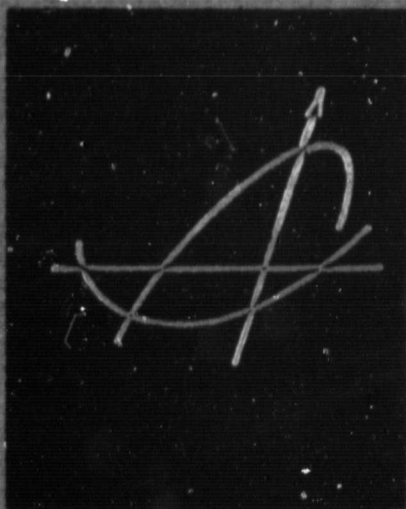


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Final Report

ECONOMIC VIABILITY OF A
SATELLITE SURVEYING SYSTEM

For

Office of Space Science and Applications
National Aeronautics and Space
Administration
Washington, D. C.

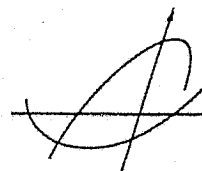
Contract No. NASw-1674

9019-030-9

December 29, 1969

By

William E. Brockman



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BOOZ · ALLEN APPLIED RESEARCH Inc.

WASHINGTON CHICAGO
LOS ANGELES

4733 BETHESDA AVENUE
BETHESDA, MD. 20014
656-2200
AREA CODE 301

December 29, 1969

Mr. Jerome D. Rosenberg
National Aeronautics and Space Administration
Headquarters
Washington, D. C. 20546

Dear Mr. Rosenberg:

In accordance with the provisions established by Task 9 under the NASA-Headquarters contract, NASW-1624, BAARINC was to determine the economic viability of carrying out surveying operations by satellites for the Geodetic Satellite Program (Code SC). Our final report on this Task is enclosed with this letter. The report contains a discussion of the surveying industry and its technology, a discussion of the market and income analysis performed, the results of this analysis, and our conclusions drawn from the study.

The approach used by the Booz, Allen study team in this determination was a series of intensive interviews with persons in the mapping, surveying, and aerial photogrammetry industry. The information gathered during the interviews contained data on the potential use of a satellite surveying system, the firm's total sales, and estimates of the total market size in which they were competing.

The market limits were expanded three times during the execution of the study in response to successive indications that the size of the market then being considered could not support a satellite surveying system.

As a result of the interviews with members of the photogrammetry industry, a Booz, Allen study team member was invited to discuss the preliminary results of the study via a formal paper given at the annual meeting of the Legislative Council for Photogrammetry. This offered the team an opportunity to feedback and test the preliminary information with some of the firms interviewed early in the study.

Mr. Jerome D. Rosenberg
NASA-Headquarters
December 29, 1969
Page Two

The question of economic viability of a satellite land-surveying system depends on two factors: income to an enterprise, and its expenses. As originally proposed, this study was directed toward estimating the income to a satellite surveying system, to the total exclusion of expense estimation. As a result, firm conclusions have been drawn concerning the potential income to a satellite surveying system, but it was not possible to draw direct, definite conclusions concerning economic viability. It is pointed out in our report, however, that even lacking the estimation of expenses, the income possible for a satellite system appears small against the probable needs to capitalize and maintain such a system.

We have found this to be an extremely interesting task, and look forward enthusiastically to similar future tasks.

Very truly yours,

William E. Brockman

BOOZ · ALLEN APPLIED RESEARCH Inc.

William E. Brockman
Project Scientist

Approved:

William P. Sommers

William P. Sommers
Vice-President

Enclosures

BAARINC

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FOREWORD

This work was performed as Task 9 under Booz, Allen's NASA Headquarters Contract, NASw 1674. Our client for this task was Mr. Jerome D. Rosenberg, Manager of Geodetic Satellite Programs, Code SA, Office of Space Science and Applications, NASA Headquarters, Washington, D. C. The work was initiated in March and completed in October of 1969 with the majority of the work being done during the period March through June. This study was performed by two Booz, Allen employees: Mr. Dudley Kircher of Booz, Allen & Hamilton, Inc., Washington, D. C., who served as the marketing expert of the team, provided much of the initial interviewing technique, and developed the first market segmentation matrix; the other member of the team was Mr. William E. Brockman, Booz, Allen Applied Research, Inc., Bethesda, Maryland, who conducted most of the interviews, was responsible for the technical inputs, and wrote the final report.

SUMMARY

NASA is constantly reassessing areas of space technology regarding their potential capabilities for conversion into a public or commercial operational system. The present study was initiated as a part of this ongoing effort, with the purpose of determining whether an operational system based on NAVAJD geodetic satellite technology could compete successfully in the commercial land surveying market.

A satellite system for land surveying can be visualized as having three subsystems: first, the orbiting satellites that will produce a signal for the ground stations to receive; second, the ground station tracking network--the permanent network that will determine the orbital position and orbital information of the satellite; and third, the portable instruments used by the ground surveyors to determine the geodetic positions on the ground using the satellites as the reference points.

The recognized method for a commercial enterprise to assess the economic feasibility of a new product is to determine the existence and size of the market for the product. While standard in commercial profit-oriented practice, this approach is a departure from the normal cost-benefit analysis techniques used by many government agencies. The present study determined what product could be sold to what group of potential users for what price and estimated the gross revenue to an enterprise operating the system.

The following conclusions were reached from the market analysis performed:

- . The gross revenue to a satellite system that serves only commercial firms operating in the U.S. and Canada would be \$1.25 million annually
- . If the system is operated worldwide for only U.S. and Canadian commercial firms, the gross revenue would be \$6.5 million annually

- . If the system is operated worldwide for all users except the governments of the U.S., U.S.S.R., and mainland China, the gross revenue would range from \$10.6 to \$18.3 million annually
- . The operation of a satellite surveying system would not produce sufficient revenue to be considered clearly economically viable.

I. INTRODUCTION

Under NASA sponsorship, several areas of space technology have been developed to the point where either commercial or public applications of the technology have been attained. Communications satellites are an example of a commercially viable space technology application that has not only been proven practical, but has reached the point of being profitable in the competitive communications market. Meteorology satellites likewise have been proven to be practical and are currently providing useful information to the public at large. NASA's mission, in the area of space applications, is to carry out development of systems to the point of proving their operational feasibility. At this point another Government agency (such as the Environmental Science Services Administration in the case of meteorological satellites) or commercial industry is encouraged to take over the continued development and operational aspects of the system. Thus, NASA is constantly reassessing systems regarding their potential capabilities for conversion into a public or commercial operational system. The present study was initiated as part of this ongoing effort.

1. PURPOSE AND SCOPE OF THE STUDY

This study was initiated to determine whether an operational system based on NAVAID geodetic satellite technology could compete successfully in the commercial land surveying market.

The scope of the study specifically excluded determination analysis of the technical feasibility of an operational satellite surveying system. Results of preliminary technical studies performed by NASA and other independent groups were encouraging enough to indicate that the performance characteristics of the system could be tailored to fit the requirements of the market. If this analysis were to indicate economic feasibility then a comprehensive technical study would be undertaken to define the satellite system. As a result the accuracies and features of a specific hardware system as compared with conventional systems was not assessed; rather, using a conceptual satellite system, determination was made of what characteristics the system must possess to be commercially competitive. This approach was felt to be realistic since a satellite

system can be designed to be very accurate if the cost can be economically justified. The early phase of effort included work in achieving firmer definitions of the accuracies required, desirable methods of operation, and the operating time constraints that would be necessary for a competitive system.

The results of this study were to provide NASA with the necessary management information to determine if the satellite surveying system is commercially, economically viable. The information was to consist of an estimate of the market size (in dollars) of present surveying that could be replaced by a satellite system for various market segments. The users considered included the commercial mapping and surveying industry, as well as government agency surveying and mappers.

2. SATELLITE SYSTEM CONCEPT

A satellite system for land-surveying can be visualized as having three subsystems: first, the orbiting satellites that will produce a signal for the ground stations to receive; second, the ground station tracking network--the permanent network that will determine the orbital position and orbital information of the satellite; and third, the portable instruments used by the ground surveyors to determine the geodetic positions on the ground using the satellites as the reference points. For this particular effort, the only parts of this system that had to be defined further are the instruments to be used by the ground surveyors and their method of communication with the satellite tracking network. Further work in defining satellites and permanent ground network configurations was not performed.

The portable instruments to be used by the surveyors would be placed at the site or sites normally occupied by a field party to collect data from the satellites. The instruments would collect and record data unattended for a maximum of two hours. Later, the data collected would be sent to the computer facility of the tracking network for computation of latitude, longitude, and altitude. The method of communication to be used in the United States would most logically be the telephone system. Upon computing the parameters of latitude, longitude, and altitude, the results or answers would be returned to the surveyor via telephone or to his central office in another city. The portable instruments used by the surveyors should be about the size and weight of the modern Electronic Distance Measuring Equipment currently in use by surveyors and would be leased or sold for about the same price.

3. MARKET STUDIES VERSUS BENEFITS ANALYSES

The recognized method for a commercial enterprise to determine whether to market a product or begin production of a potentially attractive new product is to expend a relatively small amount of funds to determine the existence and size of the market for the product. In addition, the marketing survey team may be required to determine what the people will buy; in other words, what characteristics a final product should have, as well as determining the quantity, quality and price of the product required for an economically justified expenditure of research and development funds. This approach, while standard in commercial practice, is a departure from the normal cost-benefit analysis techniques used by many government agencies.

Benefits are often estimated without a determination of who will collect them and without determining whether the so-called benefits can be marketed. In many cases, there is not an economic mechanism by which the benefit will produce a net change in dollars in someone's pocket. By doing this marketing study, which literally means determining what can be sold to whom for what price, the problems associated with benefit studies were avoided.

4. STUDY ORGANIZATION

The study was performed in the following phases:

- . Preliminary analysis of gross market and applications, preliminary identification of potential interviews, structure of data base to be acquired, and gathering of information on equipment and support services
- . Preparation of interview guide, scheduling of preliminary interviews, conducting preliminary interviews, revision of interview guide
- . Interview U.S. commercial firms, make preliminary estimate of market size
- . Complete U.S. foreign and domestic market estimate, estimate Alaskan market

- Interview Canadian market sources, obtain data on world market fur surveying
- Consolidate findings, and prepare final report.

5. MARKET LIMITS

During the course of the study, the limits defining the market to be estimated were expanded three times when it became apparent that the potential market as then defined could not support a Satellite Surveying System.

