990, the combined JSC workforce totalled 16,750 equivalent people (using NASA's terminology), excluding subcontractor staff: 3,751 NASA civil servants; 12,716 aerospace and other industry contractors; and 283 other government and services employees.[15] Peak federal employment at JSC occurred during the rapid growth of the manned space programs in the 1960s, but with the increasing use of outside firms to support the development of Space Station Freedom contractor employment at JSC is now at its height.[16]

In FY 1990 JSC received $2.5 billion from NASA's $12.3 billion budget (slightly more than 20 percent). In that year, JSC spent about $1.2 billion in the Houston area, of which $174 million was spent for federal salaries (and travel) and approximately $1 billion for contracts with and purchased goods and services from local firms. These expenditures in the Houston area amounted to about $4.6 million each working day.[17]

In FY 1990 JSC ranked second to the Marshall Space Flight Center in procurement levels but was far ahead of the other NASA centers. Because two California companies, Rockwell International and McDonnell Douglas Corporation, were the first and second largest JSC contractors in terms of procurement obligations that year, California actually received more JSC funds than did Texas. On the other hand, 8 of the 10 largest, 20 of the 25 largest, and 38 of the 50 largest contractors receiving FY 1990 JSC funds were located in Texas.[18] Texas did receive about 53 percent of JSC's education and nonprofit institution procurements in FY 1990, however, more than double Massachusetts' second place share of 25 percent. These latter procurements helped distribute total FY 1990 NASA funds to several Texas localities (see table 1).

One additional contributor to the Texas space-related economy is tourism, which will become increasingly important. The Clear Lake area of Houston has averaged more than one million tourist visitors per year. The new $60 million nonprofit tourist complex Space Center Houston at JSC is projected to attract 2 to 3 million visitors annually, becoming the top tourist attraction in Texas and contributing an additional $100 million or more annually to the Houston economy.[19]

Texas Space Grant Consortium

The Texas Space Grant Consortium (TSGC) was one of 21 space grant colleges and consortia formed in 1989 under Phase 1 of NASA's National Space Grant College and Fellowship Program. By 1992 space grant colleges and consortia existed in all states.

The TSGC fosters and strengthens relationships among the space-related university, industrial, research, and state government communities, as well as between these groups and federal agencies, especially NASA (and JSC). The consortium's purposes, which reflect the objectives of the national space grant program, are to

1. "advance educational, research, development, and commercialization activities in the State of Texas which are related to space and space-related fields (science, medicine, engineering, and technology)";

2. "increase the pool of individuals capable of contributing to space research, development, and exploration";

3. "increase the application to the needs of society from space-related research, education, and exploration";

4. "increase participation in space-related activities by women and underrepresented minorities";

5. "increase cooperative interaction between and among government, industry, and universities in space activities";

6. "strengthen industry-to-industry interactions in the State of Texas in research and development in space-related activities and . . . expand the Texas industrial base for space activity";

7. "advance national space programs and policies through research, education, and public service activities"; and

8. "strengthen the education base for mathematics, science, and technology in levels K-12 as well as in higher education."[20]

Table 1.
JSC FY 1990 Funds
Obligated in Texas
($000)

Location	Contracts	Grants	Purch. Orders	Total
HOUSTON	$996,287	$9,332	$104,881	$1,110,500
PASADENA	7,540	0	10,254	17,794
CONROE	534	26	22	582
GALVESTON	0	95	0	95
BEAUMONT	0	107	7	114
BRYAN/COLLEGE STATION	125	822	13	960
AUSTIN	3,199	742	55	3,996
SAN ANTONIO	4,602	412	71,410	76,424
DALLAS	16,478	174	43,445	60,097
FT. WORTH	0	60	201	261
AMARILLO	0	0	105	105
EL PASO	488	0	227	715
LUBBOCK	0	25	3	28
WACO	0	0	12	12
3 OTHERS <10K EA. Temple, Victoria, Wichita Falls	0	0	17	17
TOTALS	$1,029,253	$11,795	$230,652	$1,271,700

Source: Robert R. Beyer, "Economic Impact on Local Economy," Johnson Space Center, 1990. (Briefing paper.)

As of summer 1992, the TSGC had 51 members: three space grant colleges (institutions having at least three space-related Ph.D. programs and a specified level of space research -- Texas A&M University, University of Houston, and The University of Texas at Austin); 22 space grant affiliate institutions (colleges and universities with smaller space-related programs); 22 industrial members (both large and small firms); one nonprofit institute (Southwest Research Institute); and three state government agencies (Texas Department of Commerce, Texas Higher Education Coordinating Board, and Texas Space Commission). The diversity and breadth of its membership give the consortium the institutional network to carry out the programs contemplated in its charter.

Texas State Government

Over the past decade the Texas Governor's Office and the Texas State Legislature have taken several initiatives to strengthen economic development, science and technology, and, more recently, space policy/planning in Texas. The Texas 2000 Commission (1980-82), the Senate Interim Committee on Business, Technology and Education (1983-84), and the Texas Science and Technology Council (1984-85) each contributed significantly to the specification and understanding of economic and technology development trends and opportunities and helped Texas government and business leaders recognize the need for coordinated public-private action.

Several significant state actions were taken in the latter half of the 1980s to further enhance general economic and technology development, including space-related activity, in Texas. In 1987 the Texas State Legislature created the Advanced Technology Program (ATP) and Advanced Research Program (ARP) as peer-reviewed competitive university grants programs. Administered by the Texas Higher Education Coordinating Board, the ATP is designed to promote economic growth and diversification by attracting new industries to Texas, creating new products and services, expanding the technology base available to business and industry, and increasing the number and quality of scientists and engineers in Texas; its state appropriation for the 1992-1993 biennium is $41.1 million. One of the approximately ten targeted technology areas is aerospace. Complementing the ATP is the ARP, also administered by the Coordinating Board, which this biennium awarded $20.5 million in grants to fund the basic university research needed for technology development and innovation.

Also in 1987 the Texas Department of Commerce (TDOC) was established. Although its mission is to strengthen and diversify the Texas economy generally, TDOC's business and technology development activities clearly contribute to the enhancement of the state infrastructure which supports space-related economic activity. Of significance to the state's space-related economy have been the initiatives of TDOC's Office of Advanced Technology (OAT), including its coordination of the state's successful 1991 proposal to NASA to establish one of six Regional Technology Transfer Centers (RTTCs) in Texas (see the **NASA and JSC** section above) and its efforts in 1990-91 to improve communications and understanding between JSC/NASA and Texas space interests. The **General Business and Technology Development** section at the end of this chapter describes several TDOC (and OAT) programs of particular value with respect to a state space infrastructure.

Since her January 1991 inauguration, Governor Richards also has reaffirmed the importance of space industry and business development to Texas. In March 1991, in remarks at the Johnson Space Center, she personally committed herself "to protecting and enlarging this vital industry."[21] Specifically, she advocated the establishment of a multicity network of space enterprise zones, the loan of a "space coordinator" from NASA to the governor's office, an upgraded image and role of the Texas Space Commission, and the establishment of a space science engineering degree program at the University of Houston-Clear Lake. Governor Richards and the Texas Department of Commerce also have targeted the aerospace industry as one of six sectors on which to focus the state's business and technology assistance programs.[22] Other recent space-related activity undertaken by Governor Richards' office includes preliminary discussions with Mexican government officials about a satellite network linking Texas and Mexico universities.[23]

In recent years, Texas state legislators likewise have sought to strengthen the state's space economy and foster greater public-private collaboration in space business and technology development. A major legislative initiative was the creation of the Texas Space Commission (TSC) and the associated report of the Texas Senate Space Science Industry Commission in the late 1980s. The TSC is an important signal of legislative interest and intent as the state seeks to build a stronger foundation for space-related development.

Texas Space Commission

H.B. 1511, introduced by Texas State Representative Ashley Smith in the 70th legislative session (1987) and enacted later that term, created the Texas Space Commission (TSC). Its nine members are appointed by the governor for six-year terms and must have "demonstrated experience in space research, economic development in the private sector, marketing, banking, or research and development in science or engineering."[24] The TSC is charged with encouraging state economic growth by fostering the development of industries related to space commercialization and with conducting activities to advance space-related research in Texas. It also is able to solicit, accept, and expend public and private funds to administer its functions.[25]

Delaying the effective date of the law, however, was a provision requiring a positive recommendation in writing to the governor prior to September 1, 1988, by the chair of the Space Science Industry Commission, also established by the Texas Senate in the 70th session. This commission, chaired by State Senator J.E. "Buster" Brown, did provide such a recommendation. In addition, it held several hearings and produced a set of recommendations not only to guide the work of the TSC but also to develop the state's space industry and to recognize and support the role of the Johnson Space Center as a major Texas asset. In essence, it produced an initial plan for developing the state's space-related economy.

The Space Science Industry Commission's report went far beyond the TSC charge specified in H.B. 1511. Among the report's recommendations were the following:

1. formulate a space development framework linking science, technology, and economic development policy;

2. support engineering, math, and science education at all levels and provide technical training and retraining opportunities that support the aerospace industry;

3. help Texas' space assets compete and cooperate nationally for research and technology funds;

4. establish formal economic goals to support the diversification of assets in other industries, including oil, into aerospace-related activities;

5. endorse and promote JSC as the state's principal current resource for space-related development and organize the state's assets to enhance JSC in fulfilling its mission;

6. create a climate conducive to the establishment and growth of technology-based industry in support of aerospace activities;

7. encourage industry/university research partnerships through seed funding and targeted research initiatives;

8. encourage industry/government support to advance K-12 science and technical education;

9. unify Texas lawmakers on the federal level in support of aerospace projects and R&D funds; and

10. coordinate efforts to increase federal R&D funds awarded to Texas universities, industry, and

nonprofit institutes.[26]

The Space Science Industry Commission also directed several recommendations at the state's public and private sectors. These included:

1. The Texas Department of Commerce should work with TSC and JSC, provide (if needed) startup support for TSC, and establish an inventory of Texas aerospace-related companies.

2. The state should support a Texas investor network for financing commercial space ventures.

3. The state should create a state-supported foundation (TEXSPACE) to provide seed money for R&D with a reserve of $2 to $3 million annually. TSC should oversee the foundation.

4. The Texas business community should support a lobby group for the production, assembly, and operation of launch vehicles.

5. Texas industry should use the Small Business Innovation Research (SBIR) program and other federal funds for commercial space ventures.

6. The state should *examine and evaluate the development of a Texas satellite system to enhance in-*state communications.

7. The state should provide tax incentives and benefits for and eliminate obstacles to the development of aerospace projects.[27]

The TSC has held quarterly meetings since 1989. Until 1991, the TSC focused on the preparation of a mission statement and the identification of short-term projects as part of its required report to the Texas State Legislature.[28] No state appropriations were provided for the 1990-1991 biennium, although $50,000 was requested. In October 1990, TSC submitted its budget request to the legislature for $428,996 for each of the next two fiscal years; however, it received an appropriation of only $10,000 in state funds for each year. Since fall 1991 TSC has benefitted from having an executive director and a staff person on loan from Houston Lighting and Power and JSC, respectively, enabling the TSC to undertake a small number of projects. The TSC has focused its activities since fall 1991 on working collaboratively with the Texas Department of Commerce on local and regional economic development initiatives of benefit to the state's aerospace industries. As a result of 1991 state legislation sponsored by State Representative Ashley Smith, the TSC also is now able to generate funds through the sale of specially-designed space industry automobile license plates (space plates) to supplement future state appropriations and private support.

Although the Texas Space Commission has begun to advance space-related economic activity in Texas, its relative lack of authority and public-private support may limit its leadership role in space-related economic development in Texas over the next decade and beyond.

Texas Space Industry

Specification of the Texas space industry depends on the breadth or narrowness of the defining criteria for inclusion. Should large defense contractors be included, for example, or should the industry include only those firms (usually smaller and newer ones) primarily devoted to space? While the major aerospace corporations in Texas are appropriately the focus of state business development and assistance programs in view of their substantial employment levels, the development of space activity as a major contributor to the state's economy and the R&D base also will depend upon the growth of the commercial space industry.

The state's current space industry is assumed to include companies which produce spacecraft, satellites, or major systems of either of these. This definition identifies those Texas companies committed to the development of a space-based economy through the use of high technology design and production techniques (table 2). (See appendix B for company descriptions.) Not included in this definition or in table 2 are companies which produce such products as subassemblies (e.g., circuit boards, gauges, lines), "low tech" items (e.g., wire bundles, seats, structural components), or support items not unique to the space industry (e.g., forklifts, personal computers).

In a broader sense, however, given the long-term strategic framework in this project, the state's space-related industry includes not only Texas firms that currently meet the space industry definition above but also Texas nonspace companies likely and able to reconfigure themselves to join the space industry with minimal effort in the 1990s and beyond as demand for space services and products expands. These latter companies now possess most or all of the capabilities necessary to participate in the space industry in the near term or perform functions similar to the functions performed by space industry companies but currently serve different industries (e.g., software firms, technical R&D firms), and over the long term it is appropriate to include all these firms in a broader, future-oriented list of Texas space-related companies. The number of such space-related firms is generally said by Texas public officials to exceed 500.[29] (See Appendix C for a list of 521 space-related firms provided by the Texas Department of Commerce in fall 1991.)

Table 2.

Profile of the Texas Space Industry

Industry	**No. of Companies**	**Annual Sales ($Million)** **<10**	**10-100**	**>100**
Spacecraft/Space Vehicles	1	0	0	1
Space Systems	8	3	1	4
Satellites	3	2	1	0
Launch Services	1	1	0	0
Software	4	2	2	0
Consulting/Support Services	4	0	1	3
Totals:	21	8	5	8

Source: Corporate Technology Information Services, Inc., *Corporate Technology Directory*, vol. 1-4 (Woburn, MA, 1992).

General Business and Technology Development

Until the mid-1980s, public and private funding for technology-based business development in Texas was limited and unfocused. Now, however, several types of development assistance and resources are available to high technology firms during their startup or expansion phase. The three sections which follow focus in turn on business incubators and related venture capital funding, Texas Department of Commerce programs, and related organizations and programs (e.g., Texas Innovation Network System).

Business Incubators

The objective of a business incubator is to provide entrepreneurs with a nurturing, professional environment to support them in the startup and initial development of their businesses. They assist the entrepreneurs from the time the product ideas are conceived through to delivery of the initial products to customers. The incubator helps the entrepreneur develop his or her business to the point at which the business is able to exist on its own outside the protective environment of the incubator.

While economic development agencies are the most frequent sponsors of incubators, local governments, universities, and for-profit companies also play a significant role. Indeed, it is typical for an incubator to have multiple sponsors (e.g., an economic development agency with either a vocational/technical school or a local government.)[30]

This multiple sponsorship of business incubators makes it difficult to specify clearly a purpose for each one. Nevertheless, the three principal motivations for forming an incubator appear to be

1. economic development to stimulate the economy, create jobs, and diversify the local economic base;

2. commercialization of research and the transfer of technology into new applications; and

3. profits from rents and services and/or equity ownership in or royalty income from small firms, with risk minimization through investment diversification across many firms.[31]

For example, often most important to four-year university sponsors of incubators is the commercialization of research, whereas economic development agencies place high priority on diversification of the local economy and employment.[32] Indeed, increased local employment often is a significant benefit, since firms "graduating" from an incubator typically locate in that community.

Incubators differ in the services offered their tenants and how they are provided. The two general types of services are (1) shared office services and (2) management and technical assistance. Office services offered by most incubators include a conference room, photocopying, receptionist services, and word processing, as well as security services, computers, fax machines, office equipment, and a business library. Making an incubator distinct from a shared office facility are the management and technical services provided either by the incubator manager or by outside firms. Incubators themselves most commonly offer assistance with respect to business plans, government grants and loans, and tenant loan funds, while outside providers typically offer marketing, accounting, legal, tax, equity financing, patent, and other technical services, either on a fee-for-service basis or as part of the rent paid the incubator by the tenants.[33]

The most common incubator tenants are light manufacturing, R&D, and high technology firms. Retail, heavy manufacturing, and nonprofit firms rarely are accepted as incubator tenants. The number of tenants in an incubator ranged from zero to 77 in a recent National Business Incubation Association survey, but a typical number is close to ten. Incubators in existence three or more years tend to have greater numbers of tenants (about 15, on average) than do newer incubators. Incubators nationally average about two to three graduates and one failure per year. Average employment of graduate companies the first year out of the incubator is 20 to 30.[34]

By mid-summer 1992 there were approximately 500 business incubators in the United States and Canada, compared with 50 in 1984. More than half of the current U.S. incubators have opened in the last four years, with an average of four incubators starting each month.[35] In Texas, 32 business incubators were in operation in July 1992 (see appendix D). These incubators are located in 25 cities, with Austin (4), Houston (3), Odessa (2), and San Antonio (2) having more than one. Most are nonprofit and have light manufacturing, high technology, and/or services firms as primary tenants.[36]

The Austin Technology Incubator (ATI) is not only the most visible and most successful business incubator in Texas but also one of the premier programs in the United States. Established three years ago, ATI had 29 tenants as of May 1992, mainly spinoffs from other companies (e.g., the Microelectronics and Computer Technology Corporation) or from research programs at The University of Texas at Austin,[37] and had graduated three companies. A program of the Center for Technology Venturing (CTV) in The University of Texas at Austin Graduate School of Business, ATI is co-administered by the Graduate School of Business and The University of Texas at Austin's IC^2 Institute in collaboration with the Austin City Council, the Greater Austin Chamber of Commerce, the Travis County commissioners, and the private sector. It is housed in a 55,000 square foot facility and also has a 5,000 square foot wet laboratory. Its first two "graduating" companies, a UNIX software company and a desktop manufacturing company, created about 250 full-time jobs at a cost of less than $2,000 per job.[38]

ATI is an excellent example of a public-private approach to fostering new high technology businesses. Without an incubator's support, technology companies typically have only a 10 to 20 percent chance of succeeding; ATI, on the other hand, has had less than a 5 percent failure rate with its tenants, and other leading technology business incubators have similar success rates.

Also contributing to the success of the Austin Technology Incubator and other Texas technology business incubators has been the availability of venture capital to assist companies in starting up and becoming self-sustaining. Of particular significance has been the Texas Capital Network (TCN), established in Austin in 1989 to provide investors confidential, cost-effective access to a larger pool of ventures in their areas of interest and entrepreneurs more exposure to potential investors. TCN is recognized as one of the leading such networks in the United States, working with over 100 investors interested in investing more than $60 million in promising Texas companies and with more than 300 entrepreneurs. By late 1991, firms had received financing agreements totalling $3 million, ranging from $10,000 to over $1 million, for expansion capital, operating capital, and R&D; dozens of "matches" continue to be in evaluation. TCN is a nonprofit corporation started by The University of Texas at Austin's Center for Technology Venturing and sponsored by the Texas Lyceum, Leadership Texas, and the Texas Women's Alliance.[39]

Texas Department of Commerce

On September 1, 1987, following action by the Texas State Legislature, nine different state entities were merged to create the Texas Department of Commerce (TDOC). Its mission then was to "encourage a climate that will stimulate business and other economic activities resulting in the retention and creation of jobs for Texas residents."[40] In 1991, following a departmental transformation and reorganization, TDOC's mission became to "serve our customers by building partnerships that create economic opportunity and prosperity for all Texans."[41]

Two TDOC offices with primary program responsibilities consistent with this agency role are the Office of Business Finance Services (OBFS) and the Office of Advanced Technology (OAT). OBFS provides professional business finance assistance to Texas businesses desiring to expand and administers or coordinates several financial incentive programs "designed to increase capital availability to Texas businesses, aid in their expansion efforts and . . . create new jobs in Texas." [42] These financial incentive programs include, but are not limited to, the Texas Exporters Loan Fund; the Texas Capital Fund Loan Program, Infrastructure Grant Program, and Real Estate Development Program; the Governor's Special Assistance Fund for Small and Minority Businesses; the Texas Enterprise Zone Program; the Texas Development Corporation Act of 1979; the City/State Initiative of the Export-Import Bank of the United States; and the Small Business Administration's 7(a), 504, and International Trade Loan Programs.[43]

OAT's mission is "to diversify the Texas economy by expanding the number of Texas businesses developing or using new technology." To that end, it seeks to improve technology assistance resources, make technology information more available to Texas businesses, improve capital availability for technology development, and obtain federal resources to support Texas technology development. Since late 1991, OAT also has been charged with giving additional attention to the development of the critical technology industries in Texas.[44] Following are brief descriptions of OAT programs and activities of particular interest to the state's space-related constituencies.

Product Commercialization Fund (PCF).

This fund was created by the 71st Texas Legislature (1989) to provide working capital to assist Texas companies in bringing innovative technology-based products or processes to the marketplace (with an emphasis on innovation). The legislature has directed TDOC/OAT to give preference to businesses receiving assistance from Texas Small Business Development Centers (SBDCs) (see below), businesses formed to commercialize research funded in part with state funds, recipients of awards under the Small Business Innovation Research (SBIR) program (see below), and businesses developing energy-related products or processes. Funding is in the form of a loan or loan guaranty. The maximum amount of each TDOC investment is $200,000; the minimum is $25,000; and applicants must have a minimum 1:1 matching funding commitment from a co-investor. The first round of PCF funding was completed in early 1992, with four businesses recommended for loans. The second round supports the commercialization of recycling waste minimization technologies ($500,000) and renewable energy/energy-saving technologies ($1.8 million).[45]

Product Development Fund (PDF).

This fund was created by the Texas State Legislature in 1989 (and approved by Texas voters in November 1989 as an amendment to the Texas Constitution) to increase the amount of venture financing in the form of loans, loan guarantees, royalty agreements, or equity investments to Texas businesses for the development and commercialization of new technology products or processes. The same businesses receive PDF preference as receive PCF preference, with the exception of energy-related firms. TDOC may issue up to $25 million of general obligation bonds for the PDF. Bond proceeds should be used to create and fund a program to provide venture financing. In order to leverage additional private sector investment, TDOC and its PDF Advisory Board desire at least a 3:1 match of TDOC's bond proceeds, thereby creating at least $100 million of capital for Texas technology investments. TDOC also seeks to establish a PDF program which is self-supporting and has minimal administrative costs. To guide it in its design and implementation of the PDF program, in 1992 TDOC broadly solicited proposals from individuals and groups throughout Texas and is using these suggestions to create the program.[46]

Texas Technology Extension Network.

In September 1991 Texas was one of eight states funded (out of 34 state applications) by the U.S. Department of Commerce's National Institute of Standards and Technology (NIST) to create a statewide plan for a technology network "to improve manufacturing technology assistance, small business commercialization assistance, technology financing, technology transfer, workforce training for technology development, and information and communications."[47] The Texas award, in response to a proposal submitted by OAT/TDOC, was $100,000, the second largest award made by the NIST State Technology Extension Program to improve the competitiveness of small and mid-sized businesses through the applications of science and technology.[48] The statewide plan for a Texas Technology Extension Network should be completed in late 1992.

"TechTalk."

This monthly publication of OAT has a direct readership of over 1,000 people and also is distributed on electronic bulletin board systems to the technology business community in Texas.[49]

Small Business Innovation Research (SBIR) Program.

The federally funded SBIR program supports small companies whose innovative research and development activity has excellent commercial potential and is of interest to federal agencies. The program's purpose is to bring small businesses (i.e., independently-owned, for-profit U.S. firms employing 500 or less persons) into the federal government procurement process by providing hard-to-obtain funding for research and commercialization. SBIR Phase I awards are up to $50,000 for six months of preliminary research; Phase II provides awards up to $500,000 for the development of promising Phase I projects; and Phase III consists of venture funding from non-federal government sources. Eleven federal agencies, including NASA, allocate a portion of their R&D budget for SBIR awards, with the Small Business Administration providing national coordination.[50] Each agency annually invites proposals for SBIR projects in agency-established priority areas and determines its division of funds between Phase I and Phase II awards. (NASA, for example, anticipates that 50 percent of its Phase I projects will receive Phase II awards.[51]) The TDOC Office of Advanced Technology informs Texas companies about federal SBIR opportunities and assists them in competing for awards. As noted above, the PCF and PDF programs also give SBIR awardees preference. In fiscal year 1990, 62 Texas small businesses received almost $14 million in 100 SBIR awards, the tenth highest state total of awards in the United States.[52] With respect to NASA SBIR Phase I funding, in fiscal year 1991 ten Texas firms received only 12 of the approximately 300 awards made, even though the Johnson Space Center distributed 45 of NASA's awards.[53]

Not an Office of Advanced Technology program but one which strongly supports OAT activity is TDOC's *Texas Marketplace*. The program, announced by Governor Richards in October 1991 as a key feature of her New Texas Prosperity plan[54] and implemented in 1992, is designed to help Texas businesses access new market opportunities. One of the largest U.S. networks of buyers and sellers, it allows manufacturers and business service providers to advertise what they want to buy or sell through an electronic bulletin board. The Texas Small Business Development Centers work in partnership with TDOC on this program to improve access to its information and to coordinate local and regional business assistance activities.[55] A feature added to Texas Marketplace in summer 1992 is the Texas Technology Incubator (TTI), through which a technology entrepreneur can receive business guidance and gain access to information on how to bring ideas, products, or services to market. TTI also helps communities develop local business incubators.[56]

Other Programs

The following Texas business and technology development programs complement Texas business incubators and TDOC programs.

Texas Innovation Network System (TINS).

In 1987 the Texas State Legislature chartered the Texas Innovation Information Network System (TIINS) as a nonprofit 501(c)(3) organization. Its purpose is to help establish Texas as a world leader in scientific and business development by providing government, business, university, and other users in Texas with a technology transfer database network. Information products and services provided by TINS (the new name for TIINS) include the High-Tech Texas data base and associated printed directory (the 1992 edition of which contains over 3,000 technology firms); the FacProf database on faculty at more than 50 Texas colleges and universities; the Texas Research Centers database; and other online data systems, bulletin boards, library catalogue systems, and the like.[57]

Small Business Development Centers (SBDCs).

The SBDC program is the largest small business management assistance program in the United States. SBDCs counsel and train business people to manage, finance, and operate small businesses rather than actually carry out these tasks in the businesses. Texas has four regional SBDCs, each of which manages a network of strategically located satellite centers. The four regional centers are the Northwest Texas Region SBDC (Lubbock) (6 centers), the North Texas Region SBDC (Dallas) (12 centers), the South Texas Border Region SBDC (San Antonio) (8 centers), and the University of Houston Region SBDC (26 centers).[58] Preference in TDOC's PDF and PCF programs is given to small businesses receiving SBDC assistance.

Technology Business Development (TBD).

