Geophysical Services Inc.

GSI

50 Years of Innovations in the Oil Patch

1930 - 1980

TABLE OF CONTENTS

CHAPTER I
INTRODUCTION

May 16, 1980 marks the 50th anniversary of Geophysical Service Inc. (GSI), a subsidiary company of Texas Instruments Incorporated (TI). With its doodlebuggers on land and seismic mariners at sea, GSI operations extend throughout the world providing geophysical exploration services to its many clients. What are doodlebuggers? Doodlebuggers are the geophysicists, geologists, engineers, scientists, electronics technicians, and others who perform tasks associated with seismic surveys on land and at sea.

Operating within the organizational framework of the Services Group of TI, GSI maintains offices and field operations in more than 20 countries. Its clients include major U.S. oil companies, large and small independents, national oil companies, and government agencies outside the United States. Although some dozen companies make up the total organization, the name GSI applies to all these companies which, for 50 years, have carried out the search for oil and other minerals throughout the world's sedimentary basins.

Communications and supply lines extend from GSI headquarters in Dallas to field operations around the globe where GSI land, marine, and data processing crews are engaged in seismic exploration surveys.

The following chronicle of GSI's 50 years of innovation in the oil patch highlights the more important technical milestones that reflect its historical leadership role and its revolutionary technical breakthroughs in the geophysical exploration industry.

Revolutionary technical breakthroughs are those scientific advancements which change the way a company or an industry does business. In light of this definition, there can be no question that GSI--in its 50 years of innovation brought four eagerly adopted techniques to the energy search industry: reflection seismology, magnetic tape recording, digital seismic technology, and three-dimensional (3D) reflection seismology.

Doom-sayers predict a sharp decline in oil reserves by the year 2000; on the other hand, more optimistic experts claim there is more oil to be found than has previously been found. Every American experiencing the recent gas shortages wants to know more about oil reserves, but few recognize how much effort and research and development (R&D) dollars are invested annually by companies such as GSI and the petroleum industry to improve the chances of finding oil and reducing the cost of oil field reservoir development.

GSI has dared to adopt breakthrough strategies on a 5-, 10-, and 20-year plan, and its tactical R&D progresses toward the ultimate seismic system as its historical right. The results of similar strategies pursued over its 50-year history are summarized by the following list of technical milestones.

Despite the fearful mood--fear of the unknown--over the country, the enthusiastic new company moved along to explore the subsurface unknown, until at year's end (1930) there were 11 crews and 147 employees.

Those first months for the 1930 boys were busy ones-filled with ideas, trial-and-error, and energetic teamwork. The reflection method was a success and the new technique gave rise to a new industry. They were on their way.

1931 First foreign operai1ons 1n Mexico. Work also along Texas Gulf coast, in West Texas, the Penn-York area, and California. Price of crude oil drops to five and ten cents a barrel.

'32 Exploration begins in western Canada. First Louisiana marsh and swamp work. Standard GSI rotary drill rig developed

'33 The depression prevails in earnest. Some new exploration in Quebec.

'34 Newark laboratory and shop, with six employees, moves to Dallas. J. Erik Jonsson is made Secretary of the company, as well as office manager personnel director-purchasing agent.

'36 Thirty-five employees in Dallas shops and warehouse, now located at 2114 Harwood. First crews to Colombia.

'37 Parties to Saudi Arabia, Java, Sumatra, Ecuador. All travel by boat.

'38 Crews sent to New Guinea. Western Canada operations again.

'39 Persian Gulf open-water work proves effective. Work in Panama and India.

'40 Foreign situation worsens. Draft registration in October. First GSIers called to service are Buddy Bartow and Bob Everett, just returned from New Guinea hitch.

'4l November 10--Messrs. McDermott, Jonsson, Peacock, and Green acquire company from original owners. Now six crews and 100 employees. December 7-Pearl Harbor.

'42 GSI forced out of Sumatra by enemy invaders. Electronic work for Army Signal Corps and Navy begins in Dallas lab.

'43 Busy with war contracts. Ingenuity needed to keep production and operations going with short supplies and materials, tires, etc.

'44 Back to Mexico. War contracts keeping lab and shop busy.

'45 Two important dates: V-E Day and V-J Day. Cessation of hostilities. By year's end, 15 exploration crews.

'**46** First GSI parties go to Brazil. Observers School held for first time. Laboratory and Manufacturing (L&M) Group set up to administer program for supplying electronic equipment to armed services and industrial users.

'47 New Lemmon Avenue quarters occupied by office personnel and L&M group together for the first time in one building. Three hundred employees and over $3 million in sales. Oil boom speeds four GSI crews to western Canada.

'49 War surplus weasels (caterpillar-type vehicles) converted for exploration use in Canadian muskeg, heretofore almost inaccessible. Korean situation calls for acceleration military contract work by L&M group.

'50 Reorganization takes place. Broad charter to cover both exploration and manufacturing not permitted by State of Texas. For operating and administrative efficiency, the L&M facilities are set apart corporately from GSI, to become Texas Instruments Incorporated. GSI continues in geophysical work.

'51 First annual summer student cooperative plan inaugurated.

'52 Fifty-three crews--26 domestic and 27 foreign. Correspondence course set up to encourage GSIers to improve their know-how.

'53 New GSI companies formed to cover Arabia and Africa operations; also two geomarine members are added to the GSI group. M/V SONIC purchased for single-ship operation in open waters. Engineering Supply Company and Houston Technical Laboratories join the TI-GSI family of companies. TI produces first germanium transistors in commercial quantities.

'54 New line of seismic instruments developed by HTL improves operations: magneDISC, Model 7000, HR System, VLF. Seismometers weigh less than 1 lb. TI announces first commercial production of silicon transistors.

'55 Over 1,000 employees throughout the world--more than 60 parties using reflection, refraction, gravity methods of geophysical exploration.

'61 Introduced advanced digital seismic computer (TIAC system) and seismic processing software.

'63 Introduced non-dynamite sources for land exploration.

'64 Introduced digital seismic service technology (DFS* Series 9000 Seismic Amplifier); intensified seismic array and statistical discrimination techniques.

'**67** Introduced new TI870A seismic data processor and 6th generation of seismic software; added non-dynamite sources for marine exploration.

'72 Introduc ed integrated exploration system, 3D subsurface model-building capability, and Advanced Scientific Computer (ASC* system).

'73 Introduced 4th generation of integrated satellite navigation system.

'74 TIMAP* minicomputer systems employed by GSI for terminal, display and standalone processing application.

'75 Introduced 3D land and marine field

'76 Techniques and high-resolution software (3D; SEISQUARE**, SEISLOOP*, AND SEISWATH** techniques; SEISTRACK** system; SEISCROP** sections).

'77 Introduced other 3D interpretive tools

'78 (SEISMODEL** display unit and SEISCELL** display).

From a company which began as an experiment, GSI has grown to one which is expert. The first research was purely trial-and-error, experiment, and development.

When GSI was organized in 1930 by John Clarence Karcher and Eugene McDermott, it became the first independent geophysical contractor company to offer reflection seismology as a viable technique for locating potential oil reserves. Reflection seismology and its resultant seismic record is employed universally for spotting the drill and defining the extent of oil field reservoirs lying deep within the geologic formations of the earth.

The year in which GSI began held many challenges. Oil discoveries prior to May 1930 depended largely on hunch, surface indications such as oil seeps, and the geologically inspired anticlinal and fault-trending theories. These techniques had been applied successfully in Pennsylvania, Oklahoma, Kansas, California, and Texas. As oil grew more important as an industrial energy source and as more automobiles traversed roads and lanes of the country, oil companies began to gear up, focusing on techniques that were more meaningful than hunch drilling or creekology. There was, therefore, a waiting market in 1930 for the services which GSI was organized to provide.

The early '30s market, however, was in a state of oil glut. Dad Joiner's wildcatting find in East Texas drove oil prices down in a market already being flooded by the Darst Creek field (a major fault-line discovery on a creek named for a Texas patriot who lost his life at the Alamo), and the Oklahoma City blowout, which stained most of the city black-gold in 1928. This latter field was the largest in the nation until Dad Joiner's success at Van, Texas.

Refraction, as a geophysical technique, was used experimentally in the '20s. This technique involved an explosion point and detectors laid out on a straight line through the shotpoint. Travel times for the seismic waves proceeding directly from shot point to detector were plotted on a time-distance graph, and travel times for the first refracted wave to arrive at each detector were plotted against shot-detector distances. Depth to the refracting horizon was then calculated, allowing the interpreter to estimate dips, faults, or fractures in subsurface formations where oil might be trapped.

Gravity surveys also were used, particularly in locating salt domes after the first oil find at Spindletop pointed out the favorability of salt domes as potential oil traps.

Not until 1922 was it possible to import the torsion balance from Europe, but the two that were first imported in that year were used by E.L. DeGolyer and by Roxana Petroleum Corporation (Shell). DeGolyer had the first gravity success at the Nash dome in 1924.

By late 1920, geophysical contracting in the United States was still in its infancy. Techniques emulated those developed in Europe and became building blocks for geophysics as it evolved in this country. Geologists were beginning to find a niche in the oil game, university petroleum engineering curriculums were in experimental infancy, and the earth sciences as tools for the quest for oil were firmly on the threshold. Real know-how in the oil search was premium, and search hardware was crude at best oil companies, however, were abandoning creekology, trendology, dowsing, and hunch drilling for each new scientific approach to locating the oil trap (the theory being that oil or gas migrates updip in porous strata until stopped under some impervious bed or barrier). Spudding in wildcat wells to greater and greater depths defied the costs of hunch drilling in the brusingly depressed times that peaked with the fall of the stock market in 1929.

A young physicist named Karcher came upon the exploration scene with the technique that would revolutionize the quest for oil. He gave birth to the formula

$$D = 1/2\sqrt{V^2\ T^2 - X^2}$$

upon which reflection seismology is based.

Karcher is credited with being the first to experiment with sound waves as a tool for oil exploration. By explanation, reflection seismology is analogous to echo sounding at sea. It is based on the principle of measuring travel time of seismic waves generated at a point of energy release on the surface. The waves travel downward through porous medium and are reflected by some impervious, hard rock boundary, thus being recorded at the surface by seismographs that are spatially arranged near the shotpoint. These reflected seismic waves are captured in reverse profile on paper records.

In the early days, the energy point was a charge of dynamite placed into a hole drilled in the ground. With the advent of offshore exploration, the dynamite charge was set off under water. Today, more sophisticated and environmentally acceptable systems pound the earth in a controlled energy release while air gun arrays provide the seismic energy in marine surveys.

Reflection seismology changed the way of doing business in the entire exploration industry. As the first independent contractor to offer reflection seismology, GSI set the pace for the geophysical industry with established field proof of its viability as a real oil finding tool. Seismic data collected by the geophysical contractor were delivered to the client. There was little or no contractor participation in the decision-making process of whether or not to drill, where to drill, or the potential extent of oil reserves.

Karcher's innovative technique brought success to GSI in the United States and abroad during its first business decade, setting a philosophy that pervades GSI to this day technical innovation is a viable business principle.

The '30s saw development of new equipment and techniques for all aspects of field operation Sensitive instruments were built in GSI laboratories to McDermott's design and Eric Jonsson's supervision. These included the S-2 seismometer, the GSI camera, the Peerless 1000 recorder, a portable spudder- type shothole rig, a standard rotary drill rig, plus continuing research into collection and interpretive techniques. Tools had to be built and improved as time and work progressed. GSI's early devotion to research as a way to maintain technological leadership was apparent from records of field crews assigned to such research tasks as electrical logging in 1932.

In 1938, to segregate the company's oil production activity from its seismic exploration operations, the company name was changed to Coronado Corporation. At the same time, a new corporation, Geophysical Service Inc., (GSI) was formed as Coronado's subsidiary. GSI conducted geophysical exploration while the parent company, Coronado, became engaged solely in production activity. As head of the Coronado Corporation, Karcher was thus separated from the GSI organization in a management role and McDermott led GSI at that time.

As World War II clouds hovered over Europe in 1940, Coronado Corporation was engaged in a dialogue with Standard oil for the purchase of Coronado's holdings; at this time four GSIers (McDermott, Jonsson, Cecil H. Green, and Dr. H. Bates Peacock) bought GSI.

As an aftermath of Pearl Harbor and this country's declaration of war, the direction of the company's work changed. The science of reflection seismology was applied to antisubmarine warfare and GSI became a contractor to the Defense Department, a circumstance allowing Jonsson to make contact with outstanding engineering types in the Navy's war production activity. Among those contacts joining GSI when war was over were Patrick E. Haggerty and Robert W. Olson who spearheaded GSI's Laboratory and Manufacturing (L&M) department, organized after the war with military contracting as its principal role and with electronics as a future strategy.

During the war, GSI was able to continue seismic exploration on a limited scale in the United States and in some foreign countries. Manufacturing capability and facilities were enhanced by the war effort, forming a base for miracle growth after the war as GSI recruited a host of engineers for its role as a military supplier. Acquiring a license to build transistors, the electronics infant of GSI's L&M department took off, spiraling upward like a Texas tornado. As it became obvious that the company was taking a new direction, the company's name was changed in 1951 to General Instruments. In 1952, the name became Texas Instruments Incorporated (TI) with GSI as a subsidiary.

While GSI had continuously been avant-garde in reflection seismology to this time, it seized unchallenged technological leadership of the geophysical exploration industry as a direct windfall from outstanding research capability developed by TI in the early '50s. The technological advancements, all readily accepted by the industry, were achieved through collaboration between GSI geophysicists, engineers, researchers, and the vast TI research complex, Central Research Laboratories. The list of technological milestones, beginning in 1954, reflect this collaboration across division lines at TI, and a separate division was set up to pursue

GSI's former instrumentation effort and to develop product lines of seismic field systems marketed to the industry.

Approaching the mid-'50s, GSI became the first geophysical contractor to record seismic signals in variably magnetized tracts along the length of a magnetic tape. Time lines or impulses, including one for explosion time, were also recorded. Changing from paper records to taped records pointed the way to machine processing, development of the analog processor, and ultimately, digital seismic technology, a revolutionary change in the way seismic data were collected and processed. Machine processing opened doors to many data refinements which the slower process of human computation had denied. And, it was in the early '50s that the petroleum industry credited the seismic reflection technique as having increased the success ratio of wells drilled one in six, contrasted to one in sixteen using other methods.

The '50s also saw TI begin to market the transistor, 2 years ahead of the entire electronics industry. Transistorized equipment built for the geophysical industry was introduced by GSI, lightening the load of GSI field crews who often backpacked their survey systems into remote areas. The ruggedness and reliability of GSI systems were heralded, and one of these traveled to the Antarctic to be used by a team of scientists in their investigations during the International Geophysical Year.

By the early '60s, GSI introduced digital technology, where signals detected by sensitive geophones were read at millisecond intervals and recorded as binary digits across the width of a 1-inch format tape, bringing about a revolutionary change in the geophysical exploration business.

Culminating 8 years of research and development in GSI and TI, a systems approach improved, in terms of quantitative data, the amount of real subsurface information available for the evaluation of a prospect area. Thousands of integrated circuits were put to use in this special-purpose data processing equipment designed and built (with some financial support from two major oil companies) for the new digital seismic program.

These technological advancements were readily adopted by the industry. Today, digital recording on magnetic tape commonplace, accumulating huge masses of seismic data and pushing the bounds of the ordinary computer.

By 1961, GSI introduced a unified systems approach with its complete digital data gathering and processing system which exploited the electronics technology developed at TI. Analog signals were transferred in digital format to magnetic tapes that were compatible with the digital computer, TIAC* (Texas Instruments Automatic Computer). Software allowed such field tape edit preprocessing automatics as and the application of data enhancement techniques (velocity filtering, true amplitude recovery, shot, and seismometer spacing geometry corrections, and ghost energy elimination.

With the introduction in 1967 of the TI870A* seismic data processor and GSI's sixth generation of software, man-machine discourse gave the geophysicist new options, employing statistical discrimination techniques in the data reduction process. These instruments were state of the art, demonstrating the high plateau of electronics technology at TI. Beginning in 1966, another development at TI involved the beginning of a 5-year plan to design and produce a super computer, bringing into play skills and technologies from every group at TI.

Multi-staged input/output and array processing were critical features of the hardware/software systems brought on line by GSI in 1971. Regional data service centers and remote field locations utilized a host of minicomputer-based array transform processors (TIMAP*) and TI-built minicomputers at the source. This seismic data life line allowed access choice, via satellite communications links, to either regional data center or the central Data Processing Center (Dallas). Several Advanced Scientific Computers (ASC*) located in Austin, are accessible for data base and modeling capabilities.

The '70s were singularly marked by GSI's introduction of its innovative three-dimensional (3D) approach to the complex process of evaluating a prospect, contriving once again to change radically the way oil discovery and field reservoir development can be achieved. For this 3D look into subsurface lithology, seismic systems (modular, integrated systems for land and marine applications) once again reflect TI technological advances in computers, minicomputers, computer on a board, data terminals, processors, and communications components.

The 3D approach involves close collaborative performance of the geophysicist, the geologist, and the petroleum engineer as well, with the objective of cost-effectively defining reservoir limits early in field development planning stages. This new role of the geophysical contractor allows reservoir assessment without extensive test well drilling to extend previously required by oil field developers. It represents a major change in the role of the contractor who historically simply delivered his seismic data package to the client and moved on to the next prospect.

In the past, the initial phase of a petroleum exploration program began in an unknown or relatively unknown geologic setting. Normally, several geophysical surveys (referred to as reconnaissance exploration) of increasing spatial density were required to complete the phase through prospect detection. Frequently, one or more boreholes, called strat tests, were drilled during this phase so that actual physical character of rocks encountered might be examined.

Prospect delineation involved detailed geophysical exploration; the amount of information required prior to wildcat drilling varied from only a few lines to verify well location or a highly detailed (including 3D) survey to solve a complex geologic problem. Geophysical data and borehole information were then combined to determine where oil or gas was most likely to be trapped.

Step-out drilling, a trial-and-error solution was, until recently, used to achieve a more complete understanding of underlying lithology information. High-resolution seismic data and GSI's 3D technology are now impacting this stage in oil field development.

A 3D survey conducted in shallow water off the Louisiana coastline had the objective to provide a better understanding of faulting affecting an already producing field, so that reservoir compartments not previously exploited might be defined and developed. Two 24-trace bay cables and a 900-cubic inch barge-mounted air gun array, utilizing the "flying swatch" technique, yielded seismic traces on a grid 220 feet by 165 feet. Employing a two-level SEISCROP** section, the hydrocarbon/water contact was identified and its extent delineated in one part of the field.

In the Gulf of Thailand, a 3D survey outlined a potential gas field indicated by three previous wildcat wells. The result was four productive wells out of four drilled, each successive well-being located according to the survey results and the data being utilized in planning potential platform locations. To achieve such sharp fault definition, GSI used two complete and complementary survey systems to record densely spaced data that were processed using a 3D wave equation migration algorithm.

GSI's technological leadership in the energy search in the coming decades involves a High-channel capacity seismic data acquisition system utilizing an optoelectronic cable system giving an electrical interface as opposed to the current optical interface. Special software will adapt high-speed terminals for interfacing with large computer systems as programing support and management functions as well. Few geophysical contracting firms have had the R&D support which has allowed GSI to maintain its position as the principal contributor to seismic technology through its 50-year history.

*Trademark of Texas Instruments Incorporated
**Trademark of Geophysical Service Inc.

CHAPTER II
THE REFLECTION SEISMOGRAPH AND EVENTS THAT LAUNCHED GSI

A granite and marble monument on the grounds of Belle Isle Branch Library at 5501 North Villa, Oklahoma City, Oklahoma, marks the site of initial field tests of reflection seismology in 1921, using a reflection seismograph system designed by John Clarence Karcher. When the monument commemorating the 50th anniversary of the first experimental field trials of the system was unveiled in 1971, it was equally a landmark event in GSI's genealogy.

Karcher is recognized as the father of the reflection seismograph, and the method he invented has become the most widely used of all techniques employed in the geophysical industry. Many innovations have occurred in the instruments employed to collect seismic data, but the basic principles of measuring the difference between refracted and reflected sound waves to discover oil-producing strata remain essentially the same as conceived by Karcher. In the last half century, reflection seismology has spawned the creation of a multibillion dollar industry of great sophistication. Inscribed on the monument are the following words:

"The reflection method has been applied on land and sea, and the results far surpassed the wildest dreams of the men who observed the first seismic reflections in the search for oil".

"The reflection seismograph method has allowed the geophysicist to map geological formations at depths in excess of 5 miles.

"During the past 50 years, billions of barrels of oil and trillions of cubic feet of gas have been found by applying this method, enabling our nation to pass from a horse and coal economy to an industrial petroleum economy.

"Oil and gas run our automobiles, trains, and airplanes; generate electricity to run our industries, light our cities and air-condition our homes; and do a host of other good things for mankind."

The birth of the idea for the reflection seismograph did not occur inspirationally for the purpose of finding oil; it was the product of Karcher's reflection concepts which were first applied to locate enemy gun emplacements during World War I. It was the natural fallout from Karcher's work at the Bureau of Standards dealing with artillery sound-ranging and other wave detection devices as much from his natural scientific interest in topics of the hour such as dome-like reservoirs, anticlinal structures, oil entrapment in porous rocks, and sands underlying impervious limestone beds.

For many years seismologists had studied natural earthquakes and the resultant sound waves. A mid-19th century scientist, Robert Mallet, suggested using artificial seismic waves to explore the underwater areas of the globe. In 1864, Mallet published the first account of seismic field experiments. The results, said to be due to poor equipment, were so filled with inaccuracies that their publication brought violent argument in the scientific community, particularly from General H.H. Abbott of the U.S. Army, who published some field experiments in 1876.

Advances in academic theory resulted in the acceptance in 1910 of the theory of refraction profiling. It was not, however, until 1919 that a prominent German scientist, Dr. Ludgar Mintrop, recognized the practical application of refraction profiling, and he applied for a patent in Germany for its use to locate depth.

In that same year and in America, Karcher built effective geophones and collected seismic data with his experimental apparatus while working at the Bureau of Standards. By January 1919, he had begun the draft of a patent application based upon the formula he first discussed in the summer of 1917 while visiting with his associate, Dr. W.P. Haseman, in Chevy Chase, Maryland. Dr. Haseman had been professor of physics at the University of Oklahoma when Karcher was doing undergraduate study in electrical engineering and physics. When Dr. Haseman was recruited to work at the Bureau of Standards during World War I, he recruited Karcher and persuaded the Bureau to send Karcher to France to make a study of sound waves generated by the enemy's artillery fire.

In a discussion with Dr. Haseman, Karcher observed:

"Knowing the speed and determining thetravel time, we should be able to calculate the depth of any geological strata reflecting a sound wave, shouldn't we?" He then demonstrated his theory with mathematical formula, describing how the depth, shape, and even some texture of subsurface structures might be detected by sending sound waves deep into the earth's surface and recording their reflections. Haseman exclaimed: "Karch, I think you've got something."