Initially, this study was to be limited to the domestic market served by U.S. commercial firms engaged in mapping and surveying; that is, all foreign and commercial firms and governmental agencies as well as U.S. governmental agencies were to be excluded as potential users. Upon completion of the initial phase of the study, it was concluded that such a market was too small to support a satellite system.

The first expansion of market limits was to include all foreign and domestic activities of U.S. firms. The second expansion was to include the foreign and domestic activities of all Canadian commercial ventures. By including only commercial firms, the problem was reduced to the fairly normal marketing study because in this segment it is possible to determine who would pay how much for such a satellite surveying service.

The third and last expansion was to include the estimates of foreign government expenditures. Interview methods were not used for this final group because of the expense involved in obtaining data; rather, estimates were obtained from sources in the United States about the total market for mapping and surveying. A computation was then made on the basis of the total market for the amount of services that a satellite surveying system could sell to foreign governments. The U.S. Government was not included because this information is directly available to NASA from other agencies of the government.

6. ORGANIZATION OF REPORT

This report is organized into chapters that can be read virtually independently.

Chapter I introduces the study, contains its purpose and scope, a brief description of the potential product, the rationale for the Booz, Allen approach, the description of the tasks performed during the study, and a discussion of the limits of the market for the product.

Chapter II defines the industry of commercial surveying with a preliminary segmentation into Land Surveying and Aerial Photogrammetry. Relevant characteristics of the segments are discussed in terms of accuracies, methods, equipment, and personnel.

The potential application of a satellite system to each of the market segments are identified in Chapter III.

In Chapter IV, the size of each market segment is estimated.

Chapter V contains a discussion of the method used to estimate the income to a satellite system through an examination of the increased productivity of surveying personnel. The method is then used to determine the potential income for each market segment.

Chapter VI contains the conclusions of economic viability by market segment.

II. PRESENT CONVENTIONAL SURVEYING

During the study, contacts were made with a broad cross-section of those people who are concerned with determining geodetic positions for a commercial business. The data obtained from the interviews indicate that surveying can be divided into two general categories:

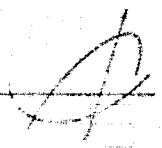
- . Type I - does not require the placement of closely spaced markers
- . Type II - requires closely spaced markers.

For these purposes, the definition of "closely spaced" can be taken to be something less than 1 mile, normally in the range of 1,000 feet or less.

In general, Type I surveying is performed over a large geographical area ranging from greater than a few hundred acres up to more than 100 miles. On the other hand, Type II surveying is normally performed in a very limited geographical area, normally less than 100 acres and usually less than 10 acres.

Included under Type I surveying are:

- . Large property and boundary surveys
- . Engineering design, especially route surveys
- . Large quantity and measurement surveys (for example, strip mining and highway construction)
- . As-built facility locations
- . Control surveys for cartography
- . Control surveys for mapping, especially engineering design mapping
- . Geodetic control surveys for national geodetic networks.



Type II surveying includes:

- . Small property and subdivision surveys
- . Construction layout including building sites
- . Engineering control networks.

1. LAND SURVEYING

From the interviews with the land surveyors in the Washington area, and also during the interview with Mr. Fennell of the American Congress on Surveying and Mapping (ACS&M), it was determined that most registered land surveyors in the country are engaged almost exclusively in Type II surveying. A small number of land surveyors are also employed in first-order* geodetic control work.

(1) Accuracy Requirements

Most surveying in the Type II category generally requires accuracies of at least a few centimeters. The distances involved are normally less than 1,000 feet. As such, to achieve second-order* accuracy the requirements are of the order of 1 or 2 centimeters. The methods generally used for Type II surveying are limited to traditional chains and transits as employed by registered land surveyors.

Methods employed in first-order geodetic control are designed to achieve accuracies on the order of a few centimeters. First-order control, even though it is done over long distances by the Coast & Geodetic Survey, is well monumented. The accuracies of a few centimeters have been maintained even when the land surveyors use electronic distance measuring (EDM) equipment.

* The generally accepted definitions for accuracy in surveying are errors in position not to exceed 1 in 25,000 for first-order work, and 1 in 10,000 for second-order work.

(2) Methods

The methods utilized by the majority of today's land surveyors have changed very little since the turn of the century. The primary equipment remains the steel chain or tape for measuring distances and the transit or theodolite for measuring angles. Accuracies achieved with this equipment are quite acceptable when considering the short distance of measurement.

Recently, very-short-range EDM equipment has been introduced that will permit accuracies of less than 1 centimeter. It is assumed that in the future greater use will be made of these instruments, particularly over the shorter ranges. However, for such applications as building site layouts it is assumed that even the short-distance EDM equipment will not be sufficiently productive so that most surveyors will continue to utilize the standard steel tape method of measuring distances, especially when the distances are under 100 feet.

(3) Geodetic Networks

The existing geodetic control networks in the United States are being expanded as rapidly as personnel and fiscal policies will permit. Rapidly advancing geodetic control networks will have a twofold effect on the surveying industry: They will save field time and they will improve the overall accuracy attainable under normal operating conditions.

1. Saving Field Time

The current program for implementing a highly dense and highly accurate network in the 500 leading counties in the United States will greatly reduce the time needed for a surveyor to complete his work. Generally, a surveyor in the urban area needs to tie in with the state datum so that all of his work will be referenced to the state coordinate system. At the present time, the control points for tying in with the state coordinate system can be as far apart as 20 miles. When the highly dense network is completed, the urban control points will not be more than 2 to 5 miles apart. For

practical purposes, the urban surveyor now keeps his own records of previous jobs that he has surveyed. Thus, in most cases he is able to tie in with control that he has previously implemented and normally would not have to go back to points in the geodetic control networks. In the rural areas, however, this is not true, and he does have to go back to points in the geodetic control networks.

2. Improving Accuracy

Opinions about the adequacy of the national geodetic control networks cover the spectrum from "totally adequate coverage" to "never being where they are needed." The nature of the opinions expressed usually reflect the function of the organization by which the person is employed. The Coast & Geodetic Survey is responsible for implementing national geodetic networks and thus feels that they are adequate. In many cases, however, the surveyors who normally use the geodetic control networks express the opinion that they are never where they are needed. Since work generally is carried on where no development exists, no geodetic control is available. Thus, geodetic control must be instituted in areas where prime development is taking place.

Most of the surveyors who work in the rural areas feel that even when the planned geodetic control networks are instituted, they will require long ties to the state coordinate system either by traditional or by EDM methods. Many of the surveyors now use the EDM method; however, many are still using the traditional tape and chain methods. The latter do not feel that the geodetic control systems presently available or planned to be available in the foreseeable future are adequate for their normal usage.

Urban measurements will be tied to the high-precision high-density control network instituted in the 500 leading counties. The control points available will be available; consequently, urban measurements will become more accurate. In rural areas where the control points are available, the secondary nets that

are tied to the high-precision transcontinental traverse network will become much more accurate; thus, the rural surveyor will be able to have better accuracy because of the tie-in with this network. His work will not be reduced, but the results he obtains will be of a higher accuracy.

2. AERIAL PHOTOGRAMMETRY

Many consulting engineering firms now use aerial photogrammetry almost exclusively for low-accuracy surveying, especially for large projects. From interviews, it is estimated that something more than 90% of the mapping for preliminary engineering design of projects having more than a few hundred acres is done photogrammetrically. This percentage has been rising recently because the consulting engineering firms cannot afford the traditional survey field parties necessary to take all the measurements to construct even low-accuracy design maps for the preliminary engineering design.

The technique of analytical bridging has reduced the need for ground control to an absolute minimum. By implementing ground control more sparsely, the cost of instituting control for the whole project is greatly reduced. The technique of computation is now perfected and is routinely used especially by the larger firms.

(1) Accuracy Requirements

With the exception of geodetic and other control surveys enumerated in Type I surveying, most Type I surveying is accomplished by photogrammetric techniques. The photogrammetrists have introduced many techniques in the past few years that have enabled them to produce maps, data, and other information for the engineers in a time scale and for a price that is consistent with the requirements of engineering. It has not been possible to use traditional surveying methods and still meet the cost and time requirements imposed by engineering projects. Photogrammetrists have been eager to improve their coverage of the types of surveying because they feel that use of photogrammetric techniques can produce the same accuracies at a much lower cost. They campaign vigorously to obtain increased use of their techniques especially by government agencies such as state highway departments who

still use traditional methods in the face of what the photogrammetrists consider clear evidence that their techniques are advantageous. Photogrammetry has become so well accepted that to speak of accuracy of surveying in the order of 3 to 6 inches is almost synonymous with speaking of photogrammetric techniques especially when the monuments are not closely spaced. Therefore, potential customers for the satellite surveying utility would appear to be primarily those firms now employing photogrammetric techniques.

The accuracy generally required for Type I surveying ranges from 3 to 6 inches in both the vertical and horizontal axes. This corresponds to approximate second-order accuracy as normally defined by the surveyors. Most of the surveying needed for engineering work is designed to produce accuracies of at least second-order or better.

Over a mile, this is equivalent to 6 inches. However, if each location at the end of the mile traverse is known to ± 3 inches, then the total distance is known to an accuracy of ± 6 inches. Thus, for a satellite surveying system to achieve second-order accuracy over a distance of a mile requires that the satellites geodetic positioning be accurate to ± 3 inches, that is, the absolute accuracy. Further, it would have to be a 2 or 3 sigma level of accuracy of 3 inches.

Almost no surveying presently performed in the United States is done to accuracies of worse than 6 inches. In general, when accuracies of worse than 6 inches are desired the information that is needed can be obtained from aerial photographs without ground control or from the quadrangle map sheets provided by the United States Geological Survey.

(2) Methods

Electronics distance measuring equipment is used almost exclusively in establishing ground control for photogrammetry. Both the normal photogrammetry and the techniques of analytical bridging require a fairly accurate distance measured over long ranges. The long ranges lend themselves quite well to the use of EDM. The quickness with which the EDM can measure distances is also important in photogrammetry

because the opportunity for good photogrammetry is limited to two periods--one in the spring and one in the fall. Much of the control work and panels for photo control must be implemented during these two short seasons and be used very quickly in order that the work can be completed before the leaves come out or snow falls.

3. EQUIPMENT AND PERSONNEL

Increases in demand for surveying services and a competition to fill that demand have provided much of the incentive for the surveying industry to become more efficient and to use new technology. The amount of large-scale development and the increased utilization of the urban areas have caused the demand for surveying services to rise in almost all categories. The present force of surveyors is insufficient to meet this demand; therefore, the surveying firms have been driven to find new techniques that will increase their efficiency and thus be able to meet the demand for an increased amount of services.