TBD is a service division of the Texas Engineering Experiment Station (TEES), a component of the Texas A&M University System. It "promotes the application of technology research to increase economic growth, encourage industrial development and enhance the standard of living in Texas" by providing (1) university research commercialization assistance; (2) technical assistance to entrepreneurs and small technology businesses; (3) economic development assistance; and (4) access to technology and market databases, publications, conferences, and seminars. A TBD initiative offering consulting services in marketing assistance, invention evaluation, manufacturing assistance, technical research, and business plan development is the Technical Assistance Program (TAP).[59] One of TBD's most important tasks has been to establish the NASA-funded Mid-Continent Regional Technology Transfer Center (RTTC) awarded to Texas in late 1991. As a result of reorganization and a refocusing of its mission during 1991 and 1992, TBD has closed its regional offices and eliminated several programs; however, it remains a potentially useful resource for business and technology development in Texas, especially given its responsibilities in the management of the RTTC.

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Chapter 4.

The Strategic Framework

Long-Range Goal

By the late 1980s, the public and private sectors in Texas generally had accepted the need for a more diverse state economy and had begun the task of formulating and implementing state economic policies to achieve the required diversity at the earliest possible time. At stake for Texas is the return to its previous high standard of economic vitality and, equally important, the establishment of a diversified economic base to sustain a satisfactory quality of life and to minimize in degree and extent the downturn effects of future economic cycles. While the overall economic condition of the state currently is improving, it is clear that longer time periods are needed for the emerging high priority, high technology sectors to become economically significant and to provide the resiliency needed for continued state economic growth. Each of the economic sectors (including space-related activity) that will make up the state's economic base in the 21st century must be sufficiently independent of other sectors to meet the intent of diversification; therefore, economic development of each sector must proceed relatively independently. Further, a vital space-related industry must exhibit a high degree of self-reliance if it is to meet the intent and purpose of a diversified economic base.

Based on the nature and intent of the restructured state economic framework, the project has concluded that the *long-range goal* of this strategic approach is as follows:

Achieve a self-sustaining space-related economy in Texas by the year 2020.

Although the quality of the space research programs in academic and nonprofit research institutions throughout the state is impressive, chiefly underwritten by federal contract funds, the bulk of these programs' economic benefits accrue to the Houston area, given its proximity to the NASA Johnson Space Center (JSC). As important as this source of federal funds is to the state economy, however, there is no evidence to suggest that the federal civil space program, and especially the JSC portion, will grow to the extent that this long-range goal could be achieved solely on the basis of JSC funding. Even if this growth were, for unapparent reasons, feasible, the wisdom of tying this important element of the state economic base to a single source (i.e., the federal civil space program) is questionable and contrary to the intent of the diversification. One need only look at the performance of the state's economy following the collapse of the energy-related sectors; the state could not anticipate and did not receive any significant increase in economic returns from JSC as a means of offsetting the effects of the recession. The conclusion seems straightforward: in order for space-related industry to achieve the level of economic significance specified in the long-range goal, the state must commit itself to a new and separate strategic initiative.

This conclusion raises a sobering question. Are there compelling arguments that significant opportunities for space-related industry exist, apart or virtually independent from the national civil program, which can be developed entirely within the institutional and economic framework of a single state? Fortunately, Texas is not the first state to address the question. As described in chapter 2 of this report, several states with space capabilities less than or equal to those in this state have answered in the affirmative and have begun development programs. All have based their decisions on a limited number of technology breakthroughs and their market potential for the state. These technology developments are in turn based almost exclusively on the downscaling, or miniaturization, of space technology hardware (e.g., space systems, space sensors, microelectronics, data processors). This radical departure in size and mass will lead to large reductions in the cost per unit of weight or volume of payloads. Small or light satellites are already under development in some states, and the parallel interest in developing smaller, cheaper launch vehicles to accommodate small payloads and to provide access to space is also underway.

In the judgment of this project's participants, the creation and development of a space-related industry broadly based on these technology potentials is well within the resources and growth capabilities of this state. Further, the market potential for this technology, in the broadest economic sense, is sufficiently large to support buildup of space-related activity to the level demanded by the long-range goal.

Consequently, it is reasonable for the state to expect that a space-related industrial economy can achieve a self-sustaining level (i.e., be able to survive and maintain sustained growth on its own merit and economic return). It is estimated that this level of economic viability could be achieved by the year 2020 at a minimum, depending on the state's commitment. The year 2020 implies that the long-range goal lies beyond the initial strategy period (i.e., the 1990s) and that a series of approximately decadal strategy/implementation periods will be necessary before achieving the goal.

The space-related economy that evolves from implementing the baseline strategy and its successors will, like the strategies, be highly integrated, broad-based, and multifaceted. It will require an aggressive and efficient organization whose range of operations is statewide; a new public-private partnership and perspective that ties together the state's industrial base with its research and development base and realigns the supporting infrastructure base; and a willingness to consider nontraditional approaches to an investment base. Thus a decision by Texas to undertake a development period of long duration and with high stakes, as this effort requires, must recognize and assess the risks and accept the likelihood that, to counter these risks, unconventional relationships and wide latitude in policymaking authority may become commonplace.

Commitment to this long-range economic goal, by virtue of its magnitude and the commensurate level of required effort, also will reasonably assure the state that it can aspire to a leadership role (presently vacant) among the space-faring states and that it can establish a strong competitive market position in the development and return of benefits from space-related industry and the commercialization of space. Given the high probability that new enabling technologies will also be available elsewhere, however, access to space is an essential capability for market development and a strong competitive position. This premise should be regarded as a fundamental underpinning to the initial strategy and its successors.

With these considerations in hand, the question then arises as to the specification of the initial strategy to advance toward the state's long-range goal.

Strategy for the 1990s (Baseline Strategy)

Any long-term strategy for economic development in the 1990s (space-related business and technology development is no exception) will need to accommodate the current weakened state of the Texas economy. While the rationale for selecting space-related development as a new major economic sector is sound, the public and private resources in Texas necessary to effect significant growth in space-related activity will likely be modest for at least the next several years. Thus, the rate of expansion of space-related activity in the 1990s will be constrained.

Nonetheless, the state's commitment to the baseline strategy will still require sustained public and private support in order to move space-related activity steadily toward a level of critical economic importance. Despite its modest character, the space strategy for the 1990s should be perceived as a challenge and should test the state's resolve and ambitions. Thus, it is obliged to strike an appropriate balance between the two considerations and in this sense truly is a baseline level of effort.

In keeping with the earlier characterization of a baseline strategy, a Texas space strategy for the 1990s should be construed as the least level of public and private effort necessary to make a major advance on the long-range goal. This requires a *baseline strategy* as follows:

Establish an organizational and operational foundation in Texas from which to address a limited number of primary and critical objectives in the 1990s that set in place the long-term direction and framework for economic development and that preserve and enhance future options to expand development, as resources and merit direct.

Specification of the primary objectives accompanying this strategy was driven by the following considerations:

1. A strategy requires an institutional base to implement it; if none exists or current organizations are not appropriately chartered, an appropriate institutional focus must be created.

2. Project findings and assessments indicate that the state's R&D base for selected technology and business development and its capability for access to and commercialization of space either do not exist or lack an adequate framework.

3. For the commercialization of space, in its broadest sense, to become a factor in the economic development of the state, a new perspective on federal-state relations is needed. The case in point for Texas is the requirement to establish a symbiotic relationship with JSC, an important consideration for its multilevel assets (e.g., technology, facilities, and scientific expertise) as well as its potential market opportunities for Texas space business.

These considerations led the project participants to specify the following required *institutional focus* and *primary objectives*:

Institutional Focus: *Establish an independent, public-private space authority to provide the institutional focus for implementing the state's space strategy for the 1990s.*

Objective: *Establish formal relationships between Texas and the Johnson Space Center (JSC) to meet selected JSC needs for state space-related R&D, technology transfer, industry, education, and infrastructure and to access JSC technology, engineering, systems management, and business development strengths and services in the implementation of the Texas space strategy for the 1990s.*

Objective: *Establish a statewide network of space business incubators in Texas emphasizing technologies that are critical or enabling to a self-sustaining space-related economy.*

Objective: *Establish an integrated payload services capability in Texas to foster the space-related business development, investment, R&D, technology transfer, infrastructure, and human resources necessary to sustain a space-related economy.*

Objective: *Establish a public-private development program for a Texas satellite system providing remote sensing, associated data management, and other communications services for industrial, commercial, scientific, educational, and governmental applications.*

Relationships Between Objectives

The institutional focus and primary objectives for this baseline strategy are, in keeping with the concept described earlier, an integrated set of action items to be addressed in Texas in the 1990s. They are intended to guide the implementation of this first strategy and to set in place the framework leading to the long-range goal. Consequently, the degree to which they are successfully carried out will determine the base on which subsequent decadal strategies are conceived and, ultimately, the length of time necessary to achieve the long-range goal.

To achieve the self-sustaining quality of the long-range goal, the space infrastructure within Texas must have an institutional focus and be organized for the sole purpose of building the space-related sector of the state economy. To elect a strategic approach to address this challenge carries certain conditions inherent in the concept: that the goal is vital and should be achieved at the earliest reasonable time and that the effort mounted to move toward the goal should, therefore, be highly orchestrated and efficiently managed. The implication is that every decision and effort to implement the strategy is taken with due regard for the larger strategic whole. The alternative (i.e., attempting to expand this segment of the state economy by a series of independent, unrelated development efforts) imposes too much risk of not achieving the goal at the earliest possible time.

Once the institutional focus has been established, all primary objectives are considered essential, and therefore all have equal weight and priority. The order in which the objectives are implemented is of no particular strategic importance; it is largely matters of tactical planning, priority, and timing that will determine their actual phasing over the period of the 1990s. However, full strategic importance is only realized with implementation of the entire set; a lesser effort will delay the attainment of the long-range goal. These objectives have been designed and constructed to be linked inextricably with each other; their strength and strategic importance are contained within the entire set. To perceive them separately or address them individually has virtually no larger strategic value. (Figure 1 portrays these interrelationships.) Taken together, the primary objectives are specific actions intended to initiate and sustain a state infrastructure to build the technology R&D base, to develop systems and capabilities to use and apply the technology, and thereby to provide the critical leverage needed to aggressively challenge and compete for a significant market share of space services.

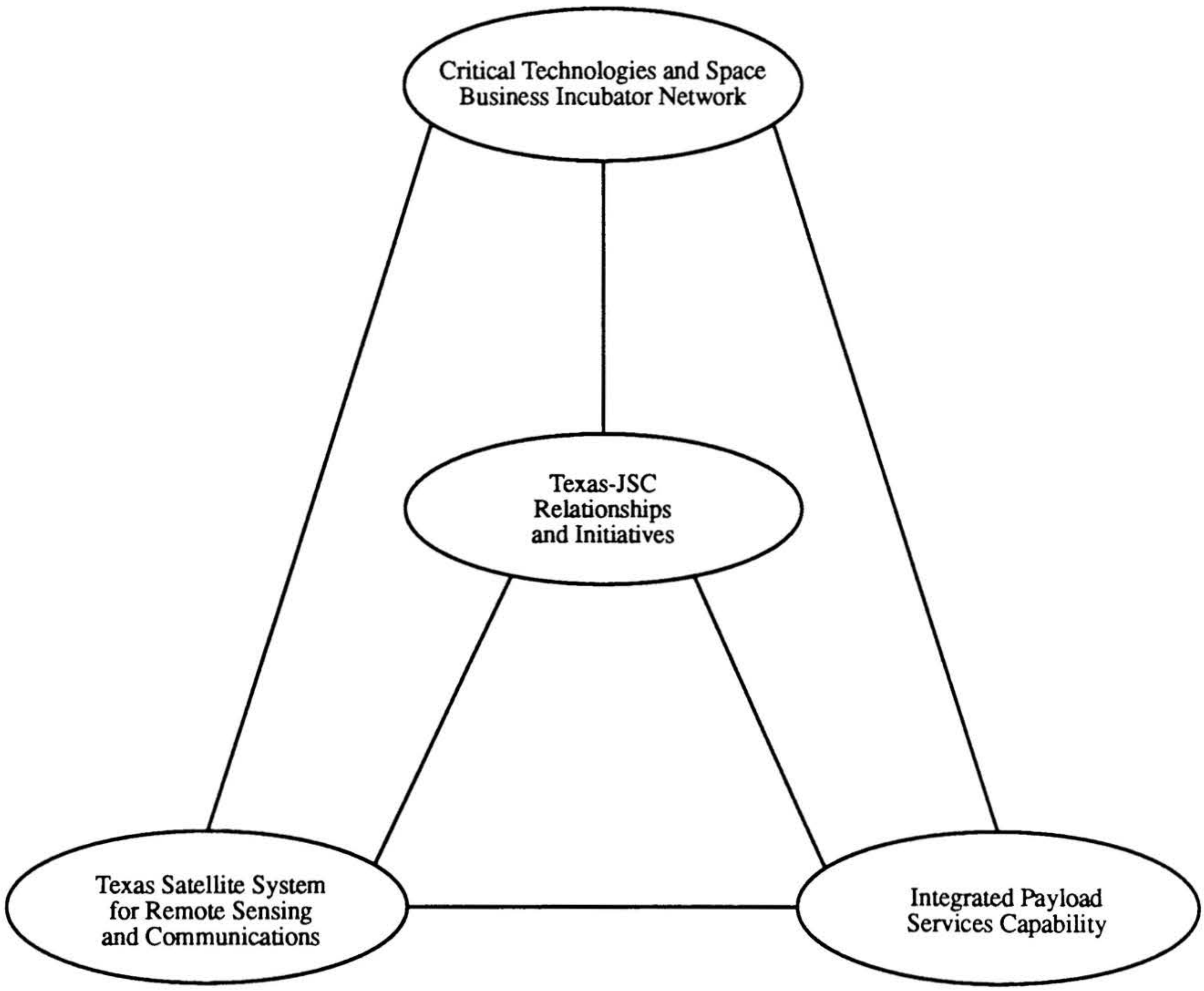
The accomplishment of the primary "mission" objectives will be substantially enhanced if the state avails itself of a recent JSC/NASA policy that offers a wide range of resources (e.g., technology development assistance and use of facilities) to outside contractors, private industry, and states. While the "mission" objectives of JSC and Texas differ, the common characteristics (including space technology, space systems, mission operations, communications, and spacecraft tracking systems) position JSC as a unique resource for the state's long-range space technology intentions. As Texas further develops its own R&D base and associated space capabilities, the project group foresees the opportunity for the state to meet some of JSC's needs in critical technology development and in the use of the state's space systems as a space environment laboratory in which to assess new technologies developed by JSC. It is unlikely, however, that these extended Texas-JSC relationships and their targeted purposes will flourish without a formal, dedicated effort and astute management.

The first priority in the selection of critical technologies on which to establish a space business incubator network is to choose for development those technology candidates that are best suited to provide the state with an independent, self-sustaining space industry. The focus must be on building an economic condition (i.e., an R&D base and technology market) in which the state is not wholly or primarily dependent on securing an increasing share of the national civil space program funding. As the economic base to build the state's capability is established, critical technology development will be extended into related areas, thereby broadening the market for Texas space technology products. Nevertheless, the first priority -- maintaining the state's self-sustaining capability -- will likely remain in place indefinitely.

The critical technology products emerging from the statewide space business incubator network as the "seed corn" for an expanded state space technology R&D base in Texas must have an outlet and a market. These products, some of which will be intended for space commercialization and related purposes, will require access to space for proof-of-concept and market development. The availability of an integrated payload services capability within Texas will provide a means to demonstrate the capabilities and potential of these products and their underlying technologies. Other critical technology developments resulting from the incubator network will be directed to advanced space hardware for remote sensing and communications from orbit. An operational state satellite system will be able to demonstrate the capability of state-produced technology for the system and its market potential.

Figure 1.

Relationships Between Primary Objectives of a Texas Space Strategy for the 1990s



In a reciprocal manner, an integrated payload services capability will depend on a continuous flow of advanced technology to create and enhance a state-of-the-art system, a strong competitive position in the marketing of space commercialization services, and the advantages and leverage which the state has at its disposal by virtue of its size, geographic location, and space infrastructure. It is equally important that new concepts and opportunities for space commercialization, whether from the statewide incubator network or from emerging new space technology businesses, be based in the state and have preferential access to space. The "packaged" nature of payload services available entirely within the state, in this sense, will be a powerful attraction for space technology R&D and commercial development.

The objective to establish a public-private development program for a state satellite system, perhaps the most ambitious of the objective tasks, similarly is closely tied to the statewide incubator network and its associated critical technologies as well as to the payload services capability. It is vitally important to develop within Texas the critical technologies and products that will enable the state to acquire an advanced, multipurpose satellite system, not only the space system hardware but also the payload hardware for sensor instrumentation, communications, and data management. Before being placed in orbit, many of the technology capabilities that ultimately will be used in a state satellite system must go through an experimental and proof-of-concept phase that will be available through the state's payload services. In this sense, there also likely will be a substantial symbiotic relationship between a satellite system and an integrated payload services capability. Despite the differences in their main purposes, both objectives require launch capability (ranging from sounding rocket altitudes to low earth orbit); payload recovery and processing; and data processing, management, and distribution.

Chapter 5.

Institutional Focus: A Texas Space Authority

INSTITUTIONAL FOCUS: Establish an independent, public-private space authority to provide the institutional focus for implementing the state's space strategy for the 1990s.

Rationale

Current Situation

Space development and the advancement of space-related activities in Texas has been pursued for several years by Texas governments, business and industry, and academia. The Texas State Legislature established the Texas Space Commission in 1987, for example, to encourage economic development in Texas by fostering the growth of industries related to the commercialization of space and to conduct activities to advance space-related research.[1] The National Aeronautics and Space Administration (NASA) designated Texas A&M University, The University of Texas at Austin, and the University of Houston as space grant colleges to enhance space-related educational and research efforts. These universities, joined by other universities and colleges, state government, industry, and the nonprofit sector, formed the Texas Space Grant Consortium to advance space-related education, research, development, and commercialization activities and cooperation in Texas.[2] Aerospace companies such as Rockwell International, General Dynamics, McDonnell Douglas, and Lockheed have major facilities in Texas, as do smaller space-related firms such as Space Industries, Inc.

State government, academia, and the private sector share primary interests in the attainment of the long-range space-related economic goal for Texas. State government seeks to improve the long-term growth and stability of the state's economy, and it has major responsibilities and challenges that can be addressed from space platforms. Universities endeavor to increase, apply, and disseminate knowledge about space and to expand their space-related research and development base. The space-related industrial sector seeks new technological opportunities and a stable business environment in which firms can grow and earn profits. Between these public and private sectors exists an interface across which information, communication, and coordination should occur with relative ease. There must be an organizational and operational foundation through which each of these sectors has a focused, proactive, participatory responsibility to ensure that space-related business and industry is a major attribute of the state's economy by the year 2020.

Numerous organizations in Texas currently are active in the commercialization and economic development of the space-related sector. The Texas Department of Commerce created the Office of Advanced Technology to stimulate development of high technology industries. This office administers the Product Commercialization Fund and the Product Development Fund, through which public monies are provided for technology business development. The Texas Space Commission is working with the Department of Commerce to foster space-related local economic development. The Texas Space Grant Consortium has attempted to increase collaboration among its members with respect to technology transfer and other shared interests. Each biennium the Texas Higher Education Coordinating Board awards approximately $60 million in public funds to university researchers through the Advanced Research Program and the Advanced Technology Program to strengthen the state's R&D base. Space-related firms also are enhancing the economic climate through contracting, entrepreneurial, and community activities (e.g., Space Business Roundtables).

Yet the current efforts of these and other state (which in this report, refers to both public and private sectors, unless otherwise noted) space organizations are limited in scope and relatively uncoordinated. While each organization is actively engaged in pursuing its own particular agenda, none is responsible for or intends to lead development of the state's space-related economy. No organizational framework exists to move Texas to a predominant leadership position in space-related economic activity in the 1990s and beyond. It is clear that a tacit laissez-faire policy has led the state to its current space infrastructure and the current economic role of space technology. This infrastructure and the economic return to the state are virtually exclusively tied, directly or indirectly, to the national civil and military space program. As pointed out earlier, however, there is no compelling evidence on which to base the conclusion that this current situation will lead, in a reasonable time frame, to the high priority economic role projected for space technology. Consequently, if the state chooses to embark on a long-range economic development effort employing a strategic framework and if this effort is to build on the current space infrastructure, then the question naturally arises as to the appropriate organization that must direct the task. The project participants have concluded that the state critically needs a clearly identifiable, separate, and independent institutional focus to guide the implementation of the state's space strategy for the 1990s and to mobilize a long-term commitment to economic growth through space-related development.

Strategic Importance

Strategic concepts, virtually by definition, are goal-oriented and, therefore, are constrained to achieve their predetermined goals by providing clear direction, priority, and focus. Long-range strategies, once committed to, demand constant attention to tactical planning and to adjustments to accommodate unforeseen circumstances and events; their duration will surely exceed the professional terms of service of practitioners and implementers. Strategies do not lend themselves to success by leaving their fate to be determined solely by market forces and conditions; indeed, economic development strategies are often adopted when independent markets and industrial factors cannot be relied on with confidence to achieve, laissez faire, critical economic goals. Lastly, it is an easy misconception that strategies end when there is a general consensus that predetermined goals have been achieved. They do not. They are essentially unending, especially, as in the case of this strategy, when the subject area it treats is large, complex, and constantly evolving and when the critical need to effect a fundamental change in the state's economic base is transformed into a need to maintain the change once it is in place. In essence, the strategic perspective undergoes periodic renewal in response to perceived long-term changes and departures from the status quo.

It is these characteristics of a long-range strategy that require an institutional focus, a single corporate body to develop the tactical plan needed to make the strategy work, to establish the record of performance and achievement, to provide continuity for the enterprise, and to maintain the state's vision and focus on the goal. When no corporate body with the appropriate charter and authority exists, it must be created.

Consequently, we conclude that an institutional focus -- a Texas space authority (TSA) -- is essential to the commitment of employing a strategic framework to develop a space-related industry and is a requirement for undertaking implementation of the primary objectives of the baseline strategy. Further, given the pervasive nature of the current and projected space infrastructure in the state and the broad base of vital space interests, it is apparent that neither a public nor a private institution is adequate to encompass effectively these factors and the infrastructure. An innovative and imaginative institutional base is needed to bridge these elements of the current economic base. We conclude that a public-private institution, vested with certain characteristics common to individual public and private institutions, can best address the particular attributes of a Texas space-based economy. Based on research findings and assessments, there appears to be no current organization that is appropriately chartered, vested with the latitude and range of operational authorities, or positioned at the public-private interface.

Operational Responsibilities

According to Peter Drucker, strategic planning is

> . . . the continuous process of making present ... decisions systematically and with the greatest knowledge of their futurity; organizing systematically the efforts needed to carry out these decisions; and measuring the results of these decisions against the expectations through organized systematic feedback.[3]

This definition captures the oversight role of a dedicated organization and the operational process by which it weaves together the principal strategic objectives into a single economic fabric.

The organizational structure of the TSA should include the following critical set of operational responsibilities: business development, investment base and financial management, technology transfer, and program management. While supplementary responsibilities may be incorporated into the TSA organizational structure, they likely will be added to enhance effectiveness and efficiency. This critical set of responsibilities should be regarded as the core of the TSA. Although they are organizationally distinct, these responsibilities collectively represent the means to implement the primary objectives of the strategy. As such they too are mutually dependent and reflect the integrated character of the first baseline strategy's objectives (i.e., all are vital and, to achieve maximum organizational efficiency, none should be eliminated or placed in another jurisdiction).

The first priority of the new public-private TSA should be the development of a comprehensive tactical plan, out of which should emerge organizational priorities, modes of operation, and management policies and practices. The substance of the plan and TSA's performance in carrying it out will be an important element and factor in measuring progress toward the goal and in determining accountability.

Business Development

The primary purpose of the TSA with respect to this operational responsibility is to ensure that business development of space industries is shaped and directed to support the primary objectives in the space strategy for the 1990s. The magnitude of the task is nothing less than a reorientation of the current space infrastructure toward the long-range goal.

In close coordination with its other operational responsibilities and focused on the primary objectives, the TSA should

1. effectively move emerging technology businesses from incubator or early development stages to a sound business footing and establish for them, by whatever means feasible, a nourishing environment and the opportunities to move them as soon as possible into competitive positions;

2. create an environment to attract entrepreneurs and firms to relocate and enlist in the state's business development program; and

3. define and redefine as necessary the market for Texas space technology and space-related industries, as well as develop a comprehensive market development plan.

Emerging commercial and industrial space activity often does not fit a typical business development pattern. There are substantial costs and unusual risks associated with these space ventures, and the investment return is often longer than desirable for venture capital sources. Nevertheless, private industry is beginning to explore these business opportunities because of the potential returns; in 1991, for example, commercial space revenues showed a 29 percent growth rate.[4] Further, the state's business development approach, with its unusual combination and scale of economic factors (including the commitment of a large, resource-rich state), should make prospective investment even more attractive.

Texas must be able to cultivate its own commercial space industry and, when necessary and expedient, attract space firms to the state if it is to position itself as a leader in space-related economic activity. In this effort, the state will be competing for space technology entrepreneurs against other states and nations, some of which already offer comprehensive economic and development incentive packages to space businesses, a factor which must be accounted for in determining Texas' space market and business development. These businesses base their site location decisions on considerations of wage rates, quality of the work force, tax structure, and government regulation. The advantages of geographic location or availability of an abundant supply of natural resources (two advantages that Texas has generally offered that other states could not match in the past) are no longer the prime factors when firms make site location decisions. Small entrepreneurial firms in high technology development especially require financial assistance, business acumen, and a sheltered environment to gain a sound business footing. Therefore, to be competitive and increase its space business activity, the Texas space authority must foster the provision of a comprehensive range of business development services and assistance for both new and existing firms.[5]

The public and private sectors, as well as universities, share an interest in developing these businesses within the state. In the public sector, some funding is provided for university basic and applied research, for product commercialization and development, and for related business development services. The business sector likewise provides incentives to firms seeking to start up, expand, or relocate in Texas. These services range from economic forecasting and planning offered by local chambers of commerce to direct business support provided through a number of business incubators located within the state. Yet, while these efforts demonstrate a general commitment in Texas to the development of commercial industry, they either are not focused on space-related businesses or are conducted relatively independently of each other.

