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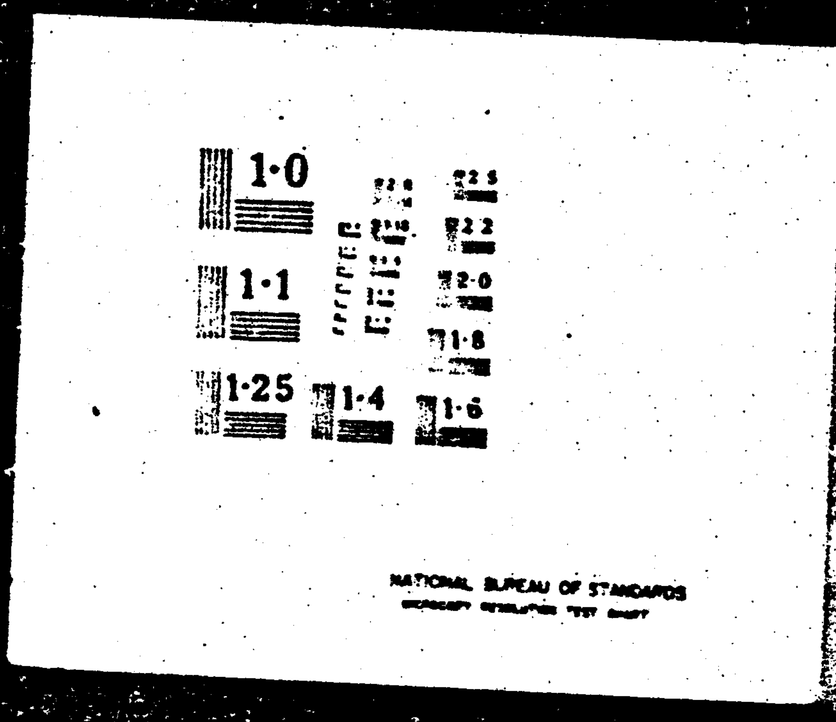