Karcher, in later years, reflected on this happening. "Since both Dr. Haseman and myself were well acquainted with the general aspects of the oil industry, particularly with reference to the manner in which searches for new deposits were being conducted, we were engaged in sound-ranging work at the Bureau only a short time before our conversation fell to the discussion of utilizing reflected sound waves to determine probable oil field structures. Since, as mentioned, we were engaged in sound-ranging experiments, no opportunity presented itself for experimenting on the commercial application of this method. Subsequently, Dr. Haseman went to the University of Michigan to conduct some experiments on supersonic waves in water, and I joined Dr. Eckhardt and Mr. McCollum for further range work. After Dr. Haseman went to Michigan, the question of a commercial application of the method was discussed no further until after the war was over."

One of the first assignments given to Karcher and Haseman at the Bureau of Standards in 1917 was a suitable detector for air sound waves as generated by the explosion of guns. They worked under Dr. F. Wenner. The direction- finding instrument was basically a development for refraction seismology. While the physical laws were similar to those governing reflection seismology, the work was more nearly an extension of Mallet's refraction theory proposed in 1846.

Shortly after Karcher returned to the University of Pennsylvania to pursue graduate work in January 1919, he began a correspondence with Dr. Haseman, who had returned to the University of Oklahoma, on the subject of using sound reflection waves for locating oil structures. Karcher recollects: "Also about this time, a draft of a patent application was started which was shown to Mr. Anton Udden. In our early correspondence, Dr. Haseman asked if I would be interested in joining a company to be organized for the purpose of developing and carrying on investigations using the sound reflection method."

In the early spring of 1919, Karcher went to the Bureau of Standards for an examination in a graduate course in thermodynamics and while there he visited with his former associates, Dr. E.A. Eckhardt and Burton McCollum. After showing them his draft of a patent application covering a sound reflection method, the matter was discussed at length and an agreement made among them to form a partnership for the purpose of pursuing Karcher's idea.

While Karcher was doing summer work at the Bureau of Standards in 1919, he assembled experimental apparatus in his spare time and collected seismic records on the campus of the Bureau of Standards, in the vicinity of an abandoned rock quarry. However, when Karcher sent his patent application to the U.S. Patent Office, it was denied due to a basic patent issued earlier in the year to Reginald Fessenden, a pioneer in sonic depth-finding whose patent covered the use of a reflection method as applied to locating mineral bodies.

After Karcher completed his graduate work at the University of Pennsylvania, he returned to the Bureau of Standards as associate physicist engaged in sound research work. Meanwhile, Dr. Haseman, still in Oklahoma, proposed the organization of a company for the development and exploitation of ideas pertaining to the use of seismic surveys of the subsurface. Geological Engineering Company was organized in 1921 by Haseman, Dr. D.W. Ohern, Irving Perrine, Frank Buttram, and the Ramsey Brothers of Oklahoma City. Karcher was invited to join and he entered into a retainer arrangement with the company with an annual salary and an interest in the company.

Because of his prearranged partnership with McCollum and Eckhardt, Karcher was reluctant to take Haseman's offer without the consent of McCollum and Eckhardt. As inducement to Eckhardt and McCollum to assign any partnership that might exist, each was given a 4 percent interest, without salary, to act as consultants. Thus, the two elements necessary to hasten the process of commercializing Karcher's idea came into focus: an assemblage of known elements to produce a new result and the framework and money for organized experimentation. While still in Washington in 1921, Karcher designed and made arrangements for the construction of suitable apparatus for the experimental work. As Cecil H. Green, one of his former associates, described it, "Karcher, with typical resourcefulness, converted a General Electric ocillograph to a three-trace seismograph recorder, built three geophones from the electrodynamic system of a Baldwin radio-telephone receiver, and acquired a half ton pickup truck, a blaster, and earth augers." Geological Engineering supplied the funds and, by May, Karcher was on leave of absence from the Bureau of Standards and on his way to Oklahoma to assemble the apparatus for field work.

As Karcher recollects: "The first trip to the field for experimental work was made on June 4, 1921. The first field party consisted of Dr. Haseman, Messrs. Perrine, Kite, and the writer; and the first observations were made in a streambed west of a concrete bridge on a roadway running north and south about 1-1/4 miles due west of Belle Isle, a suburb of Oklahoma City. This work was continued on June 6th, 8th, 9th, 10th, etc. One June 16, 1921, a profile consisting of a series of seven shots placed at distances of 100 to 700 feet from the detector and at l00-foot intervals from each other were shot and records obtained.

"On June 17th, another profile consisting of a series of shots spaced at 100-foot intervals and starting at 300 feet and extending to 1,000 feet from the detector were shot. These experiments were continued in the vicinity of Oklahoma City until early in July."

The Belle Isle site, therefore, was the birthplace of the reflection seismograph used specifically to locate subsurface structures in the search for oil. The experiments were recorded in Dr. Haseman's diary, Karcher's field notes and, of course, the records speak for themselves. As inscribed on a monument dedicated at the Belle Isle site 50 years later, these records proved the reflection seismograph was a technically innovative tool, useful in the search for oil. Karcher's daring, unlimited conceptual thinking broke through the barriers and forged the scientific frontier of reflection seismology at Belle Isle. Even more innovative techniques evolved from experiments in the Arbuckle Mountains and near Ponca City, Oklahoma.

The experimental party consisting of Haseman, Ohern, Perrine, and Karcher conducted further tests in July 1921. A number of charges of dynamite were shot and the velocity of transmission in Hunton Limestone was measured at an average speed of 11,680 feet per second. Similar observations were made on Sylvan Shale, where an average speed of 5,780 feet per second was obtained. Measurements on Viola Limestone showed a speed of 14,070 feet per second. These velocity differences between Sylvan Shale and Viola Limestone led to the belief that the ideal reflecting surface would be the contact between Sylvan Shale and Viola Limestone.

A perfect location to test this theory was suggested by Dr. Ohern, who as a former state geologist was familiar with the geology of the Arbuckle Mountains. Experiments were continued at an area about 7 miles north of Dougherty, Oklahoma, at Vines Branch, where a structural dome was known to exist. As Karcher described it: "On the east side of this dome, the Viola Limestone which was the cap rock of the dome, plunged eastward and as it plunged, was overlaid by thickness of Sylvan Shale. Taking an eastward cross section, it was apparent that a wedge of Sylvan Shale layover the Viola Limestone. It was along this line that we conducted our next series of experiments."

Describing the physical layout of the tests, Karcher said: A series of nine pairs of positions were taken. These nine pairs consisted of two rows of positions, the rows being parallel, directed down dip and 300 feet apart, while the positions on one line were used as shot points and on the other line as observing points, thus providing a series of observations taken over equal distances of 300 feet and each successive profile of observation being 100 feet farther eastward from the preceding one, so that the depth to the reflecting Viola Limestone under the Sylvan Shale would be deeper for succeeding observations. This permitted a series of observations to be taken where all conditions were uniform, except the depth to the reflecting horizon.

A series of records was obtained from this arrangement ... when laid adjacent to each other in proper order, a definite recognizable event in the records proceeded to move outward … as they were taken over increasingly deeper Viola Limestone, and as the space between shot and receiver was kept constant, it became a very ready means to identify reflections present. The cosines of reflection angles varied from less than 0.03 to greater than 0.98."

As these tests at Vines Branch came to a close, the experimental party consisted only of Karcher, Haseman, and Rex Ryan. Upon return to Oklahoma City, photographic copies of the records and Karcher's calculations were mailed to Dr. Eckhardt, the Washington consultant.

Additional work was done near Oklahoma City on August 16 and August 19, 1921, with microphones set up at a point to receive reflections from an arc of shotpoints. Another arrangement saw two microphones placed equidistant (500 feet) on either side of the shotpoint, similar to an arrangement used on June 21 in other tests.

By September 1921, Haseman, Karcher, and Ryan began a series of experiments on the Newkirk Anticline, approximately 15 miles northeast of Ponca City. A series of records was taken from shots placed in profile, with various angles of reflection being obtained. Also, in the general area of section 28, township 25 SN, range west, a survey was made for Marland Oil Company. This was the first commercial survey by a geophysical company using reflection seismology.

Other test areas included the south Ponca structure on October 14, 1921; the Kildare area on October 18, 1921; and the Deer Creek structure on October 26, 1921. "During this series of experiments," Karcher recalled, "reflections were obtained using charges planted at the surface and in holes of varied depths including holes sunk into the bedrock, in some cases as deep as 20 feet. The detecting instrument was also placed in holes under these same several conditions. Reflections were secured at angles less than 45 degrees (cosine ranging from 0.707 to 0.98) down to angles as small as approximately 10 degrees with the major portion of the reflections being secured at angles less than 30 degrees (cosines greater than 0.8665).

"As only a small amount of funds were available for continuing the work, the program was abandoned and the writer returned to the Bureau of Standards as research physicist."

And so, by January 25, 1922, with the work terminated by lack of funds, the Geological Engineering Company proceeded toward foldup, not recognizing that the exact arrangements and innovations developed near Ponca City had moved Karcher's concepts into the realm of a patentable method.

Soon after Karcher's return to the Bureau of Standards, he accepted a position with Western Electrical Company to help improve the ocean-bottom telegraph cable. During the summers of 1923-25, he directed the work of a young, electronic-minded scientist, Eugene McDermott, who was building test sets for the Development Department.

Contrasting these two men who would become business associates for more than 17 years is like describing opposite poles. Karcher was a big, husky, scientific man, full of dreams in motion. He believed the scientist's ideas should be translated into money. In most things, he believed his was the way, and he lost no time saying so. McDermott, on the other hand, was slight of build, blue eyed, and deceivingly diffident. His scientific bent was more for the sake of science than for money. Of two completely different molds, both had the zeal for applying science to productive industry, and they came together in 1925 to promote reflection seismology as a viable exploration technique.

McDermott's interest in science began very early when he tinkered with radio. He enrolled in Stevens Institute of Technology in Hoboken, New Jersey, after completing school in Brooklyn, He joined the Navy Student Training Corps at the school in 1918 and, in 1919, he classified himself as "an able bodied senior."

During his senior year at the Institute, his high I.Q. led Goodyear Rubber Company to hire him upon graduation. The company used the I.Q. test in their selection process for promising graduates who might make sales engineers. "The whole thing," said McDermott, was a misconception. I.Q. had nothing to do with personality'." As an electrical engineer, McDermott found himself in Arizona with little aptitude for the task of appraising industrial needs for rubber.

He spent only a year in the west, going to Chicago in 1920 to design new products for Commonwealth Edison. His first product was a wireless or crystal radio for which he used silicon crystals with a cat whisker for station selection. The theoretical understanding of the potential of the perfect crystalline structure was still over the horizon, but in 1954, when McDermott was chairman of the board of Texas Instruments, he was adequate' in his role of staking a claim on the future, with silicon as the new material for transistors.

McDermott left Commonwealth Edison in 1921 to go into business for himself. He built crystal radios in his home on the south side of Chicago, near Lincoln Park, He was engaged in this for about a year when, as he described it, he resigned to take a job with Western Electric where he worked a full year before entering Columbia University for graduate work and to teach physics. During the summers of 1923-25, McDermott returned to Western Electric where some of his work was directed by Dr. Karcher and where the talents of each engendered mutual, long-lasting respect.
When Karcher left Western Electric, he lured McDermott from his $1,000-per-year teaching job and research work at Columbia University to join him in a new venture.

By mid-1925, the price of oil had risen to more than $3 per barrel, and this provided an environment making the scientific approach to finding oil more affordable. The stalemate at which Dr. Karcher's reflection concepts rested was described in The Oil and Gas Journal's "Petroleum Panorama", 1859-1959: "the reflection method remained more or less dormant for several years until the formation of Geophysical Research Corporation (GRC) in 1925."

GRC was organized as a subsidiary of Amerada Petroleum Company of New York by Everett L. DeGo1yer, president and general manager, and he recruited Karcher as vice president and general manager.

DeGo1yer, born in a sod house in Greensburg, Kansas, in 1886, was introduced to prospecting very early as his father tried zinc mining in Missouri before returning to Oklahoma to examine the "land runs." As an amateur prospector, his father participated in the Cherokee

Strip run in 1889, and he moved about over Oklahoma in various endeavors without success. Young DeGo1yer was in and out of schools and often cooked in restaurants as a means of support. After his family moved to Norman, Oklahoma in 1904, he entered the University of Oklahoma in 1906, where he signed up for a course in physical geography so as to avoid a required course in Latin.

His interest in geology led him to be appointed the first student assistant. During the summers, he was camp cook for the U. S. Geological Survey camps. Here, he met up with Dr. C. Willard Hayes, head of the geological surveys, who had a contact with Sir Weetman Pearson's Tampico, Mexico, oil interests. Dr. Hayes took DeGo1yer along to Tampico; where Hayes was unsuccessful, DeGo1yer--who had stayed on--succeeded with the famous Potrero Del Llano #4, a DeGo1yer-1ocated well that proved to be one of the great producing wells in history. Other strikes were made in Mexico's Golden Lane, and in 1911 DeGo1yer returned to the University to get his B.A. degree.

From 1916 until 1932, DeGo1yer was head of the Amerada Corporation, an exploration company which was supported financially by Sir Pearson (later Lord Cowdray) and his British firm. Describing DeGo1yer's exploration company in the United States and Canada, Lon Tinkle of the Dallas Morning News wrote: "With its GRC subsidiary founded for technological innovation, Amerada became one of the historic American oil companies, primarily for its subsidy of applied geophysics in the search for oil."

DeGo1yer had used other scientific approaches to his oil search, including gravity surveys. Reported to have tried to buy a torsion balance in Europe in 1914, DeGo1yer finally got delivery in 1922 and is credited with the first gravity success in the United States--the Nash salt dome, discovered in 1924.

The torsion balance was not perfect, nor was the pendulum method of gravity measurement, and perfection of the gravity meter and its use in consonance with seismic surveys awaited the future.

DeGolyer was never one to pass up any advantage that new scientific concepts could offer. Inline refraction shooting techniques had recently been used along the Balcones Fault area by Dr. Ludgar Mintrop, who was imported from Europe by the Marland Oil Company of Oklahoma. Mintrop's refraction profiling technique met with only minor success, but several salt-dome discoveries were attributed to refraction surveys. DeGolyer was interested in Mintrop's technique and in Karcher's reflection technique as well.

As Karcher wrote: "In 1925, Mr. E.L. DeGolyer of New York became interested, as a result of conversations with H.V. Bozell, a former instructor of the writer at the University of Oklahoma. Bozell told DeGolyer of the work of Haseman and the writer … by arrangement through Mr. Bozell, the writer had an interview with Mr. DeGolyer in New York early in the year. He became so interested that he advised the writer he would finance a series of researches to further develop the method and agreed to finance such an undertaking to the extent of at least $100,000 per year for three years".

Soon, DeGolyer sent Karcher a wire to meet him in the second-floor waiting room of the Union Depot in St. Louis. Their previous understanding was transferred to GRC which DeGolyer had organized as a subsidiary of Amerada. Dr. Karcher was made vice president and manager with a 15-percent stock interest. His first employee was Eugene McDermott, who recalled, "I didn't know anything about geophysics, but I liked new and exciting things. Anything new interested me."

Karcher's first task was to design equipment for the changeover from mechanical to electrical devices. Basic designs developed by Karcher from 1917 to 1921 were utilized in the units built for the refraction crews who began their work along coastal Texas and Louisiana. GRC crews were so successful that, as Cecil Green recalled, "... he the sobriquet of '166-Salt-Dome was earning Karcher' from a satisfied refraction customer."

Bloomfield, New Jersey, was the site of the laboratory set up for building the special equipment. Upon completion of this work, Karcher and McDermott went off to the field. As McDermott recalled GRC's first geophysical contract, he said: "The research I was doing at Columbia was dull compared to this." The search for oil was like a big-game hunt; competitive oil company scouts dogged the heels of the geophysical crew. Crews lived close by their shotholes, sharing a rough camp life, and often rising at three in the morning to evade the scouts. McDermott, personally directing the crews, located ten major salt domes in his first 2 years with the company.

There was not a great deal of competition among geophysical contractors at that time. The Germans who had been imported soon had their instruments overtaken and surpassed in sensitivity, and American field methods for finding salt domes were the most advanced. Describing this circumstance in Petroleum Panorama, 1859-1959, The Oil and Gas Journal reported: "The foremost pioneer among the early American companies was Geophysical Research Co., organized by E.L. DeGolyer and J.C. Karcher." Only three American geophysical companies were in operation when Geophysical Research Corporation began operations in 1925. From the outset, GRC led the geophysical contracting industry with state-of-the art equipment, methods, policies, ethics, and procedures.

Although the early successes of GRC in refraction profiling along the Gulf Coast were phenomenal, still other oil-bearing structures defied the best performance of the refraction technique. Refraction worked well for multilayered rock sequences, provided was sufficiently thick to permit each layer seismic waves to be transmitted at higher speeds than in the sequence immediately above it. Refraction also provided data on seismic wave speed in specific rock formations, and the dip of a high speed layer and the fault or fraction position displacing it could be estimated. As Cecil H. Green described it: "… only the reflection method, with its almost vertical echoes, could provide the depth perception required to delineate other type structures."

Karcher's reflection seismograph, however, had been put on the back burner only temporarily. By July 1926, Dr. H. Bates Peacock was hired by GRC to supervise the first reflection seismograph crew. In that same year, Kenneth E. Burg was recruited from

When Peacock signed on with GRC, he immediate1y began to achieve satisfaction as party chief, doing both refraction and reflection work. Most of the field work during his 4 years with GRC was in Oklahoma and Texas areas. He came with GSI in July 1930 approximate1y 2 months after the company was formed by Karcher and McDermott. It has been said that Peacock will long be remembered as one of the ablest and cleverest geophysicists ever to work for GS 1.
Kenneth E. Burg was born in Illinois, where he graduated from high school with honors, evidencing some independent scientific interest by constructing a radio-transmitting and receiving station as a hobby. When he enrolled in the University of Texas at Austin, he was appointed student assistant in the physics department his sophomore year.
In his junior year, he became a member of Tau Beta Pi, honorary engineering fraternity. Two classical endeavors during this period were his construction of quartz crystal oscillators and electromechanical Fourier Analysis apparatus. When Burg was recruited by Karcher and Peacock in early 1927, his first assignment was observer and computer on GRC's experimental crew lead by Party Chief Peacock. They were engaged in evaluating the seismic reflection method in various areas of Texas, New Mexico, and Oklahoma.

A crucial test of the validity of Karcher's reflection concepts occurred after 2 years of mapping areas near Shawnee, Oklahoma, where Peacock operated the first field-size reflection seismograph crew. He made an exciting discovery and, as Cecil Green reported: "In the center of the Seminole plateau, surrounded by dry holes, there appeared to be a structure that defied all reasoning based on surface geology. Karcher rushed the maps to DeGo1yer, who recognized the challenge of this diagnostic test that could prove the reflection method conclusively. DeGo1yer persuaded his parent company to underwrite the drilling venture and, when the Amerada drill penetrated the Viola Limestone at about 4,200 feet on December 4, 1928, it produced the first oil well in history to be drilled on a structure mapped by a reflection seismograph."

"This and other reflection discoveries opened the great Edwards field in Oklahoma and convinced Karcher and McDermott that reflection crews would be in growing demand."

With the reflection method, dynamite charges were detonated in shot holes drilled usually less than 200 feet deep into the earth. Detonation created elastic shock, or seismic waves, which traveled downward thousands of feet below the surface and were reflected upward by various subsurface layers. Sensitive seismometers strung out on the surface detected earth movements caused by reflection seismic waves. Instruments recorded on photographic paper the time required
for seismic waves to travel downward and up the electrical engineering graduate class, University of Texas, to conduct experimental geophysical work.

Peacock, of English-Irish parentage, was born in a log cabin in Van Buren County, Iowa, approximately 7-1/2 miles from Kiosaugua. He attended grade school in a one-room school house. Upon graduation from high school at Kiosaugua, where he showed tremendous talents in the sciences, Peacock entered the University of Iowa at Iowa City where he majored in physics, earning his bachelor's, master's and doctorate degrees. Following this, he took a turn at teaching at the University of Colorado but, after 1 year approximately and his love for the wide open spaces, he felt that a change was in order. Having heard about Karcher and the reflection seismograph, he boarded a train for Houston, Texas where the two linked up, forming a long-lasting friendship.

When Peacock signed on with GRC, he immediate1y began to achieve satisfaction as party chief, doing both refraction and reflection work. Most of the field work during his 4 years with GRC was in Oklahoma and Texas areas. He came with GSI in July 1930 approximate1y 2 months after the company was formed by Karcher and McDermott. It has been said that Peacock will long be remembered as one of the ablest and cleverest geophysicists ever to work for GS 1.

Kenneth E. Burg was born in Illinois, where he graduated from high school with honors, evidencing some independent scientific interest by constructing a radio transmitting and receiving station as a hobby.
When he enrolled in the University of Texas at Austin, he was appointed student assistant in the physics department his sophomore year. In his junior year, he became a member of Tau Beta Pi, honorary engineering fraternity. Two classical endeavors during this period were his construction of quartz crystal oscillators and electromechanical Fourier Analysis apparatus.

When Burg was recruited by Karcher and Peacock in early 1927, his first assignment was observer and computer on GRC's experimental crew lead by Party Chief Peacock. They were engaged in evaluating the seismic reflection method in various areas of Texas, New Mexico, and Oklahoma.

A crucial test of the validity of Karcher's reflection concepts occurred after 2 years of mapping areas near Shawnee, Oklahoma, where Peacock operated the first field-size reflection seismograph crew. He made an exciting discovery and, as Cecil Green reported: "In the center of the Seminole plateau, surrounded by dry holes, there appeared to be a structure that defied all reasoning based on surface geology. Karcher rushed the maps to DeGo1yer, who recognized the challenge of this diagnostic test that could prove the reflection method conclusively. DeGo1yer persuaded his parent company to underwrite the drilling venture and, when the Amerada drill penetrated the Viola Limestone at about 4,200 feet on December 4, 1928, it produced the first oil well in history to be drilled on a structure mapped by a reflection seismograph."

"This and other reflection discoveries opened the great Edwards field in Oklahoma and convinced Karcher and McDermott that reflection crews would be in growing demand."

With the reflection method, dynamite charges were detonated in shot holes drilled usually less than 200 feet deep into the earth. Detonation created elastic shock, or seismic waves, which traveled downward thousands of feet below the surface and were reflected upward by various subsurface layers. Sensitive seismometers strung out on the surface detected earth movements caused by reflection seismic waves. Instruments recorded on photographic paper the time required for seismic waves to travel downward and up again, and also record pertinent events encountered in the transmission. By computing travel times and by analysis of the character of the recorded events, subsurface maps could be prepared to reflect an area's geologic structure. Some information about subsurface layer composition could also be deduced from reflection travel times. These subsurface maps enabled the geologist to locate deeply buried structures favorable to oil and gas accumulation. The basic principles of Karcher's reflection theory have not changed over the years and this chronicle of GSI technological leadership evidences the Karcher seismograph as the cornerstone of GSI success.