It is critical that the TSA business development operations target these disparate, limited resources for several reasons. First, given the condition of the Texas economy, the availability of public, private, and university business development resources will be constrained over the near term. This situation, however, is opportune to demonstrate the advantages of coordination and partnership and to obtain maximum financial leverage of available funds. Second, knowledge of the aggregate of these funds is required in negotiating and planning for sustained business development growth. Last, states such as Virginia, Florida, Alaska, and California, Texas' chief competitors, have already established space-related economic and business development programs. If Texas does not establish, and soon, an aggressive focus for its business development initiatives, other states and nations will increase their competitive advantage over Texas. Although this situation will have some effect on the state effort to develop its own independent space program, the largest negative impact will be on the potential market outside of the state. In the longer term, the substantial competitive advantages held by other states would make it even more difficult for Texas to expand its economy.

Establishing a viable Texas commercial space industry in the 1990s, even though it may be modest, is crucial to the attainment of this long-range goal. To this end, a space authority must assume the primary responsibility for coordinating and expanding space business development in Texas.

Investment Base and Financial Management

The primary responsibility of the TSA in this operational category is to ensure that a financial base is constructed to support adequately the implementation of the baseline strategy's primary objectives. In close coordination with its other responsibilities and in accordance with its tactical plan, the TSA should develop an investment base and financial management plan that

1. is characterized by baseline, multiyear financing (i.e., more than two and no more than five to six years) in order to avoid the inhibitions that annual budgeting and planning cycles impose (with the limit of the financial plan determined by the current tactical plan rather than by budgetary cycles of external funding sources);

2. defines the intermediate to long-range investment base necessary to support the financial plan, which should be sufficiently diverse to minimize negative effects during the implementation period and maintain balance among the economic sectors represented in the public-private authority;

3. provides the TSA with adequate flexibility in the acquisition and deployment of capital as implementation and development direct and merit; and

4. defines the disposition and reinvestment with the TSA of any financial yields that may result from the TSA's operational or programmatic responsibilities.

Multiyear financing is an important part of the trust that needs to be vested in the TSA. Especially in the case in which appropriated public funds are involved, there is a strong, conservative preference to keep the funding appropriation as short-term as possible or feasible in order to minimize the risk of mismanagement. Examples abound in which the requirement of annual budget cycles has become the antithesis to effective and efficient program management and development, however. New enterprises, especially those that depend primarily on bright minds for the creation of new technologies and the growth of their applications, demand time, support, and noninterference. Unless a highly motivated Texas space authority is sufficiently prescient to ward off these requirements, it is precisely this characteristic of a high technology effort that invariably suffers when the administrative overburden creates time and human resource demands that move critical people away from their principal responsibilities. When the stakes are as high as they are in Texas and in the expectations from space technology development, a primary factor in assessing the risk of multiyear financing is the tradeoff between the organization's degree of financial control and the latitude it needs to move expeditiously toward the state's economic goals. There are many opportunities, especially in the public-private institutional context, for demonstrating accountability and fiscal responsibility without resorting to excessive budgetary requirements and justifications on which the next funding appropriation is contingent.

Building diversity into the TSA investment base has the same rationale as in any other context. It is a protective attribute, intended to minimize the risks and effects of economic cycles that influence investment and thereby to ensure a high degree of funding stability for TSA undertakings. Diversity, operating effectively, precludes the possibility that the financial contribution or investment from a single source becomes sufficiently large, relative to the balance of the base, that it is able to exercise undue influence on the operations, policies, or planning of the TSA. While multiple investment sources constitute one facet of diversity, protection and flexibility should be further enhanced through the use of a variety of investment forms or vehicles. The following types are mentioned by way of example and are not intended to be all-inclusive: venture capital, economic development grants, matching fund grants, revenue bonds, tax-deductible or tax-deferred contributions, and stock offerings through the TSA.

It will not be possible for the TSA to address all the primary objectives initially. Its tactical plan will be used to guide and direct the sequence, phasing, and expansion of its program management activities. As a result, the TSA will have to manage a constantly evolving development environment, which will be conditioned by such factors as incremental funding, new technology factors to weigh and select, cyclical economic conditions, entrepreneur pools, and workforce education and training. To a substantial degree its performance and progress will be directly related to its ability to perceive and accommodate these changes and to maintain the development plan on track. As with most private corporations, the TSA cannot be bound by budget cycles in raising funds. Further, it will require the latitude and flexibility to seek additional funding and the authority to readjust or redeploy its funding base at any time. Consequently, its level of capitalization should reflect and anticipate these changing needs and not be predetermined based on an attempt to predict or constrain the TSA development pace.

Return of investment or profits from TSA activities are unlikely, except perhaps toward the end of the 1990s. Moreover, it is not a strategic concern how the TSA decides to shape its financial, corporate, or cost- or profit-sharing relationships among its programs or external contractors. However, the financial plan for the TSA should contain the necessary options empowering the institution to decide on the disposition of returns, either through reinvestment in TSA's ongoing development or through returns to investors.

Technology Transfer

The primary purpose of this TSA operational responsibility is to ensure that the appropriate critical space and nonspace technologies are made available, by any appropriate means and from any source advantageous to Texas, to support implementation of the primary technology objectives. The state's technology base (e.g., facilities, equipment, research teams) is not currently adequate to begin to address the long-term economic goal. It is expected that, with the implementation of the baseline strategy, the technology development process, from the origin of technology concepts to R&D and to commercialization, will shift into the state; however, time is always of the essence in economic development, so the TSA initially should move aggressively to acquire and transfer the critical technologies. In conjunction with the other TSA operational responsibilities and in accordance with the overall TSA tactical plan, the TSA should

1. monitor critical space and relevant nonspace technology development in all federal laboratories and R&D development centers, nonprofit research institutions, and available private sector industries;

2. develop an open access, interactive database that links the Texas incubator network, the payload services system, and the satellite system development groups to technology sources;

3. develop the technical and legal expertise to provide effective and informed "search and procure" support for the program responsibilities of the TSA, using whatever means appropriate (e.g., patent rights, technology exchange agreements, licensing, royalties);

4. establish and maintain a critical technology watch with the NASA centers, especially with JSC, to identify matches in state and JSC technology needs and to identify and negotiate access to JSC expertise, facilities, and equipment for development of state critical technologies and implementation of the strategy's primary objectives; and

5. develop and broaden the commercial applications market for critical Texas technologies as they emerge from the space business incubator system.

It is generally agreed by most technology experts that space technology is no longer, if it ever was, a major driver of U.S. technology leadership nor did it lend the national subsidy that would have led to a large commercialization of space. Infrequent access to space, high costs, long periods between missions, and infeasible development programs have often created situations in which space flight technology, despite mission successes, was conceded to be obsolete at launch. The space program generally could not accommodate the pace of technology development. Some argue that the situation provoked the move of new technology to other areas for growth and has resulted in the present condition in which nonspace technology is an obvious source for a resurgence of U.S. space technology. The new developments in miniaturization of a range of technologies, for example, did not have their origins in space applications, exclusively or primarily; thier potential application to space was only one of several important effects for R&D and commercialization that evolved during early development stages. As a consequence, nonspace technology development has become as important as (some would say significantly more important than) the development of technologies that have their original premise in space application. It is the very nature of these new technologies that has opened new R&D and commercial possibilities, at scales other than the national level, especially for those states which adopt these technologies for their own economic growth. Access to nonspace technologies, therefore, not only is an important source for transfer purposes, but also brings strength in its diversity and range for innovative use.

The federal government has played a significant role in recent years in promoting commercial space activity through the transfer of space-related technology to the commercial sector. It is important to note that these federally assisted programs almost exclusively establish commercial development relations between university and industrial R&D teams. As noted in chapter 3, two NASA Centers for the Commercial Development of Space (CCDSs) are in Texas: the Space Vacuum Epitaxy Center at the University of Houston and the Center for Space Power at Texas A&M University. These centers are charged with encouraging, to the maximum extent possible, the commercial use of space.[6] Additionally, one of the six federally chartered Regional Technology Transfer Centers (RTTCs) established in 1991 is in Houston. It is responsible for fostering and coordinating space-related and other technology transfer activities over the 16-state mid-continent region.

These centers are located in the state because of Texas universities' longstanding involvement with NASA space exploration and research programs and because of the high level of NASA-funded industry activity in Texas. For these reasons, as well as their proximity to the Johnson Space Center, the CCDSs and the RTTC in Texas offer potentially significant benefits to space businesses and entrepreneurs. However, space-related technology transfer in Texas cannot depend primarily on federally funded initiatives. Funding reductions for the Texas CCDSs or the RTTC because of federal budgetary constraints would affect Texas space industries and academic research facilities. Therefore, while it is beneficial to use federal assistance in establishing commercial centers, the state should seek to broaden and diversify the commercial market and funding base for Texas CCDS and TSA ventures for space commercialization as early as possible.

Texas must vest a state space authority with the responsibility for facilitating technology transfer for R&D and for the commercialization of space activity. The authority would complement the activities of (and have responsibilities similar to those of) the Texas-based RTTC. However, the authority must be more than a passive information clearinghouse. It should be charged to transfer technology to the state's space businesses and to coordinate industry's need for new space-related products and research with the state's research and development programs.

Program Management

The primary responsibility of the TSA in this operational area is to ensure that the baseline strategy's primary programmatic objectives (i.e., to establish the state space business technology incubator system, the integrated payload services system, and state satellite system) are in place by the end of the decade and are positioned for growth and expansion. These three objectives constitute the "missions" of the TSA for the first strategic decade. There is virtually no strategic concern regarding the organization type and structure selected for implementation, except to emphasize that institutional continuity and stability beyond the first decade are important characteristics of a development program. The choice of organizational form for this responsibility should be made with a somewhat longer perspective than a decade and with full cognizance of the TSA tactical plan.

Whatever the choice of organization, it is essential that the TSA retain oversight control of budgets, development schedules, and policies. This control should prevail whether the TSA chooses to create separate suborganizations within the TSA or to contract with existing private or public organizations to undertake the development tasks. Oversight authority is especially important in the first years, when the highly integrated nature of the objectives needs to be impressed on the TSA suborganizations in forging the links to make overall development coherent. The success of the "missions" rests on the openness and communications between these suborganizations.

The sequence or phasing of the three mission elements again will be derived from the TSA tactical plan. In accordance with this plan the TSA will have direct responsibility for

1. the selection of the critical technologies and their sequence for development in the space business incubator system and of the incubator site locations;

2. the specification of the technology, capabilities, and facilities required for a complete integrated payload services system, including its location(s) to support payload integration and launch, space flight operations, recovery, and payload processing; and

3. the identification of the technologies for development/acquisition leading to an operational multipurpose satellite system, including its capabilities and facilities (i.e., infrastructure).

The successful implementation of these primary objectives will establish the initial foundation for expansion and growth leading to the state's self-sustaining space economy. It is vital during this development process, especially through the difficult early years, to recognize the importance of establishing strong federal-state relations in space affairs. A commitment by the state to undertake this demanding economic task will, with virtual certainty, be seen and supported at the national level as a substantial initiative for the growth of space commercialization. The TSA will provide the vehicle to establish relations. In this sense, Texas is fortunate to have within its borders a national space program's organizational counterpart of the TSA, namely, the Johnson Space Center (JSC). It is especially timely for Texas that JSC's long-range strategy has, consistent with national directives, incorporated a priority outreach effort to individual states and educational institutions.

In this regard, another primary responsibility of the TSA is to ensure that formal relationships are forged with JSC very early in the implementation process and that these relationships are used in tactical planning and incorporated firmly in every operational responsibility and in the primary mission objectives of the authority. These relationships will reshape the JSC's traditional posture toward the state. While the long-range strategies of JSC and of Texas are substantially different in orientation and goals, the numerous areas of overlap will provide the following benefits:

1. the use of JSC facilities and expertise for space R&D in Texas;

2. access to JSC facilities and expertise for university research and education programs, with priority given to those programs that support the priorities of the TSA;

3. the TSA with the opportunity to direct technology development needs to the Texas space incubator system and to other established space technology industries; and

4. the TSA with the means to systemically disseminate information on JSC technology needs and technology transfer throughout the state.

Organizational Characteristics

While the determination of an appropriate private-public organization model for the TSA has been identified as a pre-implementation study task (see chapter 10), several organizational characteristics should be employed as a collective set of criteria in assessing model candidates and in arriving at an institutional form to manage a space-related growth industry. Its base must encompass the best combination of attributes of organizations in both the public and the private sectors. It must be institutionally independent in its decisionmaking processes, controlled neither by state government nor by private sector interests. It must have a clear authority to assume the state's leadership role, with recognized responsibility and expectations for coordinating the efforts of the different entities involved in the economic development of space. To ensure that it has access to a wide range of development capital sources, the authority must be able to secure both public and private funding for its operational and development program responsibilities. Finally, it must have the latitude to expend this funding in any way which facilitates the attainment of the state's baseline and subsequent strategies.

Public-Private Institution

Public-private institutions must function at an interface which, until recently, was generally viewed as unworkable in a formal organizational sense, largely because the motivation and premises of the two sides were incompatible. Only in unusual circumstances and often with limited lifetimes has public-private collaboration been employed. From the strategic perspective there is little merit in assembling arguments to justify an "unusual situation" in selecting a public-private institutional base. Rather, its choice is driven by

1. the magnitude of the economic task set for space technology development in the state;

2. the large investment demand in fiscal and human resources, which exceeds what a single sector can provide; and

3. the scope of interest within the state, demonstrated by any measure of critical infrastructure elements (e.g., market need, technology base, human and fiscal resources) as being so large and commonly held as to render the public-private interface, in practical or economic terms, virtually transparent.

The TSA's organization should be effective and efficient, lean in management structure with primary emphasis on staff performance, not organizational process. Its staff should be selected for broad-based skills; it should be team/task oriented, highly motivated, and able to perceive the opportunity to engage in a challenging high-technology enterprise and the opportunity for major public service as forged into a single purpose. Its plans, actions, achievements, and performance should all be a matter of public record.

Given the responsibilities and structure of the TSA, there is little purpose served in its clarification for tax purposes; on the contrary, especially during the formative years, tax-exempt status is an important, supportive advantage for the organization. Similarly, there is little rationale in selecting a corporate designation of for-profit, not-for-profit, or nonprofit. If a category must be selected, then the choice should not be made on narrow legal grounds but on a basis that allows the TSA the latitude for fiscal and investment capital management to address expeditiously its objectives. In this regard, it is the ability and priority to advance the state toward a self-sustaining space economy that should govern the question of corporate boundary conditions and constraints.

Independence

Given our conclusion that an institutional focus is required and should be empowered to lead the state in the economic development of its space industry, then it is a reasonable subsequent conclusion that the state space authority should be autonomous, possessing the latitude, leverage, and power to address and manage the critical needs of this task. Consensus on TSA characteristics and organization among the diverse state interests to be represented by the TSA carries with it an implicit conveyance of trust that the institution will consistently act in the best interests of the state and will do so without the need for close oversight by state government, business, education and community leaders, or special interest groups.

Leadership

From the review of the state's space infrastructure in chapter 3, it is clear that there is a mismatch between the designated economic role for space technology and the character and organization intended to implement it. Apparently, a laissez-faire policy has been adopted as the means to successful development. The burden has been placed primarily on the private sector, with the public sector assuming a support role with promotional programs, incentive packages, technology grants-in-aid, information bases, and other initiatives at levels which can be regarded as minor, relative to the task at hand, and largely uncoordinated and unfocused.

We have concluded that there is no compelling evidence to indicate, with acceptable confidence levels, that the current approach will succeed in a reasonable time frame. It appears to be motivated by the immediate and critical need to provide jobs, but with little or no attention to the long-term implications to building economic stability. With no intent to deter any effort to raise state employment levels, we have concluded that a long-range perspective is also vitally needed, that the current efforts need to be fundamentally reorganized and restructured, and that the TSA, in addition to its other duties and powers, should be formally designated as the lead organization for space technology development in Texas.

Capitalization and Revenue

As the institutional base of the TSA bridges the public and private sectors, so should its investment and funding base parallel the balance in public-private representation and in the sharing of funding support. To establish this base, the TSA will need to be empowered to raise funds from a wide variety of sources that reflect the range, diversity, and needs of its corporate operations and development programs. For example, the rationale and incentives for a funding source to underwrite the physical operations of the TSA will likely be substantially different and separate from the funding sources to support R&D development of critical technologies, the integrated payload services system, and the state satellite system. Consequently, the TSA must be allowed to raise revenues over a broad base of private and public sources.

Among public sources and funding mechanisms, the TSA should be authorized to raise revenues through traditional state and federal government means, including economic development grants, legislative appropriations, authority to issue general or revenue bonds, licensing fees, matching grants, short- and long-term loans, and creation of a venture capital corporation (for investment of both public and private investment funds). The TSA also should be able to raise capital from a diversity of private sources, including industrial memberships, fees for TSA services, endowments, direct contributions, and the establishment of a private foundation for the receipt and management of private funds.

Commensurate with the power to raise revenues the space authority must be able to disburse those funds directly in ways that support its principal mission objectives and that advance the state's economy. Further, the TSA, wherever possible and applicable, should also have the authority to use its funding potential for leveraging as a means of maximizing the use and extent of its fiscal resources.

Conclusions

It is virtually certain that a state space authority with these powers and independence will raise serious questions concerning accountability, adequate checks and balances, and risk. In order to preserve the set of organizational characteristics as described and to address these concerns, accountability should be invested, in a limited way, in the governing arm of the TSA, a small external unit charged to monitor and advise on all program and policy matters and composed of balanced representation of all sectors participating in the public-private enterprise. The governing arm should have oversight of the budget projections and the tactical plan developed by the TSA each planning period. With these two exceptions, the governing arm should not have veto and absolute approval powers; its primary function would be to provide an experienced, independent advisory body to guide the TSA in carrying out its responsibilities. That is, once a budget and tactical plan are agreed to by the governing arm, the TSA's accountability should be perceived and assessed only in terms of its performance in implementing the tactical plan.

We are not in a position, nor is it appropriate, to advance a position on risk assessment of the enterprise and the institution described. It is important, however, to set the terms of assessment in the proper context. Given the magnitude of the economic demands of space technology, the current state of the Texas economy and the degree of economic stability, the broad base of the development enterprise to spread the risk, and the essence of time in developing the vital economic role for space technology, risk assessment should be well within acceptable limits and the margin for error should be biased toward the TSA and its purposes as described.

Notes

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6. National Aeronautics and Space Administration, Office of Commercial Programs, Public Affairs Office, *Commercial Use of Space: A New Economic Strength for America* (Washington, D.C., 1990).

Chapter 6.

Objective: Texas-JSC Relationships and Initiatives

OBJECTIVE: Establish formal relationships between Texas and the Johnson Space Center (JSC) to meet selected JSC needs for state space-related R&D, technology transfer, industry, education, and infrastructure and to access JSC technology, engineering, systems management, and business development strengths and services in the implementation of the Texas space strategy for the 1990s.

Rationale

The Johnson Space Center (JSC) is NASA's primary center for the design, development, and testing of spacecraft and associated systems for manned flight. It has program management responsibility for the Space Shuttle program and major responsibility for the development of Space Station Freedom. As these two programs represent the largest portion of the federal civil space program for the foreseeable future, it is evident that JSC will continue to play a major role in those efforts. Even if NASA were forced to retrench due to budgetary constraints and to reduce the number of its centers, it is unlikely that JSC facilities and human resources could be duplicated elsewhere. In terms of current space activity, then, JSC remains the most well-known and important entity in the state.

JSC has a significant economic impact in Texas, largely confined to the greater Houston area to which it provides over one billion federal dollars annually. It employs more than 16,000 personnel, over 12,000 of whom are external, on-site aerospace and other industry contractors, and it accounts for over $2.7 billion of procurement nationwide, almost half of which stays in Texas. The multiplier effect in Texas from JSC expenditures is said to amount to $4 billion a year, and its procurement network extends throughout the state, including such cities as San Antonio, Dallas, Pasadena, Austin, El Paso, and Bryan/College Station (see table 1).

JSC also has internationally recognized technology, engineering, and systems management facilities. It is an intellectual resource and embodies much that the public approves of in U.S. affairs, namely, manned space exploration. For example, JSC has the Western hemisphere's largest vacuum chamber, a critical device in testing equipment and machines before sending them into space. JSC engineers work on a host of pioneering projects, including full-scale mock-ups of spacecraft, space suit design, robotics, and new materials testing. It has facilities to test heat shielding material in laboratory conditions that simulate re-entry and can evaluate new designs for rocket maneuvering. In the life sciences, JSC is a pioneer in the growing field of space medicine, and it is constantly exploring the effects of the space environment on the human body. It has extensive simulation facilities for human activity in space. Finally, JSC is NASA's designated center for manned space flight operations; as such, it maintains a large command center, using a worldwide tracking network for control and monitoring of every aspect of manned missions.[1]

Current federal policy guidelines state that all NASA missions and programs must now relate and give support to national education goals. It is apparent that NASA's contribution and role in this larger national endeavor will be tangibly addressed by its centers, a network that extends across the country and is charged to carry out the agency's complex tasks.[2] JSC's unique facilities, talented workforce, and challenging mission enable it to make an important contribution to the national education challenge and to enhance American leadership in aeronautics, space science, and technology development through cooperation with the education establishment. It remains the case that the responsibility for the education and training of the nation's youth is the responsibility of individual states, and it seems a reasonable conclusion that the maximum return in the federal-state context should be realized by direct, interactive linkages between federal centers and a state's university and secondary school systems. JSC has the resources to contribute directly in strengthening this state's educational and research programs. (Although somewhat outside the parameters for this strategy development, the concept of a direct linkup between JSC and Texas educational institutions also has the characteristics of a pilot project from which could emerge the models(s) for other states to use in establishing working relationships with other federal centers.) These assets exist at this moment, as evidenced by JSC's education and nonprofit procurements in Texas (see chapter 3).

Yet, while organizations like the Texas Space Grant Consortium, partially funded by NASA, are striving to foster increased math and science participation in public schools and space research at the university level, there are currently few active direct links between JSC and Texas universities. JSC has several programs which involve faculty research at both JSC and Texas universities and others which involve student research, internships, and clerkships, but there is no focused and formal organization in Texas responsible for enabling the state's educational institutions to capitalize systematically on JSC assets and to meet JSC needs. Even JSC acknowledges that, with respect to its own requirements for research and development, "there is no one place or document in which all this information on JSC's programs or needs resides."[3] At present, the state's education community must seek out this information.

Likewise, there are few formal relationships, networks, and partnerships between JSC and Texas businesses and state agencies. JSC's current strategic plan emphasizes its willingness to work with outside organizations[4], but JSC remains a federal facility and retains all the characteristics of such an operation. JSC cannot favor any particular state in terms of procurement or contracting; it must respond to the strategies and directives of NASA. JSC can enhance the state's industrial base through an emphasis on the center's own critical technology areas, but the challenge lies with the state's public and private sectors to establish and nurture relationships and partnerships with JSC that will systematically search for match-ups that leverage the development of both JSC's and the state's critical technologies.

In the next ten years, growth in the state's space industry will be related in part to JSC, due to its prominent role in the current space industry. At present, however, there is virtually no statewide focus or concentration of effort, either in education or business development, in Texas' public or private sectors to link the state's long-range space goal to JSC resources or JSC's long-range strategy.

Strategic Considerations

For the larger purposes of this strategy, which is vitally dependent on education, research, and technical and business development, this state is in a fortunate position of having one of the largest NASA centers within its borders. The concentration of economic and technological resources, human talent, and physical facilities at JSC represents a resource virtually without parallel in the state's effort to achieve the objectives of this baseline strategy. If the state is to make marked progress toward meeting these objectives, it should build upon existing and available space expertise and infrastructure to the fullest extent possible.

Therefore, in the context of this strategy, JSC is regarded as a part of the existing infrastructure within the state. This perspective is based on NASA's general policy to promote growth wherever possible in the commercial space industry; the general offers of assistance by NASA centers to make their facilities and expertise available, where feasible, to aid commercial growth; and the overlap of the mission-oriented objectives of this strategy and the established capabilities of JSC (including technology development, spacecraft flight systems and operations, and payload operations). Texas should use the advanced stage of JSC technology in establishing its own facilities and programs as rapidly as possible, thereby avoiding the long evolutionary path to achieve an advanced technology development industry. Consequently, JSC collaboration in sharing facilities and expertise early in the baseline strategy period would diminish the time and costs to Texas in creating its own facilities and human resources base. Equally important, such a partnership creates a specific way for JSC, a federal center, to contribute directly to a space commercialization enterprise that gradually builds its own self-sustaining base and becomes independent of federal assistance.

In a similar manner, in order to leverage the development and growth of its own space technology industry, Texas also must give serious consideration to JSC's (and NASA's) long-range goals and strategic plans. JSC represents an important sector of the greater future market for Texas businesses and industry, more so than it is now. During the early growth of a space-based economy in Texas, as the state collaborates with JSC to address shared or complementary development objectives, the economic returns to the state will be partially derived from or associated with JSC. Knowing JSC's program priorities will help direct the state's own space enterprise into research areas that can provide Texas and JSC with tangible benefits.

Education is the remaining area in which building relations with JSC takes on major strategic importance. Even a cursory assessment of JSC facilities and research areas, many at an unprecedented scale and advanced level, begs the question of not whether but how these resources can be effectively harnessed to the nation's and the state's education challenges. An innovative concept depicting JSC as a major adjunct teaching facility for the universities and colleges in Texas has emerged recently and requires a shift in the perspective usually applied to the center.[5] Juxtaposing the teaching and research capacity of Texas universities with the teaching potential of "hands-on access" to JSC's state-of-the-art research and test facilities would transform space science and technology curricula and significantly advance the training and competency of emerging graduate students. Such a program could be accommodated virtually entirely by computer networks, with little or no need for large movements of people between facilities. While the concept requires additional detail and evaluation, it is uniquely suited for the purposes of this strategy; its scale and potential impact are appropriate for Texas. Given its current stage of development, the project group strongly suggests that further attention be given to this opportunity for collaboration.

Establishing such a new and innovative relationship with JSC would constitute a significant factor in attracting Texas' and the nation's best students into undergraduate training and graduate research. It would be an equally important source for a steady flow of trained people essential for the Texas space-related industry, well-equipped and keenly informed about advanced space technology development and the opportunities for the entrepreneurially oriented. Moreover, since the state's space business incubators will be sited close to and associated with these same research universities and will likely be occupied by or have collaborative ties with the university research faculty and their graduate students, it is vital that the incubators be included as the third link in this teaching-research triad.

As with other areas of strategic importance, this educational concept would provide JSC with a steady flow of highly qualified people, trained and experienced in JSC systems and research categories. Further, the concept would fulfill the federal mandate to NASA to be directly involved in using the major NASA roles and missions to educate and train U.S. students. The partnership also has the potential to expand the scope and level of JSC research fields with small to modest incremental increases in funding support.