The use of EDM equipment has had a number of profound effects on surveying and aerial photogrammetry. It has resulted in the reduction of both crew size and the amount of time needed to measure for photo control. The ability to measure longer distances with acceptable accuracy has reduced the number of jobs necessary in a survey crew. The normal survey crew for vertical measurement, leveling, is normally three and for horizontal control is normally four. With EDM equipment, the vertical remains the same but the horizontal is reduced to two men, one operating each end of the equipment.

The more difficult the terrain the greater the time savings for a given job through use of EDM. The more difficult the terrain with conventional instruments, the much greater amount of time needed to cover the distances, make the measurements, and monument the area. However with EDM equipment, many of the extremely difficult parts of the terrain can be skipped entirely and the measurement can be made from accessible locations, for example, from hilltop to hilltop. The people can be dropped in by helicopter or taken from one part of the valley to a fairly distant hill. With the traditional method, much of the ground between the two surveying stations would have to be traversed in order to make the measurement, often involving the cutting of brush and removal of trees so that line of sight could be achieved.

EDM equipment now routinely produces measurements that are of a higher accuracy than would be normally needed if the measurements were being taken with the traditional means. For photo control, especially for the larger scale mapping, the EDM equipment gives accuracies of the order of a few centimeters. Present requirements are that accuracies be of the order of 10 to 20 centimeters especially for large-scale maps, and this is what would be needed for photo control. As a result, some EDM equipment is not maintained to the fullest capability; when more precise measurements are attempted, the sloppy maintenance of the equipment causes poorer measurements to be taken than would be possible with well-cared for instruments.

There will continue to be an increase in the use of sub- and para-professional personnel for surveying measurement to replace the more highly paid and skilled engineer and professional land surveyor. With improved EDM equipment, only the final value of distance needs to be read out directly and copied onto a piece of paper. The skills required to do high accuracy chaining and high accuracy sighting via the transit are no longer necessary.

The professional engineers are being better utilized in their offices to plan and design the engineering projects. In the past, to achieve the higher accuracies necessary for design work, many of the engineers were included as part of the surveying crew. The wage rates for professional engineers have been climbing with the steadily rising income of the other professional classes. As a result, surveying costs have increased sharply thus providing incentive for the use of modern equipment--utilization of the lower paid and, therefore, lower skilled people.

The Job Corps is instituting a program to train crewmen for use in surveying parties. They are able to replace the more skilled crewmen normally used in surveying parties especially when the simpler EDM equipment is utilized.

Junior colleges and technical schools are expanding programs to produce technicians to operate survey equipment. In many cases, these people are more capable than the Job Corps trainees in that they have had more mathematics and theory and thus are able to operate more than the field equipment. They understand the theory of the stereo plotters and other cartography equipment, also are taught some rudimentary engineering courses.

(1) Present Equipment

The new technology has taken the form primarily of EDM equipment. The other means of measurement--angle measuring--has somewhat lagged behind in automatic measuring techniques. There have been some attempts to provide gyro-stabilized azimuth indicators, but these have not approached the accuracy required in higher precision surveys. Therefore, the transits and theodolites that have been used in the past to measure angles between bearings will undoubtedly continue to be used at least in the foreseeable future. They are a refinement of the traditional method of angle measuring but are not a significant breakthrough.

The EDM equipment makes use of either visible or high frequency radio electromagnetic radiation to measure distances between a receiver and a sender or between a sender and a reflector.

The new EDM units for use over shorter distances are quoting accuracies of less than a centimeter plus or minus 1 part per million in some cases and 1 part in 300,000 in other cases. In general, these accuracies formerly were attainable only by the most precise taping and chaining methods. Now, they are routinely achieved by somewhat inexperienced crews operating well maintained equipment in the field.

The EDM equipment is much more portable than it was in the past. The original Tellurometer was heavier and required a much higher electrical power level to operate than the newer models do. It is the use of lasers to replace the helium and mercury arc lamps in equipment such as the Geodimeter which uses visible light instead of microwave radiation, that has reduced the weight. The use of lasers has extended the useable range of these instruments, in some cases, to well over 50 miles; in addition, it has eliminated the need for precise humidity measurement equipment to be carried with the instrument. The visible light spectrum (as apposed to microwave) radiation is not affected by humidity; both, however, are affected by temperature. The precise determination of temperature along the path of sight is still an important factor in achieving the accuracies quoted above.

The original EDM equipment, in particular the Tellurometers, contained magnetic delay lines as an integral part of the measuring equipment. It was necessary to take readings in the field from the dials during the time of measurement and then return to the office and do fairly extensive calculations on the meter readings to determine the distances that were measured. In many cases, this proved to be inconvenient because the time lag did not permit an instant verification of even the gross range of the equipment. The number meant very little to the operator of the equipment.

Manufacturers have replaced this type of readout with more sophisticated electronics packages that permit the direct reading of the distances from the face of the instrument. In many cases, the displays are electronic so that the numbers can be read directly rather than reading a dial. The result is that readings can be taken more quickly because it is easier for the operator to read the digital display than the meter. Second, the ranges measured can be instantly verified by estimating the distances to make sure that the instrument is in the right range. These changes in the operation of the instrument have greatly improved the field crew efficiency. Even over fairly long distances and in rugged country early Tellurometers were a much more efficient means of measuring the distance between two stations than the traditional chain or tape methods.

Presently, the relative accuracies of the distance measuring equipment, especially the EDM equipment, are higher than the relative accuracies of the means for measuring angles, thus reversing the traditional situation in the surveying instrumentation field. In the past, it was possible to measure angles more accurately than it was to measure long distances; therefore; triangulation was the favorite method of established geodetic control networks. More recently, with the advent of EDM equipment, the angles can then be computed from the measurement of distances between the interconnected stations of the control network (trilateration results). However, the local surveyor, who is still finding his way from one station to the next, takes many polaris or sun shots to provide a deviation from northing direction so that angles and a bearing can be established together with a distance established by EDM equipment. This is particularly true when the local surveyor is required to place many stakes; for example, for curb or street lines or for utility sewer lines, etc., where the stakes are placed every few feet. This staking is done with the traditional tape and chain and transit.

The transit is used to establish bearings; therefore, the surveyor still needs angle information. Thus, while trilateration is used to establish the basic engineering control network, the angles between stations are given so that subsequent work can be carried out more efficiently.

(2) Future Equipment

The prospect of a completely new technology impacting the surveying instrument field as lasers have done in the last decade is not bright. There is no great demand in the industry for measurements of a higher order of accuracy. As mentioned previously, the present abilities of EDM equipment exceed the requirements for accuracy. Angle measurement has not kept pace with distance measurement; however, unless the industry demands higher accuracies in angle measurement, it is unlikely that the angle instruments will be greatly improved in the next decade.

In the short term, EDM equipment will be optimized resulting in more portability, and accuracies over short range will continue to improve to compete with the traditional methods of measurement. As production units increase in numbers, the possibility of lower unit cost as well as the development of resale markets will make the EDM equipment accepted to a greater degree by the surveying community.

(3) Computation Aids

There is a growing sophistication regarding the use of automated computation techniques among surveyors. A recent survey performed by the Computer Usage Committee of the ACS&M has indicated that approximately 75 per cent of surveyors now use computers in some phase of their operation especially in routine coordinate transformation and in plat planning and development. The methods previously used to do coordinate transformation were quite laborious. In many cases the surveyor did not report his stations in terms of the state coordinate system; instead, he used only local coordinate systems peculiar to that job. However, with automatic computational techniques, the transformation from one coordinate system to another is simply a mathematical matrix multiplication that is accomplished in a few seconds with electronics computers.

The mathematical routines for plat design, layout, and planning are quite a bit more complicated and are probably some of the most sophisticated the surveyor now uses. In the past, it has been up to the draftsman to lay out a plat so that maximum utilization of land is achieved while adhering to the restrictions pertinent to that development; for example, minimum lot size, minimum frontage, and the like. The drawing of such a plat, especially for a large irregularly shaped lot, consumed many man hours of drafting and engineering work to do the calculations. Standard computer programs now exist to do much of this calculation quickly and, therefore, efficiently because they do them at a fairly low cost.

A recently developed method of geodetic positioning of aerial photographs, called "analytical bridging," requires computer usage. It is now widely accepted by photogrammetrists. This method greatly saves the amount of field control that must be implemented for the overlapping photographs to be positioned such that they represent a geographical area to the highest possible degree of accuracy. There are only a few of these computer routines available to the public. As a result, many of the smaller aerial photogrammetrist companies with the larger photogrammetrists to perform the computation for analytical bridging.

Time sharing computer systems are becoming very cost effective in survey applications, particularly in program design. The use of generally accepted languages and programming techniques has made it much easier to transfer standard computer software between time sharing systems, so that many surveyors now find it quite efficient to use them routinely.

Existing computer services, those now supplying the ordinary coordinate transformation and planning to the surveyor and photogrammetrist, could very easily be adapted to performing the necessary satellite computations. They could be done as a prelude or a preliminary step to the normal engineering calculations done in the coordinate transformation and in planning work. The calculations are basically celestial mechanics involving an optimization scheme and would not require extensive computer time to be performed. If the basic orbit data could be supplied by the satellite surveying

utility, many of the computer software time sharing organizations would undoubtedly find it advantageous to purchase this information in order to be able to complete the calculations for the positioning of the mobile receivers for their surveying customers.

III. APPLICATION OF SATELLITES TO COMMERCIAL LAND SURVEYING

Using satellites to determine geodetic positions for commercial purposes originated in the aerospace technology industry rather than in the photogrammetry/mapping/surveying industry. As a result, the applications of satellites will be explained rather carefully in this chapter and will include some information that would be obvious to a member of the surveying industry but may not be known to a member of the aerospace industry.

As with all relatively sophisticated systems, problems exist with satellite surveying that could seriously hamper the successful application of this technique. Recognition of these problem areas is appropriate and necessary at this stage.

The problem most often discussed during the interviews with the surveying industry concerned accuracy. More specifically, the problem is one of verification of the accuracy on a routine basis by the average operator. Unless the photogrammetrists have confidence that the satellite system does indeed produce geodetic positions to the accuracies specified, it simply will not be used to the extent estimated. Verification schemes have been proposed in the course of the interviews, and one or more of them will have to be included in design of the system.

Two other problems in the operational aspects of a system should also be considered: productivity of a satellite system and interstation communication networks. Almost no system that meets the requirements of low cost, portability, and ease of operation can approach the productivity in all applications of generally used surveying instruments. Thus, the use of a satellite system will have to be carefully planned so that it complements rather than competes with conventional instruments.