GRC, however, continued to utilize refraction surveys as its major tool in looking for salt domes. Burg, promoted to party chief, lead a refraction crew into East Texas, and then worked along the Texas-Louisiana Gulf Coast in search of salt domes. This was followed by additional field research to evaluate electrical-resistivity methods for locating salt domes and for mapping faults in Texas, Louisiana, and in the San Joaquin Valley of California.

Early reflection surveys, built on Karcher's equation, led to the development of a company that would be organized specifically to offer the reflection seismograph as a contract service.

Karcher and McDermott resigned from GRC to organize a new company, (GSI), Dallas, Texas, in 1930, with DeGolyer's blessing and financial backing of 51 percent. DeGolyer, already a world-famed geologist, resigned from Amerada in 1932 and moved to Dallas, Texas in 1936. Having served as U.S. assistant deputy petroleum coordinator in Washington during World War II, DeGolyer was instrumental in mapping potential oil supplies for the war and postwar needs. He is also credited with having an important role in Arabian oil development.

Reporting on DeGolyer's death in 1956, Time Magazine stated: "Through the ensuing quarter-century, Mr. DeGolyer rightly considered GSI his 'baby' too, and he always took great pride in the growth of a company that refused to let the Great Depression discourage the new undertaking."

CHAPTER III
EARLY TIMES IN THE OIL PATCH

When Dallas, Texas was selected as the headquarters of GSI in 1930, the presence of these oil-finding entrepreneurs scarcely made a ripple in the news. The local news item headlined, but not prominently: "They explore for oil GEOPHYSICAL FIRM OPENS DALLAS OFFICE. Plans Made for Local Warehouse."

The news item was quite low-key. It read:

"A new service company has opened its Dallas headquarters on the thirteenth floor of the Republic Bank Building, 1309 Main Street.

"Suite 1311 has been leased for $100 per month by Geophysical Service, the first independent company established to specialize in making reflection seismograph surveys for producing oil companies who are interested in prospecting for petroleum in promising areas.

"Officers of the new company are Dr. J. C. Karcher, president, and Eugene McDermott, vice president. They are co-founders of the company and were formerly associated with Geophysical Research Corporation of Tulsa. A subsidiary of Amerada Petroleum Corporation, GRC was formed to develop exploration methods for petroleum. Using the refraction seismograph method, GRC has for the last four years located oil traps associated with salt domes. Becoming interested in the newer scientific technique known as the reflection method, Dr. Karcher and Mr. McDermott recently incorporated their organization as Geophysical Service. They are of the opinion that the reflection method will prove an extremely important technique for locating oil deposits.

"Office manager for the Dallas group Keating Ransone and bookkeeper is W.C. Edwards, Jr. Miss Bonnie Scudder is employed as secretary.

"Arrangements are being made for placing the first of several contracted exploration parties into the field in the oil-boom areas currently active around Oklahoma City, Seminole, and Shawnee. The first of these crews, Parties 301, 302, and 303 will install locally in vehicles, their instruments which are designed and manufactured in the Newark, New Jersey, laboratory of Geophysical Service. Preliminary testing and field work are expected to get under way by mid-June. Throughout the summer months additional parties, already under contract to a number of well-known oil companies, will commence operations.

"By late summer it is planned to lease warehouse space in Dallas for storage and maintenance of automotive equipment and supplies."

Dallas at the time was Texas' second largest city, with 260,000 population. Streets were paved with brick and laced with trolley tracks. It was cosmopolitan in character and recognized as a financial and distribution center.

The skyline reflected the aura of economic millennium that prevailed in the '20s, and offices, hotels, and factories rose impress1vely out of the rich, undulating prairie where agricultural lands grew cotton, wheat, and maize.

Depression was beginning to set in, and the price of oil was quickly depressed by overproduction. Folk less daring than the co-founders of GSI might have taken these factors into account before beginning a new business in an environment that would soon move into the era of alphabetized government controls such as Roosevelt's NRA, SEC, TVA, etc. The bank holiday and going off the gold standard were additional economic factors to be reckoned with. The financial backing for GSI was secured by subscription to 1,901 shares of oil"' on stock having a par value of $1.00; more than half of these were sold to E.L. DeGolyer. Karcher and McDermott owned the balance until 1931 when 99 more shares were issued to three key employees, raising the total shares to 2,000. By today's standards, this appears quite low, but it was enough for super salesman "Doc" Karcher and an equally adept salesman and manager, McDermott. It was their astute choice, when GSI moved to Texas, to headquarter in the house of the banker.

When GSI came to Texas, it came to oil country. Oil had toppled King Cotton from his throne as the largest single source of wealth in Texas, and oil-related businesses were noticeable to bankers.

None of the oil discovered previously, however, had been found by so sophisticated a technique as the reflection seismograph surveys which GSI proposed to market. The first oil discovery in Texas was in 1866 when Lyne Taliaferro Barrett brought in his first well at an oil seep near Nacogdoches, and he later formed Melrose Petroleum oil Company, drilling numerous other wells. E.F. Hitchcock of Nacogdoches County brought in the state's first gusher at 70 feet near Barrett's first well. An oil boom began at that Texas City and was the site of the state's first oil refinery.

Oil was subsequently found southwest of San Antonio, the cradle of Texas liberty, and soon after on a farm south of Waco. These finds occurred while farmers or ranchers were searching for water. The discovery of oil at Corsicana in 1895 followed increasing and distressing evidence of oil in water wells. The development of the Corsicana field moved Texas into the arena of commercial producers. A refinery, predecessor of Magnolia Petroleum Company, was built at Corsicana to process oil and gasoline. Magnolia's flying red horse came to grace the Dallas skyline.

The Lucas salt-dome drilling south of Beaumont produced a column of dark green oil that showered the area from a height twice that of the derrick. The Spindletop geyser spouted oil for 9 days before being capped off; it ushered in an intensified search for oil in Texas salt domes, utilizing--during the late '20s--the gravity and refraction survey methods.

At Electra, on the W.T. Waggoner ranch, was an 8-million-barrel-per-year producer. Other discoveries were made near Amarillo and at Mexia, a typical oil-boom area that experienced a population growth from 4,000 to 40,000 in only a few days. Drilling success at Santa Rita in West Texas near Colorado City made the University of Texas the richest college in the nation and opened the Permian Basin.

With all these producers, Texas passed Oklahoma and California in oil production by 1929, and Columbus M. (Dad) Joiner's success near Rusk was yet to happen. He made the year 1930 unforgettable in the history of oil. A former member of the Tennessee Legislature and late of Oklahoma, he became interested in the East Texas area although leading geologists had turned thumbs-down on the section as a likely prospect.

When the first traces of oil showed in the tailings, word went out and more than 1,000 people gathered at the drill site to see a gusher blow in. It heralded the beginning of the largest oil field in the world. This find was the result of a gut-hunch of Joiner, the king of the wildcatters.

Oil from the East· Texas field glutted the world market; the price of oil dropped from $1.10 to as low as 5¢ per barrel. There was a lot of oil, low-priced oil, and it was found without the scientific approach which GSI intended to market. This condition alone could have daunted the GSI co-founders, who had it in mind to market an entirely new oil-finding tool, reflection seismology.

Most historians and economic experts who comment on the evolvement of the oil industry in Texas usually mark its expansion as beginning in 1930 (about the time that reflection seismology made its entry onto the oil scene). Dr. F.A. Buechel, a director of business research of the University of Texas, writing on the industrial economy in 1954, reported: "It should be noted in passing … that Texas did not become one of the Big Three in oil production until 1921--20 years after the discovery' of Spind1etop. Although the state's oil production was stepped up in the period of World War I and the early '20s, the really great expansion has come since 1930." The historical trends in epoch-making finds since 1930 demonstrate the advancing technology of reflection seismology.

When GSI opened its headquarters in Dallas as the first independent contractor to serve the oil industry with reflection seismograph surveys, other barriers than an economic depression and the market glut of oil awaited the new business. GSI had to build the instruments which it would use in this service.

Relying on designs developed earlier, Karcher and McDermott set up facilities to build instruments to equip, at a minimum, 11 field parties. Equipment tolerance prevalent in the oil industry were very low compared to the exacting tolerances of this GSI equipment. A laboratory and workshop set up above the Ford Motor Company sales showroom at 185 Clinton Street, Newark, New Jersey, occupied 700 square feet and was leased for $100 per month. When it opened in March, the staff consisted of Alfred Morel, draftsman; Tony Case, electrical assembler; and Henry Stoll, toolmaker. It was equipped with a drill press and bench lathe. As soon as equipment was completed, it was shipped out to Dallas and used in outfitting field crews.

One cold day in March 1930, Karcher and McDermott were looking around Newark for some aluminum pipe needed for a new piece of equipment. Karcher suggested a visit to the Newark office of ALCOA, where J. Erik Jonsson was manager and sales engineer. Jonsson and Karcher had married cousins, and Karcher thought he might help.

McDermott and Karcher, as Jonsson recalled many years later, were "wearing caps and rumpled suits and looked about one cut above the apple sellers who were hawking and walking the streets at the time."

Obligingly, Jonsson got the pipe for them and returned to his desk to ponder the new enterprise. Very soon, the co-founders of GSI prevailed upon Jonsson to assume supervison of the Newark laboratory. They needed good management and manufacturing to exact tolerances if they were to compete against all known methods for oil search. Jonsson's engineering ability was solid, proven, and he was affable and willing.

When the question arose of who would take over the laboratory while Karcher and McDermott headed up the Dallas office, Karcher asked McDermott: "What about taking on Erik?" McDermott replied: "Why take Erik away from a good substantial job with a company like ALCOA to come to one like this? We don't know what will happen to this company." By July 12, however, it was settled, and Karcher sent Jonsson a wire offering him an annual salary of $5,000 to "take charge of our Newark office and the manufacture of our instruments." Jonsson was 28, had worked previously for ALCOA, had failed in a business venture of his own, and was back at ALCOA, salary-safe and secure. Commenting on this job change, Jonsson explained: "I can't tell you exactly what motivated me to change jobs at this point, but maybe I made -the choice because I was still young and felt there was more chance to carve out a career in a short time with a small company than with a large one … and maybe because this new job would eventually take me to a new and limitless land--to Texas."

The mold for a motivated Jonsson was set in his parental background. He was born September 6, 1901, the only child of Swedish immigrant parents. He lived on the seamy side of Brooklyn until he was 13, when the family moved to the suburban town of Montclair, New Jersey. His father was a storekeeper. During teen years, Jonsson delivered groceries, worked as a mechanic in Bennett's Garage, took a summer job making fuses in a munitions factory at 25¢ an hour (10 hours a day), and one summer worked in an aircraft factory where the famed "flaming caskets" (or DH-4s) were assembled. He saved most of his earnings for college, and after completing high school in 3 years (winning a scholarship), Jonsson had the total sum of $550. With this, he entered Rensselaer Polytechnic Institute, working his way through college. ALCOA hired him after graduation. After several assignments, he reported to ALCOA's Edgewater plant where he worked until he decided to go into automobile sales. His Dumont Motor Company was unsuccessful, and as Jonsson commented: "My failure was quite a thorough accomplishment." ALCOA rehired him for less money than he made before, and he managed their sales out of the Newark office.

The news item which announced GSI's first laboratory in Newark mentioned that the services of Jonsson, graduate of Rensselaer Polytechnic Institute, as laboratory superintendent would be secured by midsummer. This news item also briefly described what it was all about:

"Earliest known field experiments conducted in development of the reflection seismograph date back to 1919 when Dr. Karcher, using apparatus he had devised, made a seismograph recording in a rock quarry near Washington, D.C. By June 1921, Karcher made additional field tests with improved instruments near Oklahoma City.

The results of these early tests have proved the ability of the reflection seismograph to obtain useful subsurface information. Contour ·maps of subsurface formations may be based on reflection seismograph data.

"In the seismograph method, explosive charges are fired in holes drilled down into a top layer of the earth's crust. Most of the force of the explosion is absorbed in the surrounding rock, but sound waves created by the explosion speed downward through deep layers. As the waves reach successive layers, they bounce back (or reflect) a portion of their energy to the surface. These returning waves, which cause less vibration on the surface than a human footstep, are received by sensitive instruments called seismometers, which convert the infinitesimal amount of energy into electrical impulses. The impulses are amplified hundreds of thousands of times and are recorded on photographic paper in the form of a seismogram. It is from interpretation of such records that the geophysical scientists get information for the maps they draw to show geological conditions buried underground. Conditions favorable to oil accumulation are found in the sands and porous rocks associated with buried geological structures--such as faults, domes, ancient folds in the earth--where oil is sealed off or trapped by a covering layer of solid rock. "

For 4 years, Jonsson supervised GSI's laboratory in Newark, New Jersey, designing and building equipment (seismometers, recording cameras, developer boxes, cable reels, and amplifiers) to supply the needs of a growing list of seismic field parties. As soon as the Peerless 1000s were shipped out, installed in vehicles, and used in the field, there was a growing list of modifications and additional demands for innovations.

By 1934, the laboratory was moved to Dallas, and Jonsson was given a desk in the three-room GSI headquarters in the Republic Bank Building. He soon wore two hats--lab supervisor and treasurer.

Finding that local supply houses would not stock quantities of the kind of materials GSI needed, an Engineering Supply Company was set up in March 1937 to provide a dependable source for the growing geophysical supply needs.

When most enterprises were cutting back during the '30s, GSI went all-out to recruit personnel for 11 field parties. Wages were high for the times: $5 a day for common labor; $250 to $275 a month for surveyors; $275 for computers; $300 for observers; and party chiefs made from $600 to $700 a month.

GSI actively recruited college students with degrees in electrical engineering, physics, geology, geography, and mathematics. During the '30s, a number of such recruits were brought into GSI and trained to become party chiefs, supervisors, and managers. One example was Robert C. Dun1ap--a geology graduate from Southern Methodist University with graduate study at Harvard University in seismology and geo1ogy--hired in 1934 as a computer. Charlie Moore, another SMU graduate with a B.S. in mathematics and physics, joined GSI in 1934. Jack Kohler, hired in 1935, was a geology graduate of Texas A&M. Neil W. Mann came to GSI immediately following graduation with a B.S. in civil engineering from the University of Oklahoma in 1934. Fred J. Agnich, a geology graduate from the University of Minnesota, came in 1937 to train as a computer.

There were no career geophysicists in those early days. Colleges and universities had no geophysics degree program; curriculums were yet to be molded by the needs of a growing new industry. GSI, however, had a nucleus of experienced people to train new personnel. They had successfully recruited a number of GRC employees. The refraction methods employed by GRC had reached the point of diminishing returns by 1930 and the techniques were not successful for the discovery of other subsurface conditions favorable for trapping oil, but field procedures for reflection methods were similar. These ex-GRC employees hired by GSI were moved about from party to party in various training roles.

They led off GSI's geophysical exploration efforts and were major contributors to the evolution of exploration seismology and units conversion through the years from an art to a science. One was Ken Burg, whose ability as an early-day geophysicist was demonstrated by such contributions as: solving logistical problems, innovative use of new methods, and shotpoint offset in continuous profiling to reduce ground roll interference.

The importance of the seismic reflection method was strengthened by each new field discovery: English Bayou, Bay Baptiste, Bayou de Large in South Louisiana, Old Ocean in the Texas Gulf Coast, and discoveries in Kansas and the Seminole area of Oklahoma. Burg was personally related to all of these discoveries.

Burg's ability to resolve logistical problems was demonstrated when he designed and engineered a marsh buggy to transport crews, instruments, and equipment into the marsh lands of South Louisiana. He also was innovator of using a centrifugal jet pump to drill shot-holes in the marshes.

This kind of personal involvement by early-day geophysicists working for GSI was typical and was the result of a special kind of work environment generated by Doc Karcher and Eugene McDermott. These co-founders of GSI were capable, personable, and inspiring individuals, and GSlers responded to the Challenge in an aura of excitement that surrounded the new seismic reflection method. Selected reports which follow demonstrate the intimate personal involvement of all the early dood1ebuggers.

GSI's first reflection crew, Party 301, reported from Shawnee and Seminole, Oklahoma:

"Now that GSI' s first reflection seismograph party has been in the field for a few months, we feel we can report some items of interest.

"Of course, it wasn't too new to some of us old hands who used to be with Geophysical Research Corporation, out of Tulsa. When Doc Karcher and Gene McDermott started this new outfit, some of us decided to get in on it, so Roland Beers, Al Storm, Ike Newton, and Bill Salvatori reported for assignments.

"Right at first we were 'busy doing some preliminary testing of the equipment when it came down from the Newark lab. We had some headaches getting it installed in the vehicles to suit us. But, in late May and early June, we did some tests near Gilmer in East Texas, where there's a lot going on these days. If Dad Joiner brings in that Rusk County well he's had a show on, it could mean much to folks around here.

"Then we headed out for Shawnee. Our computer did a good job. He was Al Storm, an Oklahoma boy, and helping him was W.D. Neff-we called him Pat after Texas' ex-governor fresh out of Texas A&M with an E.E. degree. Bill Salvatori did figgerin', too, and when Al moved over to help Party 304 get going in July, Ewin Gaby came in as a computer. Two SMU students were with us in the summer, Porter Mason and Mac Coker. When Surveyor Park went to help 305 get started, Russ Terry came over from Peacock's party to shoot the lines. We enjoy seeing Ira Cram, our client (Pure Oil) representative, when he drops by.

"Instead of drilling our shot holes by hand auger, which takes so much time, we've been using a contract drill rig out of Oklahoma City that belongs to a man named Rumbaugh. Sure saves on the wear and tear those hand augers cause on hands and backs. We had to have more water to drill the holes by machinery, so Sonny Taylor and Bob Rainey got hold of a stock-watering tank and rigged it up on a flat-bed truck. It does fine until it starts edging off the truck, and Sonny and Bob have to shove it back on--filled with water! Sonny and Neal Shadrick were with GRC, too. They know how to handle field problems from experience.

A GSI party complement consisted of party chief, computer, observer, surveyor, rodman, shooter, labor foreman, and helpers. Where hand augers were used, the job classifications' to man the augers were "hole-digger" and helper. These two categories were classed by crew members as the "rotary club." Their chief activity consisted of bearing down and turning to the right. As one reporter described it: "In time a hole-digger digs down to 20 or 30 feet, if he's man enough, and then he pots the hole out gradually, if he's shooter enough, until it will hold a 10 to 20-pound charge of dynamite. In these modern times, there must be an easier way of penetrating the earth than we're doing. Someone had tried rigging up a motor-driven drilling bit by jacking up a truck axle and running the drill off of it."

Usually, there were three two-man auger teams on a crew, and they averaged nine holes a day. A 4-inch hand auger (3/4-inch pipe) was used to dig the holes to bury the S-2 seismometer. The S-2 seismometer, first used by GSI, was a jug-like instrument weighing 35 pounds and standing 13 inches high.

Hole-digging was arduous labor, and sometimes even Karcher found himself pressed into service in the absence of the hole-diggers. It was during one of these pioneering days when a young man who had been hired as a computer was pressed into emergency service as a drill hand. He complained to the mud-covered, sweating man who was on the other end of the auger: "I'm a field observer, ' and I hired out to be a field observer when I came to GSI. I didn't hire out to dig any holes."

"Neither did I," said the tall, rangy man on the other end of the auger.

"What did you hire out to be?" asked the young observer.

"Well," said Karcher, bearing down and turning right: "I'm president. So, I guess I hired out to be president."

Having had this personal hole-digging experience, Karcher was looking at ideas being employed or suggested by the early teams. Where icy ground taxed the sinues of the most stalwart hole-diggers, the axle of a truck was jacked up to provide power to the crowbar. Another crew rigged up a gasoline-driven motor to power the auger-type drill. At Maud, Oklahoma, a Buda No. 2 dry-hole, auger-type drill (like those used at the time to drill telephone poles) was pressed into service. It could drill 28-foot holes with its 32-foot drill stem and its 4-l/2-inch corkscrew-like bit in 10 minutes, or about 20 holes per day It was not long before Karcher and Earl Johnson were sketching ideas for a truck-mounted drill, and they huddled with Mayhew Machine and Engineering Company on Commerce Street in Dallas to solve one of the most difficult tasks of the seismic survey.

A report from seismic Party 302, Oklahoma City, gives first-hand details of other problems associated with the reflection seismic work. This crew made its debut on Friday, June 13th. Party Chief Ken Burg reported: "We got our new recording truck all rigged up with the Peerless 1000s, which is the best set of instruments in the business. We did have a little trouble with the harp. Whoever dreamed up those little demoralizers sure need not expect to go to the place where the golden harps are. The package that the harp wire comes in says: 'Ten feet of copper wire. Diameter 4 ten-thousandths of an inch.' To stretch this wire and solder it to pins along with several other strands so that there are no kinks, and all of nearly equal tension, certainly is a trick requiring something more than skill.

"We had the boxes for the 35-pound S-2 seis and the cable reels mounted on the side of the truck in the garage here. We didn't have time to mount the developing box on the rear of the fender, so the JO (junior observer) spends all day riding with the box in his lap. The sun beats down on the developer box and the JO while he dunks the records. We are using two conductor wires to run from the truck to each geophone, and we started out shooting with them 200 feet apart. Each wire is wound up on a separate reel mounted just behind the truck door.

"We sure have a neat arrangement for mounting the instruments. They are on shelves just behind the front seat. The back of the front seat is folded down on the seat cushion. The observer sits on this and cranks the paper into a magazine with a small hand crank. The chief computer is already giving the observer a bad time for non-uniform cranking. Sure would be nice if some smart lab man could figure out a way to crank the paper out with an electric motor. I'll bet someone will figure that out some day.

"We looked at the records after supper last night and it looked like they were too low frequency, so we took all the seises apart and put in heavier springs, and some 600 W oi1 had to cut some shims out of a Prince Albert tobacco can to put under the springs to make the pole pieces center. Wonder if Karcher and McDermott know that those brass screws on the pole pieces work loose so that the pole piece moves. It sure would be a lot easier if they could figure out a way to change this frequency by condensers or something."

Party 303 was first at Enid, Oklahoma, working for the Indian Territory Illuminating Oil Company (part of Cities Service). Assisting Henry Salvatori, Party Chief, was Gerald Huff, the computer, who was the championship tennis player recruited from the Dallas region. The shooter was Dick Williams, a Southern Methodist University basketball star. Party 304 had several former GRC dood1ebuggers, including Dr. Peacock. They were working in Shawnee, Norman, Duncan, and Oklahoma City on contract with Carter oil Company. Party Chief Peacock's reporter wrote: "But when Peacock decided he'd try reflection methods as a charter member of the GSI Company, some of his boys decided if it was good enough for the doctor, it was sure good enough for them. These GRC boys were Jud Farmer, Al Storm, D.A. Ford, Ike Newton, and Preacher Parnell."

