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A. L. Hiebert, A. E. [illegible]

August 1980

N-1536-AF

Prepared For

The United States Air Force

Rand
SANTA MONICA, CA.

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Page 18 Under HqUSAF change:

(1) Office symbol for Dean Baerwald from AF/FMD to AF/FMO.

(2) Col. Jerry Banazak to Lt. Col. Elliott Barnes, Jr., AF/FMO.

(3) Maj. Howard J. Stears to Lt. Col. Gerald Mittelman, AF/RDSD.

Page 19 Under Space Division (Formerly SAMSO) change:

(1) Lt. Col. Dennis Beebe to Lt. Col. Larry A. Darda, YNCC.

(2) Major Gerald Fjetland to Lt. Col. Gerald Fjetland, YKX.

Page 19 Under Aerospace Defense Command change:
Maj. Robert Dickman to Lt. Col. Robert Dickman, XPCS.

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Future growth in commercial and military space systems is constrained by technical problems associated with the frequency spectrum, by orbital congestion, and by costs stemming from proliferated terminals. The authors outline an Air Force sponsored research project to design and develop a capability for predicting and analyzing the spectrum/orbital geometry requirements of current and projected U.S. and international space-related systems. The two essential components of the project are a comprehensive space environment data base and a computer analysis program. In combination, they will provide a resource for evaluating engineering and architectural designs, identifying and analyzing the impact of intentional and unintentional electromagnetic interference, and predicting probable saturation conditions in spectrum usage and satellite/orbital positions. The project will include assessments of ways to accomodate anticipated growth. It will be structured for a continuing analysis program, which will be accessible to the space community as operational capabilities are acquired.
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A RAND NOTE

TRANSMISSION AND ORBITAL CONSTRAINTS IN SPACE-RELATED PROGRAMS: PROJECT DESCRIPTION

A. L. Hiebert, A. F. Brewer

August 1980

N-1536-AF

Prepared For The United States Air Force

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PREFACE

The Rand Corporation, under the recently initiated Project AIR FORCE research program "Transmission and Orbital Constraints in Space-Related Programs," is developing a capability for analyzing the spectrum/orbital geometry requirements of current and projected U.S. and international space-related systems. Essential components of the project include development of a comprehensive Space Environment Data Base and of Analysis Codes and Computer Programs. This capability will provide a resource for evaluating engineering and architectural designs, identifying and analyzing the impact of intentional and unintentional electromagnetic (EM) interference, and predicting probable saturation conditions in spectrum usage and satellite/orbital positions. Assessments of ways of accommodating anticipated growth are included in the program.

The Directorate of Space Systems and Command, Control, Communications (AF/RDS), Headquarters, United States Air Force, will provide support for this project within the Air Force through the Program Management Directive (PMD) of the Advanced Space Communications Program (PE63431F). AF/RDS will also serve as the Office of Primary Responsibility (OPR) for the Rand effort and will assist in requesting support and participation of other DoD organizations, the Federal Communications Commission (FCC), National Aeronautics and Space Administration (NASA), National Telecommunications Information Agency (NTIA), and space-related industries. Rand will conduct the project in coordination with these agencies. The project will be structured to provide a continuing analysis program, which will be accessible to the space community as operational capabilities are required.

SUMMARY

The United States Air Force has a leadership role in the development and operation of space systems for the Department of Defense. In planning for future space systems, it is essential to consider the frequency spectrum and orbital constraints. Anticipated growth in the number of space systems, including ground networks, large multifunction satellites, and increased data-transmission rates, may have severe effects on future requirements for spectrum allocations and orbital positions.

Future growth in both commercial and military space systems is constrained by technical problems associated with the frequency spectrum, by orbital congestion, and by costs stemming from proliferated terminals. The seriousness of these constraints is shown by the fact that the useful areas and coverage of the geostationary circle are already nearing saturation: communications satellites have essentially filled these areas at C-band and are expected to saturate them at Ku-band in the near future. The military UHF and SHF frequency bands, also, are almost saturated because large portions of them are shared with terrestrial links. Future deep-space exploration systems will be characterized by high data rate mission sensors and will create additional problems by overloading the frequency spectrum and transmission capacities.

This Note outlines the research objectives and tasks required to achieve a continuing prediction and analysis capability for this problem area and to identify ways of accommodating the anticipated growth. The principal research objectives are to design and establish a comprehensive Space Environment Data Base and to develop Analysis Codes and Com-

puter Programs. The Space Environment Data Base will consist of a file, continually updated, on electromagnetic and operational characteristics and a file on the deployment status of currently active and projected U.S. and international space and ground terminal systems. The Electromagnetic and Operational Characteristics File will consist of three levels of information: a minimum data file, a nominal and expanded data file, and documentation of available information. A supplemental file will be needed to list possible intentional sources of interference and their locations and EM characteristics. The Deployment Status File will consist of four kinds of time-related information: (1) current and active deployed systems; (2) approved-for-launch systems and scheduled dates; (3) firm and funded development schedules; and (4) future development plans and schedules.