Finally, it is important to recognize that these three major areas of strategic importance for the state in JSC (i.e., shared facilities and expertise, business development, and education and training) are also important elements in the new long-range strategy for JSC. They represent a new vision of the center's role. Indeed, the compatibility of these overlapping areas of interest measurably advances the prospects of significant collaboration between the state and JSC.

Notes

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Chapter 7.

Objective: Critical Technologies and Space Business Incubator Network

OBJECTIVE: Establish a statewide network of space business incubators in Texas emphasizing technologies that are critical or enabling to a self-sustaining space-related economy.

Rationale

> Unlike research which seeks new knowledge, technology is concerned with the application of that knowledge to useful purposes. The development of advanced technology is thus crucial to the success of the exploration and exploitation of space . . . .[1]

The U.S. is no longer the unquestioned world leader in space and technology. This shift in U.S. position has been caused by a decline in U.S. space activity and an accompanying growth in that of other space-faring nations. Some salient facts from the past two decades illustrate the change. During that time the U.S. space budget decreased by more than 50 percent in real dollars, while the total U.S. budget increased more than 150 percent. By the late 1980s the former Soviet Union was launching about 90 percent of the world's satellites annually (an average of 100 launches per year), an indication of a far different national policy than the U.S. had in providing access to space. The Soviet Union developed a permanent manned presence in space about a decade before the U.S. will attain similar capability. Foreigners have flown more research experiments on the U.S. Space Shuttle than have U.S. researchers. U.S. communications satellites, long the single mainstay of space commercialization and dominated by U.S. space technology, have resorted to Europe's Ariane and China's Long March launch vehicles for transportation into space. The Ariane family of launch vehicles, for example, has captured 60 percent of the free world launch market.[2] Japan and Europe spend three and ten times more, respectively, than the U.S. on microgravity research (the most likely area from which space manufacturing enterprise will evolve), and both have committed to the development of large-laboratory modules on the U.S. Space Station Freedom that are intended to undertake fundamental research for long-range commercial applications.

Whether by strategic design or happenstance, these relative changes in its leadership position collectively point out that the U.S. space industry faces stiff challenges in developing the space and technology markets crucial to future competitiveness. The rising success of Japan and Europe, our biggest competitors, is based on efficient and reliable partnerships between the government and the private sector in those nations. These approaches have raised important questions as to whether major U.S. achievements in space and technology for the future will require similar team efforts to capitalize on the initiative and creativity of all sectors -- business, government, and academia -- through the establishment of an industrial policy in space technology. It is not clear how the U.S. will address this issue and remain competitive. What is clear, however, is that the commercial development of space is the arena in which this competition will take place. If the federal government maintains its policy of not directly participating in the commercialization of space, then the U.S. competitive base will likely devolve to a different arena or scale, namely, the states, where private-public industrial policy collaboration is virtually essential.

Technology is the single most important constraint facing individual states attempting to foster the development of the commercial space industry. This realization has prompted several states to create programs specifically designed to address technology issues. The Alaska Science & Technology Foundation, for example, fosters the growth and development of space-related technology and engineering, concentrating heavily upon technological innovation. Space New Mexico is designed to exploit the existing research centers in the state, such as the Los Alamos National Laboratories, the White Sands facilities, and state universities.

Perhaps the most interesting effort is in Virginia, where the Center for Innovative Technology has provided vital funding to space-related university and industrial initiatives and enabled Virginia to become the first state to orbit its own satellite.[3] Other states also have realized the vital importance of technology and have taken steps to develop their technological capabilities (see chapter 2).

If Texas is to develop a self-sustaining space economy, it too must first establish a viable technology base and then integrate space technology, commercial opportunity, and economic development in a complete and comprehensive process. Fortunately, the space infrastructure currently existing in Texas, although not properly focused or directed, provides the state with this opportunity. The Johnson Space Center, the Texas Space Grant Consortium and associated university research programs, state government support for space-based economic activity, the state's commercial space industry, and general business and technology development efforts (e.g., business incubators and Texas Department of Commerce programs) all are in relatively good position to be redirected to contribute to space-related economic growth (see chapter 3).

These considerations and conclusions pose the clear question as to what techniques or processes the state must employ to build its technology base and translate that technology into a high level of commercial endeavor.

Critical Technologies

For the purposes of this strategy, "critical technology" means any technology or technology area whose development is considered essential to the creation of a self-sustaining space-related economy.

Current Efforts

Given the impressive range of technologies which Texas could consider for space business development, the process of selecting those which are critical is not an easy one. Fortunately, the task of choosing the appropriate technologies is simplified once the field of candidates is significantly narrowed. This task of "narrowing the field" has been the focus of several recent national and international efforts. The United States, Japan, and the European Community, for example, have developed critical technology lists (see appendix E).

Although the applicability of any national or international list to Texas is questionable, the methods through which they are compiled often are applicable and deserve attention. According to George P. Millburn, the Executive Vice President of the National Center for Advanced Technology (NCAT), essentially three different methods can be used to identify technologies that are critical. The first method is by simple *consensus*, in which a broad-based group of expert technologists agree on which technologies are critical. (This was the approach used to generate the lists in appendix E.) The second approach, known as the systems approach, calls for these same experts to first decide upon the critical *systems* which must be developed, and then determine the essential technologies from these systems. The final approach, similar to the second, calls for the experts to develop a *strategic plan* for an industry or operation and then determine the technologies essential for the realization of this plan.[4] Any of these approaches, singly or in combination, could be applied in Texas to assist in the identification of critical technologies for state space business development, provided the long-range goal and the baseline strategy, including its primary objectives, guide the selection of the technologies.

Millburn also identifies five criteria which generally are among those used to evaluate and narrow the choice of candidate technologies.[5] These five criteria, expanded and reformulated as questions, are as follows:

1. What are the current level and source of funding for the technology?

2. What alternative technologies are available, and what are the comparative advantages and disadvantages?

3. Does the technology have broad transfer applications?

4. What is the current state of research and development in the technology? Is more needed? If so, in what R&D area?

5. How much will the technology cost?

Candidate Critical Technologies for Texas

Given the need to develop a broad consensus within the state on the critical technologies for space-related development, a combination of all three approaches is preferable. Within the strategic framework for space-related development, first identify the technology sectors (i.e., critical systems) from among which Texas should select its candidate critical technologies. Once these sectors are identified, experts from the state's public, private, and university sectors should use appropriate criteria to select the critical technologies that will underlie implementation of the baseline strategy.

Since the Texas space strategy for the 1990s specifies objectives emphasizing payload services and satellite systems, the primary criterion for selecting the technology sectors should be: *Choose only from among technologies essential for the development of the key space systems in the baseline strategy.* Using this criterion, our preliminary research suggests four sectors from which to select the state's critical space-related technologies on which to base a space business incubator network and related economic initiatives:

1. small, miniaturized configuration space systems (including space flight and satellite systems, sensor technology, telecommunications, and propulsion and power systems);

2. ground-based telecommunications/data management systems;

3. payload services (including specific payload integration services, space flight management and data collection, and payload processing); and

4. robotics in space hardware, systems, and payload instrumentation.

Selecting the state's candidate critical technologies and then the technologies themselves from these technology sectors is beyond the scope of this project. Nevertheless, the criteria used in this selection process should include the five criteria suggested earlier in this section, as well as eight additional ones. These criteria are as follows:

Primary Criterion: Choose only from among technologies important for the development of the key space systems in the baseline strategy.

Additional Criteria:

I. General Queries

1. What are the current level and source of funding for the technology?

2. What alternative technologies are available and what are the comparative advantages and disadvantages?

3. Does the technology have broad transfer applications?

4. What is the current state of research and development in the technology? Is more needed? If so, in what R&D area?

5. How much will the technology cost?

II. Commercial Applications

6. What are the potential commercial applications? Is more research needed?

7. Is the technology cost-effective? Will its commercial applications realize profits in the short or long run?

III. Texas Considerations

8. What Texas companies are currently developing or using this technology?

9. Will this technology encourage growth in new businesses?

10. How will the technology affect the Texas economy in general? How will the technology address state needs?

11. Will the technology affect Texas differentially? Will some economic, geographic, and scientific areas benefit and others not?

IV. Feasibility

12. Can the technology be applied to a space business incubator system?

13. Is the technology cost-beneficial?[6]

Using these criteria, a respected group with broad representation in space technology and commercial technology development and with a balanced composition from the public, private, and university sectors would be fully capable of applying the criteria and selecting the critical technologies for space business development in Texas.

Indeed, initial meetings with individuals from NASA and the commercial space industry already have suggested possible candidates. There is agreement, for example, that miniaturization is the key to the commercial future of space.[7] Miniaturizing computer chips, as well as motors and moving mechanisms, is already revolutionizing most industries, and this trend will continue even more rapidly. Miniaturization could significantly stimulate a state space-related economy by lowering the mass and payload size of satellites, and, as a result, the cost and difficulty of launch and recovery is significantly decreased with a smaller payload and launch vehicle capability as well.

Another potentially significant technology still in the development stage is autonomous systems, that is, spacecraft systems coupled to computer programs which work independently or with little need of human control or intervention, making their own decisions and choosing their own courses. Such systems, in addition to having new commercial market applications, will ease the requirements and costs for ground-based control payloads, thus facilitating the implementation of the objectives in the state's baseline space strategy.[8]

Conclusions

Because the choice of technologies will have such a pervasive effect on other elements and objectives of this strategy, the selection process should begin at the earliest possible time. It is strongly recommended that the Texas Space Grant Consortium, perhaps joined by other groups, should play a vital role in this process. Whatever approach is taken, however, it is most important that this task be one of the initial steps taken in the implementation of the baseline strategy's objectives. Without the identification and subsequent development of critical technologies, the strategy's other primary objectives cannot be effectively realized.

Space Business Incubator Network

Once Texas has identified the technologies critical to a self-sustaining space-related economy, it must determine the means and mechanisms to develop them. It is equally important to consider how such a technology, once developed, is then transferred to business products and commercialized.

Despite the high merit of new technology concepts and their projected commercial impact, most technology entrepreneurs have little or no business acumen in moving technology development forward to a sound business base. This deficiency alone is the principal cause of the high failure rate of new technology ventures. A large percentage of failures in the effort to build a Texas space technology cannot be tolerated; the stakes are too high. Since the entire structure of the strategy rests on the selection of critical technologies and their growth to establish the state's R&D base, it is vital to the enterprise, during the early years of development when success is tenuous and vulnerable, that the critical technologies be afforded preferential and protective treatment.

Further, as critical as the technologies are, it is no less critical that a means and process be selected and used that assures a high success ratio in establishing space technology businesses. This project concludes that the incubator concept is eminently suited for the state's purpose: the performance record of incubators in building successful business enterprises is remarkably high; they are cost-effective and affordable through the use of time-resource sharing and therefore are affordable; they are well-suited and can be positioned to receive assistance from and to focus on the joint efforts of a public-private enterprise; and, as importantly, they create a nurturing, safe environment for creative and innovative minds. Their purpose, in the context of this strategy, is two-fold: to provide a sheltered enclave for the development of critical technologies and to prepare the technology entrepreneur with the business training and base to move from the protective incubator to the competitive community of space technology business. One need only examine the record of the state's business incubators, especially the Austin Technology Incubator, to understand the justification for this concept as the means to initiate and support space technology growth.

The incubator concept, in this application, has particular characteristics that should be kept in mind as well. Technology generally is in a constant state of evolution and change. The critical technologies selected for this strategy implementation will not be the same set ten to twenty years hence. As a consequence, the need for technology development is unending, and the state's economic intentions for space technology must accommodate change to maintain the effort and to be competitive in the larger market arena. Therefore, the space business incubator should be regarded as a permanent presence in the ongoing, ever-changing task to create and nurture a space technology industry and its commercial applications.

Further, the number of separate technologies in the critical set will almost surely be too large and diverse for any single incubator to handle. The concept envisioned here, then, will require several separate incubators, their number as well as their priority or development sequence determined by the set of technologies or technology categories and by the TSA tactical plan for integrating incubator technology development with the development of technical requirements for the other primary objectives.

The diversity represented in the set of critical technologies can be addressed by siting separate incubators in proximity to and linking them to the major research universities across the state. In this way, the critical technology categories can be matched to the research interests, facilities, and expertise of single universities, providing a close association and proactive role for universities in the implementation process. Thus, the incubator concept for this strategy is in practice a network or system of separate facilities.

Using the universities of the state as a priority consideration in forming the network creates a powerful economic leveraging effect. It is well-documented that a large percentage of new businesses which spin out of incubators locate themselves in the same area. For high technology space firms that are not location dependent, and the great majority are not, there is a compelling rationale to remain close to their incubator, especially during the first years of establishing their business base. Continued access to the incubator's business expertise and assistance, maintaining relations with the incubator for follow-on technology development, and access to a university for its intellectual resources and for recruitment purposes are among the most cogent reasons for young companies to maintain close relations with their respective incubators.

Lastly, the high multiplier effect of high technology industry in generating related or support industries and increased employment is unquestioned. Space technology is no exception. While the standards for workforce training, education, and technical competence are demanding, their success and presence at local and regional levels are a strong incentive for communities to address these challenges. In the final analysis, this is the primary intent of the incubators. They are charged to produce the "seed corn" of a future space technology industry; what they produce and where they produce it is the first critical step in the process of spreading growth across the state.

A Texas space authority, with the selection of critical technologies in hand, should take immediate steps to develop a statewide network of space business incubators. This network should work collaboratively with universities and other research institutions, as well as with the Johnson Space Center and the state's commercial space industry. By forging a strong relationship among these entities, the incubator network becomes the means by which space industry growth and development is extended across the state.

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4. George P. Millburn, "How a Technology Gets Critical," *Washington Technology: The Business Newspaper of Technology*, vol. 6, no. 21 (January 23, 1992), p. 15.

5. Ibid.

6. Based on criteria specified in George P. Millburn, "How a Techology Gets Critical," *Washington Technology: The Business Newspaper of Technology*, vol. 6, no. 21 (January 23, 1992), p. 15.

7. Interview with Joe Allen, Space Industries International, Inc., and Alex Dula, Johnson Space Center, Houston, Texas, February 26, 1992.

8. Ibid.

Chapter 8.

Objective: Integrated Payload Services Capability

OBJECTIVE: Establish an integrated payload services capability in Texas to foster the space-related business development, investment, R&D, technology transfer, infrastructure, and human resources necessary to sustain a space-related economy.

Rationale

Current Situation

In recent years the federal government has repeatedly demonstrated its desire to encourage the growth of the commercial space industry. In 1983 the White House issued a directive which made federal space technology and launch resources available to private industry.[1] This action was followed in 1984 by the establishment of the Office of Commercial Space Transportation, which was chartered to "promote, encourage, and facilitate commercial space transportation" and to regulate commercial space activities.[2] Finally, in 1991, the White House released the U.S. Commercial Space Policy Guidelines.[3] These guidelines direct the federal space program to make use of private launch services to the fullest extent feasible; authorize cooperative research efforts with states, local governments, and private industry; and allow the federal space program to make available to the public all unused capacity of space assets, services, and infrastructure.

Despite these encouraging new policies, the federal government intends to continue decreasing its active role in the development of commercialization and shifting commercial space initiatives to the private sector and/or individual states. Nevertheless, it is still willing to encourage this development through both financial and technical assistance. NASA is involved in several programs intended to assist commercialization efforts through technology transfer, including the Technology Utilization Program, Centers for Commercial Development of Space, and government/industry partnerships.[4] In addition, the U.S. Department of Commerce, Department of Transportation, and Department of Defense have programs designed to assist in space-related industry development.[5]

While some states and private companies are clearly interested in the prospects from commercialization, they are tentative about assuming full responsibility. The degree of federal financial assistance is unclear, as is the size of the potential market and probable returns on investment. Even though space commerce continues to increase every year, large companies, especially those relying on federal dollars to underwrite their R&D programs, have indicated that the research and development necessary for commercialization is too large for them to pursue on their own and that government assistance is necessary.[6]

Some forward-looking, venturesome states have established their own programs designed to develop space commercialization, often with financial assistance from their legislatures. States such as Virginia, Alaska, and Hawaii have clearly demonstrated their confidence in the long-term economic benefits from developing a state-based space industry (see chapter 2). They also desire to establish lead positions in order to remain competitive as space commercialization begins to develop more broadly.

Texas already has a strong leadership position in the national civil space program due to the presence of the Johnson Space Center and the aerospace corporations which participate in the JSC program, such as McDonnell Douglas and Martin Marietta. The Texas interest in the national program aside, however, the state has not moved in an organized, systematic way to avail itself of federal assistance, and broadly-based state-level space programs are not yet being actively pursued. While space technology and related industries are known to be an important part of the state's economic base, few efforts have been made to create technology or industry that would enable Texas to build its own commercial space enterprise.

Because of the federal government's support for space commercialization and the potential economic returns for the state, it is strategically important that Texas take an active role in stimulating this commercialization. Other states, particularly Virginia and Florida, are currently ahead of Texas in organized efforts to develop their state space industry, which should provide them with economic opportunities and leverage in future space commercialization. Virginia, generally considered the national leader in state initiatives, boasts a strong public-private network of organizations working in concert to develop the space industry in the state, and it also has access to the federal launch facility at Wallops Island. Florida, meanwhile, offers SpacePort Florida, the nation's first commercial space transportation authority, and access to federal facilities at the Kennedy Space Center. Other states are also beginning to position themselves in sectors of the industry -- Hawaii, Alabama, and Alaska in launch services and New Mexico in recovery sites, for example -- and are formulating general strategies to attract and develop space business.

However, none of these states has an insurmountable lead on Texas. While a few states may have a commanding presence in one area of payload services (e.g., launch capability), no state is dominant in all, or even most, payload service areas. This is particularly important, because those states, and there are only a few, which are capable and have strategic locations and size will be able to provide a full range of services and thus gain a competitive leadership advantage. Texas is one of these few states by virtue of its existing space infrastructure, its geographic location making launch services feasible, and its thinly-populated, vast western lands available for payload recovery facilities.

Capturing a substantial share of the commercial space market will be a gradual, evolutionary process. The pursuit and development of this capability by any state, including Texas, will more than likely be paced by the growth of space commercialization. Consequently, there likely will be little compelling reason for Texas to acquire a comprehensive range of integrated payload services immediately. This should not obviate the need for Texas to enter into this market area, however, given the interest and intentions of other leading states. It should be anticipated that in the near term the leader states, including Texas, will rely on mutually beneficial partnerships with each other (as some currently have) to provide services that do not exist in each individual state. Through these initial collaborations, Texas can actively participate in space commercialization growth while pacing the development within its borders of an increasingly more comprehensive range of services.

Strategic Importance

Frequent access to space and payload recovery plus related support services are mandatory prerequisites to the building of a commercial space industry. The entity, or state, that is intent on acquiring this capability assures itself of a strong leverage advantage in capturing a significant portion of the space commerce market. The limits of the potential market for payload services have yet to be realized, but they can be assumed to be very broad and of long duration, on the order of decades (i.e., significantly larger than the investment required for market access). This market will range from domestic and foreign to civil and military to public and private; it is potentially global in scale and economic magnitude.

Like every complex technological venture, the technology of a payload services system will be in a virtual constant state of change through improvement. The commercial market demands and competitors will create technology at ever higher levels. Thus, the payload services system itself is a technology user or market and, as such, constitutes an outcome of space technology development and application. Since this mission objective of the baseline strategy occupies a major fraction of the long-range effort for economic self-sufficiency, the technology of the system must be regarded as critical, and therefore the payload services system is vitally connected to the technology output of the state's space business incubator system. The success of this interdependency will to a large degree define the relative position of Texas in serving the commercial space market and, as importantly, the commercial space applications market outside of Texas for Texas' advanced technology.

The growth of space commercialization will depend in part on the use of the space environment, principally low-gravity forces and near-perfect vacuums, for R&D leading to new technologies and their application in non-space industries (e.g., metallurgy, pharmaceuticals, and agriculture). Many of these industries currently are in their infancy; much of their activity is experimental, in small entrepreneurial firms, often working in collaboration with university research faculties. In part, research progress has been inhibited by very limited access to space, a situation which is slowly changing due to assistance from federal funding agencies. The potential is much greater, however, and the availability of a comprehensive services capability for access to space is a powerful attraction for small, nonspace entrepreneurial firms to locate close to these services. As in the case of small, space-related firms, these nonspace firms represent the "seed corn" of new technology industries. It should be anticipated, then, that nonspace industries will be an associated economic growth sector, multiplying the effects of the Texas investment in payload services capability.

Strategic Considerations

It is essential that the state move aggressively during the decade of the 1990s to develop the full range of payload services within its borders. To wait until the capability for payload services exists elsewhere is to risk market capture by states or regions as capable and as strategically located as Texas and, thereby, to deny a substantial in-state application of Texas space technology. Because the overall development of the integrated payload services package will be driven by market forces, competitors, and the availability of funds, it is not possible to predetermine the sequence and timing of the development of each component of the package. It may, for example, be tactically advantageous for Texas to develop its in-state recovery site and ancillary services first in order to have a "bargaining chip" to use in acquiring other out-of-state services initially. Adequate recovery sites are few and vitally necessary for the return of payloads. From the current perspective, however, it can only be stated generally that development will be evolutionary and that the actual initiation of the separate elements will be determined by the tactical plan of the Texas space authority (TSA).

During this evolutionary approach to a full capability, Texas, through the TSA, needs to establish its presence among other states in the commercial space arena. It is important to begin to cultivate and shape this market, for the reasons given above, well before the state is able and in a position to provide a complete range of services within the state. Moreover, it is strategically prudent to set in place, at the earliest possible moment, the concept of "packaged services," even though during the early years the "package" will likely be constructed through interstate agreements, collaboration with outside industries, trade-offs, and *quid pro quo* arrangements. As necessary as these outside collaborative arrangements may be, however, it is important to recognize that they are a transitional phase and that the ultimate goal is to provide these packaged services in the state. To rely indefinitely on agreements with non-Texas entities is to dilute the market advantages associated with in-state services and to inhibit the economic growth and return to the state.

Clearly, the dynamic relationship and the delicate balancing effort between the early phase of packaged payload services and the development of the full in-state capability has to be centrally directed and focused. Further, the relationship of this complex primary objective to the others in the baseline strategy illustrates again the pressing need for an appropriately constituted Texas space authority to organize and manage this highly integrated set of tasks.

For the purposes of this strategy, *payload services* applies collectively to all services which constitute the planning and execution of a commercial space mission. This includes (but is not limited to) early payload design, integration, and mission coordination; launch operations, including transportation, launch to selected altitudes, and associated support services (e.g., legal services, insurance coverage, and environmental regulations and considerations); payload monitoring and data collection; recovery operations, which determine vehicle/payload reentry and capture; and post-recovery processing, including data processing. Thus, *integrated payload services* consist of all the services required for the implementation and support of a complete R&D or commercial space mission, combined and marketed as a single, competitive package.

Since each area of payload services is unique with regard to its characteristics and requirements, a description of the major areas follows, along with a brief discussion of how those areas fit into the overall strategy.

Early Payload Design, Integration, and Mission Coordination

This area contains those services which must be secured to prepare a payload for launch. They include everything from the initial design and purpose of the experiment to the final step of accommodating the payload in the launch vehicle and linking to the space flight systems (e.g., vehicle control, communications, power, data acquisition, and recovery).

The design and payload integration of the experiment is a critically important initial step in the process leading to mission configuration. Before any planning can be accomplished, the client must describe the purpose and objectives of the mission to be undertaken. This description will determine the physical makeup of the payload and the environment needed to accomplish the mission, the two factors which drive the entire range of subsequent payload support services needed. Another key factor will be the manner in which the payload will be interfaced with the launch vehicle to achieve the mission objectives, a process known as payload integration. At this stage, the size of the launch vehicle, the desired use of the space environment, the orbit or trajectory to be attained, the monitoring of the experiment (e.g., communication needs), and the duration of the mission will be determined.[7] Since this early activity plays such a critical part in defining all the remaining elements of mission services, there is a clear advantage to clients and a powerful marketing advantage to the state to provide a complete, integrated package of mission services.

Launch Operations

At the current time, Texas does not possess its own ground-based launch capability, although in the early 1980s the capability for such launches over the Gulf of Mexico was demonstrated. It is important that current launch options (including land-based, sea-based, and aircraft launch platforms) be examined carefully to determine their feasibility, as well as the costs and benefits of developing such a capability early within the present strategic time frame, weighing the gains in market opportunities and leverage of doing so against the costs of developing and operating such a site.

In order to develop a launch capability within the state, several conditions must be addressed. Some of these are natural; for example, if ground-based launches are desired, the state must possess a geographic site which is suitable for that purpose. This includes not only public safety and liability considerations, but also environmental considerations such as pollution and habitation effects and mission factors such as winds, climate, and latitude. Some of these factors affect the feasibility of sea-based and aircraft-launched payloads as well. These natural factors eliminate the possibility of acquiring a launch capability for many states; however, Texas does not fall within that group. Other factors affecting launch capability are demographic or legal, including air traffic patterns, population distributions, and transportation infrastructure.

Another launch-related task which the state and its client must consider is the acquisition of insurance. Three types of insurance are generally required for a launch: first-party, second-party, and third-party. First-party insurance covers the liability of the policyholder for losses of its own equipment or investment (for example, covering the loss to a launch company of its launch vehicle). Second-party insurance covers damages to related parties, such as the damages incurred by a payload or an independent launch facility if a launch vehicle malfunctions. Third-party insurance covers losses to "innocent bystanders," those parties which are not involved in the operation but which may incur damages. Third-party insurance poses the largest problems for the space insurance industry, because it is the least quantifiable in scope and in the nature of damage or injury.[8]

This virtually unlimited exposure to liability increases the financial risks to both the launcher and the insurer and results in inflated costs of space-based activity. The coverage for this insurance typically costs as high as 20 to 25 percent of the overall launch costs, despite the fact that no third-party claims have ever been paid.[9] The entire insurance issue seems to beg for redress solely on economic grounds. If a state space authority can minimize these costs, through innovative "pooling" techniques and by establishing new bases for coverage, the state's market position will be greatly enhanced. Meanwhile, insurance representatives are urging the federal government to assume some of the third-party risks, as is currently done in Europe, China, and Russia.

Monitoring and Data Collection

Communication requirements for flight control and monitoring, as well as data acquisition, will be largely dependent on the nature of individual missions. For some missions (e.g., suborbital) a single ground station would be sufficient to monitor the vehicle. In other cases, such as extended orbital missions, it may be necessary to have additional ground stations and/or a space tracking antenna network beneath the flight path. This could involve agreements with other states and possibly other countries and would require a system capable of coordinating the network. Advances in computer and communication technology have greatly reduced the size of ground-based facilities and tracking stations to the point where they are now commercially available and affordable. The TSA should thoroughly evaluate this technology for use in a Texas payload services system.