The first GSI survey team to work in Texas was Party 305, led by L.E. Randall, and working around Palestine, Texas, for Humble Oil.

Party 306, under C.V.A. Pittman, worked around Cordell, Sayre, and Elk City, Oklahoma. His crew was trying to solve the hole-drilling tasks with crowbar and pulley drill rigged on a tripod as a makeshift spudder. This was followed by running the crowbar off the truck motor and finally a gasoline-driven motor was rigged to power the drill.

Party 306's surveyors marked their lines with bright orange or red strips of calico along the survey line on trees, posts, or bushes. When these strips began to disappear, no one could solve the mystery until the doodle buggers paid a visit to the nearby town on Saturday night. Indians from the Cloud Chief Reservation were in town too, as described by the party reporters: "some of them on horseback, others just milling around the post office and general store. Something looked kinda familiar to us doodlebuggers, too. There was our flagging, braided into the Indians' long hair, into their horses' manes and tails, and lots of other decorations."

Party 307 at Maud, Oklahoma was shooting for Empire Oil and Refining Company (a branch of Cities Service), and their representative was Gerald Westby. Party Chief R.P.T. Thompson had brought in a Buda No. 2 dry-hole auger-type drill, and the driller, Everett Stanfill, was reported to be able to "make that dirt machine eat up rock and dirt." The computer at this site was Barney Fisher, an SMU geology graduate.

Party 308, led by John P. Lukens, an electrical engineering graduate of the University of Pennsylvania, marked the beginning of GSI's long association with Shell Oil Company. In 1930, Dr. A. Van Weelden employed GSI to work around Gainesville, Texas, and Shawnee, Oklahoma. Client representative was Dr. Frank Goldstone.

Atlantic Refining Company was the customer for services of Party 309 at Whitehall and Holdenville, Oklahoma and at Andrews, Texas. Party chief was Earl Johnson of Denison, Texas, who had been recruited from Roxana Oil. One early party report described the problems associated with secrecy which pestered all of the survey work:

"Things get pretty hectic some days when we start out to the field and there is a scout waiting to "bird dog" our trail. We know better than to let him stay on the scent too long--might

as well take space in the paper to advertise where we're working as let one of them keep up with us. We've gotten pretty smart, though, in fooling one old boy who tries to keep up with us.
We start out in all the trucks and the party chief's car, following along close on each other's taillight. Then the lead car, when we're sure the scout is right behind us, cuts through a wrecked car (or salvage) lot. The last car through stops, the boys get out and drag a wreck chassis right across the narrow driveway, and the old boy is blocked. By the time he backs out, because he can't move the heavy thing alone, we're long gone.

"Sometimes each carload just heads off different directions, then meet later at a spot we've chosen. He has the devil of a time picking the man to follow, so we shake him in that way.

"We heard about some GSI gang that went down a slippery, muddy country lane, all the cars creeping along, the scout bringing up the rear. They stalled the rear car on purpose and got out to give it a shove. The scout by this time was having a hard time trying to keep from getting stuck, so the boys just assisted him--off into a ditch.

"That's part of the game of 'Hunt for Oil' these days, though. We have to try to keep our work for the client pretty quiet... those leases are hard to come by...the scouts are part of the game, too. It’s just a case of who outwits whom, and it's fair sport."

Placing these seismic survey teams in distant oil-boom areas was itself a feat during the early '30s. Although a good network of railroads existed, they did not afford entry into the developing oil patch. Air transportation was just getting winged up; many areas of the countryside were just being introduced to barnstorming. At survey teams were the beginning, however, the transported by Model T autos and trucks, but none of the fine highways that ribbon Texas and other states today were in place in 1930. Travel conditions were good if there were a two-lane asphalt or brick road. Dirt and gravel roads were sometimes to be found; while many of the lanes and trails over which the GSI doodlebuggers traveled in convoy-like formation were pure mud-wallow.

The oil patch was filled with boom towns that were overpopulated, dotted with tents, shacks, and generally had poor housing accommodations. Planked sidewalks, hub-cap deep mud in unpaved streets, and rinky-dink music floating out of local bordellos characterized many of the new towns or the old towns that were bulging at the seams.

Transients who flocked into the areas during the oil-booming late '20s succeeded in leaving a bad reputation for all transients. In East Texas, Texas Rangers were sent out to bring law and order to the scene.

By 1930 when GSI's doodlebuggers were beginning the gypsy life, they had to deal with local public opinion. One GSI recruit's bride reported: "Being known as transients is a handicap in the small towns where we have to stay, and it's hard to find decent living quarters. Somehow, having children seems to be considered not quite decent, and the ones with youngsters have the worse time finding accommodations. Apartments (such as are available) are pretty dismal these days. Usually it's a bedroom, a bath (shared with others), and kitchen (also shared). My food allowance is a dollar a day, but we eat like kings."

The most poignantly descriptive essay on the life of the pioneer crews and their families was the contribution of Ida M. Green, wife of the party chief, Cecil H. Green, of Party 310. She wrote from Maud, Oklahoma:

"Life moves swiftly in our party since moving about every few weeks seems to be our fate. After dashing around in some small town to find a place to live, we may end up with two shabbily furnished rooms, or in rare cases a nice private home which happens to be for rent. First there, first served is the policy which equalizes living conditions for everyone at some time or other, especially in these Oklahoma boom-times. If you end up living in a place where you share the bath with three other families, maybe the next time you'll hit the jackpot and get an attractive home. One soon becomes philosophical. The business is so new that small towns haven't adjusted to oil people and regard them with suspicion and concern. We try to keep a good reputation, but perhaps the last crew forgot themselves and left the barn doors open and so we find ourselves trying to close them.

"First thing the wives do after getting located is to rush around to see what the grocery stores (not more than two) have to offer in foodstuffs. Vegetables are scarce, other than turnips and mustard greens, with a few other specialties thrown in. Fresh killed yearling beef is sometimes good and then again tough. Chicken for Sunday dinner is found by going down to the local feed store on Saturday. Sacks of Purina Chow and other feeds fill the place, but out back is a pen or yard filled with fast-stepping chickens. A man snares one with a wire, and I ask him if he would mind cutting its head off. That accomplished, I return home, proceed to remove the feathers, and then do some major surgery. Come Sunday, golden brown fried chicken with cream gravy graces the festive board.

"We crew wives drop in on each other for a cup of coffee and to catch up on current news. Occasionally a bridge luncheon takes place, or a get-together of the crew with all the wives showing off their culinary art, with fried chicken and all the fixin's.

"Dr. Karcher and Mr. Me drop in, and the conversation is mostly about Viola—whether high, low, or a closure. (Viola is mighty important! For a long time I thought Viola must be quite a gal until after a few sessions I learned differently.) As long as we have a table, chairs, water tap, and some kind of flame, they are always invited to 'set up' and eat with us. Our geologist, Mr. Ronald Cullen of Twin States Oil, comes to see how things are going and he, too, shares our meals. We are happy to have him from the big city.

"Life is settling down, or so it seems. Suddenly, it is whispered around--it is rumored--that we are going to move. The women begin to lament--they have just stocked up on a lot of perishable food or groceries, or someone has been silly enough to have done some extensive housecleaning. Such things always bring on a move. Plans are made to move as quietly and as secretly as possible since the general idea is to outwit the scout and leave him behind. Locations for leasing are kept secret by the oil companies. Sooner or later the scout shows up and follows the crew to the field, and like Sherlock Holmes minus the magnifying glass, makes collection of evidence--even to small scraps of records that somehow got scattered around.

"Some of the single men are marrying, and the married folks are beginning to have families. Life isn't too monotonous and even has an element of adventure in it. The crew is like a family--our joys and sorrows are shared, and we make an effort to get along together.

"The advantages are: time for hobbies, family ties are closer, and appreciation for any kind of entertainment. Children seem precocious and extroverted, meeting people easily. There is less expense in keeping up appearances. Last, but not least, we always see and learn about something new or different, and can put away a nice nest egg for the future. Such is the doodlebugging life."

Ida Green, whose essay on the life and times reflects her personal appreciation for the historical significance of those events, is the wife of Cecil H. Green, an Englishman who was born in Manchester, England, and whose parents emigrated in 1902 to Eastern Canada. Until he was 21, his youth was spent primarily in Western Canada, and he held summertime jobs as a riveter's helper and electrician's helper. He came to the United States in the '20s but did not become a naturalized citizen until 1936.

Cecil Green enrolled in the Massachusetts Institute of Technology (MIT) in 1923 after completing undergraduate study in electrical engineering at the University of British Columbia. He earned his B.S. in electrical engineering in 1923 and his master's degree in 1924; he completed his master's thesis requirements at General Electric Company's plant in Schenectady, New York. He met Ida Mabelle Flansburg during this time, and they were married in 1926.

He entered the emerging field of electronics by joining Raytheon Manufacturing Company of Newark, New Jersey, remaining there for 2 years after which he spent a year in production engineering for the Wireless Specialty Company of Boston. Cecil was an electronics development engineer with Charles V. Litton in Federal Telegraph, a unit of IT&T, in Palo Alto, California when he became intrigued with reports of GSI and its entry into oil exploration with the reflection seismograph. By October 1930, he and Ida drove to Maud, Oklahoma, where he hired on as party chief of Party 310.

By 1934, GSI began foreign operations and, in 1936, Cecil became supervisor over a growing business in domestic and foreign survey work. This involved travel throughout the USA, Canada, Mexico, Panama, Columbia, Equador, Venezuela, Sumatra, Java, New Guinea, India, and Saudi-Arabia through 1939, when foreign operations began to drop off because of World War II.

GSI's growth had been temporarily threatened in 1933 by a patent dispute between two oil companies over the seismograph method of oil exploration. The basis for the dispute was a patent developed in 1923 by L. Mintrop (of Germany) relative to refraction methods of geological prospecting. This patent was sold to a major oil company who gave notice that use of the seismograph method was a patent infringement. The ensuing legal battle affected everyone using refraction or reflection seismology.

Although Doc Karcher was able to assemble very persuasive evidence of his 1919-21 experiments and use of his reflection seismograph prior to Mintrop's patent of 1923, it was decided by GSI management that the better part of wisdom was to support a compromise settlement and a licensing arrangement. To escape time-consuming court actions that would impede GSI business, the company purchased ten licenses for an outlay of $100,000, although they also operated under client-purchased licenses much of the time.

The basic principle of reflection seismology as originated by Doc Karcher was based on his 1917 observations of the difference between refracted and reflected seismic waves. Successful field tests of his reflection seismograph were documented as early as 1919, and he successfully proved the validity of the reflection seismograph as a useful tool in the search for oil in June 1921 on a farm near Oklahoma City. Nevertheless, the economics of licensing from the owner of Mintrop's patent avoided a costly legal patent challenge and allowed GSI to continue the commercialization of Karcher's more sophisticated concept of reflection seismology without interference.

Karcher was as interested in finding practical applications of other sciences to petroleum reconnaissance as he was in seismology. His experimental work during the early '30s extended over a range of geophysical and geochemical methods.

In 1932, Experimental Party A was activated to conduct field experiments in Kansas, Oklahoma, and Texas. Karcher assigned Morris G. Spencer, C.A. McCluney, and J.B. Polk to a project that experimented with electrical logging, a technique for evaluating such physical properties of formations as porosity and permeability. By 1934, Spencer was brought back from Caracas to work on building and assembling an electrical logging device to be put into service in the Gulf Coast area in early 1935. J.B. Polk was the party chief when this equipment was returned to the lab for modifications.

In the early '30s, GSI put a shallow water production crew to work in Galveston Bay. Following some speculation about whether or not seismic reflections could be obtained in the deeper water of the Gulf, the crew attempted an experiment and proved that offshore seismic work could be done. Details of this program are described in Chapter VIII by Bob Dunlap who was on the crew.

In 1938, experimentation began in the use of geochemical techniques for oil exploration. This was McDermott's interest, and he organized and participated in the experimentation. Contour maps were plotted from readings from a scintillation counter supported at a fixed height above the ground for a predetermined grid. The technique involved soil sampling as well. The method was cheaper than seismic surveys, but the reflection method at the time was proven and economical. Although offered to clients by 1939, geochemistry was never successfully exploited, and no good statistical test was given the technique before work was interrupted by World War II.

Unassigned field parties were the special forte of Karcher during the mid-'30s. Instead of operating under contract to an oil company, these parties worked for GSI's account. Their success eventually resulted in GSI owning several producing fields and having a substantial interest in others. This placed GSI in a critical position with some clients because of the proprietary aspects of data collection. There was a high degree of security to be maintained over information gained through surveys for each client. This was placed in jeopardy when the survey company itself was in competition with the client.

A decision was made to separate the producing arm of the company from the survey work, and the company name was changed on January 1, 1939 to Coronado Corporation, with Karcher as president. The exploration service was organized as a subsidiary, Geophysical Service Inc., headed by McDermott. By 1941, Coronado owned a good-sized property consisting of several producing fields and some capped gas wells.

Karcher became restless; he wanted to move out on his own, organizing producing oil companies. Negotiations began with Standard of Indiana (Stanolind) in 1941 for the sale of Coronado and GSI for $5 million, of which GSI represented only a small part. A price tag of $300,000 was put on GSI when four GSIers decided to buyout the geophysical company rather than be merged with Stanolind. Key employees looked on the merger as a loss of identity, and they wanted to preserve their association in geophysical exploration.

The four who joined together in a partnership to buy GSI were Eugene McDermott, Erik Jonsson, Cecil Green, and Dr. H.B. Peacock. The sale marked the close of Karcher's association with GSI, although it was he who had sparked the creation and who would in time become the recognized father of the reflection seismograph. A warm personal relationship remained over the years and is reflected in Cecil Green's 1979 Memorial "John Clarence Karcher" appearing in the June issue of Geophysics and stating: "Karcher, although not widely known outside his industry, gave the world what Everette DeGolyer called 'The Eyes of the Geologist.' A citation by the University of Pennsylvania in 1971 stated this contribution succinctly:

"Whereas John Clarence Karcher, while a doctoral candidate at this University, first conceived of seismic reflectlions as a means of prospecting for petroleum, and whereas his theory was strikingly validated five decades ago in a series of experiments in his native state of Oklahoma, and whereas this method of petroleum exploration has resulted in the discovery of more crude than through all other methods of exploration combined, and whereas, thanks to his initial conception a great industry has evolved, an industry that in turn has made possible the development of many of the mechanical achievements now taken so much for granted, therefore be it resolved that on this occasion the University of Pennsylvania expresses to John Clarence Karcher profound admiration for his ingenuity and resourcefulness, his recognition of the fundamental value of a theoretical principle, and his tenacious spirit of inquiry with which he demonstrated the usefulness of seismic exploration for the benefit of mankind' ."

CHAPTER IV
GSI, A WAR-TIME CONTRACTOR

The purchase of Geophysical Service Inc., by McDermott, Jonsson, Green, and Peacock, was consummated on December 6, 1941. McDermott was president and Jonsson vice president and treasurer, with Green and Peacock sharing responsibility for the geophysical work.

The ink was scarcely dry on Black Sunday when the Japanese bombed Pearl Harbor, plummeting the United States into World War II. Few who heard the radio broadcasts interrupted for President Roosevelt's announcement of the destruction of a major portion of the nation's fleet congregated at this Pacific port can forget the chilling pause, the near-disbelief that the U.S. was inexorably at war.

There was a great deal of uncertainty for the four partners on December 7 and for some of their crews. GSIers in Sumatra, for example, concerned themselves with getting home as the Japanese were then bombing Sumatra. Leaving all possessions behind, crew members hitched rides on a Dutch boat in the Bali Straights, were torpedoed and dumped in the briny deep, and had to take to life boats. They were picked up by a gunboat and finally got on board another ship headed for the States (via Capetown, South Africa).

As war heightened the uncertainty hanging over GSI, the status of petroleum exploration in relation to the war effort was not decided for a full year. In the meantime, deferment of key personnel and purchase priorities of materials and equipment were essentially impossible.

Oil exploration was possible only in a limited way in California, Texas, Oklahoma, Colorado, and Oregon. It was not until 1943 when U.S. Secretary Harold Ickes organized the Petroleum Administration for War (PAW) under-deputies Ralph Davis and Dallas' own E.L. DeGolyer that Selective Services' attitude was softened regarding the continued need to search for petroleum resources. To quote Cecil Green: "We had to fight to hold each key field man and, in my case, I recall working with over 90 draft boards plus some state headquarters." After that, GSI was able to man crews in Mexico, Columbia, and Canada. In the U.S., GSI crews worked in the Louisiana marshlands, the Rocky Mountain region, and the Mississippi Gulf area.

The exhilaration of ownership was quickly to depart the four partners on Black Sunday. Before a single working day had gone by, the new owners of GSI faced a crisis with losses of some $10,000 a month looming ominously in the wake of foreign business drop off and the poor deferment posture. The previous 26 crews were reduced to 6. Jonsson later described the situation as "hopeless but not serious." They countered with a 5-year plan.

Markets to which GSI would turn during the war years were being set in motion in Washington, D.C. Under the Office of Scientific Research and Development, the National Defense Research Council (NDRC) set up numerous laboratories to pull university and industry people together to tackle specific jobs in technology and design for the war effort. Among them were the Radiation Laboratories of MIT, the laboratories of Radio Corporation of America and General Electric Company, and the Airborne Instruments Laboratory affiliated with Columbia University.

Dr. Dana Mitchell of Columbia University provided the fuse igniting a useful GSI war effort in magnetic detector systems which utilized recorders and operating control electronics. E.J. (Jim) Toomey, laboratory superintendent from 1940 to 1945, described it succinctly.

"The MAD (Magnetic Airborne Detector) thing hit us when Dr. Dana Mitchell telephoned Mr. Mac (McDermott), saying he needed six devices made for test; he could not divulge what they were but he explained that he knew (having previously toured the GSI lab with Mr. Mac) that we could build them. Mr. Mac agreed to help NDRC and the country without knowing what it was we were to build, or what the cost or price would be.

"We soon got a stack of 8-1/2- by 11-inch ozalid prints of piece-part sketches and specification sheets on such important components as motor generator sets providing plate current to the many vacuum tubes in the system. There was no assembly drawing, as the NDRC was afraid to release one for security reasons. Ai Morel made subassembly sketches by matching up piece-part drawings, and it was then we knew what we were to build. The great team we had included Ai Morel, chief of drafting and mechanical design; Henry Stoll, shop foreman; Darwin Renner, electronics development; and Elmer Davis, materials man. Additionally there were some 20 others including Otto Braun, Pop Davis, Otis Hendricks, Mac McCandless, Ted Coe, John Carter, Lawrence Congdon, Bert Warrick, Mr. Weed, and Mr. Van Wagoner.

"We finally got the circuit diagram hand carried from NDRC headquarters at LaGuardia Field. The circuit never worked, but Darwin Renner redesigned it to work very well. Renner and I took the first set to Quonset Point for test, with a stopover in New York City to visit Dr. Mitchell. At Quonset Point, Renner set up the MAD in a shack out on the landing field; immediately it began to detect aircraft on the nearby runway. Next, the system was installed in a PBY flying boat and flown over steel bridges and submerged wrecks.

Our MAD was a success, and the Navy decided it had promised for antisubmarine application. By the time Renner and I returned to Dallas, Jonsson had an order for 50 or so more. By the time we finished the first six at Plant I, Plant II was shaping up for electrical assembly and systems test. Plant I was full to capacity, machining and fabricating parts.

Having pioneered much of the instrumentation in use for oil exploration, GSI had a built-in capability for its role in the war effort. Engineering and development tasks performed for the Signal Corps staved off foreclosure, but this business was soon succeeded by an emphasis on the MAD Mark II and Mark III for the Navy, work that was critical to the Navy's patrol task of seeking out enemy submarines that were knocking holes in the shipping lanes of the allies. These magnetic detector systems were first used on blimps and then on Navy patrol aircraft.

Charged with getting electronics components into production, the Navy's Bureau of Aeronautics (BuAer) was set up in the old Navy Building in Washington. This agency was led by Herbert Gutterman, a civilian who was given the rank of Lieutenant Commander. The radar section of the agency was headed by Lloyd Berkner, a geophysicist (who later became a director of Texas Instruments, the company spawned by GSI). At the outset of World War II, electronics was primarily in the entertainment field in the U.S. There was no military electronics in the sense that it exists today. It required many 70-hour weeks at BuAer to push American production lines on the upward road in military electronics. To keep ahead of the Germans, the U.S. had to bring itself abreast of the British position in radar and to protect the life-line of material moving across the Atlantic from German submarines.

GSI was only one of many contractors on the MAD project, a relatively small outfit among the giants who became BuAer suppliers. When Ensign Patrick E. Haggerty, desk officer on the MAD project, called in all the contractors to iron out difficulties and divide up the work, Erik Jonsson represented GSI at the meeting. Jonsson later recalled his relation to Haggerty: "We hit it off well from the first."

GSI's total wartime defense contracts totaled no more than a million dollars, but its good performance provided the base for post-war contracting. GSI received a Certificate of Achievement, signed by Assistant Secretary Hensel of the Navy, commemorating both the efficiency with which the MADs were built and the quality built into them.

GSI's Plant I at 2114 North Harwood contained the machine shop and Plant II at 1914 North Harwood housed the electronics assembly. Plant I also housed a stores department, automotive maintenance, and cost accounting for government contracting and GSI as well. Materials shortages created the most acute problem, and junkyards were combed for usable scrap; even galvanized iron from signboards was used for equipment housings. War Production Board rationing impacted many field crew needs such as photographic recording paper, chemicals, dynamite, tires, and hydraulic truck jacks. Although government contract requirements were met, the field crews of GSI were hard-pressed to stay mobile, often begging, and borrowing parts and supplies from each other and even from the completions.

With manpower and materials in short supply, the GSI field people were challenged to meet the task. As Cecil Green pointed out: "A tremendous amount of credit is due to the old timers who were very thinly distributed throughout the field and were responsible for keeping GSI's field entirely responsible operations afloat during these difficult times." Good production schedules and survey results were stressed in the field as a proper path to profits, and profits became increasingly important because of GSI's profit sharing trust established in 1942. Crews were inured to the proposition that wrecked equipment reduced their "shares", and they cared.

Steering GSI across the difficult war years was the principal responsibility of company treasurer, Erik Jonsson. He persuaded bankers to advance short-term capital on less than marginal asset-liability ratios during the war and in the immediate post-war period as well.

In 1943, a dialogue was begun with another geophysical company, United Geophysical, with the view of amalgamating the two companies. United was founded by Herbert Hoover, Jr. But last minute negotiations were shelved when Hoover insisted on having 51 percent of the new company's stock.