The Analysis Codes and Computer Programs will be developed for interrogating the Space Environment Data Base to determine current and projected usage/saturation levels for the spectrum allocation and orbital positions of space systems. It may be necessary to develop usage/saturation criteria for each elemental space volume (a) at various times and frequencies, (b) at mean message lengths, (c) at maximum message rates, (d) under various scenarios for different levels of conflict, and (e) for potential impact of intentional and unintentional EM interference.

Ongoing work on vulnerability/survivability, security of transmission, need and utilization patterns, and processing capabilities--and on their possible improvement--will be monitored.

Techniques that may offer ways of accommodating the anticipated increased space data traffic will be monitored and assessed as the project develops.

As now planned, the overall project will consist of three tasks: (1) design and establish the Space Environment Data Base and provide a report on the utilization of the Data Base and Analysis Codes and Computer Programs; (2) revise and develop new Analysis Codes and Computer Programs as required, and conduct preliminary analyses of candidate space-related systems to assess completeness of the data base and analysis models; and (3) provide technical advisory services to the Air Force, and prepare a report on project capabilities.

ACKNOWLEDGMENTS

Air Force personnel who contributed substantially to the project formulation and to this report include Maj. Gen. W. R. Yost, Col. J. D. Regenhardt, Lt. Col. G. W. Chesney, Lt. Col. R. V. Halder, and Lt. Col. E. A. Puscher.

Special acknowledgment is made of the support and contribution of F. E. Bond of The Aerospace Corporation, E. E. Reinhart of COMSAT Corporation, J. H. Atkinson of the DoD Electromagnetic Compatibility Analysis Center (ECAC), and B. D. Bradley, C. M. Crain, and E. C. Gritton of The Rand Corporation.

Special thanks are due to Rand colleague E. Bedrosian, who contributed substantial technical data and provided a critical review of the Note, and to Dorothy Stewart for valuable editorial assistance.

CONTENTS

I. INTRODUCTION

Projected advances in the use of space for communications, navigation, surveillance, and other mission capabilities--coupled with the prospect of substantial increases in launch rates by U.S. military, intelligence, and civil agencies, as well as by international agencies --will add substantially to data link traffic and data-processing requirements in ground-to-satellite, satellite-to-satellite, and satellite-to-ground communications and relay systems. [1-8] Data transmission requirements could expand by several orders of magnitude as new and larger spacecraft are developed. For example, LANDSAT-D, as proposed, will have its resolution increased from 1.2 acres to 0.2 acre (4850 M^2 to 810 M^2) and its IR data rate increased from 1000 to 1,000,000 bits/sec. Such expansion could severely tax the data-handling capacities of current equipment and affect the frequency spectrum allocations and orbit assignments of satellite systems. Available spectrum, and the useful orbital positions as defined by today's capabilities, may be inadequate. This could negate the operational advantage of the increased sensing capabilities now being sought in spacecraft; and increased demand in time of crisis could result in disruption of critical data transmission.

Future growth in both commercial and military space systems is constrained by technical problems associated with the frequency spectrum, by orbital congestion, and by costs stemming from proliferated terminals. The seriousness of these constraints is shown by the fact that the useful areas and coverage of the geostationary circle are already nearing saturation: communications satellites have essentially filled these areas at C-band and are expected to saturate them at Ku-band in the future. The military UHF and SHF frequency bands, also, are almost saturated because large portions of them are shared with terrestrial links. [9] National and international terrestrial systems, particularly the shared frequency bands, may provide serious additional transmission and orbital constraints.

Future deep-space-based exploration systems will be characterized by high data rate mission sensors and thus will create additional problems by overloading the frequency spectrum, planned communication links, and ground processing equipment. [10] The high data rates are based on the demand for timely and accurate sensor information covering wide spatial areas and are generated by fast detectors with high sensitivity and resolution.

The proposed project has been designed to develop a continuing program for analyzing the spectrum and orbital requirements of current space-related systems and for predicting potential saturation conditions caused by future systems. Identification and analysis of intentional and unintentional electromagnetic (EM) interference situations and their impact on saturation criteria are essential components of the project.

Development of capabilities for assessing and suggesting methods and techniques for accommodating the anticipated growth are also included in the project. This Note outlines both the research objectives and the tasks required to guide the activities of the project. Changes in the technical areas are anticipated as the work progresses. Throughout the discussion, the term "space systems" includes both space and earth segments.

The proposed list of participating space-related organizations and contacts are listed in Appendix A. This list will be expanded to include representatives from international space agencies and U.S. space-related industries.

The proposed technical data and analysis requirements are outlined in Appendix B and will be augumented as the analysis programs develop.

The project is being structured to provide a continuing analysis program that will comply with the technical criteria, rules and regulations, and coordination procedures established by the national and international spectrum management agencies.