Recovery Operations and Post-Recovery Processing

A commercial space mission requiring that the payload be returned to earth must be provided an operational means of reentry which will ensure that the payload will not be damaged or compromised by the extreme environments of reentry, that the payload will survive the recovery process, and that a means exists to transport the payload safely and quickly to the post-recovery processing facilities.

A major factor in the recovery process is the selection of the recovery site. The requirements are numerous, highlighted by a flat, open topography on the order of 50-100 miles in area to lessen the likelihood of damage upon landing and to facilitate access to the payload by the recovery team. This could be either flat, unvegetated terrain, such as prairie, desert, or salt flats, or conceivably, for some mission types, open water. In addition, the site should lend itself to a simple transportation infrastructure which can be used to retrieve the payload and deliver it to the processing area. On land, this could be a road, railroad, airstrip, navigable river, or other such means of transport, while for ocean recoveries the landing site must be within range of a boat or seaplane equipped to make the recovery.

Although the requirement that the recovery area be sufficiently distant from uninvolved parties (to minimize the likelihood and effects of unintentional damage) is useful for contingency purposes, advanced means of landing the payload with "pinpoint accuracy" are currently available and would essentially negate this problem. The prospect of unintentional damage is further decreased by the increasingly smaller payloads likely to be common later this decade. For land recovery sites, the millions of acres of state-owned land in West Texas fit the criteria required of a suitable recovery area.

The final step in the payload services process provides analysis of the data collected during the flight. The primary characteristics of a processing facility would be the ability to process the data in a timely manner, at reasonable cost, with minimal risk of damaging the data and/or payload and with maximum confidence of the results and output. For many payloads, it is essential that the post-recovery processing occur quickly upon recovery, usually within hours; therefore, access to the processing area from the recovery area is another important data services consideration.

Notes

1. U.S. Department of Transportation, "The U.S. Office of Commercial Space Transportation" (Washington, D.C., 1990). (Pamphlet.)

2. Ibid.

3. The White House, Office of the Press Secretary, "U.S. Commercial Space Policy Guidelines" (Washington, D.C., February 12, 1991).

4. National Aeronautics and Space Administration (NASA), *Vision 21: The NASA Strategic Plan* (Washington, D.C., January 1992), p. 27.

5. NASA Advisory Council, Commercial Programs Advisory Committee, *Charting the Course: U.S. Space Enterprise and Space Industrial Competitiveness* (Washington, D.C., July 1989).

6. Marcia S. Smith, "Civilian Space Applications: The Privatization Battleground," in *Space Policy Reconsidered*, ed. Radford Byerly, Jr. (Boulder, Colorado: Westview Press, 1989), p. 107.

7. Mary D. Skinner, "Payload Integration," in *An Entrepreneur's Introduction to Space Commerce and Shuttle Experiments*, vol. 1 (Houston, Texas: Space and Telecomm, 1987), pp. 35-36.

8. U.S. Department of Commerce, *Space Commerce, An Industry Assessment* (Washington, D.C., 1988), pp. 119, 126.

9. Ibid.

Chapter 9.

Objective: Public-Private Development Program for a Texas Satellite System

OBJECTIVE: Establish a public-private development program for a Texas satellite system providing remote sensing, associated data management, and other communications services for industrial, commercial, scientific, educational, and governmental applications.

Rationale

Current Situation

From a review of state agencies and educational institutions, it is apparent that Texas, because of its enormous geographic size and the complexity of state organizations required to serve its citizens, has been increasingly drawn to consider new technologies to provide essential services and to meet vital needs across the state. These technologies have generally fallen into two primary requirement areas: (1) the need to "see" and monitor phenomena over large surface areas and (2) the need for interactive telecommunications services, again over large areas of the state. Further, both of these areas have response time dependencies that range from seconds to days or weeks, depending on the communications application or the rate of change of observed phenomena.

A number of individuals, singly or occasionally in small, user-oriented groups, have concluded that satellite platforms and technology could serve state needs generally and could specifically address these two primary requirement areas. Serious consideration of acquiring space capability or, next best, access to space-acquired data and information has been fragmented or scattered, however, because the considerations have been constrained to the needs and tasks of individual agencies or institutions. Largely through actions or policies outside the state or beyond the control or influence of the state (e.g., privatization of the federal satellite system, cost of data from commercial sources, a serious recession, and shrinking budgets of state agencies and institutions), many of the efforts have come to nought.

In retrospect, it is not clear, even if the state had not suffered a severe economic setback, that such a fragmented, multiple but independent, approach to utilizing space technology would have been in the economic best interests of the state. Moreover, the project group found no effort which had acknowledged and studied the diverse range of state needs that could be addressed from orbiting space platforms and had considered the economies of scale from aggregating needs and integrating them into a single satellite system.

The following brief summary of the current situation illustrates the rationale of these conclusions and the wide range of needs and opportunities for applying satellite technology within the state.

In recent years, Texas state agencies and private companies have increasingly relied upon telecommunications systems to carry out their activities and responsibilities. These systems include traditional telephone lines, fiber optics networks, and satellites. For example, Project Bluebonnet, a nonprofit organization composed of Texas state government, private sector, and university representatives, is providing learning and training opportunities for individuals and schools not otherwise having access to such programs. It also has identified "medical networking" as an important strategic component for the future of the Texas rural health care system to give bedridden patients access to trained specialists and expensive equipment not otherwise available.[1] The University of Texas at Austin College of Pharmacy teaches students simultaneously at The University of Texas at Austin and other University of Texas System campuses through a two-way interactive video system,[2] and the Texas A&M University System is planning a similar capability for its campuses. Texas Tech University Health Science Center has had such a system linking four institutions since 1989. In addition, since 1990 it has operated MEDNET, a one-way video, two-way audio satellite link-up to 18 hospital sites in West Texas.[3] The Texas Rehabilitation Commission uses Texas Tech's facilities to broadcast to its locations in West Texas. Texas Tech has invested $3.4 million on the project, of which $1.4 million was provided by federal grants.[4]

The Texas Agricultural Extension Service is presently engaged in a five-year satellite communications project, with a goal of creating the capability to deliver its extension programs through downlinks to its offices all over Texas. Since the TEX-AN state long distance telephone system will not be adequate to serve future needs, the Texas Air Control Board is examining how best to meet its data transmission needs.[5] The Texas Department of Transportation is looking at using the Global Positioning System (GPS) to provide Texas agencies with the capability to locate objects on the ground with pinpoint accuracy. This capability would improve rescue operations, exploration and tracking, surveying, and map making. Already the Department of Transportation is experimenting with this capability in surveying rights-of-way and in locating highway mile markers for mapping purposes. The department also has experimented with cellular phone links to relay positioning data, but has found this technique to be only partially successful due to the limited coverage areas of cellular phone systems. The Water Quality Board and the Texas Railroad Commission are focusing on linking telecommunications and the GPS to create a capability to locate water, oil, and natural gas wells for mapping and regulatory purposes. Again, the same limited coverage by ground-based telecommunications carriers prevents this capability from being used in the most effective manner.

A satellite-based application of particular interest and importance to environmental and natural resources agencies and to major Texas energy corporations is remote sensing. In the early 1970s, the Texas Natural Resources Information System (TNRIS) was organized as a joint venture between the Johnson Space Center's Earth Observations Division and the State of Texas. Many state agencies, including the Water Commission, Air Control Board, Forest Service, Parks and Wildlife Department, Department of Health, Soil and Water Conservation Board, Historical Commission, General Land Office, and Department of Commerce, participated in the effort. Between 1970 and 1983, $500,000 in grant money was spent on TNRIS technology in Texas. NASA loaned imaging hardware to TNRIS and also sponsored joint projects with TNRIS. In 1983, the formal relationship with JSC's Earth Observations Division ended as NASA terminated this division.

In the 1980s, the federal government also privatized the LANDSAT remote sensing system, turning operational management and data distribution over to the Earth Observations Satellite Acquisition Technology (EOSAT) Corporation of Maryland. This company has monopoly control over the availability and cost of processed remote sensing data from the LANDSAT system. With privatization, the cost to acquire processed data rose, and Texas agencies in need of these data no longer can afford to purchase them. The only other source of remote sensing data currently available is the French quasi-private organization Spotimage, whose data pricing schedule is comparable to that for LANDSAT data sets.[6] Major energy companies currently are the only remote sensing data users in Texas with the financial resources to acquire LANDSAT data as their needs dictate.

Two Texas agencies in particular have significant needs for remote sensing data which cannot be addressed by the current system of purchasing LANDSAT data. The Texas Parks and Wildlife Department would like to use satellite remote sensing technology to improve its monitoring of biological resources in ground features of wildlife habitats in the state but can only afford four to six LANDSAT data sets per year. The Texas Air Control Board is interested in using remote sensing satellite data to monitor ozone formation and study dust storms.

Remote sensing satellites also can be used to create computer-generated simulation maps, or Geographical Information Systems (GIS), which are particularly useful for studies in community and regional planning and in environmental and natural resource protection. At The University of Texas at Austin, one GIS project involves using satellite systems to examine cotton plowdowns in the Rio Grande Valley to detect boll weevil nests and their migration patterns to help prevent the spread of crop disease. The Texas General Land Office has used GIS to create an effective oil slick response program. The Texas Public Utilities Commission has determined that GIS can provide information to map utility retail service area boundaries and transmission line routings.[7]

In recent years there has been a growing realization by Texas state agencies and Texas industry that the expanded uses of satellite services -- including remote sensing, telecommunications, and geographic positioning systems -- could enhance the efficiency and effectiveness of both private and public sector organizations. With most current and potential Texas users of satellite services having to rely on private vendors (e.g., EOSAT for LANDSAT data),[8] however, the current high costs for such services and the tight fiscal situation in Texas have combined to put most of these services beyond the reach of Texas agencies and businesses. Moreover, current licensing regulations for the sale and use of LANDSAT data make it impossible for the state to share duplicate copies of data sets it purchases (as it did in TNRIS). Having Texas create its own data processing facility to bypass LANDSAT purchases is not feasible, either, given the high cost of acquiring and implementing such a capability. Another problem currently is that even when several state agencies and businesses are using satellite services, they generally do so independently of each other. A comprehensive, integrated public-private development program for the operation of a Texas satellite system could not only improve the availability and use of satellite services but also contribute substantially to the growth of a Texas space economy.

Fiber optics networks and other earth-based telecommunications systems are frequently touted as a less expensive alternative to satellite systems. However, while fiber optics networks are more economical for many tasks, they have significant drawbacks when compared to satellite systems and are able to meet far fewer needs of state agencies and businesses. Unlike a satellite system, the cost of transmitting information on a fiber optics network is a function of distance; the cost is almost directly proportional to the length of the cable. A satellite system can also broadcast to multiple points on earth simultaneously, whereas a cable system can only communicate between two specific locations. Creating a fiber optics network capable of reaching every domicile in Texas would be prohibitively expensive; providing such access to a satellite system would be much more economically efficient.

Strategic Importance

In the commercialization of space, the market potential of satellite communications and remote sensing has already been established, and the technology is available. Affordable access to space and declining costs of telecommunications and remote sensing technology, especially through technology miniaturization, has opened up entirely new market opportunities. For parties intent on participating in the growth phase of commercialization and establishing market share, entry is opportune now in remote sensing and communications; it is not necessary to wait for growth and development in the third element of commercialization, namely, the use of low-gravity and near-perfect vacuums for materials processing in orbit. For individual states which elect to meet their multiple in-state needs initially and the broader market needs subsequently, it will be necessary to construct a development program to demonstrate technical feasibility and efficiency as well as economic cost-effectiveness.

A large commercial space market already exists in Texas by virtue of the state agencies and institutional needs -- and if such a market exists in Texas, then it also exists in other states and jurisdictions. Taken together, these complex requirements and opportunities necessitate a different approach to satellite technology, one that must satisfy a wide range of user needs integrated into a single, or a few, platform(s). It represents a technology application perspective or window that has not been exploited by commercial satellite corporations or federal program studies to date. Indeed, a large degree of the strategic importance of a satellite system is linked to demonstrating that individual states are the appropriate place and scale for space commercialization.

A development program leading to the placement of a state satellite in orbit and its operation to address state needs would demonstrate the technical and economic feasibility of multipurpose satellites. It would also demonstrate that individual states are capable of assuming control of their own futures in using space technology and need not always rely on the federal government or large corporations to direct the choices in technology applications.

Once the satellite system has demonstrated its capability to serve a multi-user community in Texas, it then becomes an effective marketing tool for applications outside Texas. By virtue of the size of Texas, its variation in geographic domains, and the complexity of its infrastructure, proof of the system's operational and economic feasibility establishes market credibility.

Like the other primary objectives of this baseline strategy, the technology demands for a state satellite system, both space- and ground-based, will be in a constant state of evolution and change, largely driven by market requirements and competitors. Since the technology of this system, like that of the integrated payload services system, is a vital factor in attaining economic self-sufficiency, it too must be regarded as critical. Therefore, the link to the state's space business and technology incubators and to its space technology development firms is established. Similarly, the state's satellite system is itself an end user for the critical technologies developed in the state. Further, once the proof-of-concept is demonstrated and the satellite system's relationship to Texas-developed technology shown, the market for Texas satellite technology will expand, as will the market for the satellite system services. The satellite system, then, has a strong multiplier effect on the state's space R&D base.

Essential Characteristics

Public-Private Development Program

The development program for a Texas satellite system should be designed and managed by a Texas space authority responsive to the needs and opportunities of both the public and the private sectors and responsible as well for coordination with other Texas space strategy objectives.

A primary element of the development program should be a comprehensive identification and assessment of anticipated state agency, business, and university uses of services that could be provided by a state satellite system over the decade of the 1990s. The full range of users -- potential as well as actual -- for a state satellite system, their projected needs and use patterns, and the extent to which the existence of a satellite system would meet those patterns require careful consideration. This information would significantly influence the satellite system design and mission requirements. Adequately addressing the needs of potential customers would enable the state space authority to begin marketing the satellite system services both in the state and beyond.

It is essential that the development program have both revision and extension capabilities. The development program must be flexible enough to enable the satellite system to meet changing state needs and to anticipate changing data requirements over time periods up to a decade. It must provide for a system able to respond to advances in technology and be upgraded as new capabilities warrant. Only in this way would the Texas satellite system continue to deliver state-of-the-art, efficient services to all its users. Ultimately, the development program should be able to guide the design, development, implementation, and operation of the satellite system.

The Texas space authority must include in the development program a market analysis with sensitivity to forms of competition and alternatives to the services provided by a satellite system. This analysis not only must focus on immediate and short-range returns, but also must consider the strategic position of the state and its industries. Rigorous cost analysis will be required to determine and regulate the costs of an operational satellite system in accordance with user needs and system design. The development program should be anchored by firm public and private financial commitments and arrangements in advance of its implementation. This is crucial to demonstrating the intent and financial credibility both of the program and of the satellite system.

A primary element of the development program is the design of technical assessments to identify the desirable characteristics and potential problems associated with a state satellite system. Completion of these assessments is critically important before initiating a pilot project to demonstrate the system. This demonstration project is essential for showing potential public, private, and university users the performance characteristics of the system in a realistic operating environment. As a marketing strategy, the demonstration project should showcase the distinctive and diverse capabilities of the system, as well as its cost-effectiveness.

Remote Sensing Capability in a State Satellite System

One of the two primary capabilities of a Texas satellite system to be developed initially should be remote sensing. The essential characteristics of a remote sensing capability must match the requirements of the users. Each user will have specific data needs, such as spatial resolution and spectral sensitivity. At a minimum the remote sensing capability must span at least the entirety of Texas with just a few satellite passes, so that thorough coverage of the state is ensured for all Texas users, regardless of their location. There must be a reliable and continuous flow of data, and the users of the system must be able to acquire these processed data in a timely manner.

The system must have provisions for storing and retrieving data. A central repository for the collection, storage, and dissemination of data collected by the satellite system will be necessary if the state is to take full advantage of the benefits of a remote sensing capability. The satellite system should have the capability of allowing data taken at different times to be comparable and of uniform quality. As new processing techniques emerge in the future, the satellite system should have the capability of processing older data sets as well as those obtained and processed through more advanced techniques. In all cases, the exact nature of the storage, processing, and retrieval systems must be driven by the needs of the market, both present and future.

A state satellite system will succeed only if adequate attention is given to satisfying customer needs at a reasonable cost. Primary customers should be included in both the development and operational phases of the remote sensing capability. The costs of obtaining, processing, storing, and retrieving data will be of major concern to all users. If and when marginal costs require increasing the cost of services, these increases need to be incremental, so that state agencies and private users alike are able to continue to afford the data.

Telecommunications Capability in a State Satellite System

The second essential capability that should be included in a Texas satellite system and developed initially is telecommunications. Again, a state satellite system must be responsive to the needs of its public, private, and university users. At a minimum, comprehensive telecommunications coverage of the state is necessary; the capability to provide services to other states also is necessary if the state decides to market the satellite services to users outside the state. The system must have enough capacity to handle multiple data streams at peak usage hours. It must have sufficient ground support equipment to provide smooth switching of data streams along communication routes. Maintaining uniform, high-quality, continuous data flow is essential.

The satellite system's primary telecommunications characteristic should be the capability to provide fixed point-to-point data transmission services. The essential elements of these services are a direct-to-user network (i.e., instantaneous communications, not delayed) and high volume trunking capability, at first on a statewide level, then later on a regional and perhaps even an international level. A secondary characteristic should be the capacity to handle compatible services in the form of mobile telecommunications services in the air, on water, and on land, as well as a broadcast and relay service capability. This capacity could include television programming distribution, two-way educational interactive video, and other data relay functions.

Notes

1. Texas Space Grant Consortium, "Project Bluebonnet," *ACTS Regional Applications Conference* (Austin, Texas, June 20, 1991), pp. 124-130.

2. Telephone interview with Tina Brown, Division of Statewide Planning and Policy, Texas Department of Information Resources, Austin, Texas, September 24, 1991.

3. Dick Stanley, "Network Links Rural Doctors to Technology," *Austin American-Statesman*, October 6, 1991, pp. B1 & B6.

4. Ibid.

5. Telephone interview with John Tate, System Support Coordinator, Information Systems Division, Texas Air Control Board, Austin, Texas, September 24, 1991.

6. U.S. Congress, House Committee on Science, Space, and Technology , Subcommittee on Space Science and Applications, *The Commercial Space Launch Industry* (testimony by Edward A. O'Connor, Jr., Executive Director, Spaceport Florida Authority, and F.C. Spreyer, Washington Representative, State of Hawaii Department of Business, Economic Development & Tourism and the Hawaii Space Development Authority). 101st Congress, 2nd Session, November 30, 1990, pp. 132-145 and 148-158.

7. Telephone interview with Mel Eckoff, Utilities Specialist, Engineering Section, Public Utilities Commission, Austin, Texas, September 24, 1991.

8. Texas Department of Information Resources and State Purchasing and General Services Commission, *State of Texas Satellite Feasibility Study: A Report to the Governor and Legislature* (Austin, Texas: February 1991).

Chapter 10.

The Space Constituency

Constituency Development

The project group has been consistently impressed in its research effort by the rich promise that the space frontier has for the quality of life in Texas. It is pervasive and multifaceted, and it has strongly influenced the course of strategy development. It has provided the rationale for the conclusion that a space economy, with its practical benefits, has the capacity and potential to expand to the point at which it will be regarded by the populace as a public utility in the fullest sense. Analogies drawn to such economic developments as the electrification of the state, the highway system, and communications networks, among others, and the dramatic effect that these developments have had on the quality of Texans' lives are appropriate to the space context.

Consequently, this state space strategy for the 1990s and its long-range framework are intended to embrace as wide an area of the state and to proliferate the space infrastructure as extensively as possible. The implication is that the economic benefits to the user community and the general citizenry of the state that are associated with the implementation of this baseline strategy similarly should affect other areas of the economy. As specified in the report's description of the strategy, these areas include the state education system (from elementary education through the university system, both public and private); potential sites for new business development and the involvement of established centers of space technology industries; the far-flung network of responsibilities and service areas of the separate state agencies; and, as importantly, the links which draw all these public and private groups together in this enterprise.

It is essential that the institutional entity charged with addressing and carrying out this baseline strategy -- the Texas space authority -- undertake an ongoing, proactive outreach to inform, educate, promote, and involve all interested organizations and citizens of Texas. If the project's conclusions about the potential and effect of a space economy on the general populace of the state are correct, then it is strategically important, even vital, that a large portion of the population support the implementation of this undertaking through their participation and through public-private investment. Obtaining this support will not be an easy task. The long-range goal is, indeed, several decades into the future, and the next several years of space economic development, essentially a bootstrap effort, will probably show only limited returns. Further, these periods are sufficiently long to expect that most of the present generation of leaders in all sectors that affect the baseline strategy implementation may have given way to new leaders with different economic and political policies and emphases.

Against these eventualities, it is therefore strategically important that the confidence and sustained support of the general populace, as well as of those public and private organizations involved in implementing the strategy, play a vital role in maintaining the economic development enterprise. That is, the goal of achieving self-reliance in space economic and business development must continue to be regarded as a public good and thus beyond political question, although there may well be mid-course changes in tactical and level-of-effort planning. For these reasons, it is essential that a space constituency of the state be widely sought and developed through focused and active programs to enable people across the state to understand the state's commitment to space and to participate meaningfully in its growth and benefits.

It should be apparent at this point that the strategic framework is intended to result in the state mobilizing its resources to establish an independent, ongoing space program of its own. Again, this is a sobering concept, but the essential nature of the long-range goal and the principal space-related attributes of the state virtually compel the development and implementation of the baseline and successor strategies to this end. Only a few states have the opportunity and the capability to think strategically in these terms: even fewer have the temerity to conceive of the long-range significance. But the boldness to extrapolate the state's future in these terms also must recognize the level of effort and the sustained commitment required.

The analogy to the national civil space program is interesting, but there are significant differences for Texas and other states. This report's state space strategy, while keyed on the development of critical technologies for space applications, is largely confined to and places its priority on economic and business development and benefits. It is broad-based and diversified, but the base cuts across public and private sectors in such a way as to require an unusual partnership which must share participation, governance, investment, and economic return. In a real sense, it brings together, at the scale of an individual state, an active collaboration of industry, academia, and state government. Indeed, the strategy and the level of effort for implementation virtually require this unusual institutional base that is intended to represent and reflect the state space constituency.

Preparation for Implementation

Because a statewide constituency is vital to sustaining the long economic development period, it is essential that the process of involving large numbers of Texas citizens and organizations begin early. This is an integral part of the formative planning stage of strategy implementation. It should concentrate on informing citizens about the state's commitment. The magnitude of this education and outreach effort should not be underestimated, and innovative and imaginative means to achieve it should be sought and employed. Since there already exist many organizational entities, both private and public, in Texas which have principal interests in space development and which have access to statewide information networks, the state institutional focus responsible for implementation of the baseline strategy should enlist these organizations in Texas in the development of the state space constituency. Such an effort, in the early stages of implementation, would serve to engage the large number of disparate space organizations in one of several tasks in which their participation is necessary to achieve a unified and integrated approach. As in the case of the general populace, these public and private organizations also are an integral part of the state space constituency.

As indicated throughout the foregoing discussion of the baseline strategy, a number of important tasks have emerged from the project. These include the following studies:

1. the specification of models of private-public authorities having the necessary operational characteristics for an effective institutional focus;

2. the selection of critical technologies for space incubators;

3. a feasibility study of the technology base for an integrated, comprehensive payload services capability;

4. a feasibility study of a state satellite system;

5. a database of the state's space infrastructure; and

6. site studies for the location of space business incubators.

The completion of these studies is a vital part of the preparation leading to the organization of the institutional base and the commencement of implementation of this state strategy for the 1990s. Because all these tasks are directed at the primary objectives, it is appropriate that they be used as part of the statewide constituency development (i.e., that as broad a cross-section of experts and geographic distribution of participants as possible be involved in these studies, in the definition of issues to be addressed, and in the debate to reach consensus on the results of the tasks). From the constituency's perspective, the results of these study tasks must be seen as fair and objective. Therefore it is appropriate to seek and invest responsibility in an organization which can provide these advisory services and which also will not have continuing, long-term operation, management, or policymaking roles during the implementation of the strategy.

The Texas Space Grant Consortium is an appropriate institution to undertake or oversee these important pre-implementation advisory studies. Its charter is directed to and concerned with most of the essential elements of the Texas space infrastructure (e.g., education, outreach, research, and public service). It is not mission-oriented, however, nor is it primarily involved in economic development per se. Its broad membership base is drawn from universities throughout the state that are engaged in space science and technology, from space industries and nonprofit research organizations, and from state agencies that have interests or roles in space applications and in fostering space R&D and technology growth. The consortium base embraces both the public and private sectors and as such provides an unusual parallel and perspective to the private-public characteristic of the strategic endeavor. From this institutional base, the consortium could provide an exceptional resource pool of experts to manage and conduct these study tasks.

Appendix A.
NASA Centers

The National Aeronautics and Space Administration (NASA) has nine primary centers through which it carries out its missions. Organizationally, these centers are in three areas of primary NASA responsibility: space flight, space science and applications, and aeronautics and space technology.

Space Flight

Lyndon B. Johnson Space Center (Texas)

The Johnson Space Center (JSC) is the focal point of U.S. human space flight activities, including spacecraft development, program management, space flight operations, and related medical research and life sciences. It has project management, astronaut selection and training, and operations responsibility for the Space Shuttle, as well as program management responsibility for Space Station Freedom and the moon and Mars initiatives. It also operates the White Sands Test Facility in New Mexico.

John F. Kennedy Space Center (Florida)

The Kennedy Space Center is NASA's primary launch center for both manned and unmanned (i.e., expendable) space missions, including the Space Shuttle. Program management responsibility for the Space Shuttle also is located here.

George C. Marshall Space Flight Center (Alabama)

The Marshall Space Flight Center designs and develops space transportation systems, scientific and applications payloads, and related systems. It is responsible for the design, test, and evaluation of the Space Shuttle's main engine, rocket boosters, and external tank, as well as the habitation and laboratory modules for the Space Station Freedom crew.

John C. Stennis Space Center (Mississippi)

The Stennis Space Center is the prime NASA facility for the static test firing of large rocket engines and propulsion systems.