By 1945, GSI had 16 crews in the field, and the upcoming cancellation of war contracts meant there would be the opportunity to redesign and refurbish all geophysical instruments and equipment, improving them with technological advances gained in the war contract experience.

Wartime taxes, however, left little in the way of cash reserves, and depreciation reserves were not adequate for new equipment at inflated prices. It was Jonsson who steered GSI across the abyss to a post-war toehold on the future. He persuaded the bankers to back a GSI expansion.

It was decided that the company's postwar sales plans could include electromechanical equipment engineering and production for the Armed Services. Developing sales of equipment to the petroleum industry and other commercial fields was also considered. With this in mind, 2 weeks after V-J Day, Jonsson placed a telephone call to Ensign Haggerty in Washington to set up a visit.

The Bureau of Aeronautics was deep in contract cancellations, rescheduling, and tapering off. Celebration of V-J Day slowed the processes, but Ensign Haggerty was busy with the chores of MAD contracts windup. He handled the business which in part brought Jonsson to Washington that is, closing out the MAD contracts. During an evening downtown which came to a close at Haggerty's home, Jonsson got around to the other business on his mind. "Why," he asked, "don't you come on and join us?"

"Well, now look," replied Haggerty, "we've talked a little about this manufacturing stuff and where we think deficiencies are. I think I see an area for opportunity, and if you will set up and cut out this part of the company where we can start an activity to do this engineering and manufacturing job in electronics, not just for the geophysical, but go on, then I'm damned interested."

Although Jonsson did not know exactly how all this would be accomplished, and he said so, he concurred with Haggerty that the world was not going to suddenly have no more need for military electronics. When Haggerty's points were up in November, he checked out of the Navy and caught a train for Texas to look GSI over and meet the other partners. Another BuAer engineer, Robert W. Olson, was also hired by Jonsson in September, and he came to Texas upon release from the Navy. These two engineers were the lead-off principals of GSI's Laboratory and Manufacturing Department (L&M) which was formally organized in May 1946.

Haggerty was born March 17, 1914 in Harvey, North Dakota and grew up in the small town atmosphere. In 1929, he was one of four North Dakota Eagle Scouts chosen to represent his state, and his hometown paid his expenses to the worldwide Scout Jamboree in England. His scholastic achievements paved the way for a Marquette University scholarship in electrical engineering. He also worked in a co-op program to carry him through his degree program, first with Glove Union and finally with Badger Carton Company. A prize paper on high-frequency tubes won him an AIEE award, but he did not pursue electrical engineering at Badger where he was permanently employed after graduation. He was assistant general manager of the company when he joined the Navy for the duration of the war. Because the Navy was traditionally the engineering service, Haggerty applied for a commission and then went by the Bureau of Aeronautics. When he went in for an interview with the Commander, he was asked: "What do you know about radar?" "Nothing," confessed Haggerty. "Okay," said the commander and when Haggerty's commission came through in March, he was assigned to active duty in the Bureau of Aeronautics to begin in June, BuAer had a special priority for electrical engineers with manufacturing experience, a circumstance that placed Haggerty in the Navy as a land sailor for the duration of the war. Olson was already at BuAer when Haggerty arrived, having come in through the Navy's recruiting effort begun in 1940, and his assignments necessitated frequent association with Haggerty of the production department.

Olson was from Minnesota, the son of a small town dentist. He worked his way through the University of Minnesota, fixing radios and doing odd jobs, taking 6 years to complete a degree in electrical engineering. In 1,938 he was hired by Magnolia Petroleum Company as a doodlebugger and then worked in their Dallas laboratory until he was recruited by BuAer.

In their travels over the country to various manufacturing contractors, appraising the capabilities of the various companies, checking records and progress of contractors, working out problems, and expediting deliveries of components and devices for military detection and communications, both Olson and Haggerty shared their thoughts on a post-war future in electronics. As Olson recalled it: "Pat and I dreamed of a company that would let us take a flight into electronics to see where we could go." GSI, already a science-based organization, provided that opportunity as Jonsson had persuaded his partners that GSI should take some new directions.

Right away, Haggerty announced to the owners that the existing plant facilities (just recently remodeled) were inadequate for the plans to: 1) become a career supplier of military electronics; 2) a manufacturer of nonmilitary electronics; 3) manufacturer of geophysical equipment; and 4) become a second source supplier. This was a request for a new plant to make products for markets and customers not yet specifically identified. The new plant was to be 37,500 square feet, the estimated cost $200,000. When a cost-plus contract was let, inflation drove the cost up to $350,000 and near foreclosure.

Construction lagged, and the lease on the downtown plant expired before the Lemmon Avenue plant was complete. The machine shop moved in onto a dirt floor. As each wall was raised, some equipment was moved in. From the time it emerged from the drawing board, the new plant was dubbed the "dream castle," and it was a primitive hull in July 1946 when the move began. As each section was completed, more functions moved: automotive, engineering, manufacturing administration, and purchasing. It was not until June 1947 that the main offices, the computing department, and personnel occupied their new facilities at 6000 Lemmon Avenue.

Olson, the L&M department's chief engineer, was concerned with development and manufacture of equipment for seismic use, general sales, and government use. Research and experimental labs were set up to create and develop seismic, electronic, mechanical, and electrical products. The tactical approach was to go after defense contracting by utilizing demonstrated capabilities and developing new areas of business. New seismic recording equipment was tested in California in 1946; new amplifiers were designed to improve seismic signals; and a new camera was on the drawing board for photographing the wiggly traces produced to display seismic reflections from the subsurface. Field experiments and research were destined to move GSI from the "cut and try approach" to technica1 superiority of instruments built for geophysical exploration.

Management of costs was not overlooked. For the control function set up in the L&M department, Haggerty recruited Carl J. Thomsen, who formerly served with him in the production department of BuAer.
Thomsen was from Fond du Lac, Wisconsin, and had a degree in industrial engineering from Rensselaer Polytechnic Institute. He had previously worked as a time and motion analyst and consultant to Westinghouse Electric. He also had taught industrial engineering at John Hopkins University before BuAer. After this he entered the Navy at discharge in th e summer visit of 1946, he was invited by Haggerty to Dallas "to see the set-up" at GSI. He stayed as controller and was soon busy with setting up cost systems, project work orders, and other functions aimed to produce effective cost controls and profitable bidding of government contracts.

When Haggerty finally got around to BuAer in Washington, he sought a contract to develop a better recorder for their airborne detection work. Not successful with this unsolicited proposal, he did return to Dallas with several small contracts for his L&M department. One contract was for an air-droppable Radiac detector and recorder to sense radiation at atomic test sites. GSI bid and won away from Farnsworth Co. of Fort Wayne, Indiana a contract on the ANAPA5A, a low-altitude bombsight. However, major capture was a development contract for the ANASQ8, a revised version of the Magnetic Airborne Detector (MAD). By negotiation and competitive bidding in the years 1947. 1948, and 1949, billings reached $1,200,000. Contracts received in 1949 for 1950 delivery lifted billings $2 million over that number. GSI's L&M department had really taken off. The company's success in these competitive bids against the country's largest and best known electronic manufacturers was indicative of the excellent technical staff in engineering and manufacturing that had been assembled by an intensive recruiting program. GSI compared favorably in technical skills with the largest producers of service electronic equipment, and it was able to operate with a high degree of cost effectiveness. To accommodate expansion, facilities were enlarged twice between 1949 and 1950 to a total of 60,000 square feet.

Supporting this engineering and manufacturing effort, some outstanding engineers were recruited during this period and some sought employment with GSI. Among these were Mark Shepherd, Jr. who had been in radar and electronics for the Navy during the war. After the war he completed his master's degree at the University of Illinois and went to work for the Farnsworth Co. Shepherd, a native Dallasite, graduated from the School of Engineering, Southern Methodist University in 1942. After graduation, he worked briefly for General Electric Company.

While at Fort Wayne, Shepherd was called in by a Farnsworth executive and asked: "What about this GSI in Dallas?" Shepherd told him what he knew of GSI and asked why the interest. "Well, they" just took one of our more lucrative government contracts, the ANAPA5," was the response. Shepherd recalled: "I allowed as how I wanted to get in touch with an outfit that could do that. And, I wanted to go back home anyway. So I dropped them a line and the next time I got to Dallas, I went to see them."

When Shepherd came to GSI, he worked first on the USQ1 Radiac detector contract. He was project engineer on the ANASQ8, the new version of the Magnetic Airborne Detector (MAD). Shepherd soon became assistant chief engineer under Bob Olson.

By 1949 Haggerty would round out the management team that would lead the L&M department to equaling the sales of the geophysical exploration group, the principal business of GSI. He hired former BuAer engineers, S.T. (Buddy) Harris and Wally Joyce. Harris headed up marketing for L&M, and Joyce took over production.

By October 1948, McDermott resigned as GSI president and Dr. Peacock moved from the Houston GSI office to Dallas to head up the company. This freed McDermott to devote his full time to the direction of GSI's enlarged program of research on fundamental exploration problems. After Peacock moved into the presidency, the other partner, Cecil Green, had the total responsibility for GSI field operations, employees, and foreign business. GSI returned to Saudi Arabia and also began long-time contracts for government-owned oil companies in Mexico and Brazil.

Management changes and company growth provided promotion opportunities for Fred Agnich and Bob Dunlap. Agnich headed up special field problem design committees and consultations; Dunlap was made vice president of the West Coast operations. J.W. Thomas was elevated to vice president, and Jack Kohler took over Mexico supervisory duties. The first Dallas office for marine operations was opened in December 1949 to support GSI's Persian Gulf operations.

Jonsson was elected president on June 25, 1950, the day the Korean War broke out. This proved helpful to the goalward drives of the Haggerty-lead L&M team. Dr. Peacock, who had preceded Jonsson as president, was never sold on GSI's increasing emphasis on manufacturing. He was all for the geophysical but was outvoted on principal decisions which reflected a 10-year growth plan in the L&M part of the business designed to make the company a "good big company" as Haggerty described his goal.

The Korean War created new and larger military markets. Sales doubled by 1951. It became apparent that a change in company philosophy was coming to the forefront. The company that had originally been organized to prove one man's ideas for the advancement of the science of geophysics had utilized that science to take it down new roads of immense potential. It was decided, although not unanimously, to increase research and development efforts and enter even broader industrial businesses. Dr. Peacock decided to sell his shares to the other partners and to some key GSI employees and leave GSI. The ownership was then principally held by McDermott, Green, and Jonsson. The way was clear for the events of the 1950's which allowed GSI to spawn the technology-based electronics company which eventually became Texas Instruments Incorporated. As Ed Kinsley expressed it in an earlier version of TI history: "GSI had spawned an operation that could no longer be contained within the confines of an exploration Company," and the impact of the developing TI technology would be felt in the oil patch.

CHAPTER V
GSI SPAWNS THE TI TECHNOLOGY CRUCIBLE IN THE FIFTIES

GSI's high technology lead among geophysical expiorationists came about in the '50s with frequency-modulated magnetic recording, signal enhancement, and the application of interpretation improvements of seismic data. For years it had been the policy of GSI to spend from $100,000 to $150,000 per year in technical research and development work connected with seismograph instrumentation and equipment, in spite of the pressures of increased military contracting by its L&M Division. The escalation of military contracting, which followed the outbreak of the Korean war in 1950, moved GSI out of the scope of its original charter and called for reorganization, out of which surfaced the crucible of TI technology. From the point of reorganization in the '50s, Texas Instruments Incorporated, and TI technology became principal characters in the chronicles of GSI.

In January 1951, the L&M Division of GSI was given the name of General Instruments Inc., and the former Field Division became Geophysical Service Inc., a wholly owned subsidiary. On January 1, 1952, the company's name was changed to Texas Instruments Incorporated, and the letters TI, superimposed on the map of Texas, became the corporate logo. The succession of Erik Jonsson to President of GSI on June 15, 1950 opened the way to the reorganizational events that followed. By 1953, all of the stockholders of the Texas Instruments-Geophysical Service family were actively engaged in management of the various organizations consolidated under TI, as directors, officers, and supervisors.

An independently owned Western Hemisphere trade corporation, Geophysical Service Incorporated, was organized in 1951 for field division exploration activities in Latin and South America. By 1953, this organization was consolidated into the TI family of companies as a wholly owned subsidiary. Another Western Hemisphere trade corporation, Geophysical Service International Corporation, was formed to include the expansion of exploration activity in Canada, and it was also consolidated into the family of companies. Exploration activities in Spain and Saudi Arabia were consolidated under Geophysical Service International, S.A., in August 1952. Engineering Supply Company and its wholly owned subsidiary, Industrial Electronics Supply Company, jointly owned by the partners and supply company executives, was consolidated into TI by February 1953.

The interlocking directorates and executive management displayed in the 1953 organization chart show how management coordination and control was achieved across the board. The scope of Jonsson's financial responsibility for upcoming growth is reflected by the fact that he was either president or treasurer of each of the companies.

An acquisition of Houston Technical Laboratories, manufacturer of precision gravity meters, gave TI the vehicle for making and marketing gravity meters and seismograph equipment.

A merger with Intercontinental Rubber Company was made in 1953, primarily to raise the number of TI stockholders to a level allowing stock exchange listing. It also added three valuable outside directors to the board: Emory G. Ackerman, Anton D. Bestebreaurtje, and Ewen

C. MacVeagh. On October 1, 1953, the ticker tape flashed on the display board: "New York Stock Exchange ... October 1, 1953 ... Market Open ... TXN 5-1/4." Jonsson brought the first 100 shares, Certificate Number One. Early ups and downs and the eventual soaring to 193-1/2 in 1959 reflect TI's high technology performance during the '50s decade.

At the outset of 1953, TI's long-term planning embraced diversification into the field of equipment and instrumentation for the petroleum industry, automatic controls for industry, and for medical physics. Care had been given to entering only into military programs with good long-term prospects such as radar, sonar, magnetics, atomic energy, and guided missiles. The goal had been set for TI to become a good big company. Research and development efforts were increased. Broader and more challenging product lines were sought.

By 1955 several small companies were added to enhance the electronics components effort: The Radell Corporation (carbon deposited precision resistors), the Burlington Instrument Company (voltmeters, ammeters, etc.), and the Wm. I. Mann Company (optical components for military and civilian use; i.e., infrared). All were moved to Dallas and united with the electronic apparatus and components manufacturing.

From 1946 through 1952, it was estimated that support of the expanding GSI field divisions had required approximately $1 million annually of laboratory and engineering effort. GSI had an average of 42 crews in the field in 1951; by 1952, the average rose to 48 crews. By 1958, there were 80 crews at work for GSI worldwide. With headquarters in Dallas, GSI provided the management and control of all GSI companies, trained the personnel, and sponsored most of the new equipment developments. They were the "guinea pigs" of all new interpretive and field operating techniques and provided experimental testing for new equipment.

Nonmilitary products included seismograph systems which TI forecasted would yield $1 million annual sales. At the outset, these included seismometers, drilling rigs, radio transmitters and receivers, and recording oscillographs. A new miniature seismometer, the S-33, was a superior detecting element used to pick up the seismic signals at the surface of the earth. The first production run of 500 went into service on GSI crews in the United States in 1952 and were for sale to the general market through Engineering Supply by 1953. A new shotho1e drill rig, designed to reduce costs, was another product line engineered for GSI use but also to be marketed to the petroleum industry. A portable seismograph radio transmitter and receiver was another product development designed to solve GSI exploration problems but scheduled also for general sale. The recording ocillograph originally designed for use by GSI was redesigned in 1952 to record 48 separate events simultaneously. It was redesigned for ruggedness and suitability for sale to the exploration industry.

Other long-term nonmilitary products planned by 1952 included magnetic recorders, magnetic amplifiers, and use of the magnetic clutch for servo systems and recorders. There was a long-term plan for entry into instrumentation in the field of medical physics and a, transistor program as well.

The transistor program initiated in 1951 was the most significant to TI history and to GSI as well. The first germanium transistor development was announced in June 1948 by Bell

Laboratories, and the Nobel Prize was awarded to Dr. Walter Brattain, John Bardeen, and their associate, Dr. William Shockley, for inventing the point contact transistor. This invention made it possible to place emphasis on materials technology, as the transistor brought miniaturization to the electronics industry.

Promoting the transistor program to TI owners, Haggerty explained: "If we are to be a giant and compete with the giants, where are we better fitted to take on a giant than in a field where the giant is also just starting?" This concept provided the touchstone for testing the superior individual qualities of the coterie of engineers recruited by GSI to support military contracting begun in 1946. It became their new venture.

TI purchased the necessary license to manufacture transistors from Western Electric for $25,000. After attending the technical symposium held at Bell Laboratories and Western Electric in April 1952, approximately $40,000 of capital equipment was installed in the old bowling alley next door to the 6000 Lemmon Avenue plant, and Shepherd was told: "We want to make semiconductors. It's your problem." By May I, 1952, modest development quantities of transistors were designed, completed, and put into use. The initial order for 10 transistors was delivered to the Gruen Watch Company in December 1952. This was the only sales for the transistor program in 1952, after an additional $50,000 had been expended for engineering. It could have been shocking to the faint of heart when Shepherd projected a budget of $250,000 for 1953 with $75,000 for additional capital equipment, with only a few customers tentatively identified.

Responding to an advertisement for an electronic researcher in Texas, Gorden K. Teal joined the transistor program in January 1953 to direct materials research aimed toward developing new types of transistors and semiconductor devices made of silicon. Teal was a chemist who had been involved in growing germanium crystals, silicon crystals, and silicon carbide at Bell Laboratories where he led a group who supplied Brattain, Bardeen, and Shockley with experimental materials. While at Bell Lab, he was co-developer of the NPN junction transistor and the borocarbon resistor. It was fortuitous that he was a native Texas wanting to get back to the region and equally interested in the research opportunities presented at TI.

Three years ahead of major semiconductor manufacturers, Teal announced the successful production of a working silicon transistor of the National Conference on Airborne Electronics at Dayton, Ohio, in May 1954, where his remarks credited the work of Willis Adcock, Morton E. Jones, Jay E. Thornhill, and Edmund D. Jackson. His demonstration clearly established TI as a company to be reckoned with among the electronics giants.

The next step beyond the transistor was the integrated circuit conceived in 1958 by a rangy, soft-spoken Kansan, Jack St. Clair Kilby. This invention eliminated the need for masses of separate transistors and a multitude of mechanical connections in an electronic system.

How the manufacturing facilities at GSI's old dream castle at 6000 Lemmon Avenue, at the expanded 5900 Lemmon Avenue, the bowling alley, and the annex at the rear of the plant were soon inadequate for the semiconductor expansion is properly the story of Texas Instruments. As the decade closed, new 238,000-square-foot facilities were being completed at the Central Expressway site. The tenor of the times, however, is reflected in a sidelight of the transistor story contributed by Paul Davis.

"One Friday afternoon in May 1954," Davis recalled," I got a call from Haggerty and went to his office. Pat, Olson, and Jim Wissemann were there. They told me: 'Look, we understand you used to be in radio before coming to TI. We need someone to head up a project to develop a transistor radio.' Having developed the first high-frequency germanium transistor, they wanted to be the first in radio, particularly since RCA and Motorola were promising the public that transistor radios would be on the market in 2 years.

"They told me to pick a team to build a transistor radio to prove its workability. As I left the office, Pat said: 'I don't need this demonstration model until next Wednesday"

Given leave to pick a team to build a transistor radio to prove its workability, freedom to ask Mark Shepherd's group to grow any crystal required, and the challenge to produce a breadboard model in less than 5 days concluded a typical TI assignment. The first model, an 8-transistor set, was delivered on Wednesday, and the team was then presented with the problem of housing a workable model before Monday.

As Davis recalls: "Saturday morning, Pat came to my office and commented that the breadboard model worked pretty good 'I need one to take with me to New York, Monday. Do you think you could package one for me to carry along? 'The request was great, but the response was equal to the need, as a 7-transistor model was constructed with components from the breadboard model installed in a battery set case, the only available package on such short notice.

Another feasibility model was built with Roger Webster, Jim Nygaard, and Regency engineers to achieve the production design. A production team was geared up, and Regency was able to produce more than 200,000 pocket radios before Christmas.

As Teal's research and development at Central Research Laboratories and Shepherd's Semiconductor Products Division paced transistor developments, Olson's engineering and research groups moved forward with new seismic field data collection and interpretation systems for GSI. Applications support was provided by Burg's Research and Engineering group, which moved seismic technology toward a statistical approach to high-speed electronic computer methods of data analysis.

A major milestone in seismic exploration was the development of magneDISC, magnetic recording of seismic data, and the 7000 Amplifier System. At the April 1954 national convention of the AAPG-SEG-SEGM in St. Louis, Missouri, a combination of men and instruments "stole the show" when new techniques and hardware were unveiled for finding more oil. This marked the beginning of a high technology approach to geophysical exploration, placing GSI in a vanguard position. Magnetic recording changed the way of doing business and was a milestone in petroleum geophysics equally as innovative as seismic reflection technology proved to be when introduced in 1930.

At the 25th annual AAPG-SEG-SEGM convention in Denver, 1955, magneTIME Delay Unit was introduced. This was an electronic package for processing magneDISC records, allowing corrections for weathering, elevation, and normal moveout. The magneSTACKER, used with magneDISC, combined up to 17 shots from one hole. A 7000-B Amplifier System which utilized a 3-speed camera, and S-39 miniature seismometers (designed for multiple arrays) were in the showcase. A Gravity Anomaly Simulator was displayed for interpreting gravity data. All of these products were from the Petroleum Instrumentation Department of Houston Technical Laboratories, acquired in 1953 specifically to market TI-built seismograph instrumentation systems and the Worden Gravity
Meter.

In 1953, TI initiated research to apply information techniques to retrieve maxim information from seismic data. This marked the beginning of the high technology approach to geophysical exploration which again placed GSI in a vanguard position. It is interesting to note that the fourth president of TI, J. Fred Bucy, was an assistant engineer assigned to the seismic research program.

Toughened by early years on a West Texas farm (hometown of Tahoka), accustomed to hard work, and equipped with a drive that took him, through Texas Tech, Lubbock, and a masters degree in physics from the University of Texas, Bucy broke out his slide rule for TI in 1953 at 6000 Lemmon Avenue, where he first learned how to operate the "TI-6000"seismic amplifier and develop a seismic record.

Bucy soon invented a hybrid analog-digital data processor for use interpreting geophysical data. The concept, named seisMAC was ordered into production at the Houston Technical Laboratories. Reporting to Olson, the young physicist was made project engineer. These seisMAC processors were soon installed for GSI in Dallas and New Orleans in the United States; in London, England, and Sumatra; and eventually at GSI regional processing centers in Canada, Venezuela, and France.

Coincidental with the expansion of TI's semiconductor technology, Bucy then was assigned the task of developing the first all-solid-state seismic amplifier, the "8000 system", or EXPLORER*. For more than 2 years, the EXPLORER was the industry's only all transistorized system. In the 1956 International Geophysical year, GSI's seismic system was used by the international team of scientists that explored the Antarctic.