II. PROJECT OBJECTIVES

The project objectives are to design and develop a capability for (1) defining the data traffic rates and the spectrum/orbital requirements of current and projected U.S. and international space-related programs; (2) predicting and analyzing the impact of these requirements on data transmission and processing equipment and on orbital positions and spectrum saturation; (3) identifying and analyzing intentional and unintentional electromagnetic interference situations and the effect of this interference on usage/saturation criteria; (4) evaluating engineering and architectural designs for accommodating the demands for spectrum allocations, orbital positions, and effective performance of proposed systems; and (5) identifying ways of accommodating anticipated growth.

Ongoing work on vulnerability/survivability, security of transmission, need and utilization patterns, and processing capabilities--and on their possible improvement--will be monitored.

Techniques that may offer ways of accommodating the anticipated increased space data traffic will be monitored and assessed as the project develops. Examples of such techniques include

- Current and potential developments in data processing and compression, multibeam antennas, etc.[11-13]
- Use of higher frequencies [14-19]
- Added spectrum allocations [20-22]
- Improved side lobes of earth station antennas
- Satellite data relay systems [23-25]

III. TECHNICAL REQUIREMENTS

To accomplish the objectives outlined in Section II, it will be necessary to design and develop a comprehensive Space Environment Data Base and Analysis Codes and Computer Programs.

SPACE ENVIRONMENT DATA BASE

The proposed Space Environment Data Base shall consist of a file on electromagnetic and operational characteristics, and a file on the deployment status of currently active and projected U.S. and international space, ground terminal, and network systems, including proprietary systems. A supplemental file should list possible intentional interference sources, locations, and EM characteristics.

The file on "Electromagnetic and Operational Characteristics" shall consist of three classes of information:

1. A Minimum Data File (see Appendix B, Attachment 1).
2. A Nominal (expanded) Data File (see Appendix B, Attachment 2).
3. Documentation, reports, manuals, and a special measurements file for obtaining data as required by related studies and analyses.

The sample format of the minimum data file on "Electromagnetic and Operational Characteristics" (Appendix B, Attachment 1) was designed for use on sensor-type space systems. Formats to cover space communications, navigation, relay, and related ground systems are being developed and will be distributed when available.

The data formats may be expanded to reflect forthcoming agreements based on the Final Acts of the 1979 World Administrative Radio Conference [21-22] and to include technical items required by the analysis programs.

The file on "Deployment Status" will consist of four kinds of time-related information:

1. Current and active deployed systems.
2. Approved-for-launch systems and schedule dates.
3. Firm and funded development schedules.
4. Future development plans and schedules.

Design of the Space Environment Data Base will be conducted by The Rand Corporation, assisted by the DoD Electromagnetic Capability Analysis Center (ECAC) and by space systems experts from participating agencies. Responsibility for constructing and maintaining the Data Base and assisting in analysis programs will be assigned to the ECAC at Annapolis, Maryland. ECAC already has the necessary computer and data-processing equipment, the trained personnel, and a substantial portion of the required space-environment data and associated analysis codes and programs. [26-29] Additional facilities may be needed to process proprietary data.

ECAC also maintains an extensive and active data base on the electromagnetic and operational characteristics of terrestrial and earth environment equipment that may affect some of the space-related programs.

Preliminary discussions with cognizant agencies have been initiated for obtaining and processing needed data at various levels of security, as well as proprietary data (see Appendix A). Appropriate means for processing proprietary information will need to be developed and approved by the cognizant agencies.

The Data Base will be made available--as needed, and under appropriate security procedures--to Rand space studies, to participants providing the data, and to agencies and other contractors sponsoring or conducting analyses in the subject areas. The Data Base will be updated periodically to provide a continuing source of information for analyzing current and future space systems.

Prediction and analysis of the probability of spacecraft collision and/or physical impact with space objects, and calculations of separation distances concerning potential intentional damage, are not addressed in this project. However, the Data Base should provide useful information on the orbital positions of current and future satellites, which is essential to such investigations.

ANALYSIS CODES AND COMPUTER PROGRAMS

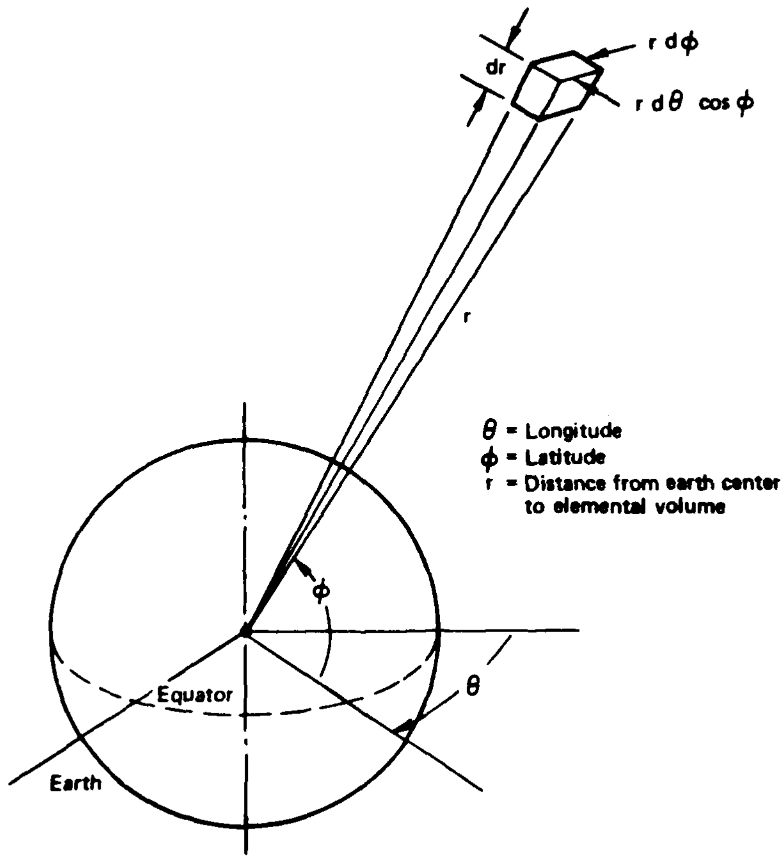
The objectives are to devise analytic codes and computer programs for interrogating the Space Environment Data Base to determine current and projected usage/saturation levels for the spectrum allocation and orbital positions of space systems.