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LMSD-6034

WS 117L

ADVANCED SYSTEM DATA PROCESSING FOR SUBSYSTEM G = 'MIDAS SATELLITE SYSTEM

CONTRACT AF 04 (647) -97

LOCKHEED AIRCRAFT CORPORATION
MISSILE SYSTEMS DIVISION
SUNNYVALE, CALIFORNIA

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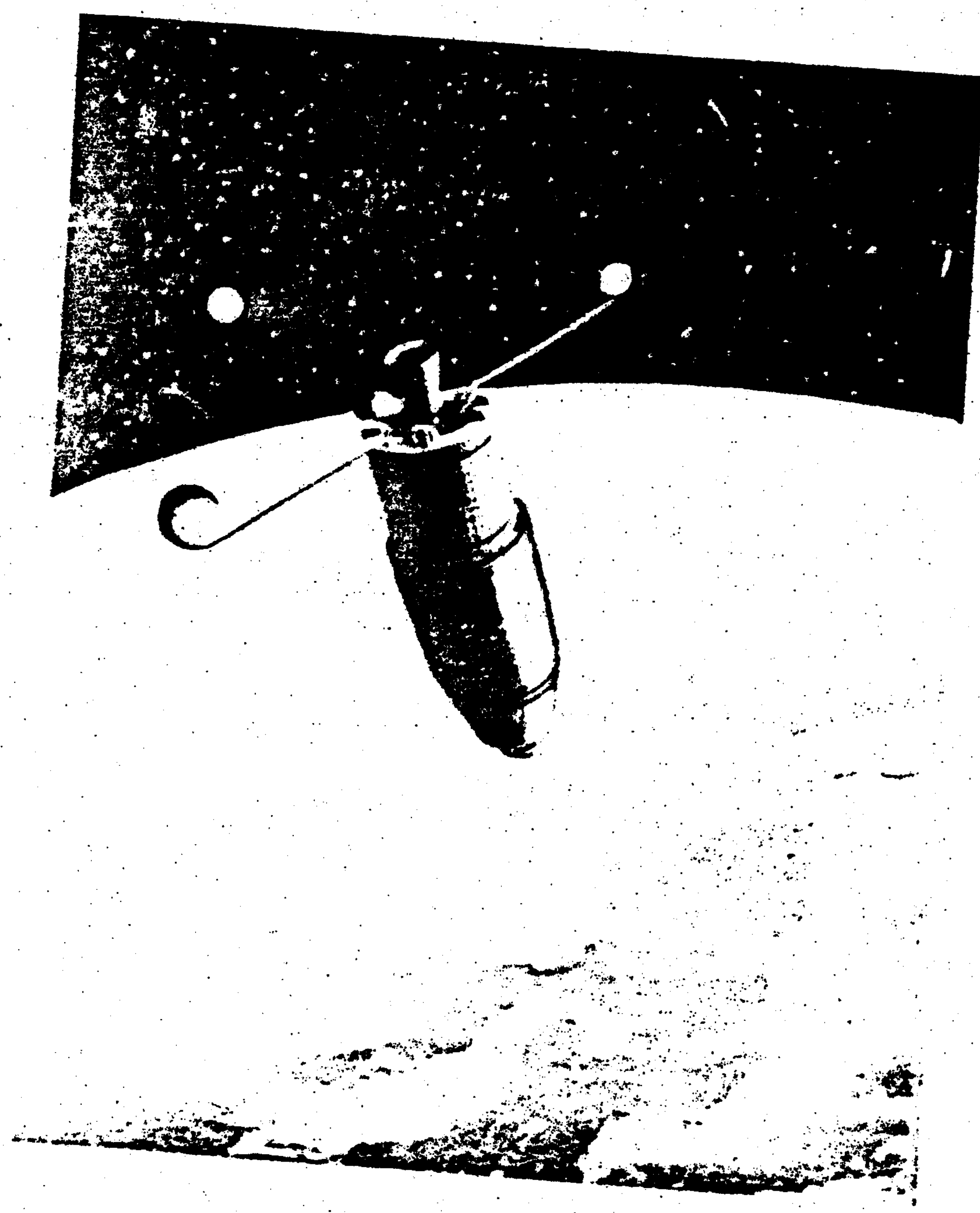

FOREWORD

This report presents the results of a study conducted by D. D. Aufenkamp of the Applied Mathematics Department, LMSD Research and Development organization. The work is being done in support of the WS-117L Project under Contract AF 04(647)-97.

The report reflects many of the ideas and opinions and much of the general philosophy that have evolved in consultations with people in LMSD's Preliminary Design Department, Data Control Department, and Subsystem C Department.

The study is part of a continuing effort, and additional reports will be forthcoming as significant progress is made.

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SECTION 4 QUANTITATIVE EVALUATION OF THE COMPUTER FACILITY

SECTION 5 CONCLUSION

PREFACE

This report is predicated on the performance of all data processing by ground-based equipment, and a discussion is made of requirements which arise from this assumption.

Subsequent to the completion of LMSD-6034, but prior to its formal release, numerous advantages became evident in the area of limited satellite-borne data processing -- as opposed to the exclusively ground-based approach undertaken in the study. As stated on Page 1-2, "... By making suitable assumptions the computer requirements can be simplified considerably over those resulting from a different set of assumptions. In fact, some apparently very difficult computer problems appear to be avoided almost entirely by appropriate equipment design...." Such major gains appear possible by, among other means, transferring part of the data-processing load to relatively simple equipment on board each satellite.

Despite the advantages of limited satellite-borne data processing, information contained herein is useful and valid in its own right under the assumptions made in the study. The report is published at this time without revisions, so that it may be available for study at the earliest date. The study will be extended, and a future LMSD report will be published on a system comprised of both satellite-borne and ground-based data-processing elements.

WS-117L ADVANCED SYSTEM
DATA PROCESSING FOR SUBSYSTEM G

SECTION 1 DESCRIPTION

1.1 PRELIMINARY REMARKS

This report investigates the data-processing facility required for the proposed Subsystem G ICBM precision tracking-prediction system. Such a study is particularly appropriate as a logical successor to the investigation described in LMSD Report 29..6, WS-117L ICBM Tracking Prediction Accuracies from Angle-only Measurements (Ref. 1). That investigation is concerned with the feasibility of using earth satellites equipped with infrared detectors for tracking ICBMs during their burning phase in order to obtain the burnout conditions of the missile with sufficient accuracy to permit a reasonable prediction of its free-flight path.