To pace the advances in instrumentation created out of TI technology, Ken Burg, GSI vice president-technical, lead a team of geophysicists and mathematicians in an applications research effort that involved high resolution techniques applied to field problems, auto- and cross-correlation procedures to extend multiple seismometer and multiple shot theory, seismic noise studies, multiple reflections, and statistical methods for seismic record analysis. As an increasing participation in water surveys moved GSI into deep-water marine work, research and software developments included MAE† (Multiple Analyzer Eliminator), designed to reduce effects of water reverberations on seismic records.

The M/V SONIC, placed in service in 1953, was GSI's first ocean-going exploration ship.

She was converted by Geomarine Service International Inc. for single-ship geophysical exploration for clients requiring offshore seismic information for evaluation of onshore concessions, or to check extension of structures adjacent to shorelines. Traveling at a speed of 6-1/2 to 7 miles per hour and averaging 50 to 60 miles of continuous profiling in a single day, she carried GSI's banner into waters off Venezuela, Caribbean, Mediterranean, Persian Gulf, West Coast of Africa, Bay of Biscay, the North Sea, and other marine areas. She is credited with a number of important oil field finds.

The SONIC carried a crew of 20 and was outfitted with special seismic recording equipment and a Decca navigation system. The seismic detectors (hydrophones) were contained in a 2,700-foot streamer towed behind the ship. The streamer was allowed to pay out from the stern of the ship and traveled through the water at depths from 10 to 20 feet.

Successive charges of dynamite slid down the cable and were fired by an electrical contact at the end of the cable, allowing shots to be detonated at 2-minute intervals.

Additional techniques and instruments introduced into field operations during the 1950s included gravity, magnetics, and geochemical techniques. Gravity and magnetics were useful in early evaluation of large, unexplored areas, while geochemical techniques provided fast reconnaissance for indicators of hydrocarbon accumulations.

Although the oil business in the U.S. during the '50s was on the decline, foreign contracts on land and sea helped to move GSI sales to just under $20 million by 1958. Most large oil companies were expanding their search for foreign oil by 1954, and by 1958 GSI contracted a maximum of 80 crews to these companies at home and abroad. GSI was the world's leading geophysical exploration company.

Recruiting and training personnel for these crews and keeping field engineers, technicians, seismologists, observers, and other technical personnel abreast of the rapidly developing high technology approach to seismic exploration required continuous training. Information concerning the latest developments in geophysical methods and theories were made available to GSIers in the field through a GSI Correspondence Program, which proved to be an effective means of sharing knowledge.

Procurement of well-oriented and properly educated young scientists was of real interest to GSI and particularly to Cecil H. Green, who realized that in the near future the company was going to need many new employees with knowledge of the latest advances in science and engineering. Where could they be found and how could they be identified?

At the same time, Dr. Robert R. Shrock, head of the department of geology and geophysics at the Massachusetts Institute of Technology, was becoming aware of the need for some kind of practical field training for the dozen or so undergraduates majoring in geophysics. Inasmuch as the students would have to forego regular employment if they were to get such training in the summer, which was the only logical time, how could they get the desired training without too much loss of income, and what employer might be interested in hiring them for such work.

On November 13, 1950, these two men were drawn together in Dr. Shrock's office, and it was not long before both men found that they had a number of common interests and needs.

The results were immediate and took the form of a concrete program of summer training. Within less than 3 months the program was organized, and by the end of February, 1951, more than a dozen MIT students had agreed to participate. GSI's Ken Burg collaborated with Cecil Green and Dr. Shrock, and the first student Orientation Program (which later became known as the GSI Student Cooperative Program) began on June 15, 1951.

Other universities became interested and participated in the 16 years that followed. It brought together carefully selected geophysics majors at the junior undergraduate level from a large number of universities, plus related faculty members, with key representatives from all major petroleum companies as well as from GSI.

The program proved to be a unique and effective means of identifying and recruiting new geophysical "naturals". Some of the technical personnel recruited by GSI from the program included: Larry Strickland, Milo Backus, John Burg, Al Sabatay, Mark Smith, Jim Sundquist, John Bedenbender, Roger Ludlum, John Gurke, Ritchie Coryell, Carl Hickman, Ed Parma, and Pete Embree, to name a few.

A large measure of credit for the success of the plan goes to more than 185 participants from some 35 petroleum and associated companies and to more than 100 faculty members representing some 41 academic institutions. Through the years, many former students of the GSI Student Cooperative Plan have risen to positions of great responsibility in the exploration and petroleum industries, putting into practice much of the knowledge acquired in these 3-month periods of practical education.

*Trademark of Texas Instruments Incorporated
†Service mark of Geophysical Service Inc.

CHAPTER VI
EXPANDING GSI TECHNOLOGY INTO OTHER GEOSCIENCE SERVICES

The combined GSI ·and TI technology brought to state-of-the-art such earth sciences as seismology, gravity, magnetics, geochemistry, and data processing. These sciences were potentially useful to the problems of military geophysics, oceanography, nuclear test surveillance, communications, antisubmarine warfare, arms control, and space-related objectives.

Beginning in the '60s and extending through the next two decades, the technological geoscience capabilities of GSI were merged with elements of TI technology to provide services contributing to such national objectives as the worldwide seismic network nuclear test monitoring, geophysical survey of oceans, signal processing for antisubmarine warfare, radar and infrared surveys, and lunar data collection. In this transf.er of geophysical technology built up by GSI for the petroleum industry into military/government applications, there was the expected feedback of new technology to GSI and TI. When defense related programs were later transferred to TI's Government Products Division, only those geoscience capabilities marketable to the petroleum industry and nonmilitary customers remained as part of the business objectives of the Science Services Division.

The Geosciences & Instrumentation was shortened to Geosciences Division, in 1962, when all GSI companies were merged into this management framework, the name was changed to Science Services Division. Industrial Products of Houston was made a TI division with its product lines becoming marketable to the total geophysical industry. As Dunlap became chairman of the board of GSI and a TI vice president over the Science Services Division, Mark Smith assumed the GSI presidency until mid-1969 when Ed Vetter became president. Geosciences management was lead first by Ed Kinsley followed by Dick Arnett, Larry Strickland, and Harry Lake. When New Service Business Development (NSBD) was organized, Strickland headed the group. After his tenure over NSBD, Ray Toole managed this segment of the Science Services Division and expanded it into ecological and environmental services.

In the first 6 years of geosciences emphasis, the division tripled its size as geophysical exploration activity increased and the division entered into major defense contracting. As a principal contractor for Project Vela Uniform, the major thrust was seismology and geochemistry, with expansion into gravity, magnetics, acoustics, and infrared.

The initial Geosciences contract utilized GSI field crews and seismic systems to survey missile sites. Seismic array studies and the application of arrays for nuclear test detection represented the first large contract for Project Vela Uniform. Soon extended into development of an experimental real-time Multiple Array Processor (MAP), the effort involved construction and operation of three seismological observatories in the United States.

Other Project Vela Uniform programs included a worldwide earthquake study, installation of seismograph stations in many parts of the world, development of an ocean-bottom seismograph and a direct digitizing seismometer, and a seismic discrimination study of techniques to distinguish nuclear detonations from earthquakes. A program to develop software for an advanced seismic computer was an outgrowth of these seismic programs.

Signal processing programs were related to underwater acoustics and antisubmarine warfare. Among these programs were the volumetric array experiment, Broadband Array Sonar System (BASS), a 252-channel data acquisition system, and a 40-channel analog-to-digital conversion system for the Naval Undersea Research and Development Center.

Geochemical reconnaissance techniques developed at GSI for petroleum exploration were adapted to on-site inspection problems tentatively linked to test band provisions in the arms limitation agreements being negotiated with the Soviet Union. Numerous programs evaluated gamma-ray spectrometry and soil gas analysis as tools for on-site inspection. An operational airborne digital gamma-ray spectrometer system was developed during the process of the on-site inspection work. Its application as a viable system for exploration of uranium and other minerals was established during the '70s. Sophisticated data processing and interpretive techniques for utilizing gamma ray data developed during the '60s were refined in the '70s.

Not all of the radiation sciences effort was directed at on-site inspection for defense purposes. Experiments were conducted to evaluate a 40-kiloton nuclear explosion as a method for stimulating gas production from low permeability fields in the Mesa Verde Formation. Radiation fallout measurements from tests conducted by countries other than the U.S. were studied from data collected at portable stations.

Tapping some 25 to 30 years of GSI experience in offshore exploration for petroleum and in the design, development, and testing of equipment for collecting data from the ocean environment, the marine-related programs began by providing an oceanographics measurements team aboard the USNS ELTANIN, which operated in the Antarctic waters under a research program funded by the National Science Foundation. Services included assistance in outfitting the research vessel, sampling tasks, and manning the electronics and chemical analysis labs.

Another contract with the U.S. Naval Oceanographic Office involved the design and building of an integrated shipboard oceanographic survey system which was installed on the USNS SILAS BENT. Another contract followed: a central data recording system was built and installed on the USNS ELISHA KANE, sister ship of the SILAS BENT. An automated oceanographic data acquisition and processing system was developed for the U.S. Coast & Geodetic Survey ship, RESEARCHER. Sea tests and training of operator personnel were part of the package.

A multimillion dollar contract with NAVOCEANO involved a major marine geophysical survey of the North Atlantic and contiguous seas, which included processing and analyzing data collected over 100,000 nautical miles of area. This was the largest joint oceanographic survey ever undertaken by private industry and government. It utilized the M/V ARCTIC SEAL and the M/V ATLANTIC SEAL, two vessels designed by TI-GSI and built by Burton Shipyard. They were the heaviest of any similar class vessel ever built by the shipyard up to that time.

Two days out of Port Arthur on their maiden voyages begun on August 24, 1965, Hurricane Betsy began closing in on these two boats. They waited out the storm at the Tongue of the Ocean near the Bahamas, withstanding the fury of Betsy's 70-mph winds and 14-foot waves.

When Betsy subsided, Hank Rowe sent a cryptic message to Dallas headquarters: "Heavy weather test completed successfully. Proceeding to Bermuda at 11 knots."

The first 3 months of operation yielded 1-1/2 tons of data (magnetic tapes, records, paper tapes, plotting charts, data logs, etc.) plus several tons of bottom cores. A major part of the project involved adaptation of computer programs developed for the survey to the Navy's CDC 3800 computer at the Navy Research Laboratory and the generation of a complete set of common format log books from the survey.

Precision depth recordings were used to map the contours of the ocean bottom, while seismic profiling was utilized to delineate the subsurface beneath the ocean floor. Bottom photography and bottom cores were products of the survey to aid marine geologists in their work of unraveling the ocean's secrets. The special "find" of the survey was discovery, by precision depth recording, of a previously uncharted seamount that rose 5,016 feet above surrounding sea floor in the eastern Atlantic in about 15,000 feet of water.

A sensor evaluation program conducted for the U.S. Coast Guard identified and cataloged state-of-the-art sensors for their potential use in the National Data Buoy Development Program and reliability studies to establish standards required for maintaining uninterrupted operation. Other programs produced a training-oriented introduction to all the scientific disciplines involved in an oceanographic survey and an introduction to the data system of the future, a completely automated oceanographic system designed by Geosciences for future Coast Guard cutter class vessels. This system provided for significant improvements in on-station data reliability testing.

A monumental Geosciences effort provided the National Aeronautics & Space Administration (NASA) with facts and ideas for selecting the surface experiments, geological observations, and geophysical tests to be made by astronauts landing on the moon. Complete specifications were furnished for a seismic instrumentation package which was to be emplaced on the lunar surface to transmit seismic data to NASA's Manned Space Center.

Another APOLLO program included a lunar landing site study to predict site selection criteria and environmental problems associated with a moon landing craft. A lunar gravity study specified design criteria for a gravity meter that would be operable on the moon's surface. A survey of lunar water exploration techniques provided NASA, within one volume, a description of all techniques for exploring for water in a terrestrial environment and a survey of available instruments with an assessment of their operability in the predicted lunar environment. Remote sensing activity began with the design of an airborne geosciences laboratory and a sensor evaluation study to select the sensors most applicable to the use objectives. Infrared and photogrammetric techniques previously applied to petroleum and mineral exploration, geographic surveys, and engineering parameters important to site selection were applied to airfield site selection, target signature analysis, detection of vehicle and troop movement, wake analysis, thermal energy, and power plant effluents.

Interpreter training, a natural spinoff from the remote sensing research, provided the Air Force and Navy with interpreter training manuals and technical advisory services to customers purchasing TI infrared scanners. More than 1,600 pages were generated in an evaluation of infrared imagery from high altitude reconnaissance.

A data analysis program for NASA of infrared data collected by the Earth Resources Technology Satellite (ERTS) provided guidelines for the utilization of ERTS data in regional geologic mapping. This program resulted in new exploration concepts developed for locating petroleum and mineral deposits of potential economic value.

After more than a decade of operation as part of military-industry team effort in the geosciences, areas of interest were broadened to support development of other new services businesses. This was first pursued by Multiscan, an airborne infrared inspection service marketed to electric power generating companies for spotting defects in power transmission lines and substations.

A remote sensing and topographic mapping program in Colorado isolated the most feasible route for the Eagle-Piney water plan. Other commercial areas for marketing remote sensing concerned rights-of-way, transmission corridors, pollution in coastal and estuarine zones, and oil spill monitoring.

In 1965, a photo geological capability was added to the Science Services Division by acquisition of Geophoto Services, Inc., of Denver, Colorado. This brought a coterie of geologists with expertise in photogrammetry and years of experience in producing surface geologic maps from aerial photography for petroleum and mineral exploration. This group became the nucleus of GSI's Exploration Services Department by 1974. A total analysis approach to structural interpretation involved data from seismic, gravity and magnetic surveys, bathymetry, and surface geology. With this detailed structural interpretation complete, correlation with the interpreted seismic maps produced a comprehensive structural picture.

In a continuing quest for hydrocarbons for the benefit of private oil companies, senior photo geologists utilized satellite imagery and aerial photography to define areas favorable to oil and gas occurrences. Landsat imagery was also used to find areas in the southeastern United States for structurally stable sites for proposed nuclear power plants.

Aside from providing geologic support to GSI exploration services, the Geophoto group engaged in photo geological surveys of Colombia and Argentina, and made detailed geology studies in the Arctic.

A coal-evaluation survey in the Hanna Carbon Basin of Wyoming was part of the USGS nationwide coal evaluation of unleased federal land. It included collection, review, and compilation of resource maps, well logs, and drill-hole information to provide data on coal bed thickness, overburden, geologic structures, and outcroppings.

Beginning in 1967, gamma-ray spectrometer surveys in fixed-wing and rotary-wing aircraft were contracted to atomic energy organizations of Brazil and France and to the U.S. Department of Energy as well. High-sensitivity gamma-ray systems built by TI were used in the National Uranium Resources Evaluation (NURE) Program in surveys of more than 65,000 line miles in Alaska, the Great Plains States, Utah, Arizona, and the Washington, D.C. area. A "Manual for the Application of NURE 1974-1977 Aerial Gamma-Ray Spectrometer Data" was prepared for the U.S. Department of Energy.

Responding to national concern over the quality of the environment in the early '70s, an array of environmental specialists was recruited to provide ecological and environmental monitoring of oceans, lakes, and running waters. An investigation of oil spill impact on the coastline of the state of Washington marked the first ecological investigation undertaken for the Environmental Protection Agency (EPA).

This was followed by a contract with Consolidated Edison Company of New York, Inc. to commence ecological studies on the Hudson River. A continuous sampling program since 1972 encompasses most of the l50-mile-long estuary of the Hudson River, providing information on the life history, distribution, population dynamics of key fish species for use in assessing potential impact of electric generating stations located along the river.

Other monitoring programs include ecosystems of the St. Clair River, Connecticut River, Arkansas River, Lake Michigan, and Lake Erie. In most cases, field studies are supported by impact evaluations and testimonial services at hearings of regulatory agencies.

A multidisciplinary study of the Outer Continental Shelf region for Department of Interior's Bureau of Land Management required extensive field sampling, laboratory processing, and data synthesis to establish the biology of the air/sea interface, the water column, and ocean-floor sediments prior to licensing for resources development.

Under contract to the EPA, TI performed an area-wide environmental impact assessment and prepared an Environmental Impact Statement (EIS) that reviewed existing data on phosphate resources development in Central Florida. Technical staffs in the fields of land use, cartography, regional planning, economics, water resources, geology, topography, radiation, geochemistry, water quality, air quality, aquatic and terrestrial ecology, effects assessment methodology, and program management directed their talents to existing and projected environment in a 7-county, 6,700-square-mile study area. Members of the technical staff participated in the seminar held in Bartow, Florida, cosponsored by EPA and TI, where differing viewpoints of industry, government, and environmentalists were aired.

A 10-month terrestrial and aquatic sampling program was required to develop a comprehensive data base reflecting historical trends and ecological conditions at the proposed DeSoto Site on the Peace River for Florida Power & Light Company. A field sampling program was designed to inventory flora and fauna of the study area and provide description of spatial and seasonal patterns in their abundances and distribution. The site consisted of more than 20,000 acres of unimproved land in north-central DeSoto County northeast of Arcadia, Florida. A baseline biological study such as this allows the utility company to address environmental considerations when considering future expansion of electric generating capacity.

Assessment of direct and indirect impact of federal actions associated with the construction and operation of a proposed coal fired electric generating complex near Colstrip, Montana resulted in a draft EIS to satisfy the needs of the USGS, Bureau of Land Management, Forest Service, Corps of Engineers, Rural Electrification Administration, Bureau of Reclamation, and Bureau of Indian Affairs.

This work was contracted with Bonneville Power Administration (BPA), the lead agency designated by the Department of the Interior for the preparation of the Colstrip EIS for the generating complex proposed by a consortium of investor-owned utilities and linked to the BPA Northwest power grid.

Although most of environmental emphasis in the Science Services Division has been in finding energy sources or supporting the energy-related utilities industry, participation in operation Sky Scan focused on saving energy. The infrared scanning group mapped heat loss from homes in more than 800 Iowa communities in a statewide program sponsored by the Iowa Utilities Association. Described by Iowa Governor Robert Ray as a "pilot project for the nation," the thermograms produced a low-cost graphical means for measuring heat loss from residential and industrial buildings. A TI-built airborne infrared scanner was used to record heat losses. An infrared digitizer digitized the analog data from the scanner, performed some limited real-time processing of the data, and wrote the resulting values onto a high-speed magnetic tape transport. Surveys over cities in Texas, Nebraska, Iowa, California, Washington, and Wyoming provided utility companies with graphic demonstration of heat leaks to accompany recommended measures for consumers to achieve energy reductions.

A combined geophysical/geochemical survey off the Pacific coast of Columbia utilized GSI-developed high-resolution seismic survey techniques in combination with sediment sampling for identifying areas of highest probability of offshore petroleum/natural gas deposits. Two vessels were used to conduct the seismic and geochemical surveys, simultaneously. This is only one example of the full array of environmental services designed to assist the petroleum industry in obtaining the best possible information to aid in exploration efforts on the continental shelves and to assist in regulatory compliance.

CHAPTER VII
DIGITAL TECHNOLOGY SPANS TWO DECADES

GSI launched the first practical application of statistical theory of communications to the search for oil early in the '60s. This resulted from a cooperative effort of GSI and TI. Seldom have the effects been as far-reaching as the innovations of the '60s which saw GSI revolutionize the seismic exploration business with its introduction of digital seismic service technology. Long before the close of the decade, digital recording and computer processing of field data were practically standard procedure for the petroleum exploration industry.

The '70s brought many innovative developments in seismic data collection utilizing the advanced electronics technology of TI. As in the '60s, the TI technology of transistors and integrated circuits were basic to the systems developments, so was TI technology in the areas of computers and distributive processing applied to achieve substantial gains in seismic data processing systems, seismic interpretive systems, and data collection systems.

By 1975, GSI began to field 3D land and marine techniques and high-resolution software, culminating in the 3D revolution discussed in some detail in Chapter IX.

Jim Toomey, GSI client representative, charted the digital events as they happened and his chart is the source for the early historical chronicle.

Research was authorized for autocorrelation studies in 1952 after Ken Burg reviewed recent studies on the subject at a GSI director's meeting, November II, 1952, and $25,000 was set aside by the board of directors for 1953 studies in the Geophysical Research department. TI's Central Research Laboratories (CRL) 1954 Report 2- 9964 dealt with automatic processing of seismic data using magnetic recording, digital filtering, correlation, automatic record splicing, and automatic plotting. A hybrid analog-digital data processor, seisMAC, resulted from this research, launching its project engineer, J. Fred Bucy, on future successes in the emerging digital field systems and processors at TI's Houston Industrial Products facilities.

A stratigraphic trap study program was funded in 1955 to investigate use of digital computers in seismic interpretation and to integrate geological and geophysical data. GSI's research activity was led by Ken Burg and Mark Smith; a companion CRL project, led by George Sarrafian and Larry Strickland, considered the integrated seismic system and high-speed computers for digital seismic data processing. By October 1956, the first digital processing of seismic data at GSI Dallas utilized an IBM 650 computer and software developed in Smith's group: Normal Movement Correlation (NMO), Correlation, Stack, Coherence Calculations, Reflection Picking, and Digital Filters.

Concepts for an experimental Data Analysis and Reduction Computer (DARC) and DARC field equipment were considered and engineering design was completed by September 1957. By 1958, field tests of the DARC digital field system designed in CRL were made in Florida. Model facilities were constructed for reflection and refraction studies and data processing software was completed in 1958 for DARC correlation programs, statics NMO, MAE DARC, digital filters, and by early 1959, coherence calculations, stack, and reflection picking.

By the fall of 1959, seismic data collected in Oklahoma with the DARC digital field system were processed for comparison with state-of-the-art analog data.

The design study for TI's 9000 amplifier began in 1959. The shakedown of DARC and the DARC field system was completed. In Smith's area, Milo Backus led in the production of 12 machine diagnostic programs, 30 library programs, and 30 seismic programs.

At the time the decision was made to apply information theory techniques to processing of digitally recorded seismic data, Ed Vetter (who had transferred from GSI to TI's Houston Industrial Products group) obtained the collaboration of two major oil company clients, Mobil Oil Corporation and Texaco Inc. These companies provided valuable help in the development of equipment specifications and some initial financial support. In return, they gained a lead over the rest of the oil industry by putting the digital systems to work, they could also buy the equipment and outfit their own seismic crews.

When the 9000 DFS* (Digital Field System) prototype was completed in the spring of 1961, the first production model was delivered to GSI by the Industrial Products group. The first digital-system-equipped crews were fielded for Texaco by February 1962. By the end of the special working agreement with Mobil and Texaco in 1963, GSI had accumulated more than 160 crew months of digital experience. Details of the new technology were revealed publicly at a press conference held in Dallas, June 1964.