New analysis techniques and usage/saturation criteria may need to be developed for each type of space communications, navigation relay, or sensor service. Since the results depend on space, time, frequency, message length, and scenario, it will be necessary to determine usage and saturation levels for each elemental space volume of the system in question at various times and frequencies, at mean message lengths, and under various scenarios for various levels of conflict. (The volumes of space that need to be considered are very large, often in the millions of cubic miles. Thus, conditions prevailing in one portion tend to be different from conditions prevailing in another portion.) An elemental volume is illustrated in Fig. 1.

For each authorized frequency band and/or channel, completely defined emissions, partially defined emissions (random in space or time), and undefined emissions (random in space and time) will have to be statistically combined and compared with receiver sensitivity, antenna gain, and system losses in order to derive a measure of band usage.

The correlation will provide a basis for projecting future demands on each allocated band in terms of the anticipated increase in users or frequency of use. After "saturation" has been defined for each type of service, it should be possible to identify those usage rates that are approaching saturation as a function of frequency and orbital position and how soon this is likely to occur.

Limits of orbital spacing are based on beamwidths of the earth station/terminal (may include mobile) antennas, electromagnetic interference criteria, and adherence to the ITU Radio Regulations. [21,22] Hence, intentional and unintentional interference situations and their impact on usage/saturation levels should be assessed. Analysis of system vulnerability to intentional EM interference is an



Elemental volume = $r^2\ dr\ d\phi\ d\theta\ \cos\phi$

Fig. 1 — Definition of elemental space volume

additional essential requirement for hardened and secure systems.

Once suitable criteria have been determined and analyzed, and programs have been developed, they will be applied to the Data Base to answer questions such as

1. What are the usage and saturation rates of existing and planned space communication systems?
2. Can a new system be added to the existing space environment and function as required? What will a new system (assuming it became operational) do to the existing system?
3. What are intentional/unintentional interference situations, sources, and effects?
4. What will defined jamming situations do to a specified military data link that is already partially saturated?
5. Which systems are the least conservative of spectrum?
6. Which systems approach orbital congestion?

Answers to questions such as these should make it possible to recommend communication practices, band allocations, and orbital assignments that will permit the transmission of essential information within the available finite spectrum.

Other objectives will be to investigate data and signal manipulation methods (compression, sifting, redundancy elimination, minimum message-length messages, modulation techniques, etc.) that can be applied to each saturated or nearly saturated service to increase traffic capacity.

Current and potential developments in the use of higher frequencies, multibeam antennas, and new technologies will be explored in an attempt to deal with the anticipated growth in data transmission.

Ongoing work on vulnerability/survivability, security of transmission, need and utilization patterns, and processing capabilities--and on their possible improvement--will be monitored.

A concerted effort will be made to secure the assistance of personnel of the participating organizations to compile and evaluate Analysis Codes and Computer Programs and to devise additional capabilities when these are required. [30-36] The Analysis Codes and Computer Programs developed under this project will be made available to government and industry to assist them in designing space systems and evaluating the demands for spectrum allocations and orbital positions in the early design and planning phases of space programs.

TECHNICAL ADVISORY AND ANALYSIS SERVICES

The advisory and analysis services are intended to provide technical assistance to the Air Force Systems Command, Space Division, Deputy for Space Systems, and to the Aerospace Defense Command, DCS/Plans and Programs Office, in using the Space Environment Data Base and Analysis Codes and Computer Programs.

Examples of current and near-term space-related programs that could be addressed are listed below:

- Defense Support Program (DSP)
- Defense Meteorological Satellite Program (DMSP)

- Global Positioning System (GPS)
- Military Satellite Communications (MILSATCOM)
- Tracking and Data Relay Satellite System (NASA/TDRSS)
- Satellite Control Satellite (DoD/SCS) [Formerly Satellite Control Data Relay System (SCDRS)]
- Satellite Control Facilities

Systems that are candidates for analysis to validate the data base and models will be selected jointly by the Air Force and Rand; selections will be based on attained capabilities and on the availability of the data base.

