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TRACKING AND DATA ACQUISITION SYSTEM FOR THE 1990's

VOLUME III

TDAS COMMUNICATION MISSION MODEL

DRAFT FINAL REPORT

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16. Abstract

This report is the Draft Final Report for Task 3, TDAS Communication Mission Model. It develops a parametric description of the communication channels required between the user spacecraft to be supported and the user ground data systems. The report covers three primary areas:

1) Scenarios of Mission Models - which reflect a range of free flyers vs space platform usage as well as levels of NASA activity and potential support for military missions.

2) Potential Channel Requirements - which identify a) bounds on TDAS forward and return link data communication demand and b) the additional demand for providing navigation/tracking support.

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PREFACE

OBJECTIVE

The objective of this report is to document the technical results obtained in the process of completing Task Assignment 3, TDAS Communication MIssion Model, on Contract NAS5-26546, "Tracking and Data Acquisition (TDAS) Study."

SCOPE OF WORK

This contract represents a two-year pre-Phase A concept definition study for the proposed Tracking and Data Acquisition Satellite System (TDAS), which will be the follow-on to the Tracking and Data Relay Satellite System (TDRSS) which is currently in development. The TDRSS is contracted for through about 1994. This TDAS study, therefore, covers a ten-year planning period starting in the early 1990's.

The types of carrier for experiments flown during the TDAS time frame are grouped into three classes:

- Free Flyers
- Platforms
- Space Stations.

In general, the platforms provide means to group experiments together in an unmanned vehicle, while the space stations provide a manned facility which may carry one or more experiments. The space shuttle is expected to be active well past the year 2000, with 5 to 7 vehicles flying during the study period.

Much of the TDAS requirement will be to support low earth orbit (LEO) missions in terms of communications, navigation, and TT&C. Additional requirements could stem from user mission activities in higher (e.g., synchronous) orbits, and in support of inter-orbital transfers of materials and men for maintenance and repair in space, or for retrieval of platforms and experiments.

Task 3, "TDAS Communication Mission Model," involves developing a parametric description of the communication requirements between the user spacecraft to be supported and the user ground data systems. The model contains useful mission related parameters needed for later tasks to support iterative tradeoff studies between capabilities of user spacecraft and ground data systems. This includes parameters such as: mission scenarios, user spacecraft orbits, TDAS contact time requirements, and forward and return link characteristic. Potential user requirements for navigation or tracking support are considered and the resulting requirements are included in the model.

STATUS

After completion of the TDAS communications mission model, NASA decided that both a space platform and a space station would not be implemented e.g., either the Power Utilization Platform (PUP) or the Space Operations Center (SOC) will be implemented. Since the communication mission model drives the system design and since the platform and station place large requirements on TDAS, STI updated the communication mission model. In addition, scenario of mission models A1 was used in the remainder of this study and this was the only model updated. The updates are presented as a series of footnotes throughout this report.

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SECTION 1

INTRODUCTION

This report is the final report on Task 3, "TDAS Communication Mission Model" under Contract NAS5-26546. The methodology used to accomplish the task and the detailed results of the effort are documented herein.

1.1 TASK ASSIGNMENT

Based on information developed in Tasks 1 and 2, the contractor shall develop a parametric description of the communication channels required between the complex of spacecraft to be supported and the user ground data systems. This model shall contain all the useful mission related parameters where required for the iterative tradeoff studies to be carried out in later tasks between the capabilities of the ground systems and the spacecraft supported by the TDAS. Examples of these parameters are bandwidth, EIRP, mission orbit, required hours per day or per orbit of coverage, and forward and return link characteristics. The various types of navigation or tracking channels will be considered and the result of this analysis will be included in the mission model in terms of the appropriate assumptions and parameters.

1.2 OVERVIEW OF METHODOLOGY

The methodology followed in pursuing the task defined above is summarized in Figure 1.2-1. The first step is to develop scenarios of mission models to provide a range of environments to consider in establishing TDAS communication requirements. Based on the mission models the next step is to define the potential user demand in terms of data volume and the capabilities required to support data communications and navigation/tracking functions. The last step is to examine the impact of various design parameters on the potential user demand. These design parameters include the use of on-board processign, mass storage limitations and scheduling inefficiencies. Further details of the methodology at each step are presented below.

1.2.1 Scenarios of Mission Models

Scenarios of mission models are developed from the experiments/missions identified in Task 1* and other support missions (Shuttle, OTV, HLLV, etc.)** Several scenarios are developed to reflect a range of free flyer vs space platform usage as well as constant vs increased levels of NASA activity. Each scenario includes tabulations of missions with flight schedules and communication requirements to help describe the TDAS environment. To assess the impact of supporting military missions, two scenarios based on an earlier STI study [11] are also included.

1.2.2 Navigation/Tracking Requirements

Communication requirements to support navigation/tracking functions are developed for various potential navigation techniques identified in Tasks 1 and 2 [1, 2]. These provide a range of options to consider in establishing the TDAS environment. For those navigation/tracking options requiring direct TDAS support, contact requirements are derived for each experiment/mission.

1.2.3 Communication Requirements

Communication requirements to support data communication functions are developed from user data volumes compiled in each scenario of mission models. The requirements are presented in terms of the distribution of the data volume as a function of time and related contact time requirements. The incremental effect on TDAS data communications requirements of supporting military missions is obtained by adding in the military scenarios of mission models.

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* See Appendix A.

** A brief description of these support vehicles or systems is given in Section 2.

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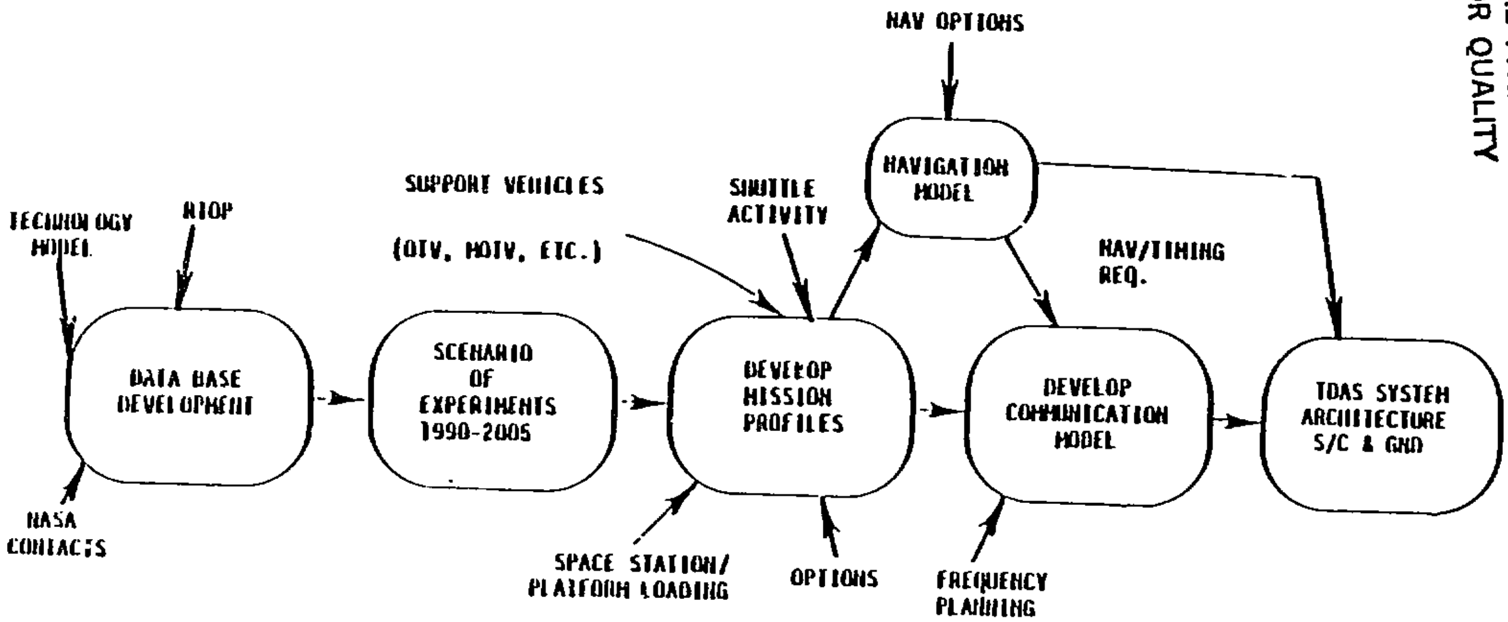
FIGURE 1.2-1

TDAS COMMUNICATIONS MODEL - METHODOLOGY



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1.2.4 Requirements Tradeoffs

Potential tradeoffs between the communication requirements and various design parameters have been identified. The design parameters include the use of mass storage on the user spacecraft, the use of data compression on the user spacecraft and the scheduling inefficiencies and acquisition time of the TDAS system. The tradeoff between the requirements and these design parameters is presented as a series of parametric curves.

1.3 SYNOPSIS

This task develops a parametric description of the communication requirements between the user spacecraft to be supported and the user ground data systems. Section 2 defines the scenarios of mission models based on scenarios of experiments from Task 1 [1], and inputs relating to various support vehicles and data on potential military users derived from [11]. Section 3 develops the communication requirements to support the navigation/tracking functions. Section 4 identifies the "busy day" scenarios for each scenario of mission models and develops communication requirements based upon each " busy day" scenario. Also in Section 4, the requirements tradeoffs are presented. Section 4 ends with an example illustrating the use of the requirements.

1.4 NEW TECHNOLOGY

There were no new technology developments under this task.

SECTION 2

SCENARIOS OF MISSION MODELS

Four scenarios of mission models were developed to provide a range of environments to consider in establishing TDAS communication requirements. This section presents an overview of the methodology employed, details on the assignment of experiments to vehicles and the resulting scenarios of mission models.

2.1 DEFINITIONS

A mission model is the simulation of an assumed mission/experiment which could be flown in the TDAS planning period, 1990-2005. A scenario of mission models is a tabulation of mission models along with flight schedules and other pertinent characteristics which describe the TDAS communication environment.