It will be necessary to communicate between earth-based stations for any type satellite system. The telephone networks existing in the United States would be completely satisfactory for the projected low data rates. A problem exists, however, when one leaves the confines of the continental United States. The problem is especially acute in

the developing areas of the world where little or no reliable means of communication exist. In these areas the satellite surveying system hardware may be required to include self-contained communication networks such as portable radio-telephones, which would increase both the initial investment and the operating cost.

The detailed solution to administrative problems is outside the scope of this task but none seem to be insurmountable. If these technical problems are considered in the system design, a satellite surveying system seems to be technically feasible and would be accepted by the large majority of photogrammetrists.

The applications by market segment will now be discussed.

1. LAND SURVEYING

There are approximately 60,000 registered surveyors in the United States. Roughly 90 percent of this number are engaged in land surveying defined as Type II in Chapter I. Recalling that their accuracies are of the order of a few centimeters and the methods primarily steel tapes and theodolites, one can conclude that a replacement to fulfill their requirements must likewise be highly productive, over short distances to centimeter accuracy. It seems quite unlikely that a satellite system could reasonably meet the requirements of land surveyors: therefore, it was concluded that a satellite surveying system would have little potential use by 90 percent of the registered land surveyors.

The remaining 10 percent of the land surveyors are primarily engaged in Type I surveying, which is characterized by widely spaced markers, lower accuracy requirements, and lower productivity. These requirements are more compatible with a satellite surveying system than are those of Type II.

The characteristics of the United States and Canada are sufficiently alike to consider them identical in this analysis.

(1) United States and Canada

Early in the interviews it was determined that a satellite system producing geodetic positions to accuracies of worse than 6-inches would find almost no use in the United States or Canada. The requirements for engineering mapping and

cartography are such that worse than 6-inch accuracy simply is not good enough, and the satellite would not be used for almost any survey requirement. Land surveyors working in engineering mapping and cartography would be potential users of a satellite system whose accuracy is better than 3 inches.

The implementation of basic geodetic control networks is the responsibility of the U. S. Coast and Geodetic Survey. The long distances of the surveyed lines would seem to lend themselves to implementation using a satellite system. The reaction from the U. S. Coast and Geodetic Survey was that a satellite system capable of 3-inch accuracy would not be acceptable by almost an order of magnitude. In general, response to a quick system was rather negative concerning use of the satellite for geodetic control. They felt that it would have to be extremely well verified that the system were capable of producing the postulated accuracies with a high degree of confidence, and even if they did the work themselves, they would probably not abandon their long-time traditional methods of geodetic positioning in favor of a quicker technique such as the satellite.

(2) Foreign

For the purposes of this analysis, foreign land surveying can be divided into two logical elements: European and non-European. For all practical purposes land surveying in Europe consists of construction and building layout work. All other requirements are met by the comprehensive control networks existing in Europe. Once again the requirements are not compatible with a satellite capability.

In non-European areas, the situation is reversed. Practically all land surveying is of the Type I category. A satellite can therefore compete successfully with conventional land surveying in practically all non-European geographical areas. Applications would include the implementation of basic geodetic control networks because the accuracy requirements are less stringent than those of the U. S. Coast and Geodetic Survey, and the increased productivity would be very attractive.

2. AERIAL PHOTOGRAMMETRY

The aerial photogrammetry industry is roughly an order of magnitude smaller than the land surveying industry. The requirements

for geodetic positioning in photogrammetry, however, are well matched to the capabilities of a satellite surveying system, especially in the area of accuracies. In general, the photogrammetry industry requires geodetic positions whose accuracies are in the range of 3 to 6 inches. The geodetic positions are used to construct coherent maps from individual photographic plates. The collection of geodetic positions utilized in this manner is called a ground control system. In such a system, the markers are widely spaced; therefore, the satellite surveying system potential customers would appear to be primarily those groups now employing photogrammetric techniques.

(1) United States and Canada

The characters of the U.S. and Canadian photogrammetry industries are very similar except for the extent of competition. The Canadian market is a strongly competitive environment resulting from an oversupply of photogrammetry firms. This in turn lessens some of the pressure on the industry to become more productive and thus somewhat reduces the attractiveness of the surveying satellite system.

The applications of the satellite to the photogrammetry industries in both countries would be almost identical. It would be used to establish horizontal and vertical ground control networks for the positioning of the photographic plates in a coherent map of a large geographic area.

In addition to the geographical and economic similarities of the United States and Canada, the respective domestic photogrammetric industries are joined by common ownership in many cases. Of the twenty firms in Canada, there are three dominant firms, all of which are approximately 50 percent owned by U.S. firms or interests.

(2) Foreign

Foreign photogrammetric industries are found almost exclusively in those countries which formerly had colonial interests in what are now the developing countries. This is apparently caused by the photogrammetric industry requiring highly skilled personnel and the operation of sophisticated equipment. The possibility of large numbers of unskilled people starting an industry with hand labor and gradually adding

equipment and automation as their technical skills grow, a situation prevalent in the developing countries, is thus eliminated.

As in land surveying, this analysis will consider the foreign work in two logical elements: European and non-European. Photogrammetry in Europe is a highly developed industry and in many applications replaces many types of work performed by land surveyors in the United States.

The geodetic control networks existing in Europe are sufficiently comprehensive to be used unsupplemented as control for aerial photogrammetry. It would seem that the satellite surveying system would probably find little use in Europe.

In non-European areas, the situation is once again reversed. Outside the confines of Europe, reliable geodetic control networks are very sparse. In virtually all jobs in photogrammetry in non-European foreign areas, ground control must be implemented commonly at a disproportionate cost when compared to the United States. A satellite surveying system could therefore compete most successfully with conventional techniques in the implementation of geodetic ground control for photogrammetry.

3. MARINE GEODESY

The applications of satellites to marine geodesy have been explored in other studies. It is sufficient to note that satellites can overcome many of the drawbacks of existing land systems, which are limited in range and accuracies. The satellite systems produce geodetic positions based on a single worldwide reference datum--a distinct advantage over the land-based systems.

The degree of governmental participation in marine geodesy is even greater than in land geodesy. The only significant commercial venture requiring marine geodetic positioning other than navigation can be found in the offshore petroleum industry.

In this industry the problem is shared by the governmental agency that grants permission to commercial firms to take oil from beneath its property. Precise positioning is necessary for the firm

to be sure that it drills in an area for which it has obtained rights; in turn, the agency is concerned with collecting revenues from the correct wells.

Positioning is now being provided by electronic navigation systems as well as special-purpose EDM equipment.

IV. MARKET ESTIMATES

The applications of the satellite surveying systems have been identified in the previous chapter. The questions that now remain are who would use such a system and how much would it be worth to them. In this chapter, these questions will be answered. The study results will provide NASA with the necessary management information to determine if a satellite surveying system is economically viable. It will take the form of an estimate of the cost of present surveying that could be replaced by a satellite system for these market segments:

- . U.S. Domestic
- . U.S. Foreign
- . Alaskan
- . Canadian Foreign and Domestic
- . Foreign Government
- . Marine Geodesy.

In Chapter V these estimates of cost replacement will be used to arrive at estimates of income to the satellite system sponsors.

In executing a marketing study, the three most difficult problems are: who should be interviewed, what information should be collected, and when should the study be terminated. A device found to be extremely useful in solving these problems can be described as an information matrix that is primarily directed toward answering what information should be collected. Once informational items have been identified, persons likely to have knowledge in the specific areas can be determined more readily. When the matrix is filled to one's level of confidence, the study can be completed and the results analyzed.

It is a standard practice in a marketing study to break the total market into manageable segments that can be analyzed as entities. This is called stratification of the market and is accomplished by

selecting parameters that divide the total market into specific segments. Accuracy was perceived initially as being the parameter that would cause the most useful stratification in surveying and mapping, as discussed in Chapter II. This parameter therefore appears as the major factor in the division of the information matrix shown in Figure 1. The other parameters useful in further stratifying the market are: applications, who does it, customers, today's equipment, and future equipment. The ultimate objective, of course, is the estimate of the value of each of the market segments. The market segments were defined as U.S. Domestic, U.S. Foreign, Alaskan, Canadian Domestic and Foreign, Foreign Government, and U.S. Government. The U.S. Government segment was not explored because estimates of their potential usage are available to NASA directly from other government agencies.

The means of obtaining data for the information matrix was a series of intensive interviews with those people identified as being knowledgeable in the specific areas of interest. Past experience has shown that interviews with a national association devoted to technical or trade interests are usually an excellent source of information for planning subsequent interviews. In this case, the national association interviewed could not provide the desired information. Therefore, a broad cross section of people, who were both users and producers of surveying services were interviewed.

Once this hurdle was cleared, the matrix rapidly filled enabling the study team to draw quick conclusions that served as a check on the direction of the effort as well as providing early returns for NASA. Succeeding interviews were used to strengthen the tentative conclusions by filling in details and giving more weight to estimates.

A total of 25 intensive personnel interviews were conducted by the Booz, Allen team during the study. In addition, 14 telephone interviews were obtained when information could be secured without extensive team travel or when preliminary information was being verified. When personal interviews were conducted, the structured interview outline shown in Figure 2 was utilized.

1. U.S. DOMESTIC

The judgment of the economic feasibility of a Satellite Surveying System will be based on estimates of the revenues that would accrue to a satellite surveying system. It was found, however, that the

INFORMATION MATRIX

RANGE OF ACCURACY	APPLICATIONS	SUPPLIERS	CUSTOMERS	PRESENT EQUIPMENT	FUTURE EQUIPMENT	VALUE OF MARKET SEGMENT

FIGURE 1

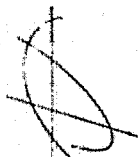


FIGURE 2
Structured Interview Outline

1. (1) What are principal applications of a satellite survey system to your business?

 (2) What other applications would be feasible?
2. Who are the principal customers for these services?
3. Who are the major suppliers?
4. What techniques are currently used for such services?
5. Are the satellite's advantages of: intervisibility, long distances, geodetic positions, important in your business?
6. How specifically would you use the satellite in your business?
7. What are the annual costs of the services that the satellite could replace? How many jobs per year does this represent?
8. What % of the total cost of surveying does this represent?
9. Is it reasonable to assume, if the satellite were proven to meet the accuracy statements we have presented, that your firm would be willing to pay _____ for this service?
10. Can you estimate the annual industry volume in these services?
11. Who else should be talk to? Can we use your name?
12. How many people are employed by your firm?

interviewees were better able to estimate what portion of their operations could be replaced by a satellite system than to estimate income to the system. Therefore, they estimated the annual costs of the services that the satellite system could replace (used in the next chapter to estimate satellite income).