The initial effort could focus on advisory support for the development of an immediate capability to support the Space Defense Operations Center (SPADOC), which would identify and analyze intentional or unintentional electromagnetic interference. Procedures for coordinating the Rand effort with SPADOC, the Air Force Electronic Security Command, and the ECAC will be explored. The Space Environment Data Base must be expanded to include information on current and potential intentional interference sources and locations and on their electromagnetic characteristics. This information is essential to the analysis process.

A longer-term effort would concentrate on the assessment, modification, and documentation of analysis techniques--including those developed under this project--that are applicable for operational use by AFSC/Space Division and SPADOC in exploiting the Space Environment Data Base.

The overall SPADOC mission responsibilities, generated by ADCOM/DCS, Plans and Programs Office, are shown in Table 1. Several of the areas are considered to be of interest to the Rand project and could be given added support.

Table 1

SPADOC MISSION RESPONSIBILITIES

Mission Area	Responsibilities
Monitor and Inform	Monitor space activity Assess mission of foreign launches Maintain status of designated space systems Correlate and coordinate threat and status Provide advance notice of activity Operational control of SPADATS
Protect	Interface satellite systems to NMCS Perform U.S. forces damage assessment Advise on defensive actions
Negate	Monitor forces Maintain targeting data bases Generate intercept opportunities Prepare battle plans Provide targeting data Direct battle Perform strike assessment Support CINCAD, NMCC, and NCA decision process

PROPOSED TASKS

The proposed tasks are outlined briefly below. The projected work schedule and level of effort will depend on the response and support of the government agencies (see Appendix A) and the space-related industries involved. More details on the technical aspects of the tasks and on the time and extent of work accomplishments will be provided as the project develops.

Task 1

a. Determine agency and industry contacts and arrange procedures.

b. Document and coordinate an implementation plan for the Space Environment Data Base. The plan will provide estimates of the amount of effort required for acquisition, processing, verification of accuracy, updating procedures, access, and utilization of the Data Base. Methods for processing proprietary information will be described. Requirements for specific ECAC support will be included to permit a resource assessment by ECAC personnel. Upon approval of the plan, design and establish the Space Environment Data Base, and the processing/maintenance of the data at ECAC.

c. Provide a report on the content and utilization of the Space Environment Data Base and on the existing and applicable Analysis Codes and Computer Programs for assessing both current and future space systems.

Task 2

a. Revise and develop new Analysis Codes and Computer Programs as required.

b. Apply Data Base and Analysis Codes on candidate space-related systems to assess the completeness of the Data Base and the Analysis Models

c. Identify methods to resolve problems identified in the Analysis Program.

Task 3

a. Provide technical advisory services to the Air Force Systems Command, Space Division, Deputy for Space Defense Systems, and to the Aerospace Defense Command, DCS/Plans and Programs Office, to assist them in utilizing the Space Environment Data Base and the Analysis Codes and Computer Programs.

b. Identify preferred methods and options for continuing assessments to accommodate the anticipated growth in spectrum/orbital requirements.

c. Provide a report on project capabilities and advisory support for transition of the project to a continuing capability in this problem area.

IV. PROJECT STATUS

This project was approved by the Air Force Advisory Group (AFAG), in May 1980, under the procedures of Air Force Regulation 20-9.

The project has been discussed extensively with people throughout the Air Force, DoD, other government agencies, and industry whose support and participation will be required (see Appendix A). The Rand Corporation, under Project AIR FORCE, will conduct and direct the project during the design and development phase, in coordination with the participating agencies.

The Directorate of Space Systems and Command, Control, Communications (AF/RDS), Headquarters, United States Air Force will provide support for this project within the Air Force through the Program Management Directive (PMD) of the Advanced Space Communications Program (PE63431F). AF/RDS will also serve as the Office of Primary Responsibility (OPR) for the Rand effort and will assist in arranging for the support and participation of other government organizations and space-related industries. Rand will establish contacts with these agencies and industry to acquire technical assistance and needed data on space-related programs.

ECAC support is being arranged through the Assistant Secretary of Defense/C^3I by AF/RDS in coordination with the Directorate of Development and Production (RDPT) at Headquarters, United States Air Force.

Appendix A

PROJECT AGENCIES AND CONTACTS*

DEPARTMENT OF DEFENSE

Office of the Under Secretary of Defense for Research and Engineering

Contacts:
James H. Babcock (Larry Castro)
Deputy Assistant Secretary of Defense (Intelligence)

Mark Epstein
Assistant for Theater Communications, Command,
Control and Intelligence

David L. Solomon (William Cook)
Deputy Assistant Secretary of Defense
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Robert D. Turner
Special Assistant for Technical Plans and Research

Defense Advanced Research Projects Agency

Contact:
Colonel Charles E. Heimach, DARPA/STO

Defense Communications Agency

Contacts:
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Deputy Director, Military Satellite
Communication Directorate

I. L. LeBow, Chief Scientist

William G. Long

Defense Intelligence Agency

Contacts:
Jack Vorona
Deputy Director for Scientific and Technical Intelligence

*The list of agencies and contacts will be expanded to include International Space Agencies and U.S. space industry and will be updated as required.