This 2-year lead allowed GSI the necessary time to evaluate the integrated system approach in the real world of varied environments. No chronicle of events should overlook the contributions made by the early digital field crews, particularly the research people and geophysicists whose creative evaluation resulted in valuable input for the modifications built into succeeding generations of hardware and software. Such names come to mind as Bob Graebner, Jack Pizante, Ben Giles, Don Rockwell, Clem Blum, Robert Roden, and Robert Cox. By the mid-'60s, area geophysicists were formally grouped under Graebner, working on a project or area crew basis. Among these "IDEA" people were Pete Embree, Mel Carter, Larry Godfrey, Norm Hempstead, Dick Matthews, Eric Pickles, and Emir Tavella, to name a few.

At Houston's Industrial Products, Bucy forged ahead on the all-transistorized special purpose processor, the Texas Instruments Automatic Computer (TIAC*). The first solid-state TIAC 101 was delivered to GSI-Dallas in the fall of 1961, and the production of TIAC systems for GSI processing centers began late in 1962. After the TI 10,000 amplifier prototype was completed, system programming began. Seismic Data Processing Package 200 was put into production use in 1963. By the year's end Bucy delivered 160 DFS units for GSI's field operations and TIAC systems were delivered for processing centers in Dallas, New Orleans, Midland, Houston, (in the U.S.) and in Calgary, Canada by June 1964.

The new Series 10,000 DFS* unveiled at the 1964 SEG Convention was on the GSI field scene by early 1965. By 1967, TIAC systems were being retrofitted and reincarnated as 4000-word memory, filter box, and standard drum 827 TIAC systems which were equipped to handle GSI's advanced computer processing systems such as the M-4 high-technology marine package.

These innovations were incorporated in the next TIAC system generation known as the TIAC 870, which also included a cathode ray tube (CRT) on-line display system, and was one of the first integrated circuit computers.

Man/machine discourse followed in 1968 with the system automatically processing data, performing quality control checks along the way, picking data, extending events across several traces, and producing a contoured map to eliminate plotting time. This three-dimensional integration and contouring represented an extension of computer use for interpretation and was the sixth generation of software advertised as the "300 package."

Interpretative personnel, who in the analog era were based close to or with the field crews, were now clustered around data processing centers in Dallas, Houston, Midland, Inglewood, Calgary, Croydon, Tripoli, Beirut, Sydney, and Singapore by the close of the '60s.

New concepts of field systems and central processing marked the close of the decade. Online, complex, and remote consoles with real time man-machine discourse evolved in 1969 and were a prelude to the '70s, when minicomputers and terminals expanded digital system concepts and introduced distributed computing as a major growth thrust.

These systems were impacted by TI technological advances in microelectronics. In 1971, TI introduced the "calculator-on-a-chip" where slices of po1ysilicon crystal are taken through a series of steps to build integrated circuit (IC) device patterns (or geometries) and interconnections through as many as 6, and up to 14, different mask levels. Without this microelectronic commodity, the size scale of which is so small that it cannot be seen with the naked eye, sophisticated electronic systems would be impotent, computers would not compute, and geophysical explorations for oil would be back in the dark ages.

By 1972, the super computer was developed by TI. This Advanced Scientific Computer (ASC") consisted of TI-built hardware and GSI generated TIPEX* seismic applications software with compatible data base terminals that allowed man-machine interactions useful in three-dimensional subsurface model-building. Not only could mass volumes of data be analyzed (30 million 32-bit floating points per second), but also alternate solutions applied for the decision process relative to potential reservoir content.

…………………………………………..

1

The name "IDEA" is an acronym for the four steps necessary to convert an idea into an innovation: 1) Identify the idea as having potential commercial value. 2) Develop the idea far enough to provide sufficient information on which a management commitment can be based. 3) Expose the developed idea directly to someone who has the authority to commit necessary TI resources. 4) Act upon the idea, by feeding it into TI's OST system for development and implementation.

The Texas Instruments Multiple Applications Processor (TIMAP*) was introduced by GSI in 1974, making possible remote processing of seismic data for immediate data analysis and quality control checks at the field crew level. Modularity in the system allowed a wide variety of applications such as computer field processing, integration with satellite navigation processing systems, local batch processing, remote job entry to the ASC network, and seismic data display. TIMAP may be optionally connected to the ASC network, where access to large data base modeling or interactive programs is desirable. TIMAP systems are mobile and can be mounted in van type vehicles to meet the demands of specific survey requ1rements.

In 1979, a new recording truck was introduced to GSI's Mexico operations in Monclova. The new truck houses two FT 1 (field TIMAP) and two DFS* V instruments which will record 240 channels and has a roll-along capability of 576 channels. TTY-770 terminals interface with network processing.

A new era in seismic processing was ushered in with the ever-growing demand for 3D land and marine data. Hardware upgrades of the ASC units in the network included additional memory, disk storage, array processors, tape transports, and a mass storage system. Additionally, an IBM computer system having 8 megabytes memory, an IBM array processor, 7.3 billion bytes positioning arm disc storage, tape transports to support 1,600/6,250 BPI density tapes, and a complement of card readers and line printers were added to the ASC communications network. Linked to the network, this system allowed existing remote job entry terminals to be used for both the ASC and IBM systems.

The need to accommodate the ever-expanding quantity of survey data and the increasing amounts of technologies being applied to survey prospects called for the utilization of high-speed terminals (TTY-770s). These terminals, with special software to adapt them to large computer systems, permit the relay of important information relative to prospect mathematics, frequency analysis, convolution filtering, and other vital information as programming support for 3D prospects.

Digital data recording and processing, allowing common-depth-point stacking of multiple shots for a better subsurface coverage, spurred the development and use of non-dynamite seismic energy sources by 1963. The Vibroseis[1] and Dinoseis[2] systems came into increased use in GSI's land operations as special field techniques tailored to environmental conditions. Explosive cord was put into use in many areas of the world where drilling was difficult and where dynamite as the energy source was not allowed.

These new energy sources have allowed crews to operate in widely diverse land environments, from traffic-swollen city streets to desolate trails in West Texas, sand dunes of Saudi Arabia, or the frozen tundra of Alaska.

[1] Registered Trademark and Service Mark of Continental Oil Company. [2] User Licensed to GSI by Atlantic Richfield

By the mid-'60s, the Vibroseis system was mounted on a crab-axle carrier designed and custom-built by GSI (Gil Kelly was program manager and Herb Coburn was project engineer). The growing requirements for higher resolution, higher frequency seismic data collection led to three major advances in system design: the TR-l in 1966, the TR-2 in 1975, and the TR-3 in 1979.

The TR-2 is a single-engine vibrator. It has 30,240 pounds peak actuator force and a special new type of automatic transmission with power take-off to power the vibrator hydraulic pump. At low speeds the transmission operates as a hydrostatic drive; at intermediate speeds the drive becomes a combination hydrostatic/mechanical drive; and at high speeds the drive is hydrostatic but geared also as an overdrive. This special transmission control system allows the TR-2 to be operated at fully governed speed for field use and modulated for moving the vehicle between sweep locations and for the road mode.

Patented control electronics of the TR-2 and TR-3 allows better phase lock control for less signal distortion, the capability for full-force up-sweeps or down-sweeps with higher force at all frequencies, and fail-safe :1/8 millisecond radio synchronized starts of multiple vibrators, and/ or multiple recorders with sweep parameters, programmable via decimal switches.

Another feature of the TR-2, and also the TR-3 introduced in the late '70s, is the convertibility from truck to tractor simply by changing axles, wheels, and tires. As the TR-2s and TR-3s went on-line, the TR-1s were refurbished to improve their performance and reliability. Improvements included front torsion bar suspension and proved vibrator pad and pad stabilizers.

While revolutionary changes were occurring in land energy sources, so did revolutionary developments take place in marine energy sources. The air gun was the product of that revolution, and Ken Burg, Fred Brock, and Ben Giles were instrumental in making air guns the standard energy source aboard GSI ships. Burg paved the way by visiting Bolt Associates in Norwalk, Connecticut, leading to an agreement for GSI to manufacture its own guns for exclusive use. Three Bolt guns were tested offshore California, and good records were acquired on the first shot. Testing continued at Grapevine Lake, where Larry Sullivan was the principal engineer assigned to the project.

Meanwhile, another marine energy source concept was being 'tested by Gil Kelly, and his 7-foot deep hole at the Maple Avenue site was dubbed Kelly's pit. The Bolt guns were also tested in the pit with the guns suspended from a short piece of rope tied to a plank that was laid across the pit. Many were the times that Kelly and company came away from the pit covered with mud and water brought about by misfires of the air guns being tested.

The Mod I gun was mobilized for the first time in late 1966, and GSI has used the tuned array method ever since. By the end of 1967, all ships were equipped with 600-cubic-inch air gun arrays made up of Mod I guns. By 1968, the design was extended to a marsh gun model. By 1969, air gun arrays had grown to 900 cubic inches, and by 1970, the Mod II design, with chamber sizes up to 120 cubic inches, was tested.

Arrays had been extended to 1200 cubic inches by 1971, and experimentation continued with different array designs using a computer aided method of designing tuned air gun arrays.

Investigations began in 1974 for ways to correctly time the air gun array to maximize energy output. This work culminated in the design and development of TIGER* air gun controller. The controller was successfully demonstrated offshore California with a 1,450- cubic-inch array. By 1977, air gun arrays had increased to 2,000 cubic inches.

Further investigations concerned even larger air guns, and a prototype was tested offshore California in deep water to determine the performance of several models at pressures ranging up to 6,000 psi and gun volumes ranging 5 to 300 cubic inches. Chief scientist on the California tests was Roy Johnston.

When it was found that there was higher efficiency at 2,000 psi, development of GSI's Mod III air gun was initiated. Developments in gun-spacing criteria allowed GSI to space the air guns closer together in the arrays so as to achieve the same output with a cost reduction in handling the arrays.

A Mod III gun, 280 cubic inches, was fired to mark the opening of GSI's new air gun test center in Dallas. This facility has a 20,000-gallon tank housed in a masonry building. Air guns are lifted into position and lowered into the tank by a 1-ton traveling hoist.

In the early '70s, Shorty Trostle proposed using air guns for seismic data collection in ice-covered Arctic bays. This idea was the beginning of techniques used in the ice environment today. By 1975, the so-called thunder wagon concept was developed, using an array of air guns lowered through holes drilled in the sea ice. Track-mounted vibrators, introduced on the North Slope in 1978, are highly productive in that area.

Horizontal control is maintained by means of an electronic radio positioning system backed by manual tellurometer surveying. Recording elements are distributed over a minimum length of 4 miles, with capacity for over 8 miles' coverage; 96 traces are recorded for every source stimulation, and up to 48 source locations are occupied in a mile.

Instrumentation for encoding data on magnetic tape consists of two basic units: an amplifier and tape transport; and a minicomputer with two tape transports and two drum memories.

The GEOFIX† satellite positioning system, developed by GSI for surveying, works in conjunction with the galaxy of USN satellites. It supplies horizontal and vertical accuracies.

CHAPTER VIII
THE GSI SEISMIC NAVY

Before going further in this chronicle, we must give attention and credit to GSI's navy, for it offers a most colorful portion of the company's history and continues to this day to be a vital part of the business. GSI ships are recognized the world over, and this chapter gives credit to the ships and to the men who work aboard them.

GSI launched its first deep-water seismic operation in 1946 and today operates a fleet of company-owned and leased ocean-going ships designed, built, and outfitted to operate in marine environments anywhere in the world. These ships are equipped with the most advanced and fully integrated marine electronic seismic systems in use today. All of the onboard equipment reflects the developing technological advances in electronics, computers, and communications as applied to marine geophysical survey work.

By December 1965, when Cecil H. Green retired as TI vice president and was made honorary "admiral of the GSI Navy," the fleet numbered more than 50 owned and leased ships.

The M/V SONIC was GSI's first self-sufficient, deep-water marine exploration ship. Others (both leased and purchased) were used in seismic surveys employed as a shooting ship and recording ship. In some instances, a three-ship operation was used. Larger ships were self-sustaining, accommodating all elements of a survey at sea, and operable in remote waters for several weeks at a stretch, By May 1960, the M/V TEXIN, a former U.S. Navy escort vessel, was bought and outfitted with Series 7000 amplifiers, magne-DISC, oscillographs, and mapping systems. Both the SONIC and TEXIN, supervised by Paul Hodge from London headquarters, could operate in water depths 6 to 7 feet, shoot continuous lines at speeds of 6 to 8 knots, and complete from 50 to 60 miles per day. The TEXIN's first assignment was the Gulf of Suez. In 1961, when the TEXIN worked off the coast of Brazil, Bubba Hard was party manager, and Emir Tavella was seismologist.

Appreciably larger than either of these ships was the M/V SEA SEARCH, a former Navy medical ship, which was equipped with TI's EXPLORER 8000 series, transistorized amplifiers, More than 40 oil companies and press representatives from Las Palmas, Canary Islands were onboard in November 1961 for a demonstration of the single-boat shooting and recording techniques,

A fourth ocean-going ship bought for the GSI fleet was the M/V KYLE ANN; Bill Blakely was its first party manager. The M/V TILMAN J. III was chartered and outfitted in July 1963; the M/V GURNARD, a 30-year-old ex-pilot boat, was put into service in the North Sea in 1963.

During the early and mid-'60s, areas of high exploration interest included the North Sea and the U.S. Gulf Coast, where GSI for several years had whole fleets of ships in operation. The Marine Operations manager for the North Sea work during this time was Frank Fuller, who recalls that at one time as many as eight parties were riding the rough seas in often inclement weather in prelude to the enormous North Sea oil discoveries.

Data were recorded in analog form and processed at Bromley; interpretation went on around the clock. After digital seismic technology was introduced to the North Sea in 1964 (initiated by Party 906, M/V EMMA), data processing, and other interpretive functions were concentrated at Croydon. Cable repair and logistics support were handled out of Middlesbrough, England.

North Sea work was seasonal; when ice and winter storms stopped operations there, ships were either dry-docked for repairs or sent to warmer waters such as the Persian Gulf, Gulf of Mexico, the Mediterranean Sea, Lake Maracaibo, or the South China seas.

Gulf of Mexico surveys extended from Florida to Texas. In 1964, a three-ship operation there consisted of M/V REBECCA THERIOT, M/V BIG JOE, and M/V STATE EXPRESS, a recording ship; a two-ship operation comprised the M/V MOROCCO, shooting ship; and M/V SABINE, the supply ship. Fixed-wing aircraft provided offshore Raydist lane count.

Many types of ships were converted to the growing marine operations. The M/V MERINO was formerly a wool transport ship. The M/V HANS EGEDE, a Norwegian fishing trawler, was converted in 1966 as the flagship of GSI's Party 910 in the Arabian Gulf. In the Gulf also was the M/V DOODLEBUG I, the smallest recording vessel in the GSI fleet, but the first to be outfitted with the Series 10,000 Digital Field System. Roscoe Newton was party manager of a three-ship operation which included the MACO PRINCE, the DOODLEBUG I, and a landing craft of World War II vintage, (LSM 371), which carried fuel, water, and powder.

During this time, Jim DeSanto directed marine work off Alaska's coastlines. Boats were specially built to grope through the ice and fog offshore of the North Slope. The M/V GREBE and M/V PUFFIN worked Cook Inlet in Alaskan waters.

On the U. S. West Coast, the search for offshore oil in 1965 employed the DigiSUE, (a Jack Proffitt invention), an experimental system of the gas exploder and digital recorder. The DigiSUE system was used in Bristol Bay when a 20-company survey was led by Union Oil Company. Taped data were sent to GSI's playback center in Inglewood, California, for stacking, filtering, and display in conventional analog form. The M/V WESTWIND, a shooting-recording vessel used by GSI to work Bristol Bay (home of sockeye salmon) and other Alaskan waters in 1966, was double SUE-equipped (Seismic Underwater Explorer). SUE was developed by GSI to replace explosives as the energy source. This system was based on Socony Mobil Oil Company's design, licensed to GSI, and made its debut off the California Coast out of Long Beach as early as July 1963. It used an oxygen-propane compressed air mixture which was fired in the A-frame-mounted guns.

The M/V WHITECOAT, equipped with SUE, was sent to Grand Banks off Newfoundland for continuous work periods of 12 days at sea and 48 hours in port for refueling and maintenance. Huff Huffstutler and Leland Tschurr helped keep her working.

GSI added three ships between 1965 and 1968 which were named for GSI past presidents: Cecil H. Green, Eugene McDermott, and R.C. Dunlap.

The M/V CECIL H. GREEN was launched in 1965, and Ida Green (Cecil's wife) christened the ship in the sweltering heat of a Texas coastal summer at Houston, on July 11. Texas Instruments Senior Vice President Buddy Harris addressed the ship with words which Bob Dunlap wrote about her namesake.

Perhaps most of the honors bestowed on the CECIL H. GREEN extends from her namesake, her priority of design, and her worldwide ports of call. She was named for "Mr. GSI," who at the time of her launching was honorary chairman of the GSI board of directors. He also was a vice president and member of the board of directors of TI.

The GREEN was GSI's first ship to be designed specifically for seismic work. Although she was built for Gulf of Mexico operations, she has been around the world twice in her work history. Constructed at Mangone Ship Yards, Houston, Texas, the GREEN is 128 feet long with 32-foot beam, 10- foot draft, and has a top speed of 10 knots.

The GREEN was classed as a mud boat, with a working platform on which the streamer reel and instrument cab were mounted to give the ship an additional 5-foot length at full beam. Her quarters accommodated a 6-man ship's crew and 18 GSI and client geophysical personnel; quarters were air-conditioned for tropical climates and heated for cooler temperatures.

Some of the GREEN's first equipment included the Sperry gyrocompass, automatic steering, two depth recorders, radar, two radios, a TI digital recording system, and air gun arrays. Contrasting this capability, the GREEN became the first GSI vessel to be equipped with the integrated marine system and was the first to be equipped with the MALT array (1,450 cubic-inch air gun array having a variable length to 240 meters).

The GREEN collected 3D data in support of the October 1977 Cook Inlet federal lease sale for several clients. A two-vessel MALT survey in the Gulf of Alaska saw the GREEN shooting and recording and the M/V SITKIN, a contractor ship, doing simultaneous recording. The GREEN's twin V-16 power plants were put to the test dragging the long arrays and streamers against Cook Inlet's dreaded currents. Also, it was crab season, and occasional floating objects such as crab pot buoys, halibut lines, logs, and debris created a challenging course for the birds and cables of the MALT system.

The GREEN's success with 3D marine surveys in the Gulf of Thailand, Gulf of Alaska, Cook Inlet, and the Gulf of Mexico are a matter of record. Since her initial seismic surveys in the Gulf of Mexico (1965-1966), she has explored for oil offshore of the U.S. West Coast, Canada West Coast, Alaska, Persian Gulf (Bahrain), Madagascar, Tanzia, South West Africa, Gabon, Angola, Ghana, Cameroon, Norway, England, Holland, Spain, Senegal, Nigeria, Honduras, Venezuela, British West Indies, Guyana, Mexico, Togo, South Africa, Seychelles, Maldive Islands, India, Thailand, Borneo, Philippines, South Vietnam, Sumatra, Java, and Burma. Her most recent activity was the Gulf of Campeche where she performed 3D seismic work.

The second ship built to TI/GSI specifications was the M/V EUGENE McDERMOTT, named for the late Eugene McDermott (1899-1973).

McDermott, discussed earlier in this history, was the pioneer geophysicist who joined with "Doc" Karcher to organize GSI in 1930 as the first independent company to specialize in reflection seismography.

The first McDERMOTT was lost at sea, and another, the M/V EUGENE McDERMOTT II was launched at Carrington Slipways, Newcastle, New South Wales on November 6, 1971. The red-hulled, 17l-foot seismic ship has a 39- foot beam, 10-foot draft, a cruising speed of 13.5 knots, and a range of 12,000 miles. For her first shooting job, which began February1972 off northwest Australia, she used TI Digital Field Systems, a 1,200-cubic-inch gun array, and an acceleration cancelling hydrophone streamer. After completing a series of prospects in the Indonesia waters, she was soon established as the most modern, well-equipped seismic vessel operating offshore of Australia.

Considerable time has been spent by the McDERMOTT II in the Bass Straits, a treacherous, wind-swept expanse of water between Victoria on the Australian mainland and the island of Tasmania. Situated at 40 degrees south, the Bass Straits lie along a latitude that has appropriately been named the "Roaring Forties" because of the wind forces which are often as high as 8 to 9 on the Beaufort scale. The area is plagued by cyclones dubbed "Willy Willies."

Moving offshore of Western Australia, the McDERMOTT II collected nonexclusive seismic data in the Exmouth Plateau area in 1976 and 1977 to provide sales packages for distribution by GSI to interested oil companies around the world.

By mid-1977 the McDERMOTT II became a CMS** II vessel. She dry docked in Hong Kong for safety inspection and retrofitting, which involved installing the integrated marine system. A new inventory control system manages the more than 12,000 spare parts carried onboard the ship.

The M/V R.C. DUNLAP is a modified oil well supply ship, 165 feet long, and possesses design features specific to the needs of seismic exploration. She has a 36-foot beam and 11-foot draft and is equipped with two 1,600-hp engines which allow a top speed of 14 knots.

The DUNLAP was named for Bob Dunlap, GSI president from 1959 to 1966, and who, at the time the ship was placed in service in 1968 in the Mediterranean Sea, was a group vice president of TI in charge of the Equipment Group. Reminiscences at the time provide some of his historical notes on GSI's entry into early shallow-water work and deep-water experimentation.

About 1936, Dunlap was on the first shallow-water production crew fielded by GSI in Galveston Bay. There had been speculation about whether or not seismic reflections could be obtained in the deeper water of the Gulf of Mexico, so an investigative effort was made by a small crew on a very calm day. He recalled some of the details.

Using shallow-water seismometers floated on the surface in dishpans, shots were detonated on the sea bottom. As Dunlap described it: "We didn't know anything about multiples and bubbles at the time. Also, the seismometers kept falling into the water and sinking, which sounds a little comical now. Later, crew members bolted the seismometers to the dishpans and intentionally let them sink to the bottom. We wanted to see if we could get anything," said Dunlap. "Sure enough, we got some things--probably all bubbles and noise--but we did prove that offshore seismic work could be done." It was three decades from these dishpan beginnings to the naming of the M/V R.C. DUNLAP, which was equipped with the sophisticated TI Digital Field System and GSI's air gun energy source.

Once again, a GSIer who was prominent to GSI and TI history was honored by having a ship named for him. This was a stern trawler, a Canadian flag ship, bought by GSI in mid-1970 and named for Erik Jonsson. The M/V J. E. JONSSON is a sturdy 17l-foot vessel, with a 36-foot beam and 19-foot draft, with a speed of 13 knots.