The precision tracking-prediction system envisaged consists of a network of satellites, each carrying an infrared search mechanism and several infrared trackers for the detection and precision tracking of ICBMs, together with appropriate ground data-processing equipment. The completed system will have a number of functions. Three basic ones are as follows:

(1) Detection of enemy ballistic missiles by the search (acquisition) gear as the missiles rise above the lower atmosphere.

(2) Tracking of each missile thus detected during its burning phase with two or more satellite-borne infrared trackers to obtain precision angular tracking data.

(3) Calculation of the position and velocity of each missile at burnout in order to predict its resulting free-flight trajectory.

A number of other functions can also be incorporated into the system depending upon the sophistication desired. For example, it may be necessary to follow the predicted free-flight path of each missile with infrared trackers in order to detect an additional thrust applied after initial burnout has occurred. Such a function would surely complicate the proposed system in general and the associated computer facility in particular. We shall defer temporarily a detailed study of this and other possible functions of the system.

In order to carry out an effective evaluation of the magnitude of the computer facility required for the proposed system, it is necessary to make certain assumptions concerning the equipment and techniques to be employed as this phase of the development is in an early stage of formulation. It should be emphasized that this investigation is a feasibility study and that suitable solutions to many problems await further study.

The computer facility associated with such a system must necessarily be a very high-speed data-processor. The sophistication depends to some extent on the functions required of the facility. On the other hand, however, given a desired set of functions to be performed, the complexity of the associated computer depends strongly on a number of factors, such as the satellite reference system; the nature of the search and, especially, of the tracking mechanism; the particular mathematical formulation used, etc. By making suitable assumptions the computer requirements can be simplified considerably over those resulting from a different set of assumptions. In fact, some apparently very difficult computer problems appear to be avoided almost entirely by appropriate equipment design. A more detailed discussion will follow. This report emphasizes the techniques which offer considerable simplification in the data-processing, and, at the same time, are within the general philosophy of the infrared precision tracking-prediction system. Where alternatives in procedures have been studied, their advantages and/or disadvantages are also pointed out. Although, in general, the computer facility probably should not determine the development of the satellite-borne equipment, any contributions that might be made in this way to improve the overall system should be carefully considered.

The data-processing facility will be evaluated relative to the IBM STRETCH computer to the extent that this is possible in order to give a better indication of the magnitude of the problems involved. Some information on STRETCH appears in Par. 4.5 although many of the details of its development have not yet been released by IBM.

An introduction to the operation of the system is given in Par. 1.2. This introduction is followed by a detailed discussion in Section 2 of the various assumptions made in connection with the satellite reference system, search gear, infrared trackers, etc. A functional block diagram of a tentative data processing system is given in Section 3, and each major block is discussed in detail. After this qualitative discussion, the proposed computer facility is evaluated in terms of the STRETCH computer (Section 4). The report concludes with a general discussion of the work (Section 5).

1.2 OPERATION OF THE PRECISION TRACKING-PREDICTION SYSTEM

Consider a network of satellites with each carrying the above indicated search and tracking mechanisms and capable of communicating through a data-link system to the data-processing equipment on the ground. The system is illustrated in Fig. 1. The number of satellites needed for satisfactory performance will depend largely on such factors as the following:

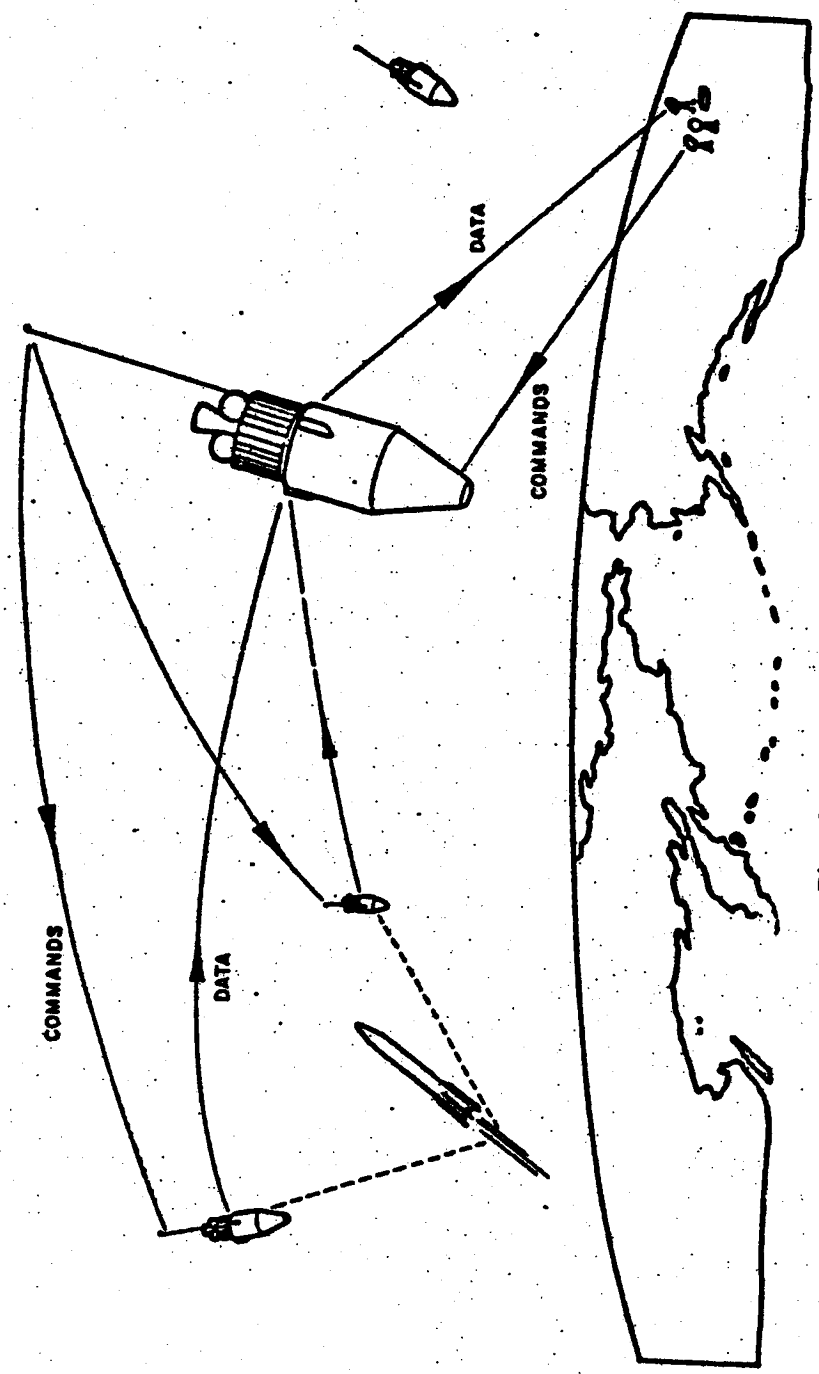

Fig. 1 Data Relay Concept

(1) Altitude and orbits of the satellites.
(2) Data-link network, including location of readout stations.
(3) Number of trackers per vehicle.
(4) Average number of trackers to be assigned to a target.
(5) Average time that a given target must be tracked.
(6) Estimated "maximum" rate of ICBM launchings in the event of an all-out enemy attack.

The "maximum" rate of ICBM launchings is defined to be the average rate of launchings during the period of maximum enemy activity in a time interval equal to the average tracking time per missile. This rate can be expected to increase as Russia's capacity develops for producing and launching missiles--especially when a solid propellant ICBM becomes operational.

In the standby state (i.e., when no heat sources are under observation) it would suffice to have only enough search gear in operation to give continuous coverage of the region of interest. The infrared trackers will be idle; however, some technique must be employed to ascertain whether or not the trackers as well as the other vehicle-borne units are in satisfactory operating condition.

Subsystem H will be tracking satellites to obtain precise present and future positional data. A very accurate attitude sensing device also must be developed to establish a satellite reference system with respect to which the high-resolution tracking measurements are given. Whether or not the attitude sensors must be functioning in the standby state will probably depend upon the procedures used. This point is developed in Par. 2.2.

When a heat source appears, as illustrated in Fig. 1, one or more search scanners will observe it and send an alarm through the data-line network to the ground master computer. The master computer analyzes the search data to determine whether a missile has been observed. If this is so, a suitable action must be taken. For example, after certain staging information is obtained, and/or after an appropriate time lapse, the computer could direct two or more vehicle-borne trackers from different observing satellites toward the heat source. The tracking data obtained is relayed to the master computer for processing. When burnout of the missile is detected, the master computer calculates the resulting ballistic trajectory so that appropriate defensive measures can be taken.