These estimates are based on the compilation of data resulting from three specific questions asked in the course of each interview:

- . What are the annual costs of the services that the satellite could replace?
- . What percentage of the total cost of surveying does this represent? or, what are your firm's total annual sales?
- . What is your estimate of the annual volume of services performed in the United States?

The majority of those interviewed felt that they could divulge their firm's sales data if it was agreed to treat the information as proprietary. Thus, only aggregate totals for industry segments are reported, completely removing any link to specific firms except when the firms were estimating gross industry estimates such as total market sizes. In those few instances where it was not possible to obtain the necessary data from the firms directly, averages, ratios, and other estimating techniques have been used to derive substitute data.

The aggregate total for the estimate of the services that a satellite system could replace were generated by adding the estimated cost of potentially replaced services obtained from the individual firms.

The aggregate total cost of services that could be replaced in the firms interviewed was approximately \$1 million annually.

The next step was to generate the total aggregate sales for the group of firms interviewed. The resulting total was approximately \$24 million annually. The ratio of total cost of services replaced to total annual sales was the means used to estimate the sales potential of a satellite system for the United States (see Figure 3). The only number necessary for that estimate is the total sales for all U.S. Photogrammetric firms.

METHOD OF ESTIMATING SATELLITE POTENTIAL

COMPANY	COSTS REPLACEABLE BY SATELLITE	COMPANY'S ANNUAL SALES	ESTIMATED NATIONAL PHOTOGRAMMETRIC MARKET
A	C _A	S _A	M _A
B	C _B	S _B	M _B
C	C _C	S _C	M _C
⋮	⋮	⋮	⋮
Z	C _Z	S _Z	M _Z
	<u>TOTAL COSTS</u>	<u>TOTAL SALES</u>	<u>AVERAGE TOTAL MARKET ESTIMATE</u>

$$\frac{\text{SATELLITE POTENTIAL}}{\text{AVERAGE TOTAL MARKET}} = \frac{\text{TOTAL COSTS}}{\text{TOTAL SALES}}$$

$$\frac{\text{SATELLITE POTENTIAL}}{\$50 \text{ MILLION}} = \frac{\$1 \text{ MILLION}}{\$24 \text{ MILLION}}$$

SATELLITE POTENTIAL IS \$2 MILLION ANNUALLY

FIGURE 3

The third question was an attempt to gather estimates of the total annual sales volume in the United States. In most cases the interviewee was able to arrive at an estimate of the total sales. Interestingly, each used a different method of estimating: for example, miles of highway constructed, construction industry sales, numbers of people employed, and so forth. The results, however, were fairly consistent in producing an estimate in the range of \$40 and \$50 million annually (see Table 1). Occasionally an interviewee would either decline to make an estimate or quote the Legislative Council for Photogrammetry's recently published estimate of \$88 million.

The marketing study team of Booz, Allen made a very careful examination of the data supplied by the Legislative Council for Photogrammetry (LCP) and has concluded that the estimate LCP used included all the related services, especially of the larger companies. For their purposes, it was a good estimate of the total sales of the photogrammetric industry in the United States. For the purposes at hand, however, those services that would not be potential users of the satellite system are excluded. Thus, it is felt that the market size the interviewees estimated was only the part of the market that would be potential users of the satellite system. Comparison of published sales totals on an annual basis with data supplied during the interviews showed that all of the large multi-service companies had reduced their total sales figure to include only the sales that would accrue from potential users of the satellite surveying system. Therefore, in reconciling the \$88 million market reported by the LCP for the total photogrammetric industry and the \$40 and \$50 million market as potential satellite surveyor users, the explanation is that Booz, Allen was estimating a much narrower and possibly better defined market than the LCP industry survey.

Therefore, an estimated of \$50 million annually has been chosen as representative of the total potential satellite using market. Since the total aggregate sales of the companies interviewed were \$24 million annually, the potential satellite usage estimate was obtained from roughly half the market. The potential annual usage estimate was \$1 million from firms having aggregate sales of \$24 million. By applying the same usage-to-sales ratio, it was concluded that for an annual sales volume of \$50 million, a satellite system could be expected to annually replace \$2 million of conventional surveying performed domestically by U.S. firms.

Table 1

POTENTIAL SATELLITE MARKETS

	TOTAL MARKET	COSTS REPLACEABLE BY SATELLITE	CUMULATIVE TOTAL MARKET	CUMULATIVE COSTS REPLACEABLE BY SATELLITE
U.S. FIRMS: DOMESTIC	\$50M	\$2M	\$50M	\$2M
U.S. FIRMS: FOREIGN	\$10M	\$5M	\$60M	\$7M
CANADIAN FIRMS: DOMESTIC & FOREIGN	\$17M	\$3M	\$77M	\$10M

It should be emphasized that \$2 million represents the value of services that could be replaced by a satellite system. This estimate must be reduced by remaining costs such as field crew travel, subsistence, and instruments to arrive at an estimate of revenue to the satellite system. While this is a considerable amount of sales, it is felt that it falls far short of the costs necessary to successfully launch and operate a satellite surveying system in the United States.

2. U.S. FOREIGN

In view of the rather small amount of potential for a satellite surveying system operated only in the United States the survey was expanded to include foreign sales by U.S. firms. Local foreign firms are highly competitive with U.S. firms in foreign markets and would be strengthened by access to a satellite surveying system. United States firms win most very large jobs because their automated techniques can be economically applied to offset higher costs of wages and equipment. U.S. firms are not competitive on small- and medium-sized jobs because of higher costs and an inability to apply automated techniques. U.S. firms feel that permitting local foreign firms access to a satellite surveying system would remove any competitive edge the U.S. firms possess and would effectively destroy all the surveying business in foreign countries performed by U.S. firms.

The approach to this estimate was similar to the U.S. domestic estimate with one important exception. The costs replaceable by a satellite system in foreign areas were estimated by averaging the interviewee estimates rather than totaling individual company cost replacement estimates. The consistency of the interviewee estimates gives us confidence in the result, but it is felt that the method produces an inherently softer estimate.

It was determined that the addition of foreign sales by U.S. firms adds \$10 million to the total market estimate and a tremendous \$5 million to the costs replaceable by a satellite system. This large potential usage in foreign areas is a result of the combination of the types of jobs performed in foreign areas and their associated high costs. It can be noted that in the estimate of total market for foreign areas, the interviewees included roughly half the total industry sales. Since this action parallels precisely what was done in the domestic areas, it is felt that they included only the sales that would reflect potential users of the satellite surveying system.

3. ALASKA

The Alaskan market for photogrammetry is dominated by U. S. Governmental agencies except for a few large private developments. The USC&GS, USGS, Bureau of Land Management, Corps of Engineers, and Army Map Service are among the principal agencies performing geodetic control, photogrammetry, and cartographic work in Alaska.

Two examples of jobs in the private sector performed by U. S. commercial firms are the route survey for the 48-inch Trans-Alaska pipeline by Geotronics, and a route survey for a series of communication towers by Aero Service.

The annual sales volume of the services performed by U. S. firms in Alaska is small; since we have excluded work performed by governmental agencies the amount of photo control that can be replaced by a satellite surveying system is likewise very small. Estimates of both these quantities have been included in U. S. market and satellite usage estimates. Employees utilized by U. S. domestic firms to service Alaskan jobs are normally drawn from the firm's U. S. pool of employees.

All non-U. S. commercial firms are effectively excluded from Alaskan work, which is consistent with U. S. firms being excluded from Canadian markets.

4. CANADIAN FOREIGN AND DOMESTIC

The character of the Canadian domestic market is very similar to the character of the U. S. domestic market except that the competition is stronger because of an oversupply of photogrammetry firms. In the foreign markets, the Canadian firms compete directly with U. S. firms and are afforded a slight advantage because of their generally recognized neutral position in world politics.

The determination and implementation of geodetic networks domestically is performed by the national governmental agencies particularly in the Department of Energy, Mines and Resources. The large bulk of work by commercial firms is for control, photogrammetry, and mapping for specific engineering projects and is obtained through the competitive bid procedure. The Canadian firms do no work in Alaska and almost none within the United States.

The Canadian Association of Aerial Surveyors is a trade group composed of all significant Canadian firms. They play a strong role in allocating contracts for photogrammetric services, thus affecting the daily operations more deeply than any U.S. technical society or lobby organization could affect U.S. firms.

The Association was the initial source of estimates for this market segment. The estimates have been further supported in interviews with university researchers and international government personnel.

The total domestic sales for Canadian firms is \$10 million per year and represents the approximate total Canadian market for commercial firms, since the extent of competition effectively excludes all non-Canadian firms. The \$10 million per year represents the market for photogrammetry since the Canadian firms in general are more specialized than their U.S. counterparts and thus do not offer the broader base of related services. Roughly 30 percent of the total for domestic photogrammetry, that is, about \$3 million, is expended for photo control. Of that amount, about \$750,000 per year could be replaced by a satellite surveying system.

The total foreign sales for Canadian firms is \$7 million per year including approximately \$1 million provided by the Canadian Agency for International Development. Approximately 40 percent of the total for foreign sales, that is, about \$2.8 million, is expended for photo control. Of that amount, about \$2.25 million could be replaced by a satellite surveying system.

The total cost, both foreign and domestic, of surveying work that could be replaced by a satellite surveying system is estimated to be \$3 million annually.

5. FOREIGN GOVERNMENT

The surveying and mapping branches of most foreign governments would reap greater benefits than foreign commercial firms because the government agencies need more geodetic position data and have less funds and less skilled personnel to accomplish their tasks.

The foreign governments must generally fund their geodetic positioning activities without assistance. The international development agencies have little interest in the establishment of national

geodetic control networks in the developing nations. Two notable exceptions are the United Nations Development Fund, which strongly encourages and occasionally assists with limited aid to the developing nation, and the Pan American Institute on Geography and History, which is involved to a lesser degree. The United Nations takes an active part in the training of citizens of the developing nations in the technical skills of mapping and surveying through educational and personnel exchange programs.

The international development agencies assist the developing nations in the implementation of specific engineering projects covering only a very small portion of a total national area. The project control network is one of the first steps in the planning of an engineering project and is implemented before specific plans can be produced. The project area is provided with a local engineering control network that is not extended to cover more than the necessary area. It is normally installed by a commercial surveying/engineering firm rather than a governmental agency.

The international development agencies consider only specific plans for engineering projects and therefore have never been concerned with funding the control network activities. The agencies feel that there will be no changes in this policy in the near future.