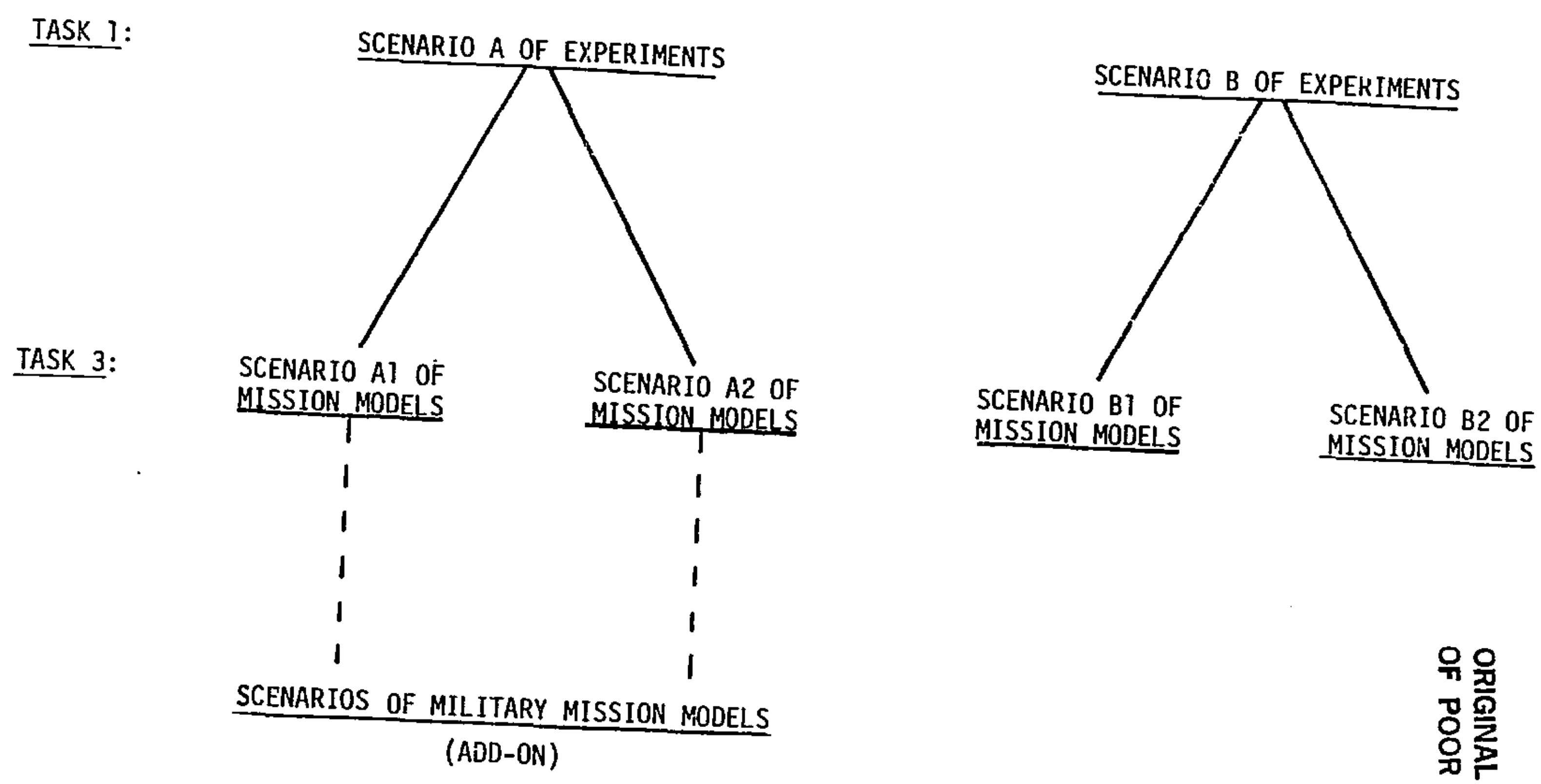
Figure 2.1-1 shows the relationship between the scenarios of experiments developed in Task 1 (see Appendix A) and the four scenarios of mission models. Scenario A1 is based upon NASA constant activity planning at the current level. This includes one second-order Power Utilization Platform (PUP)* and one Space Operations Center (SOC) in low earth orbit. Experiments/missions which cannot be loaded onto the PUP or SOC are defined as free-flyers. Scenario A2 modifies the present NASA planning by adding additional space platforms in order to minimize the number of free-flyers. The characteristics of these additional platforms are those of the PUP except for the capacity of the communication system.

Scenario B1 is based upon an increase in NASA activity and contains two second-order PUPs and one SOC in low earth orbit. The major difference between Scenarios B1 and A2 is the number of experiments/missions to be

* Scenario A1 was updated after completion of the communications mission model to delete the PUP.

FIGURE 2.1-1

RELATIONSHIP OF SCENARIOS OF EXPERIMENTS TO SCENARIOS OF MISSION MODELS



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flown. As in Scenario A2, experiments/missions which cannot be loaded onto the PUPs or SOC are free-flyers. Scenario B2 adds an additional platform in order to minimize the number of free-flyers.

Two scenarios of military mission models are introduced for assessing the incremental effect of supporting certain military missions with TDAS.

2.2 METHODOLOGY

Figure 2.2-1 illustrates the methodology used to develop the scenarios of mission models for the TDAS. The primary input used in this development was the scenarios of experiments developed as part of the TDAS User Community Characteristics (Task 1) [1]. The majority of the effort for the mission model development was: (1) to assign the experiments/missions to vehicles (i.e., Shuttle, SOC, PUP, etc.), (2) to estimate the amount of TDAS support to the Shuttle and (3) to estimate the amount of TDAS support to the support systems (i.e., HLLV, OTV, TMS, etc.).

The vehicles that will fly and/or service the experiments include:

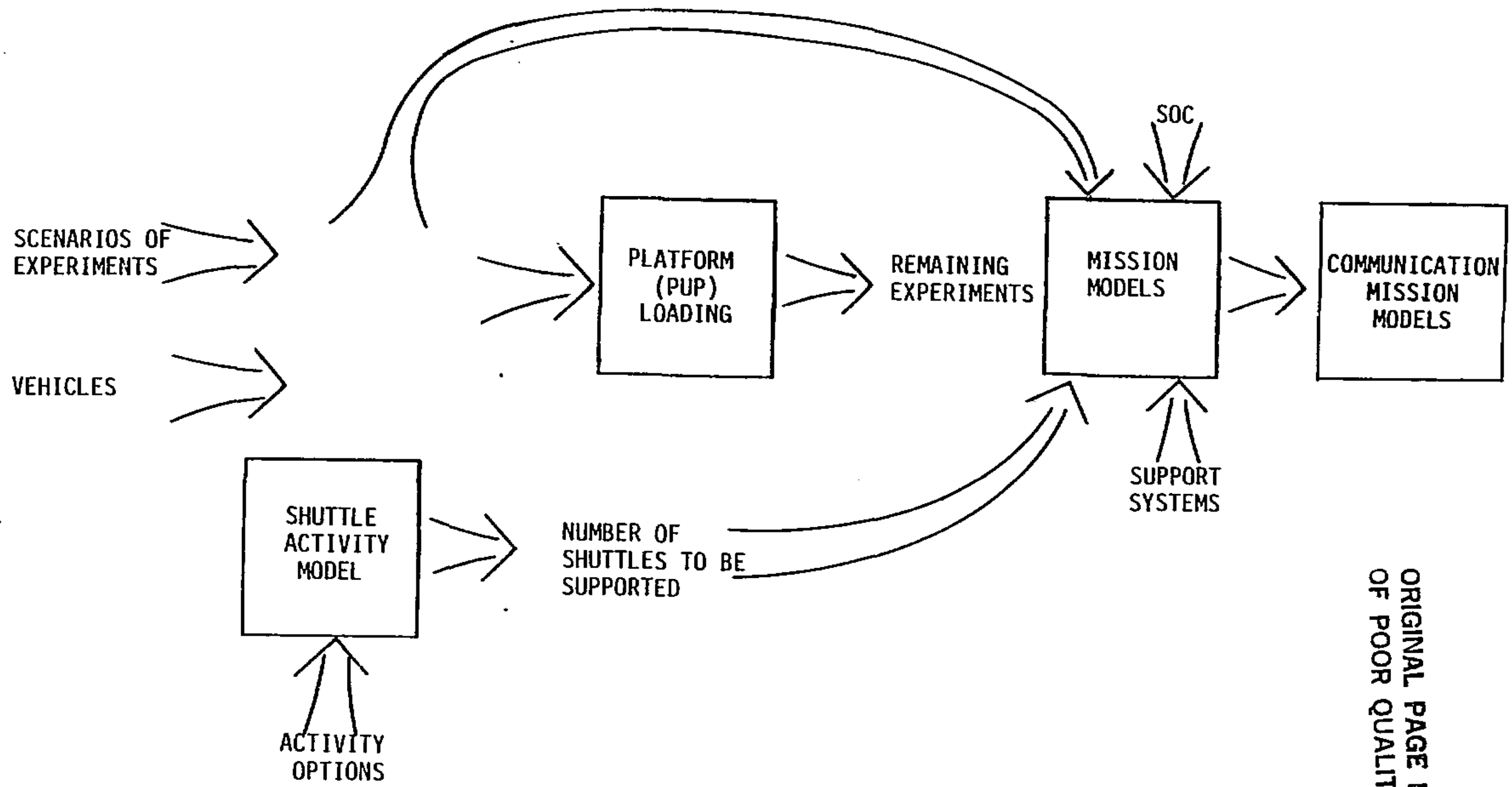
- Power Utilization Platform (PUP)
- Space Operations Center (SOC)
- Shuttle
- Heavy Lift Launch Vehicle (HLLV)
- Orbital Transfer Vehicle (OTV)
- Teleoperator Manuevering System (TMS)
- Manned GEO Sortie (MGS)

where the last four are support vehicles.

During the development of the scenarios of experiments, all experiments/missions designed to be flown on the Shuttle were screened on the basis that the experiments/missions would use the Shuttle's communication system. As a result, the remaining item is to estimate the number of Shuttles that must be supported by TDAS. A Shuttle activity model was developed to provide this information.

FIGURE 2.2-1

SCENARIOS OF MISSION MODELS - METHODOLOGY



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The PUP is a space platform that will support a number of simultaneous experiments/missions. The scenarios of experiments were analyzed to identify those experiments/missions which could be flown on the PUP. Based upon potential flight schedules, the number of PUP berthing ports and orbit parameters, the experiments/missions were loaded onto the one or more PUPs. The remaining experiments were considered free-flyers.

The scenarios of mission models are then tabulated in terms of the missions to be flown and their flight schedule during the TDAS planning period (1990-2005).

2.3 POWER UTLIZATION PLATFORM (PUP)

The PUP is a Shuttle deployed and Shuttle tended facility placed in low earth orbit for an indefinite life. The PUP provides stability, pointing, communications, power and thermal dissipation services to payloads which are transported to and from the platform by the Shuttle. The payloads can operate berthed to the platform for extended periods of time.

The baseline first-order design for the PUP [7] is an 11-12 KW system with facilities to berth with and operate at least three payload complements. The following payload resources will be provided at each payload berthing port:

- Electrical power up to the system limit of 11-12 KW (both regulated 30 volt and unregulated ~ 150 volt DC).
- Thermal dissipation (through a quick disconnect fluid loop) at least equal to the power level.
- Command and data transmission services (data packetization is planned with a peak throughput of 300 Mbps).
- Pointing and stability levels of sub-arcmin and 1-10 arcsec, respectively, are envisioned if a payload mounted fine pointing

sensor is utilized in the platform guidance loop. Payload unique fine pointing systems are also possible.

The operational modes for the PUP will include the free flying platform mode and the Shuttle attached or sortie mode. The primary operating mode is the unmanned free flying platform. The Shuttle attached or sortie mode would be utilized to:

- Exchange payloads.
- Perform platform maintenance and repair.
- Grow the platform capabilities at a future date.
- Extend the Orbiter on-orbit stay time as necessary to accomplish the above tasks and to conduct longer Shuttle experiments if that requirement develops.

The orbital inclination of the initial Power Utilization Platform has not been finalized but the system, from an operational standpoint, can be flown in any inclination from 28.5° to 98°.

The PUP program* is currently in the system definition and preliminary design phase and it is an FY 83 new start candidate with an anticipated IOC in mid FY 87. The PUP evolutionary growth options to an enhanced capability are also being analyzed in conjunction with the definition of the initial platform capability. Three principal evolutionary paths have been identified: Replication of the initial system for use in the same or other orbital inclinations, Growth in subsequent platform acquisitions or by physical modification of the initial platform, and Development of a new system for each new level of platform payload requirements.

* The PUP program and SOC program are currently being combined with either one but not both becoming a candidate for a new start in 1984. The impact of the NASA decision will be presented as a series of footnotes in this report.

The first platform assumed to be available in the 1990s will be a second-order PUP, having six berthing ports for experiment pallets. The choice of orbit inclinations for the 1990's will be either 28.5°, 63° or 98°. In some scenarios, two or more second-order platforms are assumed to be available, each having 6 berthing ports. Experiment lifetimes will be used to define the active duration of the experiment on a platform.

2.3.1 Candidate Experiments/Missions

During the SASP Accomodation Study [7], payloads were deemed unsuitable for a platform for the following reasons:

- Experiment is too large
- Experiment requires all-sky coverage
- Experiment operation is too complicated
- Experiment requires low accelerations
- Experiment requires multiple orbits

By using this same criteria, the following experiments were declared free-flyers:

- Space Telescope (already a free-flyer)
- AXAF (already a free-flyer)
- Gravity Wave Interferometer (too large)
- VLBRI (too large)
- COSMIC/100-M (too large)
- MAGSAT (low accelerations)
- Infrared Interferometer (too complicated/too large).

The remaining experiments/missions identified in Task 1 are considered candidates for the PUP.

2.3.2 28.5° PUP (P1)

Based upon the SASP Payload Accomodations Study, the six berthing ports on the second order PUP will support nine instruments for the average

PUP loading. Since one berthing port will be dedicated to materials experimentation, five ports are available for instruments. During the data collection, the number of instruments associated with each experiment/mission was determined. The corresponding berthing requirements per experiment are given in Table 2.3-1.