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Technical Assistant for Technologies

Electromagnetic Compatibility Analysis Center

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Colonel Paul T. McEachern, CC
John A. Zoellner, Technical Director, CD
James H. Atkinson, Scientific Advisor

North American Air Defense Command (NORAD)

Contact:
Colonel W. Clark, XPD

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Naval Surface Weapons Center
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Colonel Roger C. Horrigan, AF/RDSS
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Headquarters, Air Force Systems Command

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NASA Lyndon B. Johnson Space Center

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Appendix B, Attachment 1

Sample of
ELECTROMAGNETIC AND OPERATIONAL CHARACTERISTICS FILE
Level 1 -- Minimum Data

CLASSIFICATION:	UNCLASSIFIED
SPACE SYSTEM IDENTIFICATION:*	
Mission Title/Common Name	LANDSAT III
International Designator	78-026A
NORAD-Space Object Number	10702
Inter-Range Operations Number (IRON)	0702
Satellite Type (i.e., comm., nav., relay, sensor system†)	Sensor-earth resource study
Satellite Launch/Expiration Date	Mar.5,1978/Mar.1980 (Projected SC Life)
Responsible Agency [(1) R&D, (2) Acquisition, (3) Control, (4) User]	NASA (1) - (4)
Control Centers (name, location)	Goddard Space Flight Center, Greenbelt, MD Goldstone, CA; Fairbanks, AK
ORBITAL DATA/FLIGHT PROFILE:	
Eccentricity e	.0013
Inclination i	99^{o}
Right Ascension of Ascending Node Ω	84.333^{o}
Mean Anomaly M	91.391^{o}
Argument of Perigee ω	196.642^{o}
Mean Motion n	3.492^{o}/min
Epoch (yr.,mo., day, hr.) τ	78, Mar. 5d 18h
TRANSMITTER DATA:	
Type Station	Space
Type Emitter	
Transmitter Expiration Date	Mar.1980 (Projected SC Life)
Active Portion of Orbit	On Command
Frequency(ies)/Wavelengths‡	137.9 2229.5 2265.5 2287.5 MHz

*To be coded by data source. Assistance in completing the form will be provided by ECAC. The data will be extracted from source documents submitted to ECAC by agencies, developers, and operators of the space-related programs.

†Data items will be tailored to accommodate each type of space system.

‡In electro-optic systems, use wavelengths.

TRANSMITTER DATA: (continued)

Output Power/Energy (Watts)	.3 or 2	10 or 20	10 or 20	1
Modulation Type	PCM/PM	F9	F9	PCM
Emission Bandwidth (KHz)	3 or 90	20(MHz)	20(MHz)	5000
Access [i.e., TDMA, FDMA]	Not Applicable			
Equipment Nomenclature/Name	Space VHF	Space	Space	Space
Systems Nomenclature/Name	TLM/BCN	S-Band TX	S-Band TX	S-band T
Antenna Gain/Aperature	-5dB			4dB
Field of View (FOV)				
Antenna Pointing Angles or Scanning Capability				
Antenna Polarization	Circular	Vertical	Vertical	Vertical
Antenna Nomenclature or Name	Space VHF TLM	Space 1.9 2.3 GHz	Space 1.9 2.3 GHz	Space 1.9 2.3 GHz
Latitude/Longitude Locations (for Earth Stations stationery & mobile)	Not Applicable			
Channelization				

RECEIVER DATA:

Type Station	Earth
Receiver Expiration Date	Indefinite
Active Portion of Orbit	On Command
Frequency(ies)/Wavelengths*	137.9 2229.5 2265.5 2287.5 MHz
Receiver RF, IF, and Base Bandwidths	RF=400-500 MHz, IF=110 MHz BB=20MHz to 300 MHz
Access [i.e., TDMA, FDMA]	Not Applicable
Antenna Pointing Angles or Scanning Capability	Not Applicable
Detector Type Narrow Band /Wide Band	Wideband = FM
Receiver Responsitivity / Noise-Equivalent Power†	
Equipment Nomenclature/Name	(Project Unique)
Systems Nomenclature/Name	AIL-Low Noise Amp., Harris=RF Comm.Multi-Function =RX
Antenna Gain	43 dB
Antenna Polarization	Right Hand Circular
Antenna Nomenclature or Name	Appolo 30'-Cassegrain Feed
Receiver Sensitivity	-118 dBm
Required S/N Ratio	

*In electro-optic sytems, use wavelengths.

†In electro-optic systems, use joules or ergs.