A GSI pioneer, Jonsson was one of the founders of Texas Instruments, a past TI president, and in 1971, honorary TI chairman of the board. Jonsson, GSI's first laboratory superintendent, was responsible for building the equipment needed for the emerging exploration technique, reflection seismography. During the post-World War II period, he was the driving force that moved GSI's manufacturing capability toward entry into electronics and the subsequent founding of Texas Instruments.

In 1971, the JONSSON sailed out of Halifax, Nova Scotia, enroute to her first assignment offshore Eastern Canada. There she joined GSI ships M/V BRAZOS and M/V NECHES in a survey extending over the Grand Banks, the Flemish Cap, the Newfoundland Shelf, and the northern portion of the Nova Scotian Shelf. Approximately 8,000 miles of nonexclusive seismic coverage were produced by this survey.

The JONSSON was first outfitted with a 54-trace DFS III digital seismic system, a 1,200-cubic-inch tuned air gun array, an acceleration cancelling geophone streamer, and a GEONAV[†] system (including loran C, two radar systems, two autopilots, an automatic direction finder, three fathometers, and one side-scan sonar system). She also had a sono-buoy refraction system onboard.

By 1972, eyes had turned north in the oil search. In that year, the M/V GSI MARINER was built for GSI at land-locked Edmonton, Alberta, Canada, and shipped in three sections to Hay River. There, she was reassembled, launched, outfitted, and tested on the Great Slave Lake. She was a short, barge-type vessel, with an operating speed of 9 knots and berthing 24 persons. After two seasons in the Arctic, she was increased to her present 99-foot, l0-inch length; she has a 30-foot beam and 5-foot draft.

The GSI MARINER, christened at Hay River, N.W.T., on May 30, 1972, was the first Canadian-built exploration ship designed for surveying in both shallow and deep waters. William R. Brown, the architect, and Al Kneller, shipbuilder, were on hand when the ship's sponsor, Mrs. J.A. Bergasse (wife of the assistant director of the Northwest Territories department of industry and development) and J. Hargreaves, ship captain, performed the champagne bottle-breaking ceremony. Also on hand for the dedication were GSI officers Grant Dove, Dick Rainey, Jack Proffitt, Dave Einarsson, and GSI Marine Manager Roy Fuller.

Flying the Canadian flag, the GSI MARINER moved from Hay River north on the Mackenzie River to Inuvik, where she went into service in the summer of 1972, collecting seismic data in the Beaufort Sea, as soon as the ice moved out. The work lasted from mid-July through September, when she was frozen in at Tuktoyaktuk for the 1972-1973 winter season.

The 1973 shooting season began in mid-August. Tuk-Tuk served as operations base with supplies expedited from Inuvik and dropped onto the vessel's rear deck by helicopters. By October, the MARINER was again demobilized in Tuk-Tuk and dry-docked for the winter at Hay River, awaiting changes in her configuration.

Extensive changes included the addition of a new and large ice-cracking bow. It was trucked to Hay River by the piece and installed on the vessel to give her the present length and profile. Bow thrusters, designed by Herb Coburn of Dallas Engineering, Jack Thompson's group, were built, and installed to reduce the wide turnaround previously required for a turn. Bill Schilling went to the Arctic to QC bow fabrication, installation, and normal mobilization tasks.

Fabrication in subzero weather required a special Quonset-type shelter to house the work so that the welds met QC standards. After bow installation was complete, the shop was painted inside and out, cleaned, equipment repaired, supplies and fuel contracted, permits and inspections completed, and the vessel towed out of dry-dock. She was then fueled and ready to meet the rugged test that the polar ice pack presents to the daring seismic mariners operating in the Beaufort Sea.

The MARINER has met the challenge of eight Canadian Arctic shooting seasons, her decks washed with storms and tried by the summer's often angry winds. By October, the short shooting season is over and she is again in deep freeze, sealed off for the winter until spring thaws bring her decks alive with sounds of inspecting, cleaning, supplying, testing, repairing, and refurbishing.

The 1977 Arctic season was very successful. She averaged more than 115 kilometers/day. Beginning on July 16 east of Tuk-Tuk, she moved north along the west coast of Banks Island and into Prudhoe Bay. As soon as there was open water on the Search Prudhoe II prospect, the work began. She dodged ice floes in the fog part of the way. Daily ice movements were monitored by fixed wing and helicopter flights and the Dead horse base camp.

The M/V ARCTIC EXPLORER became a polar record breaker. Built in 1974, the icebreaker class (lAl Ice) vessel was leased first for the 1975 shooting season. Sailing with M/V CARINO, she was one of the first seismic ships to shoot in M'Clure and Fitzwilliam Straits and went 30 miles nearer the North Pole than any previous seismic survey ship. The Sverdrup Basin was sealed off during the 1975 season, with only a few open leads to the west to open waters. Cutting through ice that was sometimes up to 10 feet thick, and with ice freeze-up behind the ships as fast as they cut through, the ARCTIC EXPLORER and the CARINO forged ahead in one of the most severe Arctic marine seasons to achieve a record-breaking survey in the polar region.

The ARCTIC EXPLORER is 162.5 feet long with a 37.75-foot beam and l5-foot, 10-inch draft. Normally, her cruising speed is 14 knots, but during her initial polar assignment, she often would steam for hours to make 1 mile in the thick, pack ice. Each season, this ship is chartered for 6-month operations offshore Eastern Canada and in the High Arctic.
Each year she must be completely demobilized since her owners use her for other purposes during March and April. Rigup of such a chartered ship involves mobilization and often modifications that follow the annual shakedown cruise preceding regular survey work. Her operations are supported by a full-time helicopter onboard and fixed-wing aircraft from Resolute Bay, NWT.

Another 1A sealer-class ship, the M/V CARINO, was chartered for the 1973 season and for the first time, GSI marine crews were working less than 600 miles from the North Pole. The l45-foot converted sealing ship was transformed into a seismic vessel after weeks of welding, wiring, and woodworking in Liverpool, Nova Scotia, before being put into service in the Sverdrup basin.

When passage through the islands was clear of ice, the CARINO moved through Jones Sound and Hell Gate leading to Norwegian Bay and the Parry Islands. Whenever the ice pack forced a halt, the CARINO began the tedious business of slicing the ice at full power until the bow would ride up, then back off; this process was repeated until the ship could be maneuvered towards open leads and channels.

The most northerly extent of the 1973 season was 597 nautical miles from the North Pole; however, in 1975 the CARINO led the ARCTIC EXPLORER to north Baffin Bay and into Parry Channel as far as Resolute Bay, within 500 nautical miles of the Pole. These waters were previously un-navigated, and the two GSI seismic ships broke all records for penetration of polar waters.

The first GSI ship to have the full complement of safety equipment meeting the new TI Standard of Safety (TISOS) was the M/V TASMAN SEAL, chartered in 1978. She is a mud boat class ship, 165-feet long, with a 38-foot beam, II-foot draft, and cruising speed of 12 knots. Rigged in Singapore in early January, she sailed for the Philippines on a shakedown cruise. Rigging included DFS V, a 96-trace cable, MARISAT communication satellite system, and TI's Configurable Marine System. Her first 3D work in the Philippines was over the newly discovered NIDO field.

The M/V ARCTIC SEAL, a chartered ship, has the distinction of beginning service in 1966 as a marine geophysical survey ship and of participating in a 3-year survey over broad areas of the North Atlantic Ocean and contiguous seas, the largest such survey contract ever awarded to an industrial organization by the U.S. Naval Oceanographic Office. The ship was leased by TI for the duration of that program, but since that time she has been chartered and outfitted by GSI for seismic surveys.

The ARCTIC SEAL has an overall length of 165 feet, 38-foot beam, and 12-foot draft. Its steel-plated hull gives it the heaviest bow of any similar class vessel built by Burton Shipyard at the time. She has a cruising speed of 10 knots and facilities for 25 persons.

One of the newest in a growing line of seismic exploration ships to join the GSI fleet was christened the M/V PATRICK E. HAGGERTY on March 28, 1979.

Ceremonies were held at the Zigler Shipyard, a division of Lee-Vac Ltd., Jennings, Louisiana, and Mrs. Bea Haggerty, wife of Pat, christened the ship by breaking the customary bottle of champagne across the bow. Dolan McDaniel, GSI president and TI vice president, was master of ceremonies for the occasion.

Patrick E. Haggerty, a general director and honorary chairman of Texas Instruments Incorporated (parent company of GSI), figured prominently in the development of TI as an engineering and manufacturing company and in charting its course to a position of leadership in the electronics industry.

A plaque onboard the HAGGERTY spelled it out: "His technical and managerial abilities played a significant role in such industry firsts as the production of the first commercially available silicon transistors, the invention of the integrated circuit, and the development of digital seismic data collection and processing systems.

"The results of these revolutionary achievements are pervasive throughout our society and have contributed far-reaching benefits to mankind."

The first prospect for the HAGGERTY was offshore West Germany in the buoy- and fishing boat-infested shipping lanes to Bremen and Hamburg. Utilizing chase boats, the pilot Gutte: BELLATRIX and the fishing boat AGENES ENGEL, the HAGGERTY completed the job with only minor-damaged cables.

They were off again to the North Sea to survey a 3D prospect in the cold, inhospitable Norwegian waters near the Beryl oilfield. There were occasional midnight rendezvous with the ARCTIC SEAL and the JONSSON, both working nearby. Resources were stretched to the limit with all three ships at work, making mutual assistance between the three crews essential.

During the last half of 1979, GSI chartered the BRETON SHORE, the BLACK SEAL, and the KARUNDA as part of its seismic exploration fleet.

The BRETON SHORE, an ice-class vessel, was converted to a seismic configuration at Dartmouth, Nova Scotia, Canada. This Canadian registry vessel was built in 1973, is 185 feet long, with a 39-foot beam, l3.5-foot load draft, and a cruising speed of 14 knots. It is an 821-gross-ton vessel with facilities for 35 geophysics personnel and the ship's crew. It is equipped for 3D geophysical data collection utilizing the DFS* V digital field system, CMS** II Configurable Marine System, and 96-trace streamer. The energy source is a 1,450-cubic-inch 2000-psi tuned air gun array supplied by seven PB44 compressors.

In January 1980, the BRETON SHORE was purchased by GSI and renamed the M/V EDWARD O. VETTER in honor of Ed Vetter, GSI past president and TI executive vice president, who contributed significantly to the growth and development of GSI and TI during his years of service to the corporation.

The BLACK SEAL, chartered from Seal Fleet, accommodates 33 people, is 185 feet long, with a 38-foot beam and l4- foot draft. She is fully outfitted for 3D work with 96-trace DFS V instruments, CMS II unit, and 96-trace streamer. The energy source is a 2000-cubic-inch, 2000-psi tuned air gun array supplied by six Price Airgun Master compressors.

The KARUNDA is a chartered landing barge converted into a seismic vessel and is operating in the South China Sea. This ship is equipped to do 3D surveys in shallow water.

On April 3, 1980, the M/V R.W. OLSON, named in honor of Robert W. Olson, was dedicated at a gathering in Middlesbrough, England, while the M/V FRED J. AGNICH was being mobilized in Nova Scotia. Both ships are similar in construction to the EDWARD O. VETTER and will be collecting 3D seismic data in the world's oceans this year.

All GSI ships now have the full complement of safety equipment in compliance with TISOS, TI Standard of Safety.

----

*Trademark of Texas Instruments Incorporated.

**Trademark of Geophysical Service Inc.

†Service mark of Geophysical Service Inc.

CHAPTER IX
3D INNOVATIONS FOR THE 1980s

As oil field drilling and development costs in the '80s continue to rise and prospects become smaller and more difficult to find, research and development at GSI moves toward the ultimate seismic system, an exploration technology that will image the oil reservoir of economic interest at greater depths and in more tectonically complex areas. With the introduction of digital recording and common depth point (CDP) stack during the '60s, GSI significantly improved image resolution in a two-dimensional (2D) sense. The innovative three-dimensional (3D) techniques introduced by GSI in the '70s, together with advances in 3D wave equation algorithms, dramatically improve the acoustical photograph of the subsurface one can now obtain, making prospect drilling, and oil field development more economical than ever before.

The acoustical photograph of the subsurface, which is the product of the seismic method, is analogous to optical photography. A 2D reflection profile has been described as equivalent to taking a picture with a camera having a long, narrow lens aperture. The quality of the subsurface photograph is a function of computer-controlled focusing within the constraints of a 2D aperture. By comparison, 3D methods employ a rectangular lens aperture and produce an acoustic photograph of the total 3D subsurface volume.

The accurate imaging of the subsurface afforded by GSI's innovative 3D techniques is now a matter of record. Numerous case histories have been compiled by GSIers and published in Geophysics, Oil & Gas Journal, Science, and other trade publications to signal the oil industry that 3D data collection, processing, and display techniques are innovative tools for future oil and gas exploration and field development. Some of these include papers by Backus and Chen (1974), Teg1and (1977), Kurfess, Giles and Bone (1977), Schneider (1978), Dahm and Graebner (1978), Brown (1979), Hautefeuille and Cotton (1979), Graebner, Wason and Meinardus (1980), and Graebner, Steel and Wason (1980).

A paper of particular significance was presented by Dahm and Graebner (1978), entitled "Field Development with Three-Dimensional Seismic Methods in the Gulf of Thailand." The data represented 1,400 kilometers of recording and were shot over two periods by the M/V EUGENE McDERMOTT and the M/V CECIL H. GREEN. The densely spaced data were processed with the 3D wave equation migration algorithm to produce a set of seismic traces vertically below a grid of depth points spaced at 33-1/3 x 100 meters. As a result of the interpretation made on this data, the natural gas deposits of the Gulf were assessed at well over 2.0 trillion cubic feet. The economic value of this assessment was obvious, and the trade-off between the cost of the 3D survey and anything less than a 100-percent success ratio of drilling development wells cannot be ignored.

3D applications fall generally into the pre-discovery or prospect delineation phase and the post-discovery of field development phase. Since the average cost of a 3D survey over 1 square mile is approximately 2 to 5 percent of the cost of a dry development well, the seismic technique is very cost effective.

3D economics in field development for a North Sea field indicate several major benefits. Potential benefits are reduced capital expenditures (includes minimizing dry development wells), increased recoverable reserves (by determining optimum number, location and ratio of development wells and pressure maintenance wells to maximize production), and speedup in oil field development.

The most innovative approach yet developed to direct hydrocarbon detection were GSI's 3D subsurface model-building techniques introduced in 1972. This was followed by 3D land and marine data collection systems and interpretive techniques in 1974, 1975, and1976. Further advances in the ensuing years, particularly in processing and display innovations, which include direct electron beam-on film recording, have provided very high resolution displays. Color displays are now being used to further aid in the interpretation of these vast data volumes.

Areas chosen for 3D data collection on land are not always ideal for placement of geophones and energy source units. Surface layouts must be adapted to the surface terrain, yet yield acceptable production rates; they must provide adequate spacing of depth points, acceptable range of offsets for each CDP, and sufficient fold to yield good velocity and statics information. Innovative layout concepts trademarked by GSI include SEISQUARE**, SEISLOOP**, and SEISWATH**. These methods allow data to be collected economically under a wide range of surface conditions and access limitations.

On-site layout processing and preproduction testing allow the field seismologist to actively participate in the system design. Previously, seismologist" was a job category found only in GSI's digital seismic data processing centers, which might be centrally or regionally located. With the analysis capability brought to the field by the TI 770 terminal and the FT 1 (field TMAP) units, a field seismologist provides valuable input to the layout design.

The marine environment allows a somewhat more unified approach to 3D data collection. As the survey comprises a suite of closely spaced parallel lines, usually 75 or 100 meters apart. GSI's innovative SEISTRACK** system, introduced in 1975, permits tracking the recording streamer cable and provides coordinate information for each receiver group relative to the vessel. There are sensors in the cable to determine feathering angle or degree of deflection of the streamer from the shooting line, a condition created by tides or cross-currents. This positioning system allows the location accuracy required for processing, displaying, and interpreting the 3D seismic reflection data.

Processing of seismic data is provided by a network of digital seismic data processing centers and custom service centers. An analysis capability ranges from the simplest data manipulation to the avant garde structural/stratigraphic delineation systems. The systems include long wavelength statics, velocity modeling, 3D migration, and seismic log processing and provides GSI with a capability of producing high-quality subsurface images, and seismic logs, under a wide range of data collection circumstances.

Innovative display modes developed by GSI for scanning the large quantity of data now fall into two categories: 2D slices through the data volume and 3D displays of the data volume itself. The data volume can be sliced to produce 2D sections of seismic data in any chosen plane.

Vertical sections can be sliced parallel to the shooting direction, or in the perpendicular direction, or extracted along a diagonal line at any azimuth.

Horizontally slicing the data volume affords a view of the whole prospect area at one record time. A series of horizontal slices through the 3D data base develops a number of horizontal time planes.

SEISCROP** display, so-called because of its close similarity to the sub-crop map of the geologist. A SEISCROP section is the intersection of a horizontal time plane with a number of geological surfaces as opposed to a contour map, which may be thought of as the intersection of a geological surface with a number of horizontal time planes.

SEISCROP sections that are sliced from the data volume each sample period, e.g., every 2 or 4 milliseconds, can be integrated in movie format for scanning to detect the sense and direction of the dip on each event. This allows a seismic event, identified for mapping, to be drawn at each level for which a contour is required, eliminating timing and posting procedures. In practice, vertical 3D sections are used to identify key horizons, dips, and fault locations. Strike, spatial distributions of geologic formations, and knowledge of how to connect the faults are exhibited on the SEISCROP displays.

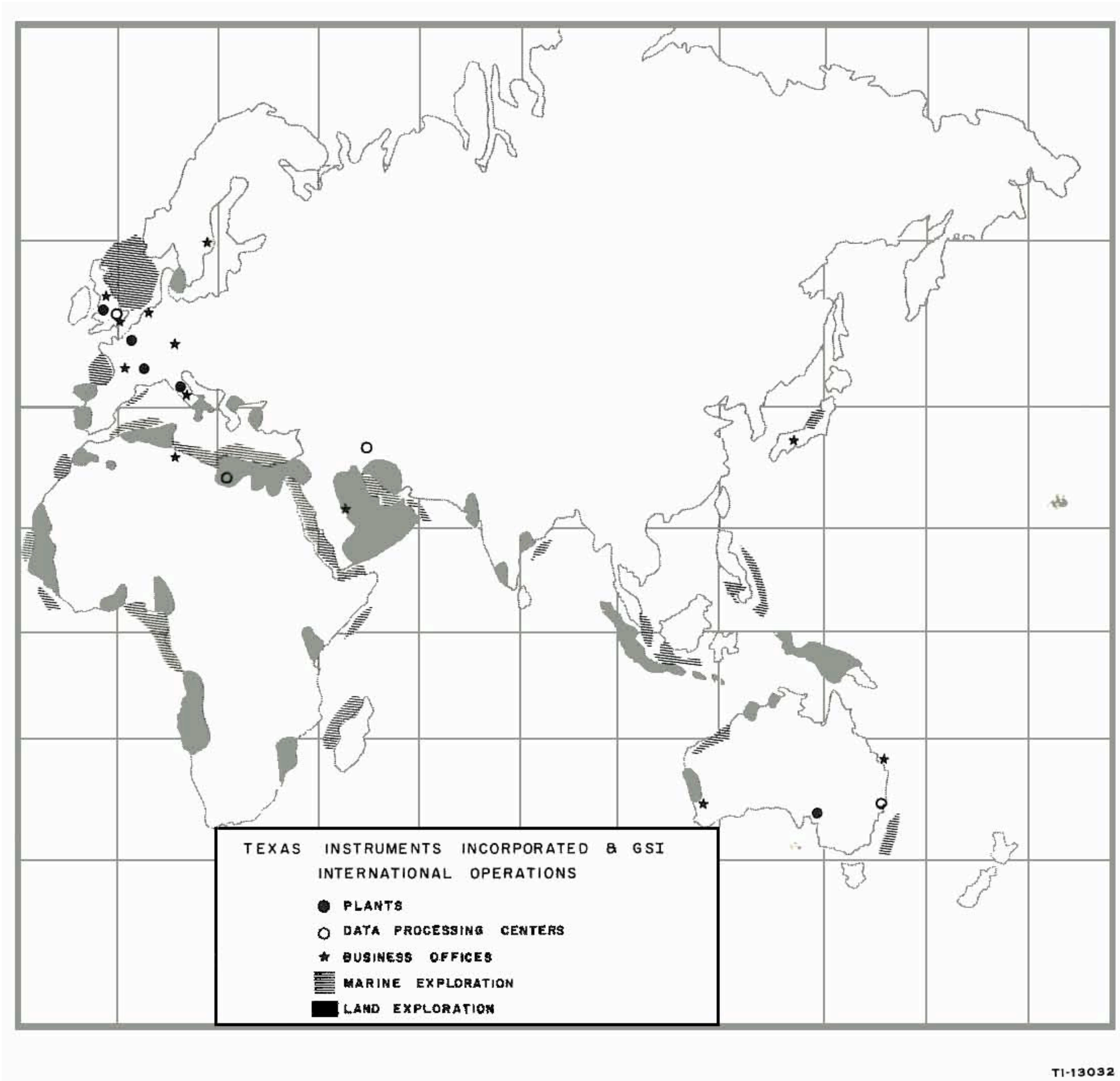
Methods for displaying a 3D data volume three-dimensionally include SEISMODEL** and the seismic data hologram. The display unit generally can accommodate a subset of between 25 and 40 transparent plates on which vertical slices through the data volume have been printed. As the subset of plates is illuminated from the back of the unit, it is possible to align the eye along any subsurface feature shown. For example, one can look along a fault, look down into a graben, or around a salt dome. Subtle features such as minor faults are identifiable as the full 3D form of a fault plan is observable. Horizons be mechanically digitized directly from transparent plates for computerized posting and contouring.

Once the 3D data have been processed, seismic logs can be estimated from the data volume. The technique uses a modeling procedure in which the interval velocity model is adjusted until the estimated data matches the actual processed data. On this type of application, the color display is particularly effective. On this type of application, the color display is particularly effective.

While steady evolutions will continue, the potential exists for a major transition from the use of seismic data as a means of obtaining subsurface images to a total 3D characterization of reservoirs. Techniques now use direct hydrocarbon indicators, waveform correlation, and seismic acoustic impedance logs to describe the subsurface condition. This represents but a part of the information that is available in the seismic data.

In concluding the highlights of GSI's "50 Years of Innovation", it is safe to assume that the '80s and decades to come will provide us with many innovative techniques based upon seismic data and the reflection seismograph system first introduced by Dr. John Clarence Karcher in 1930 as a practical oil finding tool.

**Trademark of Geophysical Service Inc.


TEXAS INSTRUMENTS INCORPORATED & GSI
INTERNATIONAL OPERATIONS
PLANTS
DATA PROCESSING CENTERS
BUSINESS OFFICES
MARINE EXPLORATION
LAND EXPLORATION
TI-13032