All experiments applicable to a 28.5° orbit inclination were considered for scheduling on the platform. Figure 2.3-1 shows the selected PUP payloads for the TDAS time frame under the assumption of constant activity. This PUP, designated P1A, is about 75% loaded on the average. Figure 2.3-2b shows the resulting PUP payloads for the TDAS time frame under the assumption of increased activity. This PUP, designated P1B, is about 96% loaded on the average.

2.3.3 Polar PUP (P2)

The polar PUP will be in a sun synchronous orbit with an altitude of 705 km and an inclination of 98°. The nodal crossing time has been set at 0930 LST as a compromise between the various meteorology, ocean and land observing instruments as recommended in the SASP Payload Accomodations Study [7]. This second order PUP will have five earth pointing berthing ports.

The resulting platform will be almost exclusively an operational platform, i.e., almost all instruments will be associated with one of the operational systems. The capacity of the PUPs communication system had to be increased to 2 X 10^{13} bits per day to handle the data from the various instruments. Otherwise all characteristics of the PUP are unchanged.

Figure 2.3-2a shows the resulting PUP payloads for the TDAS time frame under the assumption of constant activity. Figure 2.3-2b shows the resulting payloads under the assumption of increased activity. This PUP, designated P2B is about 69% loaded.

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TABLE 2.3-1

POSSIBLE EXPERIMENT ACCOMMODATIONS ON PUP

CATEGORY	EXPERIMENT	# INSTRUMENTS	# PORTS
Astrophysics	Large OPT./UV Telescope		1
	LAMAR	1	1
	Orbiting Submm Telescope	3	2
	LADIR	1	1
	AG-1,2,3,4	-	1
	X-Ray Observatory	6	4
	AG-5	-	4
	AG-6,7	-	1
Solar-Terrestrial	SCADM	6	4
	SG-1,3,5	6	4
	Solar Terrestrial Observatory	-	1
	SG-2,4	-	1
Resource-Observation	MAGSAT B	2	1
	Soil Moisture	-	1
	OERS	-	1
	RG-1,2,3	-	1
Global Environment	Advanced Thermal Mapper	-	1
	RG-4	-	1
	TOPEX	-	3
	EG-2,5,6,8	-	3
	OSAR	1	1
	EG-1,3,4,7	-	1
Meteorology	Meteorology	-	2

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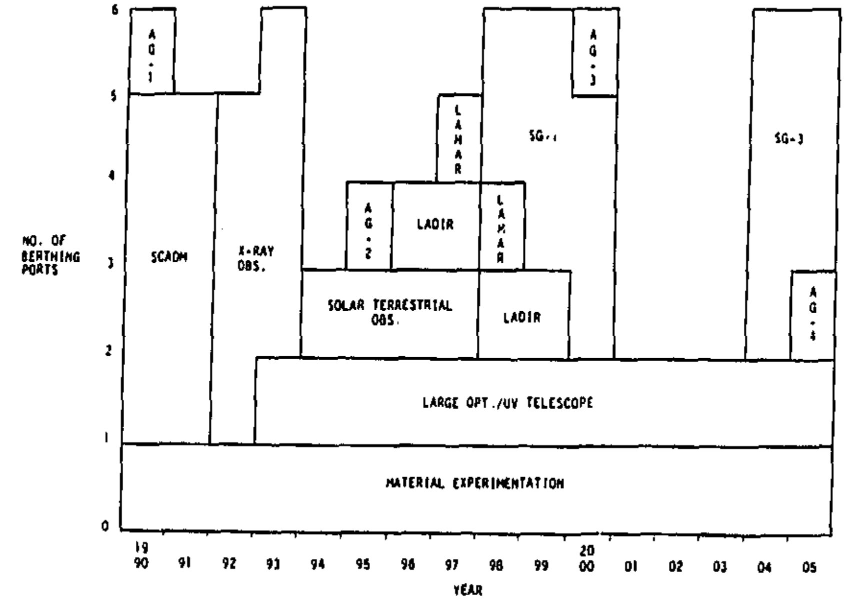
FIGURE 2.3-1

EXPERIMENT LOADING FOR PUP-P1 (400 KM/28.5° ORBIT)

a) PUP-P1A (CONSTANT ACTIVITY, 75% LOADED)



b) PUP-P1B (INCREASED ACTIVITY, 96% LOADED)

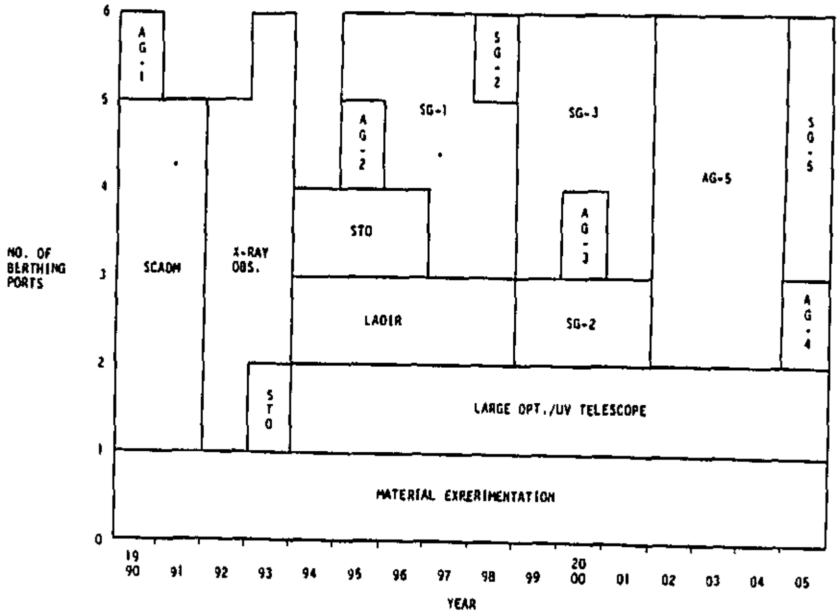


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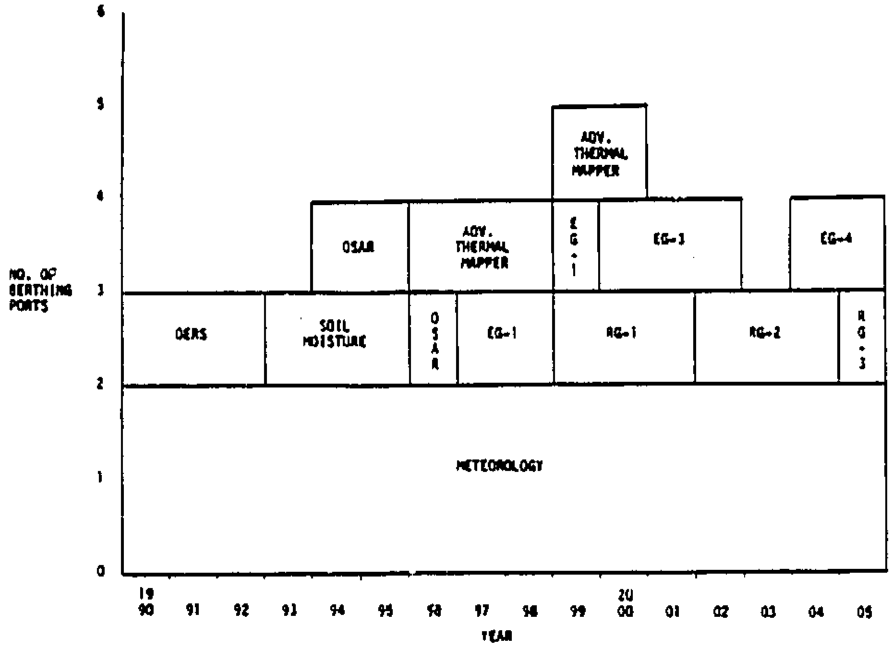
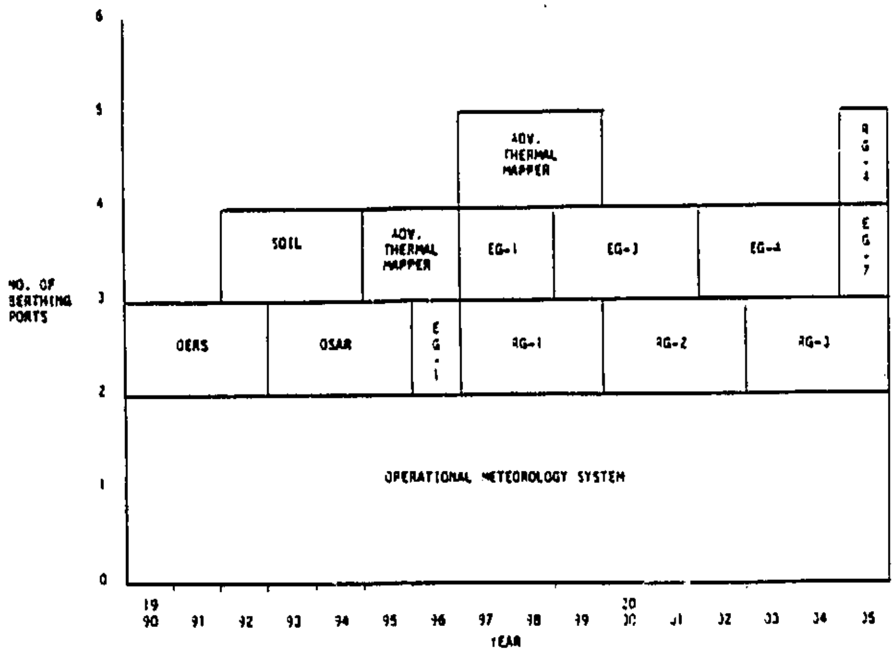
FIGURE 2.3-2

EXPERIMENT LOADING ON PUP-P2 (705 KM/98° ORBIT)

a) PUP-P2A (CONSTANT ACTIVITY, 63% LOADED)



b) PUP-P2B (INCREASED ACTIVITY, 69% LOADED)



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2.3.4 63° PUP (P3)

For scenario B2 an additional platform was assumed to operate in a 63° orbit at an altitude of 1330 km. It accomodats ocean observing instruments. The choice of instruments for this platform was sparse and as a result the platform utilization is not very good. The navigation requirements of the loaded instruments are severe and include TOPEX and similar generic experiments as shown in Figure 2.3-3.

2.4 SPACE OPERATIONS CENTER (SOC)*

The SOC is a shuttle-serviced, permanently manned facility in low earth orbit for operational support of space activities in the 1990s. The SOC is planned to evolve from the PUP space platform with the addition of habitability modules. The approach is to have the SOC as a permanent manned facility in low earth orbit (LEO) and to transfer extended timeline missions from the shuttle to the SOC. Additionally, the SOC will be used for satellite and platform servicing as well as staging for high energy missions.

For constant activity scenarios initial operation of the SOC is assumed to be in 1994.** For increased activity scenarios initial operation will occur in 1992.

2.5 SHUTTLE

As discussed previously, all experiments/missions utilizing the Shuttle's communication system were deleted from the scenario of experiments. Consequently, the remaining problem is to estimate the number of Shuttles which must be supported by TDAS. In order to arrive at this estimate, the following assumptions were invoked:

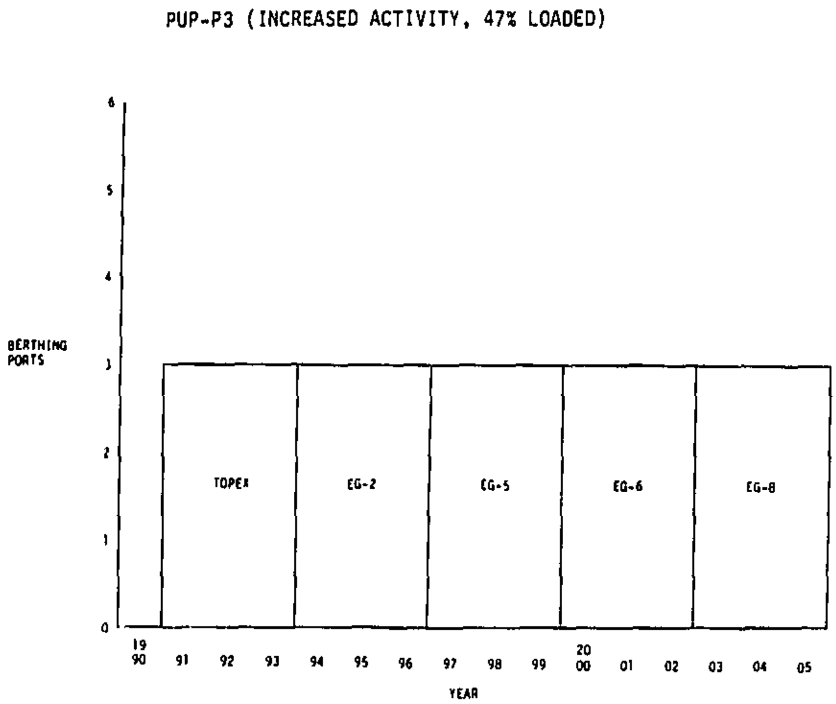
---

* PUP and SOC will not co-exist based upon current NASA planning.