Space Science and Applications

Goddard Space Flight Center (Maryland)

The mission of the Goddard Center is to facilitate the expansion of human knowledge of Earth, its environment, and beyond through the development and use of near-Earth orbiting spacecraft. It plays a major role in the Earth Observing System (EOS) and the development of Space Station Freedom and also operates the Wallops Flight Facility in Virginia.

Jet Propulsion Laboratory (California)

The Jet Propulsion Laboratory (JPL), located at the California Institute of Technology, has as its primary mission the unmanned scientific exploration of the solar system through investigation of the planets, their satellites, and deep space.

Aeronautics and Space Technology

Ames Research Center (California)

The Ames Research Center has major technical responsibilities in such areas as the life sciences, human factors and man-machine interactions, fluid dynamics and heat transfer, flight dynamics, flight stability and control, and project management. It also operates the Dryden Flight Research Facility in the Mojave Desert, which is responsible for high performance flight research programs, including those on test flights and Space Shuttle landings.

Langley Research Center (Virginia)

The Langley Research Center is a world leader in aeronautical and space-related R&D in aerodynamics, materials, structures, information systems, controls, acoustics, and atmospheric sciences. A major project is technology development for the National Aero-Space Plane.

Lewis Research Center (Ohio)

The Lewis Research Center is NASA's lead facility for R&D in aeropropulsion, space propulsion, space power, and space science/applications (e.g., microgravity experiments and Advanced Communications Technology Satellite (ACTS) development and flight). It is responsible for developing the Space Station Freedom electric power system.

Source: NASA, *Selling to NASA*, n.d., pp. 30-47.

Appendix B.
Texas Space Industry

Company Name	Vital Statistics*	Activities
Barrios Technology, Inc.	City: Houston Sales: 22 Employees: 512 Founded: 1980	Provider of custom programming of aerospace software for the aerospace industry.
Cimarron Software Services	City: Houston Sales: 3.75 Employees: 50 Founded: 1981	Publisher of custom aerospace software and test confirmation integrated software. Contracted by Johnson Space Center.
Communications Data Systems Associates, Inc.	City: Webster Sales: 1 Employees: 11 Founded: 1984	Manufacturer of satellite/ microwave equipment. Provider of telecommunications related services.
Eagle Engineering, Inc.	City: Houston Sales: 14 Employees: 150 Founded: 1980	Provider of aerospace engineering consulting services; systems engineering support for space stations used in the Mars-to-moon initiative during launch payload integration.
Gardiner Communications Corp.	City: Garland Sales: 15 Employees: 110 Founded: 1979	Manufacturer of communications satellite components.

ILC Space Systems	City: Houston Sales: 15 Employees: 158 Founded: 1978	Manufacturer of high temperature thermal insulation for military and spacecraft applications; tools and equipment for NASA space program use. Produces a wide range of crew-related products from astronaut hygiene equipment to satellite retrieval equipment. Insulation includes heat shields, cork products, and multi-layer insulation for spacecraft and missile applications.
KRUG International/ Technology Life Sciences Division	City: Houston Sales: 105 Employees: 320 Founded: 1959	R & D organization specializing in space biomedicine and space stations for aeronautical applications.
Lockheed Engineering & Sciences Co., Inc.	City: Houston Sales: 250-500 Employees: 4,708 Founded: 1979	Provides technical support in areas including spacecraft systems development, remote sensing of the earth and its environment; environmental sampling and data analysis; test range engineering; operation and maintenance; propulsion testing and aircraft materials analysis; spacecraft payload development; high energy laser testing.
Lockheed Missiles & Space Co./Austin Division	City: Austin Sales: 190 Employees: 1,600 Founded: 1932 (parent)	Software technology research services and aerospace support services.
Loral Space Information Systems (Ford Aerospace Corporation)	City: Houston Sales: 110 Employees: 1,200 Founded: 1916	Provider of systems integration and engineering services for the Space Shuttle.
LTV Missiles and Electronics Group/ Missiles Division	City: Dallas Sales: 550 Employees: 5,000 Founded: 1952	Manufacturer of missiles, rockets, and space systems.

McDonell Douglas Space Systems Co/Space Station Division-Houston	City: Houston Sales: 16,250 (parent) Employees: 500-999 Founded 1972	Provider of engineering, scientific, and computer science support services for space-related programs; includes vehicle and systems design verification, flight design, flight preparation, mission operations, and flight support.
Oceaneering Space Systems	City: Houston Sales: 147 Employees: 1,500 Founded: N/A	Provider of aerospace engineering services for the U.S. space program.
Performance Metrics, Inc.	City: San Antonio Sales: <1 Employees: 5 Founded: 1983	Research and development organization specializing in aeronautical training simulation software.
Phytoresource Research, Inc.	City: College Station Sales: <1 Employees: 9 Founded: 1982	R&D organization specializing in the development of hardware for plant experiments in space.
R&D Aeronautical Engineering Co., Inc.	City: Plano Sales: 1.5 Employees: 20 Founded: 1977	Provider of aerospace prototype manufacturing, aerospace engineering, and unmanned aircraft engineering services.
Satellink, Inc.	City: Garland Sales: 2.6 Employees: 25 Founded: 1982	Manufacturer of receiving equipment for satellite communications and telemetry. Also manufactures radio frequency microwave amplifiers and frequency converters.
Space Industries International, Inc.	City: Webster Sales: 2.5-5 Employees: 85 Founded: 1983	Provider of design engineering services for commercial space ventures.
Space Services Incorporated of America	City: Houston Sales: 1.5 Employees: 16 Founded: 1980	Provider of launch services according to customer payload specifications and rocket engine assembly services.

Tracor Flight Systems, Inc.	City: Austin Sales: 27 Employees: 248 Founded 1966	Manufacturer of aircraft and airborne test systems and software simulation systems.
Triton Technologies, Inc.	City: Austin Sales: 260 (parent) Employees: 10 Founded: 1986	R&D organization specializing in electronic digital accelerometers with aerospace, automotive, and industrial applications. Developer of space programming communication satellites for space shuttles.

Source: Corporate Technology Information Services, Inc., *Corporate Technology Directory*, vol. 1-4. (Woburn, MA, 1992).

*Sales in millions of dollars

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Appendix C. Texas Space-Related Industry

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP	S
1	A E E	13667 FLOYD CIRCLE		DALLAS	TX	75243	3
2	A O S, INC	2420 WESTRIDGE		PLANO	TX	75075	3
3	AAA TECH & SPECIALTIES COMPANY, INC	3000 ROGERDALE RD		HOUSTON	TX	77040	7
4	ACCOUNTING PROFESSIONALS SOFTWARE	4210 WEST VICKERY BLVD		FORT WORTH	TX	76107	7
5	ACCUGRAPH CORPORATION	5822 CROMO DR		EL PASO	TX	79912	7
6	ACME COMMUNICATIONS TECHNOLOGY SYSTEMS CORPOR	4000 MCEWEN	SUITE 244	DALLAS	TX	75234	4
7	ACS INTERNATIONAL	1325 CAPITAL PARKWAY	SUITE 109	CARROLLTON	TX	75006	3
8	ADVANCED RESEARCH TECHNOLOGY, INC	404 APOLLO CT	SUITE 320	RICHARDSON	TX	75081	3
9	AEROCOMP	P O BOX 223957		DALLAS	TX	75222-3957	3
10	AGENT SYSTEMS	1430 REGAL ROW	SUITE 360	DALLAS	TX	75247	[illegible]
11	AGRO SYSTEMS CORPORATION	P O BOX 64539		LUBBOCK	TX	79464	[illegible]
12	AHLERS & ASSOCIATES, INC	300 GLADE RD	BOX 18	COLLEYVILLE	TX	76034	[illegible]
13	AIMS PLUS, INC	1001 SOUTH SHERMAN ST		RICHARDSON	TX	75081	[illegible]
14	AIRWAVE, INC	3620 BYERS AVE	BOX 9028	FORT WORTH	TX	76417	[illegible]
15	ALDERGRAF SYSTEMS, INC	10810 OLD KATY RD	SUITE 102	HOUSTON	TX	77043	[illegible]
16	ALSOFT, INC	P O BOX 927		SPRING	TX	77383	[illegible]
17	ALTAI SOFTWARE	624 SIX FLAGS DR	SUITE 150	ARLINGTON	TX	76011	[illegible]
18	ALTSYS CORPORATION	269 WEST RENNER RD		RICHARDSON	TX	75080	
19	AMERICA HEALTH COMPUTER SERVICES, INC	3950 FOSSIL CREEK BLVD	SUITE 101	FORT WORTH	TX	76137	
20	ANALYTICAL SOFTWARE, INC	10939 MCCREE RD		DALLAS	TX	75238	
21	ANDREW CORPORATION/ELECTRONIC PRODUCT DIVISIO	1850 N GREENVILLE, SUITE 100		RICHARDSON	TX	75081	
22	ANTRIM CORPORATION	101 E PARK BLVD	SUITE 1205	PLANO	TX	75074	
23	APOGEE COMPUTER SYSTEMS, INC	3630 PIONEER PARKWAY	SUITE 201	ARLINGTON	TX	76013	
24	APPLICATION DEVELOPMENT COMPANY	3010 LBJ FRWY		DALLAS	TX	75381	
25	APPLIED CONCEPTS	717 SHERMAN	SUITE 300	RICHARDSON	TX	75081	
26	APPLIED CREATIVE TECHNOLOGY, INC	10495 OLYMPIC DR	SUITE 102	DALLAS	TX	75220	
27	APPLIED DATA SCIENCES, INC	P O BOX 814209		DALLAS	TX	75381	
28	APPLIED MICROS, INC	10701 CORPORATE DRIVE	SUITE 290	STAFFORD	TX	77477	
29	APPLIED SYSTEMS ENGINEERING	8623 HWY 377 SOUTH		FORT WORTH	TX	76126	
30	ARGO DATA RESOURCE CORPORATION	15301 DALLAS PARKWAY, SUITE 74		DALLAS	TX	75248	
31	ARMATEK	601 N GLENVILLE DR	SUITE 125	RICHARDSON	TX	75081	
32	ARTHUR STONE COMPANY	535 E WOODWARD	BOX 3896	AUSTIN	TX	78704	
33	ASH CONCEPTS, INC	P O BOX 36385		DALLAS	TX	75235	
34	ASK COMPUTER SYSTEMS, INC	14881 QUORUM DR	SUITE 600	DALLAS	TX	75240	
35	ASTAR SYSTEMS, INC	9230 MARKVILLE	SUITE C	DALLAS	TX	75243	
36	AT&T COMPUTER SYSTEMS SERVICE ORGANIZATION	8300 ESTERS ROAD	SUITE 920	IRVING	TX	75063	
37	AT&T CONSUMER PRODUCTS	624 SIX FLAGS DR , SUITE 230		ARLINGTON	TX	76011	

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP
38	AT-80	3827 DISMOUNT		DALLAS	TX	75211
39	AUSTIN MICRO SYSTEMS, INC	1826 G KRAMER LN		AUSTIN	TX	78758
40	AUSTIN RESEARCH ASSOCIATES	1101 S CAPITAL OF TEXAS HWY	BLDG B-210	AUSTIN	TX	78746-6437
41	AUTOMATE COMPUTER SOFTWARE	7551 CALLAGHAN RD		SAN ANTONIO	TX	78270
42	AUTOMATIC POWER, INC	213 HUTCHESON	BOX 230738	HOUSTON	TX	77223
43	AUTOMATION RESEARCH AND DEVELOPMENT	525 INTERNATIONAL PKWY		RICHARDSON	TX	75081
44	AZAR COMPUTER SOFTWARE SERVICES, INC	800 WEST AVE	SUITE 102	AUSTIN	TX	78701
45	BARRIOS TECHNOLOGY	1331 GEMINI	SUITE 3	HOUSTON	TX	77058-279
46	BEHAVIORTECH, INC	5215 N O'CONNOR BLVD	SUITE 2510	IRVING	TX	75039-371
47	BELL AND MURPHY AND ASSOCIATES, INC	P O BOX 816188		DALLAS	TX	75381
48	BENSMILLER COMPUTER SYSTEMS, INC	DRAWER D		WHITSETT	TX	78075
49	BIG G SOFTWARE	RT 2, P O BOX 111		ALLEYTON	TX	78935
50	BILES AND ASSOCIATES INC	6161 SAVOY DR	SUITE500	HOUSTON	TX	77036
51	BMC SOFTWARE, INC	P O BOX 2002		SUGAR LAND	TX	77487
52	BOEING AEROSPACE OPERATIONS	1045 GEMINI		HOUSTON	TX	77058
53	BOEING ELECTRONICS, INC	3131 WEST STORY ROAD		IRVING	TX	75038
54	BOFFIN, INC	6859 MAIN ST		FRISCO	TX	75034
55	BONDURANT CORPORATION	2509 BERRY ST REAR		FORT WORTH	TX	76109
56	BONNECAZE, MCLEROY & HARRISON, INC	4125 KELLER SPRINGS RD , SUITE		DALLAS	TX	75244
57	BONNER & MOORE CONSULTING SERVICES INC	2727 ALLEN PARKWAY	SUITE 1200	HOUSTON	TX	77019
58	BOS NATIONAL, INC	2607 WALNUT HILL LN	SUITE 200	DALLAS	TX	75229
59	BR BLACKMARR & ASSOCIATES	2515 MCKINNEY AVE	SUITE 1700	DALLAS	TX	75219
60	BROADCAST AUTOMATION, INC	4125 KELLER SPRINGS, SUITE 122		DALLAS	TX	75244
61	BRUCE G JACKSON AND ASSOCIATES	17629 EL CAMINO REAL	SUITE 207	HOUSTON	TX	77058
62	BSA COMPANY, INC	1714 BROGAN ST		SAN ANTONIO	TX	78232
63	BUSINESS COMPUTER SOLUTIONS	1200 COPELAND	SUITE 200	ARLINGTON	TX	76011
64	CALDWELL SPARTAN	17171 PARK ROW		HOUSTON	TX	77084
65	CAM-I, INC	1250 EAST COPELAND RD	SUITE 500	ARLINGTON	TX	76011
66	CANNON COMPUTER COMPANY	4975 PRESTON PARK BLVD		PLANO	TX	75093
67	CAPTIVA COMPUTER SERVICES, INC	5910 N CENTRAL EXPWY	SUITE 1900	DALLAS	TX	75206
68	CARBON-CARBON ADVANCED TECHNOLOGIES	5144 S E LOOP 820		FORT WORTH	TX	76140
69	CARBOTEK, INC	16223 PARK ROW	STE 100	HOUSTON	TX	77084
70	CARDIO-RESPIRATORY MANAGEMENT SYSTEMS	711 LAMAR	SUITE 202	ARLINGTON	TX	76001
71	CARTER PERTAINE	1500 S DAIRY ASHFORD	SUITE 400	HOUSTON	TX	77077
72	CASS SYSTEMS, INC	17000 DALLAS PARKWAY	SUITE 126	DALLAS	TX	75248
73	CASTLEBERRY INSTRUMENTS	817 DESSAU RD		AUSTIN	TX	78753
74	CD WORD LIBRARY, INC	TWO LINCOLN CENTER, SUITE 240	5420 LBJ FREEWAY	DALLAS	TX	75240-62

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP
75	CE SERVICES, INC	2895 113TH ST		ARLINGTON	TX	75050
76	CENTEX DATA SYSTEMS, INC	128 EAST MAIN ST		FREDERICKSBURG	TX	78624
77	CENTURY FLIGHT SYSTEMS INC	AIRPORT RD	BOX 610	MINERAL WELLS	TX	76067
78	CGA COMPUTER, INC	TWO GALLERIA TOWER, SUITE 1600	13455 NOEL RD , LB 66	DALLAS	TX	75240
79	CHAMBER DATA SYSTEMS, INC	15221 BERRY TRAIL #510		DALLAS	TX	75248
80	CHELTON, INC	P O BOX 976		LEWISVILLE	TX	75067
81	CHEMSHARE CORPORATION	P O BOX 1885		HOUSTON	TX	77251-18
82	CHRIS SCHAEFER & COMPANY	1500 SOUTH DAIRY ASHFORD	SUITE 400	HOUSTON	TX	77077
83	CHUCK ATKINSON PROGRAMS	3737 RAMONA		FORT WORTH	TX	76116
84	CIRCUIT SYSTEMS COMPANY	2619 COLORADO CIRCLE		ARLINGTON	TX	76015
85	CLASSIC SYSTEMS, INC	2501 CENTRAL PARKWAY	SUITE B-16	HOUSTON	TX	77092
86	COGNISEIS DEVELOPMENT, INC	2401 PORTSMOUTH		HOUSTON	TX	77098
87	COLLINS PRODUCTS CO	P O BOX 382		LIVINGSTON	TX	77351
88	COMCO, INC	66 33RD ST , NORTH MESA	SUITE 601	EL PASO	TX	79912
89	COMMUNICATIONS INDUSTRIES, INC	3811 TURTLE CREED BLVD		DALLAS	TX	75219
90	COMMUNITY HEALTH COMPUTING, INC	5 GREENWAY PLAZA	SUITE 2000	HOUSTON	TX	77046
91	COMPAQ COMPUTER CORPORATION	20555 SH 249		HOUSTON	TX	77070
92	COMPONENT DATA COMPANY	831 NORTH SAINT MARY'S ST	SUITE A	SAN ANTONIO	TX	78205
93	COMPU-SHARE, INC	SENTRY PLAZA III	5214 68TH ST , SUITE 200	LUBBOCK	TX	79424
94	COMPUCON, INC	251 W RENNER RD		RICHARDSON	TX	75080
95	COMPUTER APPROACHES	4851 KELLER SPRINGS RD	SUITE 209	DALLAS	TX	75248
96	COMPUTER EXPERTISE	811 ALPHA DR	SUITE 359	RICHARDSON	TX	75081
97	COMPUTER EXTENSION SYSTEMS, INC	16850 TITAN DR		HOUSTON	TX	77058
98	COMPUTER LANGUAGE RESEARCH, INC	2395 MIDWAY RD		CARROLLTON	TX	75006
99	COMPUTER START-UP, INC	2437 RAINTREE		PLANO	TX	75074
100	COMPUTER SUPPORT CORPORATION	15926 MIDWAY		DALLAS	TX	75244
101	COMPUTERS & BUSINESS SYSTEMS, INC	1620 13TH STREET	P O BOX 2954	LUBBOCK	TX	79401
102	COMSTAR INC	2825 WILCREST	SUITE 250	HOUSTON	TX	77042
103	COMTEK, INC	309 BREESPORT		SAN ANTONIO	TX	78216-26
104	CONCEPTUAL SOFTWARE, INC	P O BOX 56627		HOUSTON	TX	77256
105	CONTACT SOFTWARE INTERNATIONAL, INC	1625 W CROSBY RD	SUITE 132	CARROLLTON	TX	75006
106	CONTINENTAL DATA PROCESSING, INC	P O BOX 100008		FORT WORTH	TX	76185-00
107	CONTINENTAL ELECTRONICS CORPORATION	4212 BUCKNER BLVD , BOX 270879		DALLAS	TX	75227
108	CONTINUUM COMPANY, INC	9500 ARBORETUM BLVD		AUSTIN	TX	78759
109	CONTROL ASSEMBLIES COMPANY	700 NORTH LOCUST		DENTON	TX	76201
110	CONTROL TECHNOLOGY, INC	1881 WEST STATE STREET		GARLAND	TX	75042
111	CONVEX COMPUTER CORPORATION	3000 WATERVIEW		RICHARDSON	TX	75080

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP
112	CORE SOFTWARE, INC	26303 OAK RIDGE DR		SPRING	TX	77380
113	CORTEST LABORATORIES	11115 MILLS RD		CYPRESS	TX	77429
114	CRAY RESEARCH, INC	5005 LBJ FREEWAY, SUITE 800	LB - 50	DALLAS	TX	75244
115	CREDIMATION SYSTEMS, INC	10222 DUDE RD		HOUSTON	TX	77064
116	CRITICAL SYSTEMS INC	5815 GULF FRWY		HOUSTON	TX	77023
117	CTI LIMITED, INC	14135 MIDWAY, SUITE 230		DALLAS	TX	75244
118	CYBERTEK CORPORATION	7800 N STEMMONS FWY , SUITE 60		DALLAS	TX	75247-
119	CYBEX TECHNOLOGIES CORPORATION	12520 SCHROEDER RD	SUITE 104	DALLAS	TX	75243
120	DAC SOFTWARE, INC	4801 SPRING VALLEY RD , BLDG 1		DALLAS	TX	75244
121	DALTECH INTERNATIONAL, INC	14275 MIDWAY ROAD	SUITE 220	DALLAS	TX	75244
122	DALTON TOOL INC	10612 METRIC BLVD		AUSTIN	TX	78758
123	DANDOL ENTERPRISES INC	807 S MAIN		HIGHLANDS	TX	77562
124	DARRYL E PARKER, INC	750-A N CARROLL AVENUE	P O BOX 92624	SOUTHLAKE	TX	76092
125	DATA GENERAL SERVICES, INC	7423 AIRPORT FRWY		FORT WORTH	TX	76118
126	DATA INDEX, INC	9400 N CENTRAL EXPRESSWAY	SUITE 314	DALLAS	TX	75231
127	DATA INTERFACE SYSTEMS CORPORATION	8701 N MOPAC EXPWY	SUITE 415	AUSTIN	TX	78759
128	DATA MANAGEMENT SYSTEMS, INC	12308 TWIN CREEK RD		MANCHACA	TX	78652
129	DATA-LINK COMPUTER SYSTEMS, INC	2002 GREENLEAF, SUITE A		LONGVIEW	TX	75605
130	DATAPOINT CORPORATION	1950 STEMMONS FRWY	SUITE 2060	DALLAS	TX	75207-
131	DATATRONICS CONTROL, INC	5130 DEXHAM RD		ROWLETT	TX	75088
132	DATOTEK, INC	3801 REALTY RD		DALLAS	TX	75244-
133	DATRONIC SYSTEMS, INC	P O BOX 863549		PLANO	TX	75086
134	DAVOX CORPORATION	959 EAST COLLINS BLVD		RICHARDSON	TX	75081
135	DEL NORTE TECHNOLOGY, INC	1100 PAMELA DR		EULESS	TX	76040
136	DEL STEHLE CO	9505 SUMMERHILL		DALLAS	TX	75243
137	DELL COMPUTER CORPORATION	9505 ARBORETUM BLVD		AUSTIN	TX	78759-
138	DESCRIPT COMPANY	7328 O'ROURKE LANE	LR RANCH	EL PASO	TX	79934
139	DIBRELL FINANCIAL CORPORATION	P O BOX 841		RICHARDSON	TX	75081
140	DIGITAL EQUIPMENT CORPORATION	4851 LBJ FREEWAY, SUITE 1100		DALLAS	TX	75244
141	DISTRIBUTIVE NETWORK OF AMERICA, INC	7557 RAMBLER ROAD	SUITE 1050	DALLAS	TX	75231
142	DPC & A	6510 ABRAMS RD	SUITE 410	DALLAS	TX	75231
143	DRESSER INDUSTRIES, INC	P O BOX 718		DALLAS	TX	75221
144	DRILLING TECHNOLOGY, INC	5808 WAVERTREE	SUITE 1000	PLANO	TX	75093
145	DUN & BRADSTREET	4100 ALPHA RD	SUITE 1100	DALLAS	TX	75244
146	DYTRONIX CORPORATION	11910 GREENVILLE AVE	P O BOX 742228	DALLAS	TX	75374
147	E-SYSTEMS, INC	P O BOX 660248		DALLAS	TX	75266-
148	E-SYSTEMS, INC /GARLAND DIVISION	1200 JUPITER RD	BOX 660023	GARLAND	TX	75266-

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP
149	E-SYSTEMS, INC /GREENVILLE DIVISION	P O BOX 6056		GREENVILLE	TX	75403
150	EAGLE ENGINEERING, INC	16915 EL CAMINO REAL	SUITE 200	HOUSTON	TX	77058
151	EASYSPEC, INC	17629 EL CAMINO REAL	SUITE 202	HOUSTON	TX	77058
152	ECOTOMIC GROUP, INC	611 RYAN PLAZA DR , SUITE 700		ARLINGTON	TX	76011
153	EL DORADO SYSTEMS, INC	1350 EAST ARAPAHO RD	SUITE 200	RICHARDSON	TX	75081
154	ELECTRICAL MANUFACTURING AND DISTRIBUTORS, IN	1411 TWIN OAKS		WICHITA FALLS	TX	76302
155	ELECTRODELTA INC	999 CHEROKEE TRACE		WHITE OAK	TX	75693
156	ELECTRONIC COMMUNICATIONS, INC	3630 CAVALIER DR	BOX 461485	GARLAND	TX	75046
157	ELECTRONICS OF AUSTIN	9603 SAUNDERS LN	BLDG K	AUSTIN	TX	78758
158	ELECTROSPACE SYSTEMS, INC	P O BOX 831359		RICHARDSON	TX	75081-
159	ELEGANT SOFTWARE, INC	2922 SAN DIEGO		DALLAS	TX	75228
160	ELITE SOFTWARE DEVELOPMENT, INC	P O DRAWER 1194		BRYAN	TX	77806
161	EMBROIDERY PUNCHING CENTER OF AMERICA	2901 E ABRAM		ARLINGTON	TX	76010
162	ENERGY INDUSTRIES	1450 N 1ST		GARLAND	TX	75040
163	ENGINEERING DYNAMICS, INC	16117 UNIVERITY OAK		SAN ANTONIO	TX	78249
164	EOA SYSTEMS, INC	15054 BELTWAY DR		DALLAS	TX	75244
165	EXCEL COMPUTER SYSTEMS, INC	1200 POST OAK BLVD	SUITE 200	HOUSTON	TX	77056
166	EXECUCOM SYSTEMS CORPORATION	108 WILD BASIN RD		AUSTIN	TX	78746
167	EXECUTIVE INSTRUMENTS, INC	4141 LINDBERG	BOX 216	ADDISON	TX	75001
168	FAIRFIELD TECHNOLOGIES/MANUFACTURING DIVISION	10627 KINGHURST	BOX 42154	HOUSTON	TX	77042
169	FERGUSON INDUSTRIES	1900 W NORTHWEST HWY		DALLAS	TX	75220
170	FINANCIAL SENSE, INC	6310 LEMMON AVE	SUITE 218	DALLAS	TX	75209
171	FINANCIAL SERVICES MARKETING CORPORATION	12900 PRESTON RD #500		DALLAS	TX	75230
172	FORD AEROSPACE CORP/SPACE INFO SYSTEMS OPERAT	1322 SPACE PARK DR	BOX 58487	HOUSTON	TX	77258
173	FORECASTING PLANNING ASSOCIATES	1950 STEMMONS FRWY	SUITE 5037M	DALLAS	TX	75207-
174	FOY, INC	100 MCKINNEY ST		FARMERSVILLE	TX	75031
175	FULTON BUSINESS MACHINES, INC	1920 MCKINNEY AVE		DALLAS	TX	75201
176	FYI, INC	P O BOX 26481		AUSTIN	TX	78755
177	GAMCO INDUSTRIES INC	SNYDER HWY	BOX 1911	BIG SPRING	TX	79721
178	GARDINER COMMUNICATIONS CORPORATION	3605 SECURITY		GARLAND	TX	75042
179	GARRETT COMPUTING SYSTEMS, INC	2828 ROUTH, SUITE 500		DALLAS	TX	75201
180	GARY AIRCRAFT CORP	MUNICIPAL AIRPORT		HONDO	TX	78861
181	GENERAL DYNAMICS CORP/ABILENE FACILITY	300 WALL	BOX 1401	ABILENE	TX	79604
182	GENERAL ELECTRIC INFORMATION SERVICES COMPANY	14001 NORTH DALLAS PKWY #750		DALLAS	TX	75240
183	GENERAL INSTRUMENT CORPORATION/COMPUTER PRODU	11801 MIRIAM DR	SUITE B-1	EL PASO	TX	79936
184	GENESYS BUSINESS SYSTEMS	8515 GREENVILLE AVENUE	SUITE N106	DALLAS	TX	75243
185	GEOQUEST SYSTEMS, INC	5858 WESTHEIMER	SUITE 800	HOUSTON	TX	77057