Data to support estimates of governmental expenditures for photogrammetry on a worldwide basis are limited. The only identified source of data is a continuing research project conducted by Dr. A. J. Brandenberger, Université Laval, Quebec, Canada, and supported by the National Research Council of Canada. The research project has produced data based on questionnaires sent to about 150 countries and supplemented by informal and third-part contacts maintained by Dr. Brandenberger. There are other sources of photogrammetric inventory data such as the Army Map Service, Aeronautical Chart Information Center (ACIC), and the United Nations Department of Economic and Social Affairs, but the inventories do not contain economic data and in most instances are not available for general usage.

Coverage of the data is not truly worldwide as a result of a lack of response from many countries. Dr. Brandenberger and others feel that many countries declined to answer the detailed questionnaire because the answers would reveal intelligence-like data.

Retrieval of information from the data is a difficult process, and often information is additionally adjusted to reflect current professional opinion. The low volume and constant turnover of fresh data coupled with the varied response formats and research nature of the projects dictate a manual data system. The methods of retrieval is to use graduate students to comb the questionnaire responses for all relevant data to form a base from which to extrapolate to the total population by both mathematical and judgmental methods.

Within these qualifications, the following estimates made by Dr. Brandenberger can be considered as order of magnitude estimates for a satellite surveying system. Detailed discussions of these estimates can be found in papers written by Dr. Brandenberger.* For 1968, the total worldwide expenditure for mapping and surveying was \$1.5 billion. Approximately 20 percent of the total is expended for the establishment of geodetic control amounting to \$300 million. About half of the total expended for geodetic control could be replaced by a satellite system capable of second-order accuracy. This represents about \$150 million annually or about 10 percent of the total expended for all mapping and surveying.

The \$150 million estimate must be further refined by the following considerations. Roughly \$700 million was expended in the United States and must be removed since the U. S. Federal Government has been excluded from the study (See Chapter I.5, Market Limits) and the private sector has been estimated independently.

The Soviet Union spends about \$280 million and mainland China about \$150 million per year, therefore, \$430 million will be removed since it is felt that it would be very unlikely that either of these governments would purchase services from an "American" satellite surveying system.

* "A Survey on Surveying and Mapping on a World Wide Basis," American Society of Photogrammetry, Washington, D. C., March 1969.

"Economic Impact of World Wide Mapping," Photogrammetric Engineering, April 1969.

By removing these portions of the world market, the total for mapping and surveying is reduced to \$370 million. If Dr. Brandenberger's estimate that 10 percent of the \$370 million expended for mapping and surveying represents those types of geodetic control that could be replaced by a satellite surveying system, then the total potential market estimate for the satellite system is \$37 million annually.

6. MARINE GEODESY

The degree of governmental participation in marine geodesy is much greater than on land because the state of development is such that commercial firms, except for some of the petroleum industries, have not invested in marine facilities.

The U. S. Marine Sciences Commission has recommended an average expenditure of \$40 million annually for the next ten years for all phases of marine charting, mapping, and surveying for U. S. Federal nondefense programs. It is felt that governmental participation will continue to be much larger than participation by commercial firms. Thus, the amount of revenue that would accrue to an operational satellite system from use by commercial firms in marine geodesy would appear to be negligible.

Since the U. S. Federal Government has been excluded from this study (see Chapter I.5, Market Limits), it was concluded that revenue from the marine geodesy market segment would be negligible.

V. INCOME TO A SATELLITE SYSTEM

The market estimates developed in the previous chapter included estimates both of the total industry sales and of the costs of services that could be replaced by a satellite system. It should be emphasized again that the costs replaceable by a satellite system cannot be equated to income to a satellite system. To arrive at estimates of income to a satellite system, it is necessary to estimate the productivity increase and the attendant decrease in costs that would accompany the utilization of such a system.

1. PRODUCTIVITY INCREASES

The attractiveness of a satellite surveying system stems entirely from reducing the amount of labor to accomplish a specific job. During the last 5 or 6 years, the industry has witnessed a significant productivity increase through the use of EDM equipment. The equipment introduced has been able to maintain or increase accuracy and perform work faster especially over long distances. The increased cost of the instrumentation is more than offset by savings in field crew labor.

The very same criterion by which EDM equipment was measured will be used by the surveying industry to evaluate a satellite surveying system. The potential users of a satellite system are for the most part commercial ventures operating on the profit motive. If a satellite system does not increase their individual profits, it simply will not be used. Prestige, glamour, style, and sophistication are important factors in marketing studies of consumer products and services but would play an insignificant part in the marketing of a satellite system. A cost effective increase in productivity will be the most important factor in a potential user's decision to purchase a satellite system service.

The most significant element of cost that would be reduced by using a satellite system would be Direct Labor. In addition, the funds necessary to sustain a field crew member would be reduced because for a given job, he would spend less time in the field.

In the types of surveying where the application of a satellite surveying system appears feasible, estimates of productivity increases (made during the interviews with commercial firms) measured in the reduction of Direct Labor hours has ranged from 30 to 70 percent in the United States. The average estimate was approximately 50 percent; therefore, it will be used in estimating income to the satellite system for the U. S. domestic market. The range for foreign work by U. S. firms was 10 to 50 percent and an average of 33 percent will be used for the U. S. foreign market.

2. INCOME BY MARKET SEGMENT

The method used to estimate income to a potential satellite system was to prepare an accounting Comparative Balance Sheet showing the cost elements for a hypothetical "standard" 1 man year job performed conventionally and to compare it with the same job performed using the Satellite Surveying System. The numeric values for the cost elements shown in the Comparative Balance Sheet have been supported in conversations with industry spokesmen.

In the comparisons it was assumed that if the total cost for a satellite-system-performed job were less than or equal to a conventional job, it would be used in preference to the conventional technique. The comparison between the standard and satellite methods therefore enabled the analyst to determine the amount the surveyor would be willing to pay to the Satellite System to perform the same job at the same total cost. From this analysis, a numeric factor was derived that when multiplied by the cost to the customer of services replaced will yield the estimated income to a satellite system.

Comparative Balance Sheets have been prepared for a standard job by a U. S. firm in both domestic and foreign environments (see Figures 4 and 5). Since the satellite system will permit faster completion of a job, it is conceivable that a customer will pay a premium for the faster service. Since the portion of labor saved is only a part of the total job, the premium has been limited to 10 percent of the costs of services replaced.

Personnel and related costs in Canada are lower because of both the smaller sized companies and the extreme competitiveness of the market. The Canadian industry average annual sales per man year are slightly more than \$14,000 while in the United States they

FIGURE 4
U. S. and Canadian Domestic Comparative
Balance Sheet and Income Ratios

<u>Costs</u>	<u>Standard</u>	<u>Satellite</u>	<u>10% Premium Satellite</u>
Direct Labor	\$ 9,000	\$ 4,500	\$ 4,500
Travel	1,800	1,800	1,800
Subsistence	1,800	900	900
Subtotal	<u>\$12,600</u>	<u>\$ 7,200</u>	<u>\$ 7,200</u>
Overhead-Including Equipment 65%	8,200	4,700	4,700
Subtotal	<u>\$20,800</u>	<u>\$11,900</u>	<u>\$11,900</u>
Satellite System Usage Cost	-	8,900	10,980
Subtotal	<u>\$20,800</u>	<u>\$20,800</u>	<u>\$22,880</u>
Profit - 10%	2,080	2,080	2,288
Total Cost to Customer	<u>\$22,880</u>	<u>\$22,880</u>	<u>\$25,168</u>

INCOME RATIOS

Standard/Satellite Ratio = \$ 8,900/20,800 = 0.43

Standard/10% Premium Satellite Ratio = \$10,980/22,880 = 0.48

FIGURE 5
U. S. and Canadian Foreign
Comparative Balance Sheet
and Income Ratios

<u>Costs</u>	<u>Standard</u>	<u>Satellite</u>	<u>10% Premium Satellite</u>
Direct Labor	\$ 9,000	\$ 2,700	\$ 2,700
Travel	3,600	3,600	3,600
Subsistence	<u>3,600</u>	<u>1,200</u>	<u>1,200</u>
Subtotal	\$16,200	\$ 7,500	\$ 7,500
Overhead Including Equipment 65%	<u>10,530</u>	<u>4,875</u>	<u>4,875</u>
Subtotal	\$26,730	\$12,375	\$12,375
Satellite System Usage Cost	<u>-</u>	<u>14,355</u>	<u>17,028</u>
Subtotal	\$26,730	\$26,730	\$29,403
Profit - 10%	<u>2,673</u>	<u>2,673</u>	<u>2,940</u>
Total Cost to Customer	\$29,403	\$29,403	\$32,343

INCOME RATIOS

Standard/Satellite Ratio = $\$14,355 / \$26,730 = 0.54$
Standard/10% Premium Satellite Ratio = $\$17,028 / \$29,403 = 0.58$

are about \$16,500. The field crew labor represents only a portion of the total used for the average, but this portion is more expensive. It approaches \$23,000 in the United States and is proportionally lower in Canada. Since all Canadian costs are felt to be proportionally lower than in the United States the same ratios will be used for both the U. S. and Canadian market segments.

The conditions existing when foreign governments use the satellite surveying system preclude a straightforward analysis. Labor costs vary widely throughout the world and are further confused by political and economic factors. Most developing countries stress in-service training of their citizens in technical skills to reduce dependence on foreign citizens. It is felt that some countries would continue to use traditional methods of geodetic positioning rather than use the satellite system to maintain training levels in these skills. A side benefit of such a policy is the lessening of balance of payments problem for the developing country. Data do not exist to estimate the impact of these factors. It is felt that they are significant, but estimates of their impact vary widely. Therefore, income from foreign government usage will be reported as a range rather than a point estimate.

Jobs performed by the U. S. and Canadian domestic market segments will be used as the baseline for estimating income from foreign governments. In these market segments, it is felt that all jobs that are economically feasible to perform by a satellite system will be so performed. Therefore, the ratios developed for these market segments represent the maximum satellite utilization, and therefore, maximum satellite income. It is estimated that foreign governments will choose to utilize conventional techniques in preference to satellite techniques in 25 to 75 percent of the jobs. The ratios to determine the range of income from foreign governments will therefore be determined by computing 25 and 75 percent of the standard ratio for the U. S. and Canadian domestic market segments. The ratios are as follows:

Baseline

- The U. S. and Canadian Domestic Standard/Satellite Ratio is 0.43

. Low Range Estimate

- If the foreign governments utilize the satellite on 25 percent of all possible jobs then:

Low Range Estimate (0.25×0.43) is 0.11

. High Range Estimate

- If the foreign governments utilize the satellite on 75 percent of all possible jobs then:

High Range Estimate (0.75×0.43) is 0.32.

Since the ratios and the market estimates have been established, the income to a satellite system can be estimated.