** Revised to be mid 1990.

FIGURE 2.3-3

EXPERIMENT LOADING ON PUP-P3 (1330 KM/63° ORBIT)



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- NASA will procure the fifth Shuttle based on constant activity planning and will procure the sixth and seventh Shuttle based on increased activity planning.

- With 5 shuttles, 37 flights per year are possible and with 7 shuttles, 55 flights per year are possible. All possible flights will be made each year.

- NASA will support Department of Defense Shuttle flights with TDAS.

The Flight Assignments for Committed Payloads [8] were obtained from NASA Headquarters and contain the Shuttle flight schedule through February 1987. An analysis of this schedule provided the following distribution of flight durations for the Shuttle:

Flight Duration (Days)	Probability
2	3/47
3	7/47
5	7/47
7	30/47

Since the Shuttle will be modified to also support 14- and 30-day missions, a distribution of flight durations for the Shuttle in the TDAS time frame is assumed to be:

Flight Duration (Days)	Probability
3	1/8
5	1/8
7	1/2
14	1/8
30	1/8

This implies an average flight duration of 10 days.

For constant activity (37 flights per year), 370 Shuttle days of support must be provided, i.e., slightly more than one Shuttle must be supported by TDAS. Thus,

- One Shuttle will usually be in orbit
- Two Shuttles will sometimes be in orbit
- Three Shuttles will never be in orbit (this is assumed).

For increased activity (55 flights per year), 550 Shuttle days of support must be provided, i.e., approximately one and a half Shuttles must be supported by TDAS. Thus,

- One Shuttle will always be in orbit
- Two Shuttles will usually be in orbit
- Three Shuttles will sometimes be in orbit.

In order to account for any optimism in the flight duration distributions, TDAS should be sized to support one Shuttle continuously and a second Shuttle one-half of the time. The remaining time, i.e., when two Shuttles are not flying simultaneous missions, can be scheduled for other missions. For the increased budget, TDAS should be sized to support two Shuttles simultaneously and a third Shuttle ten percent of time. As before, the remaining time on the third Shuttle channel can be scheduled for other missions.

2.6 HEAVY LIFT LAUNCH VEHICLE (HLLV)

The HLLV will be an unmanned launch vehicle capable of placing up to 84,000 kg in low earth orbit. The HLLV must be supported from launch to payload deployment by TDAS. Although a launch schedule for the HLLV has not been defined by NASA, the HLLV has modest data rate requirements (16 kbps return, 2 kbps forward). As a result, the mission model will include support to one HLLV continuously. Initial flights of the HLLV have been assumed to occur in 1996.

2.7 ORBITAL TRANSFER VEHICLE (OTV)

The OTV is a large transfer vehicle which will be used to place spacecraft and/or assemblies into higher orbit. The OTV may also be used with the Manned GEO Sortie to carry men to GEO and return to LEO. The OTV will have a slow scan TV with a return data rate of 6 Mbps (possibly processed to 2 Mbps) and a forward data rate of 2 kbps. The ground personnel will use the TV to monitor the OTV environment once per orbit for 45 minutes. The flight activity profile for the OTV has not been determined. For purposes of the mission model, one OTV will be supported continuously with 8 contacts per day and 0.75 hours per contact starting in 1990.

2.8 TELEOPERATOR MANEUVERING SYSTEM (TMS)

The TMS is a support system which provides remotely manned placement and retrieval of satellites, maintenance and repair of satellites and servicing operations. The TMS will initially be launched in the late 1980's and will be active in the tDAS time frame. Present operational concepts include man-in-the-loop control from a ground site via TDRSS and eventually TDAS.

During a TMS mission, continuous contact with the TMS via TDAS will be required. For the purposes of the mission model, it will be assumed that 3 TMS's will be procured based on constant activity and 4 with increased activity. It will furhter be assumed that each TMS will require TDAS support for four one-day missions each month with 24 hour contact during each TMS mission.

2.9 MANNED GEO SORTIE

The manned GEO sorties is a manned orbital transfer vehicle (MOTV) to be used to service spacecraft at GEO. Flights for this vehicle will begin in the year 2000 with constant activity and 1998 with increased activity. There will be only one vehicle in the planning period through 2005. For purposes of the mission model, the manned GEO sortie will be assumed to have a seven day mission each month with 24 hour contact during each mission.

2.10 REAL-TIME COMMUNICATION REQUIREMENTS

Several of the missions identified above have a requirement for real-time communications during their mission duration. Typically, continuous requirements involve voice and TV transmissions as well as data required to monitor the health and well being of the satellite. The non-continuous requirements involve real-time return of science data. Real-time continuous forward link requirements have also been identified. These requirements are identified and discussed below.

2.10.1 Power Utilization Platform

A real-time continuous return link having a data rate of 50 kbps is required by the PUP to monitor the health and well being of the platform and associated experiments.

2.10.2 Space Operations Center

A real-time continuous return link having a data rate of 50 Mbps is required by the SOC. The return link will transmit digitized TV (2 channels) and 1 Mbps of data to monitor the health and well being of the station. In addition several voice channels are included.

The SOC also requires a 1 Mbps real-time continuous forward link consisting of voice and data. An optional requirement for 22 Mbps of digitized TV on the forward link has also been identified.

2.10.3 Orbital Transfer Vehicle

A real-time return link having a data rate of 6 Mbps is required by the OTV once every 2 hours for 0.75 hours. The return link will transmit slow-scan TV and data.

2.10.4 Teleoperator Maneuvering System

For the duration of the TMS mission, a real-time continuous return link is required having a data rate of 15 Mbps. The return link will transmit slow-scan TV (2 channels) and data. In addition, a real-time continuous forward link having a data rate of 4kbps is required for interactive control of the TMS from the ground site.

2.10.5 Manned Orbital Transfer Vehicle

For the duration of the MOTV mission, a real-time continuous return link is required having a data rate of 15 Mbps. The return link will transmit slow-scan TV (2 channels), data and voice. In addition, a real-time continuous forward link having a data rate of 20 kbps is required to transmit voice and data.

2.10.6 Heavy Lift Launch Vehicle

For the duration of the HLLV mission (launch through return to earth), a 16 kbps real-time continuous return link is required and a 3 kbps real-time continuous forward link is required for interchange of commands and data.

2.10.7 Shuttle

For the duration of the Shuttle mission, a 192 kbps real-time continuous return link is required which contains voice and data. In addition, real-time TV is intermittantly transmitted on a 4.5 MHz analog channel. The forward link (real-time continuous) has a data rate of 72 kbps and contains voice and data.

2.10.8 Other Missions

For all other missions, it is assumed that the engineering data required to monitor the health and well being of the satellite will be returned in real-time and continuously.

2.10.9 Advanced Land Observing System (ALOS)

ALOS will perform land observatins only during daylight over land. For the purposes of the mission model, the ALOS will be assumed to generate science data only over daylight land which corresponds to about 240 minutes per day of data collection. There is a strong possibility that ALOS will not use a dump mode for returning science data for the following reasons:

1. Quick look data is required one hour after the data collection.

2. Space qualified tape recorders at the required high data rates are large and at least two are required for simultaneous record and playback.

3. The data is collected each orbit ranging from 6 to 32 minutes per orbit with an average of 17 minutes per orbit. There are, on the average, 14 orbits per day.

Assuming that ALOS will not use a dump mode for transmission of science data, real-time scheduling for return of the science data must be implemented so that the science data can be transmitted as it is being collected.

2.10.10 Space Telescope

The space telescope has a requirement for real-time return of science data at a data rate of 1.024 Mbps for 10 minutes each orbit or for 60 minutes per orbit for four orbits once per week. This requirement is in addition to the real-time continuous return of engineering data.

2.10.11 Very Long Baseline Radio Interferometer (VLBRI)

The VLBRI mission requires real-time return of its science data to the ground.

2.10.12 Shuttle Payloads

Some of the shuttle science payloads (e.g., SPACELAB) have requirements for real-time return of the science data via the shuttle's communication system. For example, typically Spacelab will require that the real-time return of science data will be required for 80-100 hours of the 168 hour mission. Since the Shuttle manifest is unknown for the 1990 to 2005 time frame, a reasonable approach is:

- 25% of the shuttle flights carry science paylaods (from shuttle manifest)
- Each science payload will require a dedicated real-time science channel for 100 hours during the mission.

The worst case scenario defined below will assume that both shuttles are carrying science payloads and require a 50 Mbps dedicated return channel. Typically, when two shuttles are in orbit, only one would carry a science payload.

2.11 SCENARIOS OF MISSION MODELS

The scenarios of mission models presented below are a tabulation of the information discussed above and the TDAS User Community Characteristics and Scenarios of Experiments from Task 1 [1]. Also included is a military mission model defining the characteristics of certain military satellites operating in the TDAS time frame.

2.11.1 Scenario A1

Figure 2.11-1* provides the mission models under the assumption of constant activity and presently planned platforms, one PUP (PIA) and a SOC.

* In Figure 2.11-1a, it has been assumed that NASA will implement the SOC and not the PUP. As a result, the experiments previously loaded on the PUP must now be free-flyers (experiments are not suitable for manned facility).