SECTION 2 BASIC ASSUMPTIONS

2.1 PRELIMINARY REMARKS

As stated in Par. 1.1, it was necessary to make a number of assumptions concerning the techniques and equipment to be used for collecting and processing data in order to carry out an effective evaluation of computer requirements. In part, use has been made of assumptions in a forthcoming report, LMSD-2869, First Annual Report: Feasibility Study of a Data Relay Network for the WS-117L Project, Subsystem G (Ref. 2). However, the nature of the tracker mechanism has been changed in view of a considerable simplification of the data-processing techniques concerned. With reference to the complexity of the overall data-processing facility, two general factors which should be kept in mind are as follows:

(1) The sophistication of the system with reference to the functions it must perform.

(2) The extent to which techniques--mathematical, procedural, and other--are developed to simplify the data-processing for a given set of required functions.

It is clear that the data-processing becomes much more complicated as the number of missiles to be tracked in a given time increases. A computer facility that would handle, say, ten missiles simultaneously would be considerably more complex than one designed to process only one missile at a time. It is difficult to estimate the maximum rate at which the system would have to process data on enemy missiles; however, for the purposes of this evaluation, the basic assumption is made that the infrared precision tracking-prediction system will have to process missiles at a rate of 30 per minute. This rate would represent a portion of an all-out attack in which, say, 450 ICBMs were successfully launched at rando ...ring a 15-minute interval.

It is of the utmost importance that the rate of processing missiles be approximately equal to the rate at which they are launched. If, for example, 450 missiles were launched in 15 minutes, and if it took an average of four seconds to process a given missile instead of the two seconds assumed above, at least 30 minutes would be required to process all 450 missiles. Therefore, some of the missiles would already be approaching their targets before any calculations could have been made.

With reference to the satellite configuration, the model assumed in the data-link feasibility study will generally be used in this report. In particular, a network of 96 satellites will be considered, with five infrared trackers per satellite, distributed on selected orbits. The orientation of the various orbits is not critical for the present evaluation. If it is required that trackers follow the predicted free-flight paths of missiles, the total number of trackers needed increases considerably. The data-link report reasoned that a configuration of 50 satellites would be able to handle missiles at an average rate of 30 per minute. This conclusion is based in part on the assumption that each vehicle-borne tracker will be in a position to view two missiles simultaneously. This assumption is not made here for reasons given in Par. 2.3.

2.2 SATELLITE REFERENCE SYSTEM

The infrared precision tracking-prediction system envisages tracker mechanisms whose precision is such that the angular accuracy of the overall system is to within 1.4 x 10⁻⁻ radians. Such precision is of little value unless the measurements are given with respect to a satellite reference system whose orientation relative to the ground is known very precisely. If the attitude of the vehicles were known perfectly, there would be no problem Since, in practice, this will not be the case, some technique will be required for determining carefully a reference system for each satellite.

It is assumed for the present evaluation that an applicable technique exists. The particular method used is of concern in this study to the extent that computer specifications are involved. One possible realization of a satisfactory reference system from the computer viewpoint is taken as a basis for discussion in this report. It is assumed that the satellites will ordinarily be well stabilized although some long-term drift may be present. The satellite's position is assumed known on the ground from Subsystem H calculations. Two reference directions are determined by assigning two star trackers to track different known stars. These two directions are sufficient to establish a unique coordinate system; hence the angular measurements of each tracker can be given with reference to these two directions. If these two directions correspond to coordinate axes, a third axis can be determined by a given cross product of the two associated unit vectors. While the two star trackers are occupied, a third star tracker will be ordered from the ground to seek out a third known star in order that a reference system moving with the vehicle can be provided at any time.

Since the motion of the star trackers relative to the vehicles will probably be somewhat restricted, communication must be maintained between the satellites and the associated star trackers so that any long-term drift of the satellites' orientations can be detected and corrected. It might be necessary, in this scheme, to have continuous star tracking from the time the vehicle is placed in orbit to insure that the reference system can be maintained at all times since otherwise even a small