The total costs replaceable by a satellite in the U. S. domestic market were \$2 million/year and those in the Canadian domestic were \$.75 million/year for a total of \$2.75 million/year. The standard cost productivity ratio is 0.43, and the premium cost is 0.48. Therefore, the total U. S. and Canadian domestic market income to a satellite system for standard cost is \$1.18 million/year, for premium cost, \$1.32 million/year.

The total costs replaceable by a satellite in the U. S. foreign market were \$5 million/year, and Canadian foreign were \$2.25 million/year for a total of \$7.25 million/year. The standard cost productivity ratio is 0.54, and the premium cost is 0.58. Therefore, the total U. S. and Canadian foreign market income to a satellite system for standard cost is \$3.92 million/year, for premium cost, \$4.21 million/year.

The total costs replaceable by a satellite in foreign government markets were \$37 million/year. The low productivity estimate was 0.11 and the high 0.32, with a resulting estimated income ranging from \$4.07 million/year to \$11.83 million/year.

These estimates are summarized in Table 2. If all the low estimates are added, the total is \$9.17 million/year. If all the high estimates are added, the total is \$17.36 million/year. A satellite system covering all these markets could expect income of between \$9.2 and \$17.4 million annually, with an average of \$13.3 million.

Table 2
Summary of Annual Income Estimates
in Millions of Dollars

U. S. & Canadian Domestic - Standard	\$ 1.18	
U. S. & Canadian Domestic - Premium		\$ 1.32
U. S. & Canadian Foreign - Standard	\$ 3.92	
U. S. & Canadian Foreign - Premium		\$ 4.21
Foreign Governments - Low Estimate	\$ 4.07	
Foreign Governments - High Estimate		\$11.83
Low Total	<u>\$ 9.17</u>	
High Total		<u>\$17.36</u>

VI. CONCLUSIONS

A satellite surveying system represents a sophisticated solution to some of the needs for increased productivity in geodetic positioning. The primary application of a satellite system would be to establish ground control for photogrammetry.

Based on the analysis conducted during this study, a satellite surveying system that is limited to use only in the United States and Canada for domestic commercial firms would have a total market of from \$1.2 to \$1.3 million of gross revenue annually. This range compares to the total domestic market for photogrammetry of \$40 to \$50 million.

If the operations were to include foreign geographical areas but sales were limited to U. S. and Canadian firms, an additional \$5.1 to \$5.5 million of gross revenue could be realized annually. The total foreign market for photogrammetry is \$17 million.

Through the use of less rigorous means, an estimate of sales to foreign governments has been made as well. Its range is \$4.1 to \$11.8 million annually for the satellite system. The total foreign government market, excluding the U. S. S. R. and mainland China, is \$370 million for mapping and surveying.

Since the purpose of this study was to determine the economic viability of a satellite surveying system, several conclusions can be drawn from the market estimates.

- . The operation of a satellite surveying system for use by U. S. and Canadian commercial firms in their domestic markets is clearly not economically viable.
- . If the system is expanded to include foreign areas served by U. S. and Canadian commercial firms, the potential income is greatly increased but with an accompanying increase in operating problems so that the economical viability is still doubtful.
- . If foreign governments are permitted access to the system, its economic viability is enhanced but the system is still not clearly viable.

APPENDIX A

LIST OF INTERVIEWS

1. John Allen & Ray Koenig, Allen & Koenig Assoc., Bethesda, Md.
2. Earle Fennell, ACS&M, Washington, D. C.
3. Bro. B. Austin Barry, Manhattan College, New York City
4. Victor Ghent, Cross & Ghent, Alexandria, Va.
5. Carl Rantzow, Svedrup & Parcel, Washington, D. C.
6. E. Addi, Addi & Assoc., Vienna, Va.
7. Jeff Lawrence, Photo Sciences Inc., Gaithersburg, Md.
8. Ray Maddox, Maddox & Assoc., Bethesda, Md.
9. Rich Heller, Alster & Assoc., Washington, D. C.
10. Capt. Louis Strecher, OSD, DDRE, Pentagon, Washington, D. C.
11. Lansing Simmons, Geonautics Inc., Falls Church, Va.
12. Capt. L. Swanson, USC & GS, Rockville, Md.
13. Red Dupuy, Aero Services, Philadelphia, Pa.
14. Al Quinn, A. A. Quinn Assoc., Wyncote, Pa.
15. Jack Mitchell, Lockwood, Kessler & Bartlett, Syosset, N. Y.
16. John Urban, Edwards & Kelcey Inc., Newark, N. J.
17. Ralph Kauffman, Abrams Aerial Sur., E. Lansing, Mich.
18. Don Mohr, Chicago Aerial Sur., Chicago, Ill.

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19. W. Sidney, Park Aerial Sur., Louisville, Ky.
20. Charles Logan, Ohio PE & RLS Board, Columbus, Ohio
21. Wm. Baker, Michael Baker Inc., Beaver, Pa.
22. Joe Burns, Mark Hurd Aer. Sur., Minneapolis, Minn.
23. Ed Sokolowski, Int'l Aerial Mapping, San Antonio, Texas
24. C. J. Montgomery, Getty Oil Co., Houston, Texas
25. Merle Barber, Geotronics, Long Beach, Calif.
26. Stacy Struble, Olympus Aerial Survey, Salt Lake City, Utah
27. Bruce J. Wooden, Booz, Allen Applied Research Inc.,
Washington, D. C.
28. Bruce Vogelsinger, Legislative Council Photogrammetry,
Washington, D. C.
29. Bruce Vogelsinger, Legislative Council Photogrammetry,
Washington, D. C.
30. Red Dupuy, Aero Service, Philadelphia, Pa.
31. W. Harry Godfrey, Lockwood Survey Corp., Toronto, Canada
32. D. McLarty, Canadian Assoc. of Aerial Surveyors, Ottawa,
Canada
33. A. J. Brandenberger, L'Universite Laval, Quebec, Canada
34. Erik O. Dahle, United Nations, New York, N. Y.
35. Mr. Kollman, AID, Washington, D. C.
36. W. Drewes, Pan Am Development Fund, Washington, D. C.
37. F. Doleman, World Bank, Washington, D. C.

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- 38. Col. Colvocoresses, U.S. Geological Survey, McLean, Va.
- 39. Mario Picaggli, World Bank, Washington, D. C.

APPENDIX B

Annual Meeting of the Legislative Council for Photogrammetry
Denver, Colorado, August 21, 1969

COMMERCIAL MARKET FOR GEODETIC POSITIONING BY SATELLITE

The science of using satellites to determine geodetic positions has been practiced since the early days of orbiting satellites. The Office of Space Science and Applications of NASA has selected geodetic positioning as one of the more mature space technologies that could immediately be utilized by a segment of the general public, specifically the commercial mapping and surveying industry. The questions that must be answered before the application can be realized are: who would use it?, and how much would it be worth? NASA chose my firm, Booz, Allen Applied Research, to provide the answers to these questions. As a member of the Booz, Allen Hamilton group, the world's largest management consulting firm, we have been providing the necessary blend of the technical and economic skills for the solution of such problems for many years.

The results of our study will provide NASA with the necessary management information to determine if a satellite surveying system is economically viable. The form of the management information we will supply to NASA is an estimate of the costs of present surveying that could be replaced by a satellite system for various market segments.

The conclusion of our study is that while satellites have many practical, commercial applications, they clearly are not a threat to replace all current or projected conventional techniques of geodetic positioning. That is, we have found many specific areas where the satellite surveying system could successfully compete with conventional techniques, but it could not compete in all applications.

I will describe first the ground rules for our study and then discuss our approach to the problem. Initially the scope of our study was limited to considering the domestic market served by U.S. firms. That is, all foreign commercial firms and governmental agencies as well as U.S. governmental agencies were to be excluded as users. Upon completing the initial phase of the study we concluded that the market was too small to support a satellite system. We were then

directed to include all foreign and domestic activities of U.S. and Canadian commercial firms. By including only commercial firms, the problem was reduced to a fairly normal marketing study in which we were to determine who would pay how much for such a service.

This approach represents a departure from the normal cost benefit analysis technique used by many government agencies to decide whether or not a project should be undertaken. "Benefits" are often estimated without a determination of who will collect them, and without determining whether the so-called "benefits" can be marketed. In many cases, there is not even an economic mechanism by which the benefit will produce a net change in dollars in someone's pocket. By doing a marketing study, which literally means determining what can be sold to whom at what price, we avoided the problems associated with benefit studies.

The scope of our study specifically excluded an analysis of the technical feasibility of a satellite surveying system. The results of preliminary technical analyses performed by NASA and other independent groups were encouraging enough for NASA to undertake this economic analysis. If this rather comprehensive economic analysis were to indicate economic feasibility then a comprehensive technical feasibility study would be undertaken. As a result, we did not assess the accuracies and features of a specific hardware system against conventional systems. Rather, we worked with only a conceptual satellite system and determined what characteristics the system must possess to be commercially competitive. This is a realistic approach since a satellite system can be designed to be very accurate, if the cost can be economically justified. The early phase of our effort included work in achieving firmer definitions of the accuracies required, desirable methods of operation, and operating time constraints that would be necessary for a competitive system.

The accuracies required will be discussed later. The operational characteristics of a competitive satellite system, as seen from a surveyors point of view, could be described as follows:

Portable instruments would be placed at the site or sites normally occupied by a field party to collect data from the satellites. The instruments would collect and record data, unattended, for a maximum of two hours. At some later time the data collected would be sent to a computer facility for computation of latitude, longitude, and altitude. The method of communication would most logically be

the telephone system in the U.S. The portable instruments used by the surveyor would have a size and weight similar to modern Electronic Distance Measuring equipment and would lease or sell for about the same price.

In executing a marketing study, the three most difficult problems are: who should be interviewed, what information should be collected, when should the study be terminated. A device we have found to be extremely useful in solving these problems can be described as an information matrix which is primarily directed toward answering what information should be collected. In addition, however, since informational items have been identified, persons likely to have knowledge in the specific areas can be more readily determined. When the matrix is filled to one's level of confidence, the study can be completed and the results analyzed. It is a standard practice in a marketing study to break the total market into manageable segments which can be analyzed as entities. This is called stratification of the market and is accomplished by selecting parameters which divide the total market into specific segments. We perceived that the parameter which would cause the most useful stratification in surveying and mapping was accuracy. This parameter therefore appears as the major factor in the division of the information matrix. The other parameters useful in further stratifying the market are: applications, who does it, customers, today's equipment, and future equipment. The ultimate objective of course being the estimate of the value of each of the market segments.