FIGURE 2.11-1

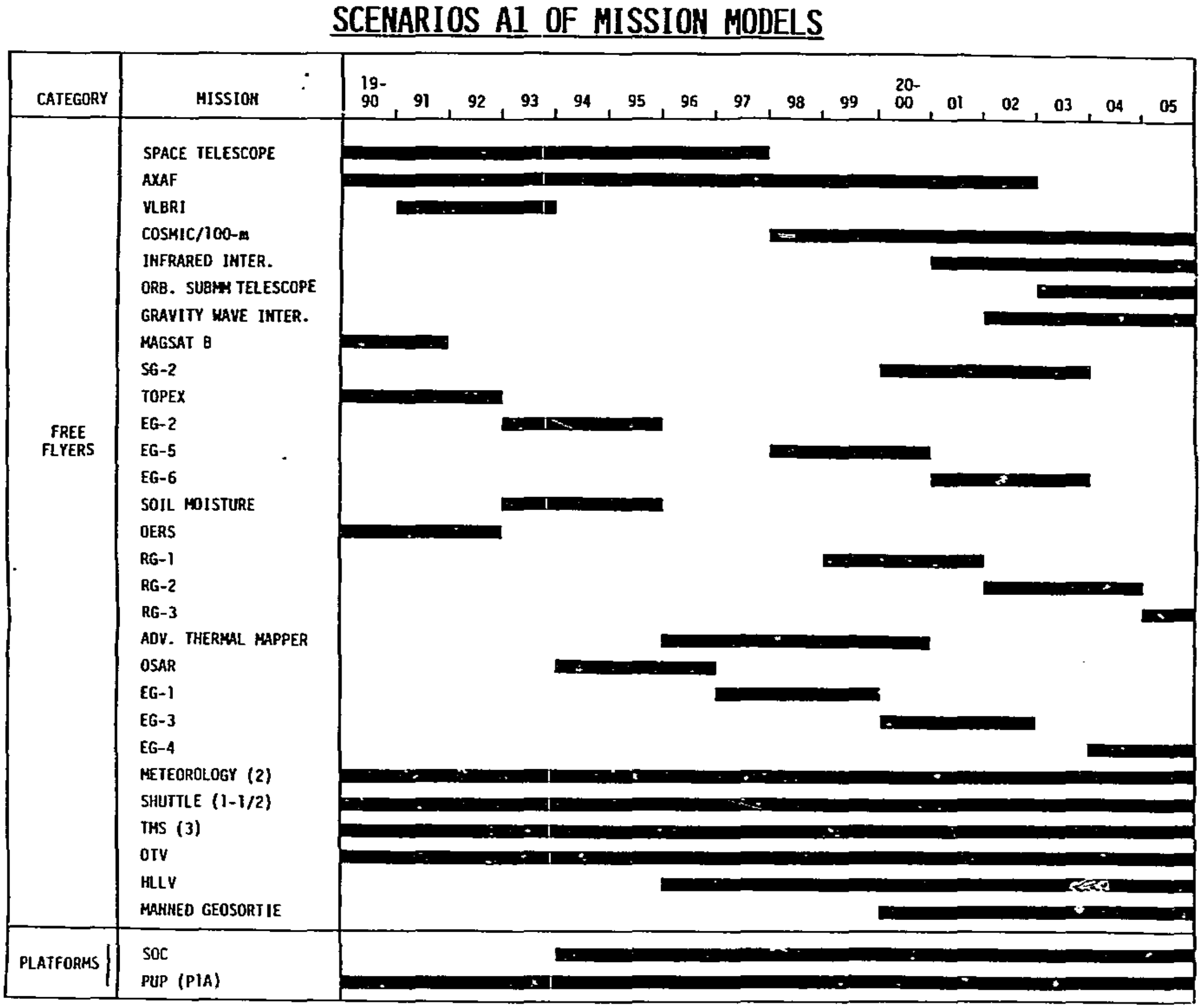

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FIGURE 2.11-1A: SCENARIOS A1 MISSION PROFILES, CONSTANT ACTIVITY, NO DOD

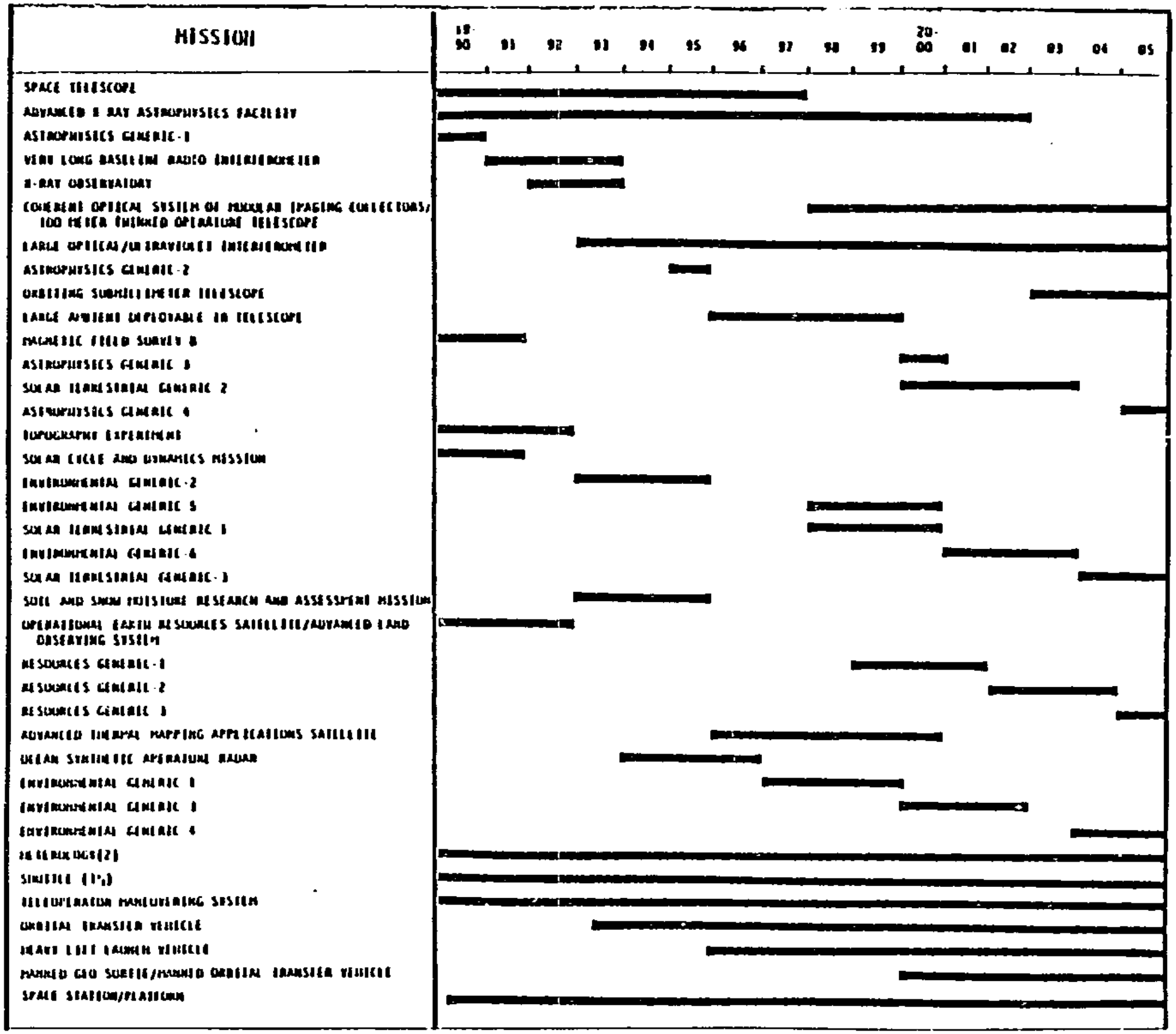

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Table 2.11-1 provides the communication and orbit characteristics of the various missions.

2.11.2 Scenario A2

Figure 2.11-2 provides the mission models under the assumption of constant activity and implementation of multiple platforms, two PUPS (PIA, P2A) and a SOC. Table 2.11-2 provides the communication and orbit characteristics of the various missions.

2.11.3 Scenario B1

Figure 2.11-3 provides the mission models under the assumption of increased activity with multiple platforms, two PUPS (P1B, P2B) and a SOC. Table 2.11-3 provides the communication and orbit characteristics of the various missions.

2.11.4 Scenario B2

Figure 2.11-4 provides the mission models under essentially the same assumptions as Scenario B1 plus implementation of an additional PUP (P3) beginning in 1991.* Table 2.11-4 provides the communication and orbit characteristics of the various missions.

2.11 5 Scenarios of Military Mission Models

Low and medium altitude missions corresponding to military mission models used in the Satellite Control System (SCS) Study [11] were taken directly as an input to this study. Table 2.11-5 provides the communication characteristics for two scenarios of mission models.

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* A corresponding one year slippage was assumed for TOPEX and EG-2 missions which are loaded on PUP-P3 in this scenario.

NOTE: plus those previously assigned to PUP.

TABLE 2.11-1
SCENARIO A1 CHARACTERISTICS

MISSION	COMMUNICATION CHARACTERISTICS						ORBIT PARAMETERS	
	SCIENCE DATA BITS/DAY	PROCESSED DATA VOL. BITS/DAY	EQUIVALENT REAL TIME DATA RATE	SCIENCE DMDS-DATA VOLUME	S/C CMDS-DATA VOLUME	BEGINNING DATA	ALTITUDE km	INCLINATION °
SPACE TELESCOPE	10^{10}		0.12	$3 X 10^{6}$	$6 X 10^{6}$	4kbps-RT		
AXAF	10^{8} - 10^{11}		0.01 - 1.2	$3 X 10^{6}$	$6 X 10^{6}$	4kbps-RT	600	28.8
VLBRI	10^{11} - 10^{18}		1.2 - 115.	$3 X 10^{6}$	$6 X 10^{6}$	2kbps-RT	450	28.5
COSMIC/100-m	10^{11}		1.2	$3 X 10^{6}$	$6 X 10^{6}$	2kbps-RT	400-5000	45
INFRARED INTERFEROMETER	10^{11}		1.2	$3 X 10^{16}$	$6 X 10^{6}$	2kbps-RT	500	28.5
ORB. SUBMM TELESCOPE	10^{5} - 10^{6}		$1.2X10^{6}$-$13X10^{6}$	$3 X 10^{6}$	$6 X 10^{6}$	2kbps-RT	400-700	28-57
GRAVITY WAVE INTERFEROMETER	10^{11}		1.2	$3 X 10^{16}$	$6 X 10^{6}$	2kbps-RT	1000	Sun-Sync
MAGSAT B	1.5 X 10 [illegible]		$1.7 X 10^{3}$	$3 X 10^{6}$	$6 X 10^{6}$	2kbps-RT	250	Any
SG-2	$3 X 10^{12}$		34.7	$3 X 10^{6}$	$6 X 10^{6}$	2kbps-RT	300	97
TOPEX	$7 X 10^{8}$		$8 X 10^{3}$	$1.4 X 10^{7}$	$3 X 10^{7}$	2kbps-RT	400	57
EG-2,5,6	$7 X 10^{8}$		$8 X 10^{3}$	$1.4 X 10^{7}$	$3 X 10^{7}$	2kbps-RT	1334	63.4
SOIL MOSITURE	$1 X 10^{7}$		$115 X 10^{6}$	10^{7}	$2 X 10^{7}$	2kbps-RT	500	63
OERS	10^{13}	$5 X 10^{12}$	115	$2.5 X 10^{8}$	$2.5X10^{8}$	2kbps-RT	400-700	60-98
RG-1,2,3	$1.5 X 10^{13}$	$5 X 10^{12}$	173	$1.5 X 10^{7}$	$3 X 10^{7}$	2kbps-RT	705	99
ADV. THERMAL MAPPER	$3 X 10^{9}$		0.035	$1.7 X 10^{7}$	$3.5X10^{7}$	2kbps-RT	700	98
OSAR	$2 X 10^{12}$		23	$3 X 10^{7}$	$3 X 10^{7}$	2kbps-RT	620	97.8
EG-1,3,4	$2 X 10^{12}$		23	$3 X 10^{7}$	$3 X 10^{7}$	2kbps-RT	790	Polar
METEOROLOGY (2)	$6 X 10^{10}$		0.69	$9 X 10^{6}$	$8 X 10^{7}$	8.32kbps-RT	790	98
SHUTTLE (1.5)	$<4 X 10^{12}$		50	$6 X 10^{9}$	72kbpsRT	192kbps-RT	830	98.7
TMS (3)	-	-	-	-	4kbps-RT	15Mbps-RT	185-1110	28-5-57
OTV	-	-	-	-	$4 X 10^{7}$	6Mbps-RT	1000	Various
HLLV	-	-	-	-	3kbps-RT	16kbps-RT	LEO-GEO	Various
MANNED GEO SORTIE	-	-	-	-	20kbps-RT	15Mbps-RT	200-500	Various
SOC	$<10^{13}$		100	$2.5 X 10^{10}$	1Mbps-RT	50Mbps-RT	370	Various
PUP (PIA)	$<10^{13}$		100	$2.5 X 10^{10}$	***	50kbps-RT	400	28.5