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP
186	GEOSOURCE, INC	6909 SW FREEWAY		HOUSTON	TX	77074
187	GHG CORPORATION	1300 HERCULES	SUITE 111	HOUSTON	TX	77058
188	GLOBE UNIVERSAL SCIENCES INC	9800 TOWN PARK		HOUSTON	TX	77036
189	GOOD SOFTWARE CORPORATION	13601 PRESTON RD	SUITE 500 W	DALLAS	TX	75240
190	GREENLEAF SOFTWARE, INC	16479 DALLAS PARKWAY	SUITE 570	DALLAS	TX	75248
191	GRUMMAN SPACE SYSTEMS	12000 AEROSPACE AVE		HOUSTON	TX	77034
192	H O BARNETT COMPUTERS	6812 LAKE JUNE		DALLAS	TX	75217
193	HAL SYSTEMS & SERVICES, INC	3410 MIDCOURT	SUITE 110	CARROLLTON	TX	75006
194	HALSEY ENGINEERING & MANUFACTURING, INC	209 MAYHILL RD		DENTON	TX	76201
195	HARRIS CORP/FARINON DIVISION	5727 FARINON DR		SAN ANTONIO	TX	78249
196	HARTEC ENTERPRISES, INC /PRODUCTS DIVISION	12572 DARRINGTON RD		EL PASO	TX	79927
197	HERCULES, INC /AEROSPACE PRODUCTS GROUP/MCGRE	1101 JOHNSON DR	BOX 548	MCGREGOR	TX	76657
198	HERNANDEZ ENGINEERING, INC	17629 EL CAMNINO REAL	SUITE 206	HOUSTON	TX	77058
199	HOFFMAN MARITIME CONSULTANTS, INC	520 POST OAK BLVD , SUITE 260		HOUSTON	TX	77027-9
200	HOGAN SYSTEMS, INC	5080 SPECTRUM DR	SUITE 400E	DALLAS	TX	75248
201	HOLT RINEHART AND WINSTON/SCHOOL DIVISION	1627 WOODLAND AVE		AUSTIN	TX	78741
202	HOOPER & COMPANY, INC	2023 WILSHIRE BLVD		FORT WORTH	TX	76110
203	HORIZON TECHNOLOGY, INC	650 INTERNATIONAL PKWY	SUITE 180	RICHARDSON	TX	75081
204	HOUGHTON MIFFLIN COMPANY	13400 MIDWAY RD		DALLAS	TX	75244
205	HOUSTON COMPUTER SERVICES, INC	11331 RICHMOND AVE	SUITE 101	HOUSTON	TX	77082-2
206	HOUSTON DATA CENTER	6801 PORTWEST DR	SUITE 170	HOUSTON	TX	77024
207	HOWARD MEASUREMENT COMPANY, INC	P O BOX 660134		DALLAS	TX	75266
208	HUGHES SIMULATION SYSTEM, INC	2200 ARLINGTON DOWNS		ARLINGTON	TX	76011
209	HUMPHREYS & GLASGOW, INC	10375 RICHMOND AVE		HOUSTON	TX	77042
210	HUNTER & READY, INC	12850 SPURLING RD	SUITE 200	DALLAS	TX	75230
211	HYDROSCIENCE, INC	2659 NOVA DR		DALLAS	TX	75229
212	HYPERGRAPHICS CORPORATION	308 N CARROLL ST		DENTON	TX	76201
213	IBC SYSTEMS CORPORATION	10925 ESTATE LANE	SUITE 215	DALLAS	TX	75238
214	IBM CORP/ENTRY SYSTEMS DIVISION	11400 BURNET RD		AUSTIN	TX	78758
215	IBM/FEDERAL SYSTEMS DIVISION	3700 BAY AREA BLVD		HOUSTON	TX	77058
216	ICL, INC	909 E LAS COLINAS BLVD	SUITE 1600	IRVING	TX	75039
217	IDC CORPORATION	1630 N 10TH		MCALLEN	TX	78501
218	IDEA COMPUTERS, INC	300 JACKSON STREET		RICHMOND	TX	77469
219	IDEAL LEARNING, INC	8505 FREEPORT PKWY	SUITE 360	IRVING	TX	75063-
220	ILC SPACE SYSTEMS	16665 SPACE CENTER BLVD		HOUSTON	TX	77058
221	IMAGE DATA	11550 IH 10 WEST	SUITE 200	SAN ANTONIO	TX	78230
222	IMAGE SCIENCES, INC	5910 NORTH CENTRAL EXPRESSWAY	SUITE 800	DALLAS	TX	75206-

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP
223	IMSL, INC	2500 CITY WEST BLVD	PERMIAN TOWER	HOUSTON	TX	77042
224	INDUSTRIAL COMPUTER SYSTEMS, INC	7255 ENVOY CT		DALLAS	TX	75247
225	INFISY SYSTEMS, INC	333 E NORTH BELT	SUITE 1280	HOUSTON	TX	77060
226	INFORMATION PLUS CORPORATION	4231 SIGMA RD		DALLAS	TX	75244
227	INFORMATION RESOURCES, INC	2301 OHIO DR	SUITE 207	PLANO	TX	75093
228	INFORMATION RETRIEVAL METHODS, INC	1525 N STEMMONS FRWY		CARROLLTON	TX	75006
229	INFORMATION STRATEGIES, INC	888 S GREENVILLE	SUITE 121	RICHARDSON	TX	75081
230	INSTRUMENT SPECIALTIES COMPANY, INC	1111 STANLEY DR	BOX 365	EULESS	TX	76039
231	INSTRUMENT TECH	P O BOX 1012		ADDISON	TX	75001
232	INTELCOM SUPPORT SERVICES	14372 PROTON RD		DALLAS	TX	75244
233	INTELECT, INC	670 INTERNATIONAL PKWY	SUITE 190	RICHARDSON	TX	75081
234	INTELLEX CORPORATION	P O BOX 721495		HOUSTON	TX	77272
235	INTELLIGENCE TECHNOLOGY CORPORATION	16526 WESTGROVE DRIVE		DALLAS	TX	75248
236	INTELLISOURCE MIS	12700 PRESTON RD	SUITE 215	DALLAS	TX	75230
237	INTERGRAPH CORPORATION/THE RAND GROUP DIVISIO	17430 CAMPBELL RD	SUITE 114	DALLAS	TX	75252
238	INTERNATIONAL BUSINESS MACHINES (IBM)	1507 LBJ FREEWAY		DALLAS	TX	75234
239	INTRATECH CORPORATION	1517 W CARRIER PKWY W	SUITE 140	GRAND PRAIRIE	TX	75050
240	IONWERKS	2215 ADDISON		HOUSTON	TX	77030
241	ISC BUNKER RAMS	5615 HIGHPOINT		IRVING	TX	75038
242	ITM, INC	818 EAST MYRTLE		SAN ANTONIO	TX	78212
243	J D CARREKER AND ASSOCIATES, INC	5550 LBJ FREEWAY,	SUITE700	DALLAS	TX	75240
244	J G P SOFTWARE	13150 PENNY STONE		FARMERS BRANCH	TX	75234
245	JMA TECHNOLOGY, INC	5645 HILLCROFT	SUITE 502	HOUSTON	TX	77036
246	JMS CONSULTANTS, INC	11908 E NORTHWEST HWY		DALLAS	TX	75218
247	JOHNSON ENGINEERING	1290 HERCULES	SUITE 201	HOUSTON	TX	77058
248	JOHNSON YOKOGAWA CORPORATION	1201 WEST CROSBY ROAD		CARROLLTON	TX	75006
249	JSM INFORMATION SYSTEMS	9016 WESTBRIAR DR		DALLAS	TX	75228
250	JUST TECHNICAL ASSOCIATES, INC	2777 STEMMONS FRWY #1320		DALLAS	TX	75207
251	KESTRAN, INC	12600 EXECUTIVE DR		STAFFORD	TX	77477
252	KMK ENTERPRISES, INC	701 N BROADWAY	SUITE 204	PLAINVIEW	TX	79072
253	LANDMARK GRAPHICS CORPORATION	333 CYPRESS RUN	SUITE 100	HOUSTON	TX	77094
254	LASER DATA CORPORATION	P O BOX 272292		HOUSTON	TX	77277
255	LAWSON ASSOCIATES	5400 LBJ FRWY #617		DALLAS	TX	75240
256	LCW ENGINEERING COMPANY	624 SORITA CIRCLE		ROCKWALL	TX	75087
257	LEASPAK INTERNATIONAL, INC	2120 LEASPAK PARKWAY		BEDFORD	TX	76021
258	LEPCO, INC	1750 STEBBINS		HOUSTON	TX	77043
259	LIBRA SYSTEMS	1700 ALMA	SUITE 400	PLANO	TX	75075

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP
260	LOCKHEED CORP/AUSTIN DIVISION	6800 BURLESON RD		AUSTIN	TX	78744
261	LOCKHEED ENGINEERING & MANAGEMENT SERVICES CO	2400 NASA ROAD ONE		HOUSTON	TX	77058
262	LOCKHEED MISSILES AND SPACE COMPANY, INC	1150 GEMINI AVE		HOUSTON	TX	77058
263	LOCKHEED SPACE OPERATIONS COMPANY	2400 NASA ROAD ONE	MAIL CODE: A-20	HOUSTON	TX	77058
264	LOGIC, INC	9330 LBJ FREEWAY	SUITE 600	DALLAS	TX	75243
265	LOGICAL SOLUTIONS	2217 TIMBERWOOD	SUITE 104	CARROLLTON	TX	75006
266	LOMAS INFORMATION SYSTEMS, INC (LIS)	C/O MATTHEW S JACOBS	1750 VICEROY DRIVE	DALLAS	TX	75265
267	LOVELACE SCIENTIFIC RESOURCES, INC /BIOMED TE	6901 CORPORATE DR	SUITE 111	HOUSTON	TX	77036
268	LTV AEROSPACE AND DEFENSE COMPANY-VOUGHT AIRC	9314 W JEFFERSON BLVD		DALLAS	TX	75265
269	LTV AIRCRAFT PRODUCTS GROUP	9314 W JEFFERSON BLVD	BOX 655907	DALLAS	TX	75265
270	LTV ENERGY PRODUCTS CO/AUTOMATED FLUID SYSTEM	2310 STEVEN RD		ODESSA	TX	79764
271	LTV MISSILES AND ELECTRONICS GROUP/MISSILES D	1701 W MARSHALL DR	BOX 650003	DALLAS	TX	75265
272	M A P SYSTEMS, INC	18100 UPPER BAY RD	SUITE 100	HOUSTON	TX	77058
273	M-USA BUSINESS SYSTEMS, INC	18111 PRESTON ROAD, SUITE 500		DALLAS	TX	75252
274	MAGEC SOFTWARE, INC	P O BOX 260319		PLANO	TX	75026
275	MANAGEMENT SCIENCE AMERICA, INC	4100 ALPHA RD #1100		DALLAS	TX	75244
276	MANUFACTURING MANAGEMENT SYSTEMS, INC	700 ROCKMEAD DR	SUITE 214	KINGWOOD	TX	77339
277	MARATHON COMPUTER SERVICES	5952 ROYAL LN		DALLAS	TX	75230
278	MARCON & ASSOCIATES, INC	11520 N CENTRAL EXPWY, #210		DALLAS	TX	75243
279	MARK PRODUCTS, INC	10502 FALLSTONE RD		HOUSTON	TX	77099
280	MARMON MOTOR COMPANY	SHILOH RD AND FAIRDALE AVE	BOX 462009	GARLAND	TX	75046
281	MARTIN MARIETTA CORPORATION	1730 NASA ROAD ONE	SUITE 106	HOUSTON	TX	77058
282	MARVEL COMMUNICATIONS CORPORATION	6000 D OLD HEMPHILL RD		FORT WORTH	TX	76134
283	MATERIALS ANALYSIS, INC	10338 MILLER RD		DALLAS	TX	75238
284	MATRIX SYSTEMS, INC	7676 HILLMONT	SUITE 355	HOUSTON	TX	77040
285	MAXIM ENGINEERS, INC	P O BOX 59902		DALLAS	TX	75229
286	MCC SYSTEMS CORPORATION	14950 HEATH ROW FOREST PARKWAY	SUITE 260	HOUSTON	TX	77032
287	MCCAW COMMUNICATIONS	8620 BURNET RD , SUITE 122		AUSTIN	TX	78758
288	MCCRARY ENGINEERING, INC	P O BOX 180332		DALLAS	TX	75218
289	MCDONNELL DOUGLAS ASTRONAUTICS CO/ENGINEERING	16055 SPACE CENTER BLVD		HOUSTON	TX	77062
290	MCDONNELL-DOUGLAS COMPUTER SYSTEMS COMPANY	1501 LBJ FRWY	SUITE 7000	DALLAS	TX	75234
291	MD FRIEDMAN & ASSOCIATES, INC	9241 LBJ FREEWAY, #100		DALLAS	TX	75243
292	MECHANIZED AUTOMATION DATA, INC	9223 WHITEHURST		DALLAS	TX	75243
293	MEDDIC COMPUTER SYSTEMS	110 WILD BASIN RD	SUITE 160	AUSTIN	TX	78746
294	MEDIA MAGNETICS, INC	990 N BOWSER	SUITE 840	RICHARDSON	TX	75081
295	MEDICAL GROUP SYSTEMS, INC	8730 KING GEORGE DRIVE	SUITE 104	DALLAS	TX	75235
296	MEGASOURCE, INC	5001 INFOMART	1950 STEMMONS FRWY	DALLAS	TX	75207

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP
297	MEMBERSHIP SERVICES, INC	2727 CHEMSEARCH BLVD		IRVING	TX	75062
298	MEPCO/CENTRALAB, INC /CAPACITOR DIVISION	7158 MERCHANT AVE		EL PASO	TX	79915
299	MERCRON, INC	P O BOX 831466		RICHARDSON	TX	75083
300	MERIT SYSTEMS, INC	3232 MCKINNEY AVE	SUITE 2110	DALLAS	TX	75204
301	MERRILL CONSULTANTS	10717 CROMWELL DR		DALLAS	TX	75229
302	MESA SOFTWARE	3435 GREYSTONE DR	SUITE 106	AUSTIN	TX	78731
303	MICHAEL MEAD & ASSOCIATES	15181 BUSINESS AVENUE		DALLAS	TX	75244
304	MICON ENGINEERING	100 GRAHAM RD		COLLEGE STATION	TX	77845
305	MICRO ASSOCIATES, INC	2349 MEMORIAL BLVD		PORT ARTHUR	TX	77640
306	MICRO MODE, INC	4006 MT LAUREL		SAN ANTONIO	TX	78240
307	MICRO POWER AND LIGHT COMPANY	12810 HILLCREST RD	SUITE 120	DALLAS	TX	75230
308	MICRO-SYNC	1655 HICKORY DR	SUITE B	HALTOM CITY	TX	76117
309	MICROGRAFX, INC	1820 N GREENVILLE AVE		RICHARDSON	TX	75081
310	MICROLINK INC	8533 ALMEDA GENOA		HOUSTON	TX	77075
311	MICRONYX, INC	1901 N CENTRAL EXPWY	SUITE 400	RICHARDSON	TX	75080
312	MICROSOLUTIONS	10670 N CENTRAL EXPY #105		DALLAS	TX	75231
313	MICROSPEC, INC	840 EAST CENTRAL PARKWAY	SUITE 100	PLANO	TX	75074
314	MICROX, INC	9444 OLD KATY RD	SUITE 103	HOUSTON	TX	77055
315	MICROX, INC /HOUSTON TIME SHARING DIVISION	9444 OLD KATY RD	SUITE 103	HOUSTON	TX	77055
316	MID CONTINENT DATA SERVICES, INC	2828 WHITE SETTLEMENT RD		FORT WORTH	TX	76107
317	MIL-COM ELECTRONICS CORP	3503 CROSSPOINT		SAN ANTONIO	TX	78217
318	MIMICS, INC	7000 REGENCY SQUARE BLVD	SUITE 210	HOUSTON	TX	77036
319	MINCO TECHNOLOGY LABS, INC	1805 RUTHERFORD LN		AUSTIN	TX	78754
320	MIS SOFTWARE COMPANY	8900 SHOAL CREEK BLVD	SUITE 113	AUSTIN	TX	78758
321	MITEK SYSTEMS CORPORATION	2033 CHENNAULT DR	SUITE 100	CARROLLTON	TX	75006
322	MIX SOFTWARE, INC	1132 COMMERCE DR		RICHARDSON	TX	75081
323	MODULAR DATA SYSTEMS, INC	2525 BAY AREA BLVD	3RD FLOOR	HOUSTON	TX	77058
324	MORGAN COMPUTING COMPANY	1950 STEMMONS FRWY	SUITE 2045	DALLAS	TX	75207
325	MORTON & MORTON SOFTWARE	820 NORTHWOOD		FORT WORTH	TX	76107
326	MTECH	P O BOX 152055		IRVING	TX	75015
327	MURDOCK ENGINEERING COMPANY	5100 AIRPORT FREEWAY WEST		IRVING	TX	75061
328	NANCY A MATHEWS	P O BOX 796033		DALLAS	TX	75379-
329	NAPP, INC	2104 KRAMER LN		AUSTIN	TX	78758
330	NATIONAL BUSINESS CONTROL SYSTEMS	2120-E W BRAKER LN		AUSTIN	TX	78758
331	NATIONAL INSTRUMENTS CORPORATION	6504 BRIDGE POINT PKY		AUSTIN	TX	78730-
332	NEW HORIZONS SOFTWARE, INC	206 WILD BASIN RD	SUITE 109	AUSTIN	TX	78746
333	NEW WORLD SYSTEMS	5001 INFOMART	1950 STEMMONS FRWY	DALLAS	TX	75207

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP
334	NEWMAN DATA SERVICES	3424 EAST GLEN		EL PASO	TX	79936
335	NOTCH + ASSOCIATES	2603 CYPRESS HILLS CT	SUITE 200	ARLINGTON	TX	76006
336	NOVA GRAPHICS INTERNATIONAL CORPORATION	1515 CAPITAL OF TEXAS HWY S		AUSTIN	TX	78746
337	NYKE SYSTEMS	10031 MONROE DR	SUITE 106	DALLAS	TX	75229
338	OASIS BUSINESS SYSTEMS	17070 DALLAS PKWY #106		DALLAS	TX	75248
339	ODESSA ENGINEERING, INC	2013 WELLS BRANCH PARKWAY	SUITE 204	AUSTIN	TX	78728
340	OGRE PARTNERS, LTD , DBA DPC & A	6510 ABRAMS RD #410		DALLAS	TX	75231
341	ON-LINE DATA, INC	1177 ROCKINGHAM		RICHARDSON	TX	75080
342	ON-LINE RESOURCES	P O BOX 925393	1050 DEL NORTE	HOUSTON	TX	77018
343	OPCODE, INC	4901 SPICEWOOD SPRINGS RD		AUSTIN	TX	78753-8
344	OPEN + VOICE, INC	4975 PRESTON PARK BLVD	SUITE 150	PLANO	TX	75093
345	OPTIC-ELECTRONIC CORPORATION	11545 PAGEMILL RD	BOX 740668	DALLAS	TX	75374
346	OVERHEAD DOOR	6750 LBJ FREEWAY, SUITE 1200		DALLAS	TX	75240
347	P & H ENGINEERING	P O BOX 1711		DICKINSON	TX	77539-1
348	PALANTIR, INC	4455 SOUTH PADRE ISLAND DR	SUITE 43	CORPUS CHRISTI	TX	78411-4
349	PANDEL INSTRUMENTS, INC	2100 NORTH HIGHWAY 360	SUITE 1607	GRAND PRAIRIE	TX	75050
350	PARSEC, INC	10345 BROCKWOOD RD		DALLAS	TX	75238
351	PATE-WEST INTERESTS	3939 BRAXTON		HOUSTON	TX	77063
352	PEGASUS SOFTWARE SYSTEMS	4909 AIRPORT FREEWAY		FORT WORTH	TX	76117
353	PENMAN PRODUCTS CORPORATION	705 N BOWSER #125		RICHARDSON	TX	75081
354	PENQUIN TECHNOLOGICAL RESOURCES	1320 S UNIVERSITY #113		FORT WORTH	TX	76107
355	PERFORMANCE MANAGEMENT, INC	1050 NORTH POST OAK	SUITE100	HOUSTON	TX	77055
356	PERFORMANCE METRICS, INC	5825 CALLAGHAN	SUITE 225	SAN ANTONIO	TX	78228
357	PERMIAN BUSINESS GROUP	2500 N BIG SPRING SUITE 275	P O BOX 10963	MIDLAND	TX	79705
358	PERSONAL COMPUTER SYSTEMS	3107 TAM O'SHANTER LANE		RICHARDSON	TX	75080
359	PERTROL INTERNATIONAL, INC	8935 EMPRESS ROW		DALLAS	TX	75247
360	PETROCOMP SYSTEMS, INC	1111 NORTH LOOP WEST	SUITE 940	HOUSTON	TX	77008
361	PETRODATA BUSINESS SYSTEMS, INC	6510 ABRAMS RD	SUITE 500	DALLAS	TX	75231
362	PETROLEUM COMPUTING, INC	4925 GREENVILLE AVE	600 ONE ENERGY SQUARE	DALLAS	TX	75206
363	PETROLEUM SOFTWARE, INC	400 N ST PAUL	SUITE 1110	DALLAS	TX	75201
364	PFT, INC	999 CHEROKEE TRACE		WHITE OAK	TX	75693
365	PHILIPS COMPONENTS	7158 MERCHANT AVE		EL PASO	TX	79915
366	PHILIPS GROUP, INC	P O BOX 14668		HOUSTON	TX	77221
367	PHILIPS INFORMATION SYSTEMS, INC	15301 DALLAS PARKWAY	SUITE 300	DALLAS	TX	75248
368	PINSON ASSOCIATES, INC	P O BOX 9648		AUSTIN	TX	78766
369	PLATTEL, CONYNGHAM & AGNEW	5001 INFOMART	1950 STEMMONS FRWY	DALLAS	TX	75207
370	PLENARY SYSTEMS, INC	11969 PLANO RD	SUITE 130	DALLAS	TX	75243

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP
371	PMC ENTERPRISE/COMPUTER STUFF	123 EAST 7TH ST		AUSTIN	TX	78701
372	POCKET SOFT, INC	7676 HILLMONT	SUITE 195	HOUSTON	TX	77040
373	PRECISION, INC	8404 STERLING STREET, SUITE A		IRVING	TX	75063
374	PRICE WATERHOUSE/ACTRON DIVISION	2212 ARLINGTON DOWNS RD	SUITE 100	ARLINGTON	TX	75006
375	PRODUCTS DIVERSIFIED INTERESTS	9720 BEECHNUT	SUITE 406	HOUSTON	TX	77036
376	PROF MICRO SYSTEMS, INC	P O BOX 211056		BEDFORD	TX	76095
377	PROJECT SOLUTIONS CORPORATION INC	2450 FONDREN ST	SUITE 300	HOUSTON	TX	77063
378	PROPOSAL MASTERS, INC	4540 IDLEDELL DR		FORT WORTH	TX	76116
379	PROSE SOFTWARE	2921 BROWN TRAIL #230		BEDFORD	TX	76021
380	PROTOS SOFTWARE COMPANY	7004 BEE CAVES RD	SUITE 2200	AUSTIN	TX	78746
381	PSI ENVIRONMENTAL SERVICES, INC	201 WEST WALL	SUITE 401 EAST	MIDLAND	TX	79701
382	PTXI	2000 WESTRIDGE DR		IRVING	TX	75038
383	QUADSTAR CORPORATION	5220 SPRING VALLEY RD #200		DALLAS	TX	75240
384	QUINTESSENCE COMPUTING, INC	2904 GUADALUPE ST		AUSTIN	TX	78705-
385	R & D AERONAUTICAL ENGINEERING COMPANY, INC	P O BOX 861108		PLANO	TX	75074-
386	R & E BUSINESS SYSTEMS, INC	5310 HARVEST HILL	SUITE 139	DALLAS	TX	75230
387	R D INDUSTRIES	2361 FORT WORTH	BOX 531483	GRAND PRAIRIE	TX	75053-
388	R SYSTEMS, INC	10920 SWITZER	SUITE 113	DALLAS	TX	75238
389	R&W SOFTWARE, INC	7718 WOOD HOLLOW DR	SUITE 200	AUSTIN	TX	78731
390	RADIAN CORPORATION	8501 MOPAC BLVD	BOX 201088	AUSTIN	TX	78759-
391	RAINBOW SOFTWARE SYSTEMS, INC	2715 BISSONNET ST	SUITE 213	HOUSTON	TX	77005
392	REAL-E-DATA, INC	2634 S CARRIER PKWY	SUITE 107	GRAND PRAIRIE	TX	75051
393	RECOGNITION EQUIPMENT, INC	2701 E GRAUWYLER RD		IRVING	TX	75061
394	REDBIRD ELECTRONICS, INC	P O BOX 763775	REDBIRD AIRPORT	DALLAS	TX	75376
395	REED PRODUCTS INC	4129 SOUTHERLAND RD , BLDG D		HOUSTON	TX	77092
396	REPUBLIC DATA SERVICES	4241 MCCART AVE	P O BOX 11405	FORT WORTH	TX	76115
397	REXCOM SYSTEMS CORPORATION	10333 RICHMOND AVE	SUITE 400	HOUSTON	TX	77042
398	RIBIGITAL ELECTRONICS, INC	3327 WINTHROP AVE	SUITE 157	FORT WORTH	TX	76116
399	ROBINSON ENGINEERING COMPANY	1914 SILVER STREET		GARLAND	TX	75042
400	ROCKWELL SPACE OPERATIONS COMPANY	600 GEMINI AVENUE		HOUSTON	TX	77058-
401	ROCKWELL/AUTONETICS MARINE & AIRCRAFT SYSTEMS	9566 RAILROAD DIRVE	BOX 4859	EL PASO	TX	79924
402	ROCKWELL/COMMAND & CONTROL SYSTEMS DIVISION	3200 E RENNER ROAD		RICHARDSON	TX	75081
403	RODKE & ASSOCIATES	P O BOX 1261		BEDFORD	TX	76095
404	ROUGHNECK SYSTEMS, INC	13663 JUPITER RD	SUITE 401	DALLAS	TX	75238
405	ROUTEWARE, INC	3815 LISBON ST	SUITE 201	FORT WORTH	TX	76107
406	RT SYSTEMS, INC	P O BOX 809		ALLEN	TX	75002
407	RUBICON CORPORATION	1217 DIGITAL DRIVE, SUITE 125	P O BOX 852099	RICHARDSON	TX	75085-