One means of obtaining data for the information matrix is a series of intensive interviews with those people identified as being knowledgeable in the specific areas of interest. Our past experience has shown that interviews with a national association devoted to technical or trade interests is usually an excellent source of information for planning subsequent interviews. An interview with an executive of the ACS&M, a leading association, however, did not produce the desired results. We therefore conducted a variety of selected interviews, i. e., "shot-in-the-dark" interviews, before we were able to collect usable data and expand our potential interview list. As a side note, we feel the existence of an association in the United States whose functions are as encompassing as those of the Canadian Association of Aerial Surveyors would be very useful to its members, and would incidently have made our initial task much easier.

Once this hurdle was cleared the matrix rapidly filled enabling the study team to draw quick conclusions which served as a check on the direction of our effort as well as providing early returns for our client. Succeeding interviews were used to strengthen our tentative conclusions by filling in details and giving more weight to estimates.

Our findings can be grouped into three major areas: applications, problems, and market estimates, and I will present them in that order. Soon after starting to fill in the information matrix we discovered that accuracy was not the only controlling factor in surveying. Another factor we found to be at least as important is a characteristic we have called marker spacing which is a measure of the distance between stations normally occupied by a surveying field party, and is some measure of the productivity required by the measurement technique used.

We have defined the Type I category as including those types of surveying which do not require closely spaced markers. We have included:

- Large property and boundary surveys
- Engineering design especially route surveys
- Large quantity and measurement surveys, e. g., strip mining, highway construction
- "As-built" facility locations
- Control surveys for cartography
- Control surveys for mapping especially engineering
- Geodetic control surveys

in this category.

We have called those types of surveying requiring closely spaced markers Type II and have included:

- Small property and subdivision surveys
- Construction layout including building site
- Engineering control networks

in this category.

The marker spacing parameter is highly correlated with the measurement technique. With the exception of geodetic control most Type I surveying is accomplished by photogrammetric techniques while the methods generally used in Type II surveying are limited to traditional chains and transits occasionally supplemented by Electronic Distance Measuring equipment operated for the most part by the Registered Land Surveyor.

The marker spacing parameter is also highly correlated with required accuracy. In general, Type II surveying required accuracies of at least a few centimeters, while the accuracy generally required for Type I surveying ranges from 3 to 6 inches in both the horizontal and vertical, except for geodetic control surveys. Methods employed in first order geodetic control are designed to achieve accuracies on the order of a few centimeters.

Almost no surveying presently performed in the U.S. is done to accuracies of worse than 6 inches. We have determined during the interviews that a satellite system producing geodetic positions to accuracies of worse than 6 inches would find almost no use in the U.S. Requirements for accuracy in surveying in the order of 3 to 6 inches is almost synonymous with speaking of photogrammetric techniques especially when the monuments are not closely spaced. Therefore, the satellite surveying system potential customers would appear to be primarily those firms now employing photogrammetric techniques.

Looking at these three parameters: marker spacing, accuracy, and measurement technique, a matrix can be constructed as follows:

	Type I	Type II
Marker Spacing	Not close	Close
Accuracy	3 to 6 inches	Few centimeters
Measurement	Photogrammetric	Chain and transit

An examination of this matrix reveals that the characteristics of a satellite surveying system would be much more closely matched with the Type I category than the Type II. As a result of the measurement techniques, we find we are interested in applications in the photogrammetry business almost to the exclusion of the land surveying business.

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The potential uses for a satellite surveying system by the commercial firms therefore is reduced to the determination of geodetic positions for use as ground control for photogrammetry.

As with all relatively sophisticated systems, problems exist which could seriously hamper the successful operation by the potential user. The problem areas should be explored so that we recognize that they do exist and should temper our enthusiasm.

In exploring these problems, the one most often discussed in the course of our interviews concerned accuracy. More specifically the problem is one of verification of the accuracy on a routine basis by the normal operator. Unless the photogrammetrists have confidence that the satellite system does indeed produce geodetic positions to the accuracies specified, it simply will not be used to the extent we have estimated. Various verification schemes have been proposed in the course of the interviews and one or more of them will have to be included in design of the system.

Two other problems in the operational aspects of a system should also be considered. They are the productivity of a satellite system and interstation communication networks. Almost no system which meets the requirements of low cost, portability, and ease of operation can approach the productivity of generally used surveying instruments, and therefore will not compete in all surveying applications. The use of a satellite system will have to be carefully planned so that it compliments rather than competes with the conventional instruments.

It will be necessary to communicate between the earth based stations for any type satellite system. The telephone networks existing in the U. S. would be completely satisfactory for the projected low data rates. A problem exists however when one leaves the confines of the continental U. S. The problem is especially acute in the developing areas of the world where little or no reliable means of communications exist. In these areas the satellite surveying system hardware may be required to include self-contained communication networks such as portable radio-telephones, which would increase both the initial investment and operating costs.

The detailed solution to administrative problems is outside the scope of this task but none seem to be insurmountable. If the technical problems mentioned above are considered in the system design, a satellite surveying system seems to be technically feasible and would be accepted by the large majority of photogrammetrists. We will consider the economic feasibility next.

The judgment of the economic feasibility of this venture was initially based on our estimates of the revenues that would accrue to a satellite surveying system from domestic sales to U. S. firms. Our estimates are based on the compilation of data resulting from three specific questions asked in the course of each interview. The questions were:

- What are the annual costs of the services that the satellite could replace?
- What percentage of the total cost of surveying does this represent? or, what are your firm's total annual sales?
- What is your estimate of the annual volume of services performed in the U. S. ?

The majority of those interviewed felt that they could divulge their firm's sales data if we would agree to treat the information as proprietary. We have made a strong effort to do so by reporting only aggregate totals for industry segments thus completely removing any link to specific firms except when the firms were estimating gross industry estimates such as total market sizes. In those few instances where we were unable to obtain the necessary data from the firms directly, we have used averages, ratios, and other estimating techniques to obtain substitute data.

The aggregate total for the estimate of the services that a satellite system could replace were generated by simply adding the estimated cost of potentially replaced services obtained from the individual firms. The total cost of services that could be replaced in the firms interviewed was approximately \$1 million annually.

The next step was to generate the total aggregate sales for the group of firms interviewed. The result was approximately \$24 million annually. The ratio of total cost of services replaced to total annual sales was the means by which we planned to estimate the sales potential of a satellite system for the U. S. The only number necessary for that estimate is the total sales for all U. S. photogram-metric firms.

The third question was an attempt to gather your estimates of the total annual sales volume in the U. S. In most cases the interviewee was able to arrive at an estimate of the total sales. But interestingly,

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each used a different method of estimating, for example, miles of highway constructed, construction industry sales, numbers of people employed etc. The results however, were fairly consistent in producing an estimate in the range of \$40 to \$50 million annually. Occasionally an interviewee would either decline to make an estimate or quote the Legislative Council for Photogrammetry's recently published estimate of \$88 million.

The occasional market size quote was our first contact with your organization. The existence of an organization possessing a photogrammetry market estimate and the fact that the estimate was quite different from the others aroused our curiosity. We have had a number of conversations with Bruce Vogelsinger in an effort to resolve this substantial difference in estimates. We have made a very careful examination of the data supplied by the Legislative Council for Photogrammetry and have concluded that the estimates they used included all the related services, especially of the larger companies, and for their purposes were a good estimate of the total sales of the photogrammetric industry in the U.S. For our purposes, however, we wish to exclude those services which would not be potential users of the satellite system. We concluded that in estimating the market size our interviewees estimated only that part of the market which would be potential users of the satellite system. In comparing published sales totals on an annual basis with data supplied during the interviews we concluded that all of the large multi-service companies had reduced their total sales figure to include only the sales that would be potential users of the satellite surveying system. Therefore, in reconciling the \$88 million market reported by the LCP for the total photogrammetric industry and the \$40 and \$50 million market as potential satellite surveyor users, the explanation simply was that we were estimating a much narrower and possibly better defined market than the LCP industry survey.

We, therefore, have chosen an estimate of \$50 million annually as representative of the total market we were trying to estimate. Since the total aggregate sales of the companies we have interviewed was \$24 million, we have obtained the potential satellite usage estimate from roughly half of the market. The potential usage estimate was \$1 million from firms having aggregate sales of \$24 million. Applying the same usage to sales ratio we have concluded that for an annual sales volume of \$50 million, a satellite system could be expected to annually replace \$2 million of conventional surveying performed domestically by U.S. firms.

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It should be emphasized that \$2 million represents the value of services that could be replaced by a satellite system. This estimate must be reduced by remaining costs such as field crew travel, subsistence, and instruments to arrive at an estimate of revenue to the satellite system. While this is a considerable amount of sales, we feel it would fall far short of the costs necessary to successfully launch and operate a satellite surveying system in the U. S.

In view of this we expanded our market survey to include the foreign sales by U. S. firms. Our approach to this estimate was similar to the U. S. domestic estimate with one important exception. We estimated the costs replaceable by a satellite system in foreign areas by averaging the interviewee estimates rather than totaling individual company cost replacement estimates. The consistency of the interviewee estimates gives us confidence in the result, but we feel that the method produces an inherently softer estimate. The addition of foreign sales by U. S. firms adds \$10 million to the total market estimate and a tremendous \$5 million to the costs replaceable by a satellite system. This large potential usage in foreign areas is a result of the combination of the types of jobs performed in foreign areas and their associated high costs. It can be noted that in the estimate of total market for foreign areas, our interviewees included roughly half the total industry sales. This is exactly what they did in the domestic areas, and once again we feel that they included only the sales that would be potential users of the satellite surveying system.

In an effort to further increase the satellite market potential, we again expanded our survey to include the Canadian commercial firms because of their strong geographic and financial links to the U. S. industry. The total foreign and domestic sales by Canadian firms is \$17 million. This would add an estimated \$3 million to the total cost of services replaceable by a satellite surveying system. These estimates were obtained from fewer sources than the U. S. estimates and thus we consider them to be softer yet than the U. S. foreign estimates.

The large potential market for a satellite system in foreign areas must be qualified by additional considerations.

More expensive communications networks must be maintained.

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- Foreign governments or large commercial firms could make unauthorized use of the system.
- If foreign governments were permitted access to the system, the U.S. and Canadian foreign commercial business could be placed in severe jeopardy.

In summary our conclusion is that even though a satellite surveying system represents a sophisticated solution to the need for increased productivity in geodetic positioning, its operation only in U.S. for commercial firms can not be justified on a strictly economic basis. If the system were to be operated world wide for commercial firms, the potential market is greatly expanded, but additional serious problems should temper the enthusiasm especially if access is also permitted to governmental agencies.