*** Included with science commands

RT - Real Time

(1) Also-TV-RT-Non-continuous

(2) Option for 22 Mbps TV

(3) 0.75 hours every 2 hours

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FIGURE 2.11-2

SCENARIO A2 OF MISSION MODELS

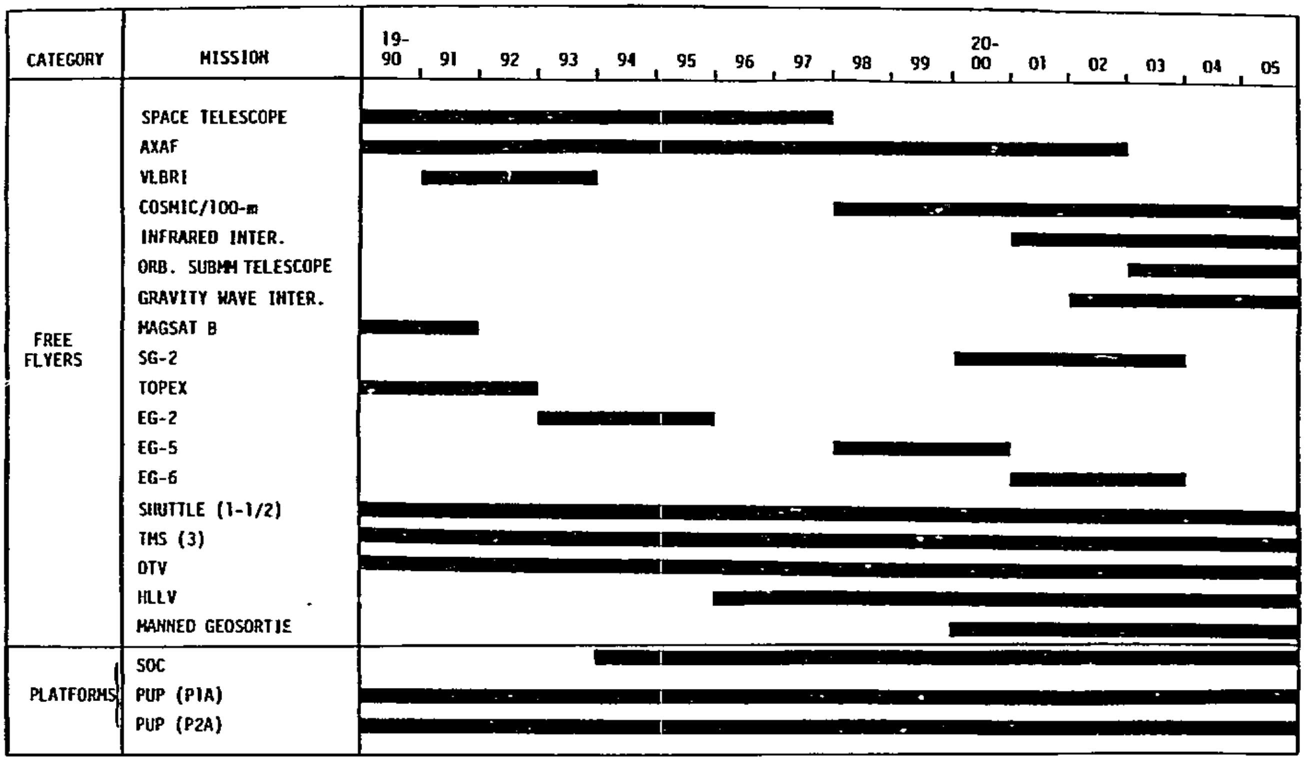

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TABLE 2.11-2

SCENARIO A2 CHARACTERISTICS

MISSION	COMMUNICATION CHARACTERISTICS						ORBIT PARAMETERS	
	SCIENCE DATA BITS/DAY	PROCESSED DATA VOL. BITS/DAY	EQUIVALENT REAL TIME DATA RATE/MBPS	SCIENCE CMDS-DATA	S/C CMDS DATA VOL BITS/DAY	ENGINEERING DATA	ALTITUDE km	INCLINATION °
SPACE TELESCOPE	10^{10}	-	0.12	3×10^6	6×10^6	4kbps-RT	600	28.8
AXAF	$10^9 - 10^{11}$	-	0.01 - 1.2	3×10^6	6×10^6	4kbps-RT	450	28.5
VLBRI	$10^{11} - 10^{13}$	-	1.2 - 115	3×10^6	6×10^6	2kbps-RT	400-5000	45
COSMIC/100-m	10^{11}	-	1.2	3×10^6	6×10^6	2kbps-RT	500	28.5
INFRARED INTERFEROMETER	10^{11}	-	1.2	3×10^6	6×10^6	2kbps-RT	400-700	28-57
ORB. SUBMM TELESCOPE	$10^5 - 10^6$	-	$1.2 - 12 \times 10^{-6}$	3×10^6	6×10^6	2kbps-RT	1000	Sun-Sync
GRAVITY WAVE INTERFEROMETER	10^{11}	-	1.2	3×10^5	6×10^6	2kbps-RT	250	Any
MAGSAT B	1.5×10^8	-	1.7×10^{-3}	3×10^6	6×10^6	2kbps-RT	300	97
SG-2	2×10^{12}	-	34.7	3×10^6	6×10^6	2kbps-RT	406	57
TOPEX	7×10^8	-	8×10^{-3}	1.4×10^7	3×10^7	2kbps-RT	1334	63.4
EG-2,5,6	7×10^8	-	8×10^{-3}	1.4×10^7	3×10^7	2kbps-RT	500	63
SHUTTLE (1.5)	$< 4 \times 10^{12}$	-	50	6×10^9	72kbps-RT	192kbps-RT	185-1110	28.5 - 57
TMS (3)	-	-	-	-	4kbps-RT	15Mbps-RT	1000	[illegible] - 104 Various
OTV	-	-	-	-	4×10^7	6Mbps-RT	LEO-GEO	Various
HLLV	-	-	-	-	3kbps-RT	16kbps-RT	200-500	Various
MANNED GEO SORTIE	-	-	-	-	20kbps-RT	15Mbps-RT	370	Various
SOC	$< 10^{13}$	-	100	2.5×10^{10}	1Mbps-RT	50Mbps-RT	400	28.5
PUP (P1A)	$< 10^{13}$	-	100	2.5×10^{10}	***	50kbps-RT	400	28.5
PUP (P2A)	2×10^{13}	7×10^{12}	231	2.5×10^{10}	***	50kbps-RT	705	98

See Table 2.11-1 for notes.

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FIGURE 2.11-3

SCENARIO B1 OF MISSION MODELS

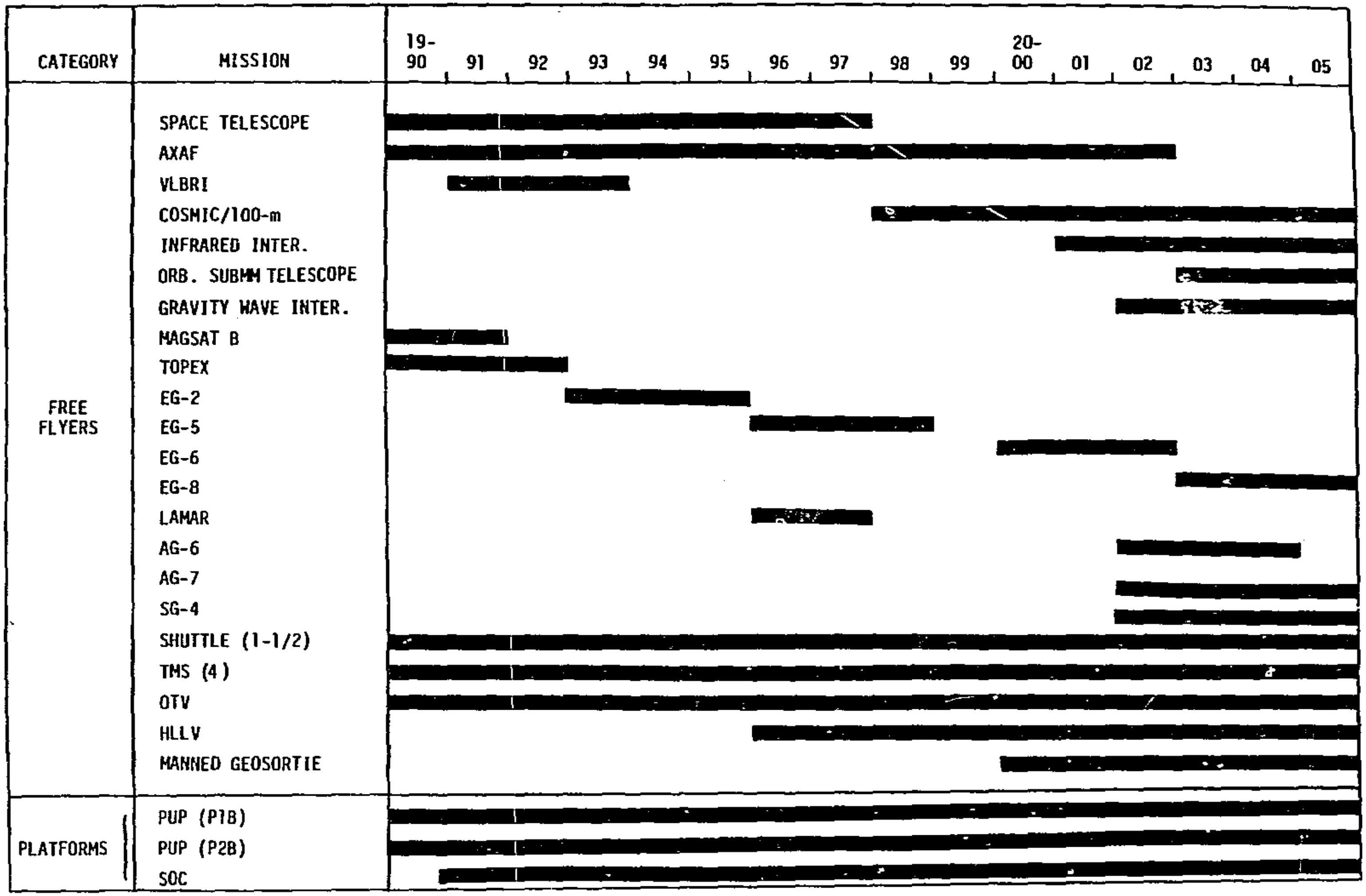

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TABLE 2.11-3

SCENARIO B1 CHARACTERISTICS

MISSION	COMMUNICATION CHARACTERISTICS							
	SCIENCE DATA BITS/DAY	PROCESSED DATA VOL. BITS/DAY	EQUIVALENT REAL TIME DATA RATE	SCIENCE CMDS-DATA VOLUME BITS/DAY	S/C CMDS-VOLUME BITS/DAY	ENGINEERING DATA	ALTITUDE km	INCLINATION °
SPACE TELESCOPE	10^{10}	-	0.12 Mbps	3×10^6	6×10^6	4kbps-RT	600	28.8
AXAF	$10^9 - 10^{11}$	-	0.01 - 1.2	3×10^6	6×10^6	4kbps-RT	450	28.5
VLBRI	$10^{11} - 10^{13}$	-	1.2 - 115	3×10^6	6×10^6	2kbps-RT	400 - 5000	45
COSMIC/100-m	10^{11}	-	1.2	3×10^6	6×10^6	2kbps-RT	500	28.5
INFRARED INTERFEROMETER	10^{11}	-	1.2	3×10^6	6×10^6	2kbps-RT	400 - 700	28-57
ORB. SUBMM TELESCOPE	$10^5 - 10^6$	-	$1.2 - 12 \times 10^{-6}$	3×10^6	6×10^6	2kbps-RT	1000	Sun-Sync
GRAVITY WAVE INTERFEROMETER	10^{11}	-	1.2	3×10^6	6×10^6	2kbps-RT	250	Any
MAGSAT B	1.5×10^8	-	1.7×10^{-3}	3×10^6	6×10^6	2kbps-RT	300	97
TOPEX	7×10^8	-	8×10^{-3}	1.4×10^7	3×10^7	2kbps-RT	1334	63.4
EG-2,5,6,8	7×10^8	-	8×10^{-3}	1.4×10^7	3×10^7	2kbps-RT	500	63
LAMAR	7×10^8	-	8×10^{-3}	3×10^6	6×10^6	2kbps-RT	400	28.5
AG-6,7	7×10^8	-	8×10^{-3}	3×10^6	6×10^6	2kbps-RT	400	28.5
SG-4	3×10^{12}	-	34.7	3×10^6	6×10^6	2kbps-RT	400	57
SHUTTLE (2.1)	$< 4 \times 10^{12}$	-	50	6×10^9	72kbps-RT	192kbps-RT	185 - 1110	28.5-57 70 - 104
TMS(4)	-	-	-	-	4kbps-RT	15Mbps-RT	1000	Various
OTV	-	-	-	-	4×10^7	6Mbps-RT	LEO-GEO	Various
HLLV	-	-	-	-	3kbps-RT	16kbps-RT	200 - 500	Various
MANNED GEO SORTIE	-	-	-	-	20kbps-RT	15Mbps-R	370	Various
SOC	$< 10^{13}$	-	100	2.5×10^{10}	1Mbps-RT	50Mbps-RT	400	28.5
PIIP(P1B)	$< 10^{13}$	-	100	2.5×10^{10}	***	50kbps-RT	400	28.5
PIIP(P2B)	2×10^{13}	7×10^{12}	231	2.5×10^{10}	***	50kbps-RT	705	98