RECEIVER DATA: (continued)

Latitude/Longitude Locations [for Earth Stations only]	Goddard 38 59 54N. 076 59 25W. Goldstone 35 20 30N. 116 52 24W. Fairbanks 64 58 37N. 147 30 54W.
Effective System Noise Temperature	86° Kelvin (K)
G/T Ratio	26 dB/K

SYSTEM DATA

Uplink Margin in dB* ______

Downlink Margin in dB ______

Uplink Information Conveyed (Data Rate Capacity or Signal Bandwidth) ______

Downlink Information Conveyed (Data Rate Capacity or Signal Bandwidth) ______

PERSON COMPLETING FORM

Name ______

Organization ______

Address ______

Zip Code ______

Phone ______

Remarks: ______

DEFINITION OF TERMS

TDMA: Time Division of Multiple Access

FDMA: Frequency Division of Multiple Access

S/N: Signal-to-Noise Ratio

G/T: Gain to Temperature Ratio

Note: LANDSAT III data was used to illustrate the use of the form and for the information required for the data base. Additional forms suitable for computer processing are being designed.

*Ratio of minimum required signal level versus available signal level expressed in dB.

Appendix B, Attachment 2

Sample of
ELECTROMAGNETIC AND OPERATIONAL CHARACTERISTICS FILE
Level 2 -- Nominal Data

CLASSIFICATION:

SPACE SYSTEM IDENTIFICATION:*

I. TECHNICAL DATA

Mission Title/Common Name ____________

International Designator ____________

NORAD-Space Object Number ____________

Inter-Range Operations Number (IRON) ____________

Satellite Type
(i.e., comm.,nav.,relay,sensor system+) ____________

Responsible Agency

[(1) R&D, (2) Acquisition,
(3) Control, (4) User] ____________

Control Centers (Name, Location) ____________

ORBITAL DATA/FLIGHT PROFILE:

Eccentricity e ____________

Inclination i ____________

Right Ascension of Ascending Node Ω ____________

Mean Anomaly M ____________

Argument of Perigee ω ____________

Mean Motion n ____________

Epoch (yr., day, hrs., min., sec.) τ ____________

Nodal Period ____________

Apogee Altitude ____________

Perigee Altitude ____________

NONCOMMUNICATION SENSORS AND RECEIVERS:

Type and Function ____________

Spectrum or Bandwidth ____________

Sensitivity ____________

Sensors/Receiver Output Format ____________

Antenna Gain or Optical Magnification ____________

Scanning or Tracking Provisions ____________

*To be coded by data source. Assistance in completing the form will be provided by ECAC. The data will be extracted from source documents submitted to ECAC by agencies, developers, and operators of the space-related programs.

+Data items will be tailored to accommodate each type of space system.

APPENDIX B
Attachment 2

SPACE SYSTEM IDENTIFICATION: (continued)

I. TECHNICAL DATA (continued)

NONCOMMUNICATION RADIATORS:

Type and Function ____________

Spectrum or Bandwidth ____________

Center Frequency ____________

EIRP (Effective Isotropic Radiated Power) ____________

Antenna Gain or Optical Magnification ____________

Scanning or Tracking Provisions ____________

OBSERVABLES (FROM EARTH):

S-Band Back-Scattering Area ____________

X-Band Back-Scattering Area ____________

Radiance at Visual Frequencies ____________

IR Radiance ____________

COMMUNICATION DOWNLINK:

Carrier Frequency ____________

Base Band ____________

EIRP ____________

Antenna Gains and Patterns

Satellite ____________

Earth Terminal ____________

Beam Steering

Satellite ____________

Earth Terminal ____________

Modulation and Coding Employed ____________

Intelligence Conveyed (Data Rate) ____________

Band-Reduction and Data-Compression

Satellite ____________

Earth Terminal ____________

Earth Terminal(s)

Location(s) ____________

Maximum Operating Range ____________

Receiver Losses ____________

Receiver System Noise Temperature ____________

APPENDIX B
Attachment 2

SPACE SYSTEM IDENTIFICATION: (continued)

I. TECHNICAL DATA (continued)

COMMUNICATION DOWNLINK: (continued)

Minimum S/N Required

Probability of Detection ________________

False Alarm or Digital Error rate ________________

Link Margin

Minimum ________________

Maximum ________________

Receiver AJ Margin ________________

Minimum S/N Required

Probability of Detection ________________

False Alarm or Digital Error Rate ________________

Link Margin

Minimum ________________

Maximum ________________

Receiver AJ Margin ________________

COMMUNICATION UPLINK:

Carrier Frequency ________________

Base Band ________________

EIRP ________________

Antenna Gains and Patterns

Satellite ________________

Earth Terminal ________________

Beam Steering

Satellite ________________

Earth Terminal ________________

Modulation and Coding Employed ________________

Intelligence Conveyed (Data Rate) ________________

Band-Reduction and Data-Compression

Satellite ________________

Earth Terminal ________________

Earth Terminal(s), including mobile

Location(s) ________________

Maximum Operating Range ________________

APPENDIX B
Attachment 2

SPACE SYSTEM IDENTIFICATION: (continued)

I. TECHNICAL DATA (continued)

COMMUNICATION UPLINK: (continued)