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP
408	S-C SOFTWARE CORPORATION	2331 GUS THOMASSON	SUITE 125	DALLAS	TX	75228
409	S-TEC CORP	RT 4 BLDG 946	FORT WOLTERS COMPLEX	MINERAL WELLS	TX	76067
410	SAVANT CORPORATION	11211 KATY FWY	SUITE 250	HOUSTON	TX	77079
411	SCHINDLER MACHINE WORKS	4954 W OREM DR		HOUSTON	TX	77045
412	SCIENTIFIC AND ENGINEERING SOFTWARE	1301 W 25TH ST , SUITE 300		AUSTIN	TX	78705
413	SCIENTIFIC COMMUNICATIONS, INC	2908 NATIONAL DR		GARLAND	TX	75041
414	SCOTT INSTRUMENTS CORPORATION	1111 WILLOW SPRINGS DRIVE		DENTON	TX	76205
415	SEI CORPORATION/BENEFIT SERVICES DIVISION	2777 STEMMONS FRWY , SUITE 700	SUITE 700	DALLAS	TX	75207-
416	SEISMIC ENGINEERING COMPANY	2659 NOVA DR		DALLAS	TX	75229
417	SERCON CORPORATION	4611 NORTH LINDHURST		DALLAS	TX	75229
418	SERV-AIR, INC	P O BOX 6669		GREENVILLE	TX	75401
419	SHARED FINANCIAL SYSTEMS, INC	15301 NORTH DALLAS PKWY	SUITE 600	DALLAS	TX	75248
420	SHAW SYSTEMS ASSOCIATES, INC	6200 SAVOY	SUITE 600	HOUSTON	TX	77036
421	SHERRILL ENVIRONMENTAL CONSULTANTS, INC	150 N MACARTHUR		IRVING	TX	75061
422	SMALLWOOD AND SON MACHINE COMPANY	3657 E KIEST BLVD		DALLAS	TX	75203
423	SMARTECH SYSTEMS, INC	10015 W TECHNOLOGY BLVD		DALLAS	TX	75220
424	SMITH INTERNATIONAL, INC	16730 HARDY ST	P O BOX 60068	HOUSTON	TX	77205
425	SOFTSYSTEMS, INC	1 SUMMIT AVE , SUITE 300	MALLICK TOWER	FORT WORTH	TX	76102
426	SOFTWARE DYNAMICS CORPORATION	1800 WEST LOOP SOUTH	SUITE 960	HOUSTON	TX	77027
427	SOFTWARE INTERNATIONAL CORPORATION	12221 MERIT DR #920		DALLAS	TX	75251
428	SOFTWARE RECORDING CORPORATION OF AMERICA	6060 NORTH CENTRAL EXPRESSWAY	SUITE 122	DALLAS	TX	75206
429	SOFTWARE SHAPERS, INC	P O BOX 639		GRAPEVINE	TX	76051
430	SOFTWARE UNLIMITED MEMORY SYSTEMS	P O BOX 3628		LAREDO	TX	78044-
431	SOUTH COAST DATA, INC	1815 CORAL ST		HOUSTON	TX	77012
432	SOUTHERN AVIONICS COMPANY INC	5000 BELMONT	BOX 5345	BEAUMONT	TX	77706
433	SOUTHWEST TEST, INC	903 N BOWSER, SUITE 140		RICHARDSON	TX	75081
434	SOUTHWESTERN BELL CORPORATION	208 S AKARD	ONE BELL PLAZA	DALLAS	TX	75202
435	SOUTHWESTERN LABORATORIES, INC	P O BOX 224227		DALLAS	TX	75222
436	SPACE INDUSTRIES	711 W BAY AREA BLVD	SUITE 320	WEBSTER	TX	77598
437	SQUYRES SOFTWARE, INC	9451 LBJ FREEWAY	SUITE 102-LB68	DALLAS	TX	75243
438	SST RESEARCH, DEVELOPMENT & SUPPORT, INC	P O BOX 171378		ARLINGTON	TX	76003
439	STALLION SOFTWARE, INC	P O BOX 1505		SUGAR LAND	TX	77487
440	STERLING SOFTWARE	9441 LBJ FRWY #410		DALLAS	TX	75243
441	STERLING SOFTWARE/DIRECTIONS DIVISION	15301 NORTH DALLAS PKWY #400		DALLAS	TX	75248
442	STEWART SYSTEMS, INC /STEWART HANDLING CENTER	3730 FOREST LANE		GARLAND	TX	75042
443	STONEHOUSE & COMPANY	4100 SPRING VALLEY ROAD	SUITE 400	DALLAS	TX	75244
444	STRATEGIC TECHNOLOGY SERVICES, INC	1912 AVENUE K	SUITE 100	PLANO	TX	75074

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP
445	STUBBS OVERBECK & ASSOCIATES, INC	12727 SOUTHERWOOD DR	SUITE 200	HOUSTON	TX	77034
446	SUMMIT SOFTWARE, INC	15301 DALLAS PARKWAY	SUITE 750 LB16	DALLAS	TX	75248
447	SUMMIT SOLUTIONS	4020 MCEWEN	SUITE 158	DALLAS	TX	75244
448	SWP, INC	1000 W FULLER		FORT WORTH	TX	76115
449	SXCELL SYSTEMS, INC	2428 GRAVEL ST		FORT WORTH	TX	76118
450	SYMBOLICS FINANCIAL SYSTEMS, INC	1750 REGAL ROW		DALLAS	TX	75235
451	SYNERCOM TECHNOLOGY, INC	2500 CITY WEST BLVD	SUITE 1100	HOUSTON	TX	77042
452	SYNTEC CORP	2201 DONLEY DR		AUSTIN	TX	78758
453	SYSTEMIC COMPUTER SERVICES	2802 34TH ST		LUBBOCK	TX	79410
454	SYSTEMS ENGINEERING SERVICES	1218 W MARY		CLIFTON	TX	76634
455	SYSTEMS RESEARCH LABORATORIES/SAN ANTONIO REG	750 E MULBERRY	SUITE 310	SAN ANTONIO	TX	78212
456	SYSTEMS SOFTWARE, INC	16302 SEALARK		HOUSTON	TX	77062
457	SYSTEMS SPECIALISTS, INC	3030 LBJ FREEWAY	SUITE 1700 LB15	DALLAS	TX	75234
458	SYSTEMWARE, INC	12770 COIT RD	SUITE 1008	DALLAS	TX	75251
459	T C TECH	3617 RAIDER DR		HURST	TX	76053
460	TALON TECHNOLOGY CORPORATION	1819 FIRMAN DRIVE, SUITE 137		RICHARDSON	TX	75081
461	TANDEM COMPUTERS INC	14231 TANDEM BLVD		AUSTIN	TX	78728-
462	TANDY BUSINESS PRODUCTS	6363 GRAPEVINE HIGHWAY		FORT WORTH	TX	76180
463	TANDY CORPORATION/TANDY ADVANCED PRODUCTS	1001 NORTHEAST LOOP 820		FORT WORTH	TX	76131
464	TANDY HOME COMPUTERS	1001 NORTHEAST LOOP 820		FORT WORTH	TX	76131
465	TDC DEFENSE SYSTEMS GROUP	621 SIX FLAGS DR		ARLINGTON	TX	76011
466	TECH-SYM CORPORATION	10500 WEST OFFICE DR		HOUSTON	TX	77042
467	TECHNICAL EVALUATION & MANAGEMENT SYSTEMS, IN	5151 BELTLINE RD	1110 PRESTONWOOD TOWER	DALLAS	TX	75240
468	TECHNICAL SOFTWARE & ENGINEERING, INC	801 E CAMPBELL RD	SUITE 345	RICHARDSON	TX	75081
469	TECHNOLOGICAL SUPPLY, INC	P O BOX 331509		FORT WORTH	TX	76163
470	TECHTRONIC DATA SYSTEMS, INC	407 NORTH BIG SPRING	SUITE 100	MIDLAND	TX	79701
471	TECHWORKS COMPUTER SERVICES, INC	16950 DALLAS PARKWAY	SUITE 105	DALLAS	TX	75248-
472	TELECOMMUNICATIONS DATA SYSTEMS COMPANY	50 BUSINESS PARKWAY	SUITE B	RICHARDSON	TX	75081
473	TELECOMMUNICATIONS SUPPORT SYSTEMS, INC	2775 VILLA CREEK	SUITE 250	DALLAS	TX	75234
474	TELXON CORPORATION	7280 WYNNWOOD	BOX 7478	HOUSTON	TX	77248
475	TERRA MARINE ENGINEERING	10451 BROCKWOOD RD		DALLAS	TX	75238
476	TEXAS AEROSPACE SERVICES INC	3550 MAPLE ST		ABILENE	TX	79602-
477	TEXAS INSTRUMENTS	13500 N CENTRAL EXPWY		DALLAS	TX	75265
478	TEXAS MICROSYSTEMS, INC	10618 ROCKLEY RD		HOUSTON	TX	77099
479	TEXAS PROCESSOR, INC	8122 DATAPOINT DR	SUITE 910	SAN ANTONIO	TX	78229
480	TEXASOFT, INC	P O BOX 1169		CEDAR HILL	TX	75104
481	TEXSCAN CORPORATION/COMMUNICATIONS PRODUCTS D	10841 PELLICANO DR		EL PASO	TX	79935

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP
482	THE FLAGSHIP GROUP	12221 MERIT, SUITE 400		DALLAS	TX	75251
483	THE LTV CORPORATION	LTV CENTER	P O BOX 655003	DALLAS	TX	75265
484	THE PERSONAL ROBOT COMPANY	P O BOX 815608		DALLAS	TX	75381
485	THE SOFTWARE FACTORY, INC	17610 MIDWAY RD	SUITE 134	DALLAS	TX	75287
486	THE SYSTEMS CENTER, INC	2477 GATEWAY,	SUITE 101	IRVING	TX	75063
487	THE THORSON COMPANY SOUTHWEST	4445 ALPHA RD , SUITE 109		DALLAS	TX	75244
488	THIOKOL CORPORATION-LONGHORN DIV/LONGHORN ARM	P O BOX 1149		MARSHALL	TX	75671
489	TIDELAND SIGNAL CORP	4310 DIRECTORS ROW	BOX 52430	HOUSTON	TX	77052
490	TILTRAC CORPORATION	4302 SUNBELT DRIVE		DALLAS	TX	75248
491	TIME ENERGY SYSTEMS, INC	3200 WILCREST DR	SUITE 440	HOUSTON	TX	77042
492	TITUS COMMUNICATIONS, INC	1001 ROSS AVE		DALLAS	TX	75202
493	TOKHEIM AUTOMATION CORPORATION	9303 SAM HOUSTON PKWY		HOUSTON	TX	77099-52
494	TRACOR AEROSPACE INC /LAREDO OPERATIONS	306 FLIGHT LINE		LAREDO	TX	78041
495	TRINITY COMPUTING SYSTEMS, INC	11 GREENWAY PLAZA	SUITE 1212	HOUSTON	TX	77046
496	TRIPLE/S DYNAMICS INC	1031 S HASKELL	BOX 11037	DALLAS	TX	75223
497	TRW, INC	2525 BAY AREA BLVD	SUITE 620	HOUSTON	TX	77058
498	TURNAROUND COMPUTING, INC	2912 MOLLIMAR		PLANO	TX	75075-63
499	TYMLABS CORPORATION	811 BARTON SPRINGS	SUITE 511	AUSTIN	TX	78704
500	U S DATA CORPORATION	1551 GLENVILLE		RICHARDSON	TX	75081
501	UDD INDUSTRIES, INC	129 LUTTRELL ST		ARLINGTON	TX	76010
502	UOP, INC	8434 GAULT LANE		SAN ANTONIO	TX	78209
503	UNIRAS, INC	5429 LBJ FREEWAY, SUITE 650		DALLAS	TX	75240
504	USA ELECTRONICS	9090 N STEMMONS FRWY		DALLAS	TX	75247
505	VALUATION TECHNOLOGY	4124 COLE AVE #210		DALLAS	TX	75204
506	VDM WOODRUFF, INC	P O BOX 210233		BEDFORD	TX	76095
507	VE HOLDING CORPORATION	920 113TH ST		ARLINGTON	TX	76011
508	VEECO INTEGRATED AUTOMATION, INC	10382 MILLER RD		DALLAS	TX	75238
509	VERTICAL MARKET SOFTWARE	800 E CAMPBELL	SUITE 199	RICHARDSON	TX	75081
510	WACOM PRODUCTS INC	HWY 6 W AND SPUR 412	BOX 21145	WACO	TX	76702
511	WARDLAW, CUNNINGHAM & CO , P C	14200 GULF FREEWAY	SUITE 203	HOUSTON	TX	77034-53
512	WATSON STEACH & COMPANY	1333 WEST PIONEER PARKWAY, SUI	P O BOX 701	ARLINGTON	TX	76013
513	WEATHER SCAN INC	LOOP 132 AND THROCKMORTON HWY	STAR RT BOX 26	OLNEY	TX	76374
514	WESTERN ATLAS INTERNATIONAL, INC /INTEGRATED	10205 WESTHEIMER RD		HOUSTON	TX	77042
515	WESTERN GEOPHYSICAL COMPANY OF AMERICA	P O BOX 2469		HOUSTON	TX	77252
516	WESTINGHOUSE ELECTRIC CORP/DEFENSE ELECTRONIC	7807 E BY-PASS		COLLEGE STATION	TX	77845
517	WESTRONIC SYSTEMS CORP	1735 ANALOG DR		RICHARDSON	TX	75081
518	WILFRED BAKER ENGINEERING	P O BOX 6477		SAN ANTONIO	TX	78209

COMPANY NAME AND ADDRESS

REC#	NAM	AD1	AD2	CIT	STA	ZIP
519	WINSYSTEMS, INC	715 STADIUM DR EAST	SUITE 100	ARLINGTON	TX	76011-9
520	XEROX CORPORATION	222 WEST LAS COLINAS BOULEVARD		IRVING	TX	75039
521	ZADALL	1903 CENTRAL DRIVE	SUITE 300	BEDFORD	TX	76021

Source: Company information provided by the Texas Innovation Network System through the Office of Advanced Technology, Texas Department of Commerce, 1991.

Appendix D.
Texas Business Incubators

Abilene

Business Innovation Center
Mr. Gus Holt & Mr. James Campbell
674 East Hwy. 80
Abilene, Texas 79601
Tel: 915/676-3241
Nonprofit
Lt. Mfg., service & other

Austin

Austin Technology Incubator
Ms. Laura J. Kilcrease, Director
8920 Business Park Drive, Suite 150
Austin, Texas 78759-7405
Tel: 512/794-9994 Fax: 512/794-9997

Greater Austin Small Business Incubator
(formerly Huston-Tillotson)
Mr. Walter Stafford
1820 East 8th Street
Austin, Texas 78702
Tel: 512/476-7421 Fax: 512/474-0762
Nonprofit
Light manufacturing, services

Southeast Business Incubator
Edith Valdespino, Manager
2020 East St. Elmo Road
Austin, Texas 78744
Tel: 512/499-6362 Fax: 512/499-6360
Nonprofit
Manufacturing, high tech & services

Southwest Software
Mr. Thomas Burns
P.O. Box 26823
Austin, Texas 78731
Tel: 512/345-2493

Beaumont

Beaumont Business Incubator
Ms. Beverly Hatcher
1090 South 4th Street
Beaumont, Texas 77701
Tel: 409/835-1000 Fax: 409/832-2540
Nonprofit
Services, agri-business

Brenham

Promethean Corporation
Mr. Doug Hutchins
406 West Horton
P.O. Box 417
Brenham, Texas 77834-0417
Tel: 409/836-6525 Fax: 409/836-1056
For Profit
Manufacturing, high tech & service

Brownwood

Brownwood Economic Development Corporation
Mr. Ed Latta
P.O. Box 1389
Brownwood, Texas 76804-1389
Tel: 915/646-6751

Bryan

Bryan Business & Technology Center
Ms. Cindy McLemore, Manager
P.O. Box 1000
c/o Bryan Development Foundation
Bryan, Texas 77805
Tel: 409/361-3607 Fax: 409/361-3885
Nonprofit
High tech

Corsicana

K-Wolen's Industrial Incubator
Ms. Melinda Sharpley
200 North 12th Street
Corsicana, Texas 75110
Tel: 903/654-4841 Fax: 903/654-4997

Dallas

Dallas County Community College District Business Incubation Center
Mr. Mark Keith
1402 Corinth Street
Dallas, Texas 75212
Tel: 214/565-5851 Fax: 214/565-5817

El Campo

El Campo Business Incubator
Mr. Kyle Smith
Chamber of Commerce, P.O. Box 446
El Campo, Texas 77437
Tel: 409/543-6271
Nonprofit (Incubator without walls)
Manufacturing

Fort Worth

Fort Worth Incubator Corporation
Mr. Reinaldo (Renny) Rosas
221 West Exchange, #202
Fort Worth, Texas 76101
Tel: 817/626-2874 Fax: 817/336-3299
For profit
Mfg., high tech & services

Galveston

Galveston Economic Development Corporation
Mr. J. William Lauderback
2106 Seawall Boulevard
Galveston, Texas 77550
Tel: 409/762-8355

Garland

Business Ventures of Garland
Mr. Frank O'Donnell
Mr. Harry Swanson
2734 West Kingsley, Suite L2
Garland, Texas 75041
Tel: 214/278-8784 Fax: 214/205-2794
Nonprofit

Houston

Entrepreneurial Development Center
Mr. C. Dean Kring, Director of Research
5320 Gulfton, #11
Houston, Texas 77081
Tel: 713/845-2400 Fax: 713/665-1359
For Profit
Manufacturing & services

Palm Center Business & Technology Center
Mr. Joel Flowers, Director of Operations
5330 Griggs
Houston, Texaas 77021
Tel: 713/845-2400 Fax: 713/641-3853
Nonprofit
Services

Houston (continued)

Women's Business Center
Ms. Sandy White, Chairman
8845 Long Point Road
Houston, Texas 77055
Tel: 713/864-7733
For profit
Women-owned businesses

Lubbock

Lubbock Center for Innovation
Mr. Frank Espino & Ms. Lori Oswalt
2579 South Loop 289, Suite 100
Lubbock, Texas 79423
Tel: 806/748-1515 Fax: 806/748-1659

Marshall

Marshall Business Development Center
Mr. Charles Fletcher
110 S. Bolivar, Suite 200
Marshall, Texas 75670
Tel: 903/935-0092 Fax: 903/935-1372
Nonprofit
Manufacturing

Midlothian

Midlothian Economic Development Commission
Ms. Pam Mundo
P.O. Box 609
Midlothian, Texas 76065
Tel: 214/775-8500 Fax: 214/775-8932

Odessa

Noel, W.D./Odessa College Business Incubator
Mr. Jeff Melton, Director
201 W. University
Odessa, Texas 79764
Tel: 915/333-7409 Fax: 915/333-7413

University of Texas Permian Basin Center for Energy & Economic Diversification
Mr. Bob Boothe
4901 E. University Blvd.
Odessa, Texas 79762-8301
Tel: 915/561-5500 Fax: 915/561-5534
Nonprofit
Energy related light mfg., high tech & services

Pharr

Pharr Industrial Foundation
Mr. Ralph DeAnda, E.V.P.
P.O. Box 59
Pharr, Texas 78577
Tel: 512/781-1676
Nonprofit
Manufacturing

Richardson

Advanced Technology Innovation Center
Ms. Judy Crovisier, Director
2201 Waterview Parkway
Richardson, Texas 75080
Tel: 214/690-2250 Fax: 214/699-6678
Nonprofit

San Antonio

El Parian
Mr. David Garza
1410 Guadelupe Street
San Antonio, Texas 78207
Tel: 512/225-1311 Fax: 512/223-3792
Nonprofit
Retail, service

Texas Research & Technology Center
Mr. York Duncan
& Ms. Stephanie Blandford
14785 Omicron Drive
San Antonio, Texas 78245
Tel: 512/677-6000 Fax: 512/677-6070
Nonprofit
Manufacturing, high tech

Stafford

Free Enterprise Center
Mr. Ray Arnett, Director
13600 Murphy Road
Stafford, Texas 77477
Tel: 713/499-4870 Fax: 713/499-8194
Nonprofit
Manufacturing, high tech & service

Sweetwater

People for Progress
Mr. Gary Spaulding
301 Arkansas
Sweetwater, Texas 79556
Tel: 915/235-4806 Fax: 915/235-4950
Nonprofit
Manufacturing

Tyler

Tyler Research & Technology
Mr. Glenn Galiga, Manager
1530 S. SW Loop 323
Tyler, Texas 75701
Tel: 903/510-2975 Fax: 903/510-2978
Nonprofit
Manufacturing, high tech & service

Victoria

Victoria Business Center
Mr. Tom Murrah
700 Main Center, Suite 102
Victoria, Texas 77901
Tel: 512/575-8944 Fax: 512/572-8852
Nonprofit
Manufacturing & services

Waco

Heart of Texas Business Resource Center
Mrs. Lu Billings, Executive Director
4601 North 19th Street
Waco, Texas 76708
Tel: 817/754-8898 Fax: 817/756-0776
Nonprofit
Manufacturing & services

Source: Austin Technology Incubator, "Texas Business Incubators" (unpublished listing), July 1992.

Appendix E.
Critical Technology Lists

U.S. Office of Science and Technology Policy
Panel on National Critical Technologies

Aeronautics and Surface Transportation
Aeronautics
Surface Transportation Technologies

Biotechnology and Life Sciences
Applied Molecular Biology
Medical Technology

Energy and Environment
Energy Technologies
Pollution Minimization, Remediation, and Waste Management

Information and Communications
Computer Simulation and Modeling
Data Storage and Peripherals
High Definition Imaging and Displays
High Performance Computing and Networking
Microelectronics and Optoelectronics
Sensors and Signal Processing
Software

Manufacturing
Flexible Computer Integrated Manufacturing
Intelligent Processing Equipment
Micro- and Nanofabrication
Systems Management Technologies

Materials
Ceramics
Composites
Electronics and Photonic Materials
High Performance Metals and Alloys
Materials Synthesis and Processing

Source: White House, Office of Science and Technology Policy, *Report of the National Critical Technologies Panel* (Washington, D.C.: U.S. Government Printing Office, March 1991).

Japanese Ministry of International Trade and Industry (MITI) Basic Technologies for Industry

New Materials
High-Temperature Superconducting Materials
Nonlinear Optoelectronic Materials
Ferromagnetic Materials
Molecular Functioning Materials
Advanced Composite Materials
Alloys/Metallic Compounds
Fine Ceramics
Carbon Materials
Amorphous Materials
Highly Pure Polymer Materials
Silicon Chemical Materials
Microelectronic Materials

Electronics
Superconducting Devices
Quantized Elements
Power Electronic Elements
Optical Elements
Large Area Circuit Elements

Biotechnology
Animal and Plant Cell Engineering
High Performance Enzymes and Biomaterials
Genetic Engineering
Biodatabanks
Screening and Isolation of Genes from All Sources
Bioreactor Technology

New Material/Electronics-Related Technologies
Atomic Level Precision Manipulation Technologies
Metallic and Inorganic Materials Process Technologies
Precision Molecular Alignment Technology
Evaluation, Analysis and Measuring Technology
Design and Simulation Technology
Photoreactive Process Technology
Processing Technology for Extreme Environments

Bioelectronics
Protein Alignment Technology
Biomembrane Technology
Analysis of Bio-Related Materials

Biomaterials
Bio-Mimicking Materials
Biocompatible Materials
Biochemical Technology
Bioprocessing

Computer Software and Systems Engineering
Self-Organized Data Processing Systems
Self-Organized Neural Networks
Ultraparallel Processing Architecture
Integrated Mechanical Control Software
Software Development Transfer
Disaster Prevention Technology
Environmental Control Technology
Human-Related Technology
Resource and Energy Technology
Robotic Technology

Source: Japanese Ministry of International Trade and Industry, *Trends and Future Tasks in Industrial Technology* (Tokyo: Sangyo Gijutsu no Doko to Kadai, October 20, 1988).

European Community Critical Technologies

Information Technology and Telecommunications
Electronic Components
Software and Information Processing
Peripherals
Fundamental Research
Prenormative Research (e.g., standards)
Broadband Infrastructure
Broadband Equipment
Broadband Services

Industrial Materials and Technologies
Quality and Reliability Technologies
Techniques for Shaping, Joining and Assembly, and for Surface Treatment
Catalysts and Membranes
Powder Technology
Other High-Value Materials (e.g., composites)
Superconducting Materials

Aeronautics
Aerodynamics and Flight Mechanics
Materials
Acoustics
Computation
Airborne Systems and Equipment
Propulsion Integration
Design and Manufacturing Technologies

Life Sciences
Basic Plant Biology
Molecular Investigation of Genomes of Complex Organisms
Neuroscience
Biotechnology Based Agro-Industrial Research and Technology Development

Energy
Controlled Nuclear Fusion
Non-Nuclear Energy
Renewables
Energy Efficient Technologies
Energy from Fossil Fuels
Energy Modeling and Environment

Source: Commission of the European Communities, *First Report on the State of Science and Technology in Europe* (Brussels, Belgium, Fall 1988).

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