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FIGURE 2.11-4

SCENARIO B2 OF MISSION MODELS

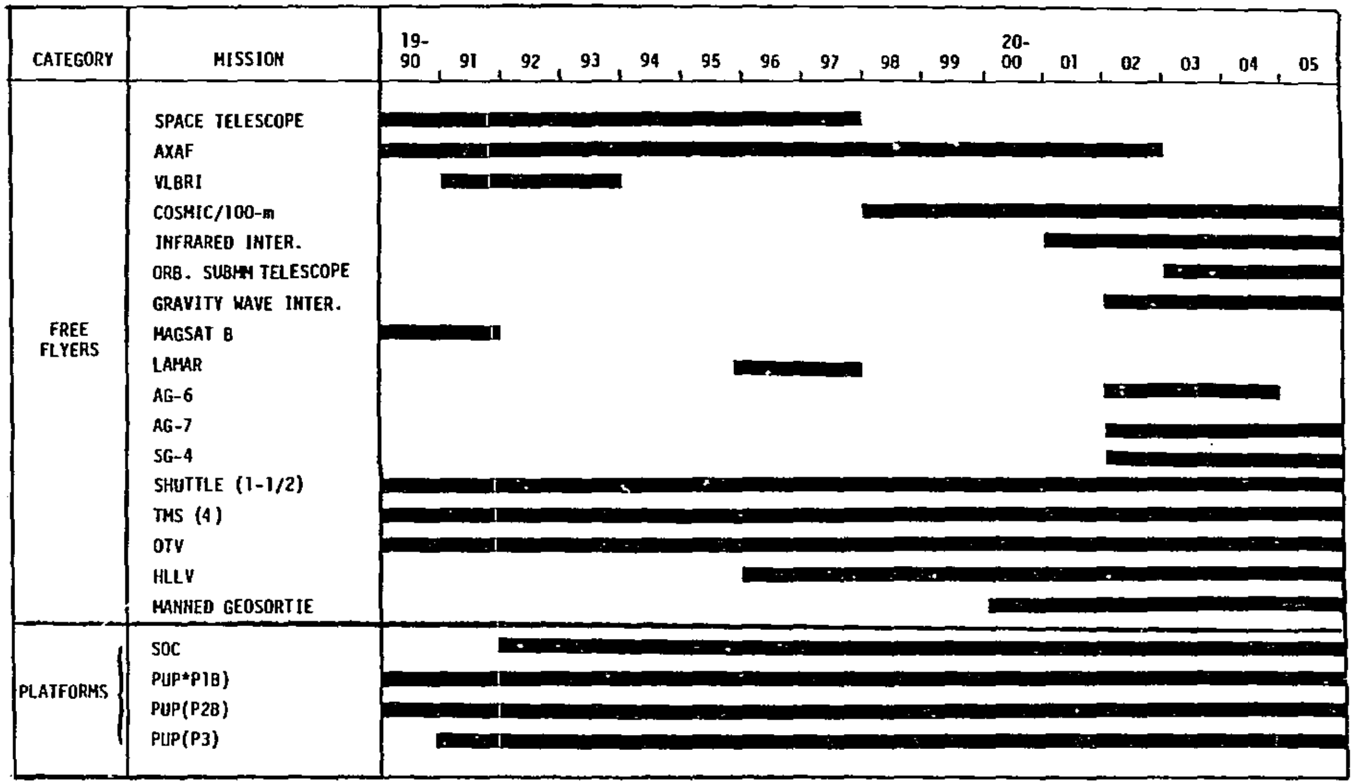

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TABLE 2.11-4

SCENARIO B2 CHARACTERISTICS

MISSION	COMMUNICATION CHARACTERISTICS							
	SCIENCE DATA BITS/DAY	PROCESSED DATA VOL. BITS/DAY	EQUIVALENT REAL TIME DATA RATE	SCIENCE CMDS-DATA VOL BITS/DAY	S/C CMDS VOL BITS/DAY	ENGINEERING DATA	ALTITUDE km	INCLINATION °
SPACE TELESCOPE	10^{10}	-	0.12	3 X 10^6	6 X 10^6	4kbps-RT	600	28.8
AXAF	10^9 - 10^{11}	-	0.01 - 1.2	3 X 10^6	6 X 10^6	4kbps-RT	450	28.5
VLBRI	10^{11} - 10^{13}	-	1.2 - 115	3 X 10^6	6 X 10^6	2kbps-RT	400-5000	45
COSMIC/100-m	10^{11}	-	1.2	3 X 10^6	6 X 10^6	2kbps-RT	500	28.5
INFRARED INTERFEROMETER	10^{11}	-	1.2	3 X 10^6	6 X 10^6	2kbps-RT	400-700	28-57
ORB. SUBMM TELESCOPE	10^5 - 10^6	-	1.2 - 12 X 10^{-6}	3 X 10^6	6 X 10^6	2kbps-RT	1000	Sun-Sync
GRAVITY WAVE INTERFEROMETER	10^{11}	-	1.2	3 X 10^6	6 X 10^6	2kbps-RT	250	Any
MAGSAT B	1.5 X 10^8	-	1.7 X 10^{-3}	3 X 10^6	6 X 10^6	2kbps-RT	300	97
LAMAR	7 X 10^8	-	8 X 10^{-3}	3.X 10^6	6 X 10^6	2kbps-RT	400	28.5
AG-6,7	7 X 10^8	-	8 X 10^{-3}	3 X 10^6	6 X 10^6	2kbps-RT	400	28.5
SG-4	3 X 10^{12}	-	34.7	3 X 10^6	6 X 10^6	2kbps-RT	400	57
SHUTTLE (2.1)	< 4 X 10^{12}	-	50	6 X 10^9	72kbps-RT	192kbps-RT	185-1110	28.5-57
TMS (4)	-	-	-	-	4kbps-RT	15Mbps-RT	1000	70 - 104 Various
OTV	-	-	-	-	4 X 10^7	6Mbps-RT	LEO-GEO	Various
HLLV	-	-	-	-	3kbps-RT	16kbps-RT	200-500	Various
MANNED GEO SORTIE	-	-	-	-	20kbps-RT	15Mbps-RT	370	Various
SOC	< 10^{13}	-	100	2.5 X 10^{10}	1Mbps-RT	50Mbps-RT	400	28.5
PUP (P1B)	< 10^{13}	-	100	2.5 X 10^{10}	***	50kbps-RT	400	28.5
PUP (P2B)	2 X 10^{13}	7 X 10^{12}	231	2.5 X 10^{10}	***	50kbps-RT	705	98
PUP (P3)	7 X 10^8	-	8 X 10^{-3}	2.5 X 10^{10}	***	50kbps-RT	1334	63.4

See Table 2.11-1 for notes.

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TABLE 2.11-5

DATA COMMUNICATION REQUIREMENTS FOR TWO SCENARIOS OF MILITARY MISSION MODELS [11]

PROGRAM	Total. Spacecraft	TLM Data Rate (KBps)	TLM Contacts/Day	TLM Hrs/Contact	TLM Entry Region	CMD Data Rate (KBps)	CMD Contacts/Day	CMD Hrs/Contact	MISSION Data Rate (MBps)	MISSION Contacts/Day	MISSION Hrs/Contact	MISSION Data Entry Regions in Conus	GLOBAL/Mobile Max. Data Rate (KBps)	Theater Nuclear Priority Assumed	ORBIT Location
S-3	8	128	6	0.8	4,5	5	6	0.8	10	6	0.8	4,5	0	1	Med
S-5	4	128	6	0.8	4,5	10	6	0.8	10	6	0.8	4,5	0	1	Low
S-7	4	128	6	0.8	4,5	2	6	0.8	10	6	0.8	4,5	0	2	Low
S-8	1	128	6	0.8	4,5	5	6	0.8	0	0	0	--	0	2	Low
S-9	1	128	6	0.8	4,5	5	6	0.8	0	0	0	--	0	2	Low
S-10	7	128	6	0.8	4,5	5	6	0.8	0	0	0	--	0	1	Med
S-11	4	128	6	0.8	4,5	5	6	0.8	0	0	0	--	0	1	Med
S-13	3	128	6	0.8	4,5	10	6	0.8	0	0	0	--	0	1	Low
C-1 DSCS	6	1	6	0.8	4,5	1	6	0.8	0	0	0	--	0	3	Sync
C-2 LEASAT	3	1	6	0.8	4,5	1	6	0.8	0	0	0	--	0	3	Sync
C-4 NATO	4	1	6	0.8	4,5	1	6	0.8	0	0	0	--	0	3	Sync
H-1 DMSP	3	10	6	0.8	4,5	1	6	0.8	6	6	0.8	4,5	0	1	Low
O-3 STP	2	32	6	0.8	4,5	2	6	0.8	20	6	0.8	4,5	0	3	Low
	3	32	6	0.8	4,5	2	6	0.8	20	6	0.8	4,5	0	3	Sync
O-4 SDS	3	1	6	0.8	4,5	5	6	0.8	0	0	0	--	0	2	12-Hr
TOTAL	40	NON-SYNCH													
	16	SYNCHRONOUS													

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TABLE 2.11-5 (CONTINUED)

DATA COMMUNICATION REQUIREMENTS FOR TWO SCENARIOS OF MILITARY MISSION MODELS [11]

PROGRAM	Total Spacecraft	TLM Data Rate (KBps)	TLM Contacts/Day	TLM Hrs/Contact	TLM Entry Region	CMD Data Rate (KBps)	CMD Contacts/Day	CMD Hrs/Contact	MISSION Data Rate (MBps)	MISSION Contacts/Day	MISSION Hrs/Contact	MISSION Data Entry Regions in Conus	GLOBAL/Mobile Max. Data Rate (KBps)	Theater Nuclear Priority Assumed	ORBIT Location
S-1	5	128	1	24	3,5	1	1	24	1.024	1	24	1,3	0	1	Sync
S-3	8	128	6	0.8	3,5	5	6	0.8	10	6	0.8	3,2	0	1	Med
S-5	4	128	1	6	3,3	10	1	6	10	1	6	3,5	0	1	Low
S-7	4	128	1	6	1,4	2	1	6	10	1	6	1,4	0	2	Low
S-8	1	128	6	0.8	4,5	5	6	0.8	0	0	0	---	0	2	Low
S-9	1	128	6	0.8	4,5	5	6	0.8	0	0	0	---	0	2	Low
S-10	7	128	6	0.8	4,5	5	6	0.8	0	0	0	---	0	1	Med
S-11	4	128	6	0.8	4,5	5	6	0.8	0	0	0	---	0	1	Med
S-12	3	128	1	24	4,5	10	1	24	1000	1	24	5,1	0	1	Sync
S-13	3	128	6	0.8	4,5	10	6	0.8	1000	6	0.8	1,3	0	1	Low
C-1 DSCS	6	1	6	0.8	3,5	1	6	0.8	0	0	0	--	0	3	Sync
C-2 FSC	3	1	6	0.8	4,5	1	6	0.8	0	0	0	--	0	3	Sync
C-3 SSS	4	1	6	0.8	3,5	1	6	0.8	0	0	0	--	0	3	5X
C-4 NATO	4	1	6	0.8	4,5	1	6	0.8	0	0	0	--	0	3	Sync
N-1 GPS		4	6	0.8	3,5	3	6	0.8	0	0	0	--	0	2	12-Hr
H-1 DISP	3	10	6	0.8	2,4	1	6	0.8	6	6	0.8	1,2,4	0	1	Low
O-3 STP	2	32	6	0.8	4,5	2	6	0.8	20	6	0.8	4	0	3	Low
	3	32	6	0.8	4,3	2	6	0.8	20	6	0.8	4	0	3	Sync
O-4 SDS	3	1	6	0.8	4,5	5	6	0.8	0	0	0	--	0	2	12-Hr
TOTAL	68	NON-SYNCH													
	24	SYNCHRONOUS													

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SECTION 3

NAVIGATION/TRACKING SUPPORT

A key input to the TDAS communication mission model involves the additional communication requirements for navigation/tracking support. Although technically, this includes orbit, time and attitude determination, orbit determination is the driving function and will be the primary focus here*. To enable subsequent comparisons in the study between options requiring various degrees of TDAS support, four potential system implementation options are defined which could support orbit/time determination. For those which would utilize TDAS communication channels, the objective is to identify the contact requirements per day per experiment/mission.