Receiver Losses ____________

Receiver System Noise Temperature ____________

Minimum S/N Required ____________

Probability of Detection ____________

False Alarm Rate ____________

Link Margin

Minimum ____________

Maximum ____________

Receiver AJ Margin ____________

COMMUNICATION CROSSLINK:

Carrier Frequency ____________

Base Band ____________

EIRP

This Satellite ____________

Relay Satellite ____________

Antenna Gain and Patterns

This Satellite ____________

Relay Satellite ____________

Beam Steering Provision

This Satellite ____________

Relay Satellite ____________

Modulation and Coding Employed ____________

Intelligence Conveyed (Data Rate)

Band-Reduction and Data-Compression

This Satellite ____________

Relay Satellite ____________

Maximum Link Operating Range ____________

Receiver Losses

This Satellite ____________

Relay Satellite ____________

Receiver System Noise Temperature

This Satellite ____________

Relay Satellite ____________

SPACE SYSTEM IDENTIFICATION: (continued)

I. TECHNICAL DATA (continued)

COMMUNICATION CROSSLINK: (continued)

Minimum S/N Required

This Satellite ____________________

Relay Satellite ____________________

Link Margin

Minimum ____________________

Maximum ____________________

How Is It Allocated:

Fading? ____________________

Aging? ____________________

Atmospheric Attenuation? ____________________

Other? ____________________

II. OPERATIONAL/ARCHITECTURAL DATA*

WHAT IS THE MILITARY PRIORITY OF THE TRANSMISSION? ____________________

WHAT IS THE CIVILIAN PRIORITY OF THE TRANSMISSION? ____________________

DOES THE MODULATION EMPLOYED CONSERVE SPECTRUM:

In Light of Error-Coding Requirements? ____________________

In Light of Anti-Jam Requirements? ____________________

In Light of the Real Rate at Which Information† Is Being Transmitted? ____________________

HOW MUCH OF THE TIME IS THE LINK OPERABLE? ____________________

---

*Answers to questions posed may be derived from the data base surveys, by selective analysis in the Space Data Project, or provided by organizations with programmatic and architectural responsibility.

†Information is used here in a basic sense; not just as the source data before encoding, but as that portion of the source data that the receiver must obtain to accomplish his intended purpose.

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HOW MUCH OF THE TIME IS THE LINK OPERATED [i.e., TRANSMITTING USEFUL DATA]? Give schedule, if regular. ____________

HOW MUCH OF THE TIME IS THE LINK RADIATING, BUT NOT TRANSMITTING USEFUL DATA? Give schedule, if regular. ____________

IS THE LINK PART OF A MULTIPLE-CONNECTIVE NETWORK? ____________

- Is Packing Switching Employed? ____________
- Is Network Routing Otherwise Adaptive? ____________
- Is Network Routing Programmed ? ____________
  - By Whom? ____________
  - On What Basis? ____________
  - How Far in Advance? ____________

IS LINK SUBJECT TO, OR A SOURCE OF, UNINTENTIONAL INTERFERENCE? ____________

IS LINK SUBJECT TO JAMMING? ____________

- Probable Jammer Platform
  - Earth ____________
  - Airborne ____________
  - Satellite ____________
- Probable Type of Jamming
  - CW ____________
  - Noise ____________
  - Repeater ____________
  - Frequency Follower ____________
- State-of-the-Art Applicable Jammer
  - Power Generated ____________
  - Antenna Gain ____________
  - Probable Location ____________
- Probable Enemy Priority on Jamming This System ____________

IS SOURCE DATA TRANSMITTED UNPROCESSED?

- Is it technically feasible to refine data before transmission? ____________
- Is it economically feasible? ____________

APPENDIX B
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IS SOURCE DATA TRANSMITTED COMPRESSED/EXPANDED?

Which? ____________________

How much? ____________________

Is spectrum conserved thereby? ____________________

Is compression/expansion a military requirement? ____________________

DO THE ANSWERS TO THE ABOVE QUESTIONS INDICATE THAT THIS LINK SHOULD BE MORE CAREFULLY STUDIED FOR:

Spectrum conservation? ____________________

Operating practices? ____________________

Interference? ____________________

Other reasons? ____________________

IS, OR CAN, THE LINK TRANSMISSION BE SCHEDULED TO PERMIT TIME SHARING WITH OTHER SERVICES AT THE SAME FREQUENCY? ____________________

UTILIZATION OF ASSIGNED BAND

What Fraction of Operating Time Does Transmitted Signal Occupy? ____________________

SYSTEM DATA RATE CAPACITY

Uplink Margin in dB* ____________________

Downlink Margin in dB ____________________

Uplink Information Conveyed (Data Rate Capacity or Signal Bandwidth) ____________________

Downlink Information Conveyed (Data Rate Capacity or Signal Bandwidth) ____________________

PERSON COMPLETING FORM

Name ____________________

Organization ____________________

Address ____________________

Zip Code ____________________

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*Ratio of minimum required signal level versus available signal level expressed in dB.

APPENDIX B
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Phone ______________________

Remarks ______________________

Note: Additional forms suitable for computer processing are being designed.

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