3.1 NAVIGATION/TRACKING SYSTEM OPTIONS

Four of the various orbit/time determination (OD/TD) options identified in TDAS Tasks 1 and 2 are presented in Figure 3.2-1. The degree of TDAS support ranges from a minimum in Option 1 to a maximum in Option 4. The two autonomous options do not require use of TDAS data communication channels whereas ground supported options do. A brief description of each follows: see [1] for further details.

- Option 1: Autonomous OD/TD via GPS - A user spacecraft receives GPS navigation signals continuously and derives its position and time via on-board processing. Supporting navigation data (e.g., GPS ephemeris parameters, clock corrections, etc.) are provided on the navigation signal. User orbit position is assumed to be reported to the ground as a part of normal telemetry data as well as packetized experiment data.

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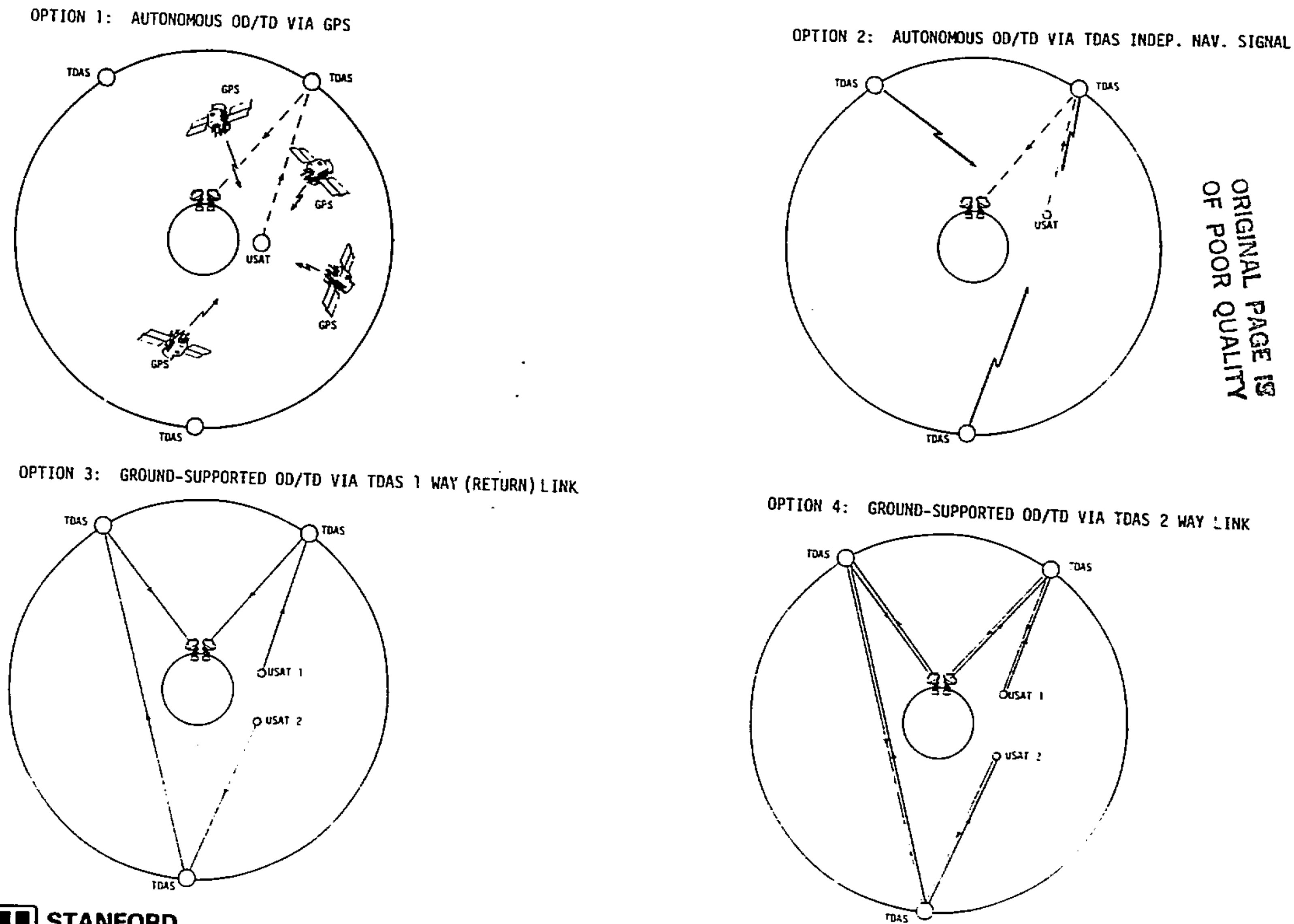
* Attitude determination is assumed to be performed autonomously and requires only occasional ground support (e.g., for star table updates and attitude verification via data stripped from packetized telemetry).

FIGURE 3.2-1: SYSTEM OPTIONS FOR ORBIT & TIME DETERMINATION



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- Option 2: Autonomous OD/TD via TDAS Independent Navigation Signal - A user spacecraft processes signals broadcast continuously by TDAS satellites and designed specifically for on-board OD/TD support. TDAS satellite ephemeris and time reference data are included in the navigation signal. User orbit position is reported as in Option 1.

- Option 3: Ground-Supported OD/TD via TDAS 1 Way (Return) Link - User spacecraft transmissions during specified tracking intervals are processed on the ground to derive ephemeris and clock offset data. The user state vector corresponding to a certain epoch is periodically uplinked to the user which propagates it forward via a suitable model to derive current position and time between updates. With enhanced ground processing capabilities an updated state vector may be available within 10-15 minutes following a given tracking interval.

- Option 4: GROUND-Supported OD/TD via TDAS 2 Way Link - The ground initiates two-way signalling and processes the return signal to determine user ephemeris and clock offset data analogous to TDRSS. User state vector updates and on-board propagation for current position are performed as in Option 3. The difference is that both forward and return links are required throughout the tracking interval.

3.2 NAVIGATION/TRACKING COMMUNICATION REQUIREMENTS

The objective of this section is to estimate the communication requirements to support each of the four navigation/tracking system options described above. Clearly no additional support is required for Option 1 which utilizes GPS. Option 2, as defined, would require an additional forward link channel on each TDAS satellite to provide the independent navigation signal*. For Options 3 and 4, the navigation/tracking function is assumed

* Specific characteristics of such a signal remains to be defined, of course.

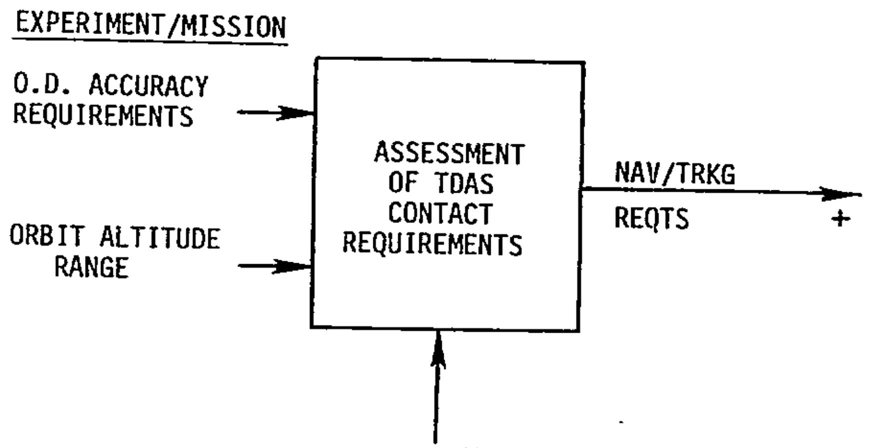
to be supportable concurrently with the data communication functions. Thus, to determine the additional communication requirements, it is necessary to first estimate the contact time requirements for navigation/tracking support in these two options.

Figure 3.2-2 illustrates the elements considered in developing the navigation/tracking contact requirements for Options 3 and 4. For any given experiment/mission these will vary depending on the required position accuracy as well as user altitude. In discussions with NASA/GSFC personnel [9] it was suggested that contact requirements per experiment/mission be assigned based on the accuracy/altitude criteria listed in Figure 3.2-3. Depending on the orbit period which is a function of user altitude this can be converted to required tracking contacts per day.

Table 3.2-1 lists the position accuracy requirements and operational altitudes (and corresponding orbits/day) for all of the experiments/missions considered. Based on the procedure described above the total required contacts per day were estimated. The results are listed in the last column of Table 3.2-1.

FIGURE 3.2-2

METHODOLOGY FOR DERIVING NAVIGATION/TRACKING CONTRACT REQUIREMENTS FOR GROUND-SUPPORTED ORBIT DETERMINATION



CRITERIA:

- 2 CONTACTS/ORBIT* - ALTITUDE: ≤ 700 km
  ACCURACY: < 50 m
- 1 CONTACT/ORBIT - ALTITUDE: > 200 km
  ACCURACY: 50-200 m
- 7 CONTACTS/DAY - ALTITUDE: > 200 km
  - ACCURACY: > 500 m

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*5 MINUTES PER CONTACT FOR TRACKING DATA

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TABLE 3.2-1

EXPERIMENT/MISSION TRACKING CONTACT REQUIREMENTS FOR GROUND-SUPPORTED ORBIT DETERMINATION OPTIONS

EXPERIMENT/MISSION	POSITION ACC. REQT. (METERS)	ORBIT ALTITUDE (KM)	ORBITS PER DAY	TRACKING CONTACTS PER DAY+ TOTAL REQ'D.	ADD'L REQT. FWD LINK	ADD'L REQT. RTN LINK
ASTROPHYSICS						
SPACE TELESCOPE	200/1000*	600	15	15	11	0
LAMAR	ST*	400	16	16	12	↓
LADIR TELESCOPE	"	400-700	14-16	14-16	10-12	↓
INFRARED-INTERFEROMETER	"	"	"	"	"	↓
COSMIC/100 M TELESCOPE	"	500	15	15	11	↓
LARGE OPT./UV TELESCOPE	"	450	"	"	"	↓
X-RAY OBSERVATORY	"	300	16	16	12	↓
AG-5,6,7	"	400	"	"	"	↓
ORB. SUBMM. TELESCOPE	"	1000	14	14	10	↓
VLBRI	1000	400-5000	7-14	7	3	↓
GRAVITY WAVE INTERFEROMETER	>1000**	250	16	"	"	↓
AXAF	"	450	15	"	"	↓
AG-1,2,3,4	"	LEO	14-16	"	"	↓
SOLAR TERRESTIAL						
SCADM	>1000**	575	15	7	3	0
SG-1,3,5	"	"	"	"	"	↓
SOLAR TERRESTIAL OBSERVATORY	"	400	"	"	"	↓
SG-2,4	"	"	"	"	"	↓
RESOURCE OBSERVATION						
MAGSAT B	30	300	16	2 x 16++	0	0
ADV. THERMAL MAPPER	50	620	15	15	↓	↓
SOIL MOISTURE	100	400-700	14-16	14-16	↓	↓
OERS	10	750	14	2 x 14++	14	↓
RG-1,2,3,4	"	700	"	"	"	↓
GLOBAL ENVIRONMENT						
TOPEX	2-3 (0.1 ALT)	1330	13	13	0	0
EG-2,5,6,8	"	"	"	"	↓	↓
OSAR	50	790	14	14	↓	↓
EG-1,3,4,7	"	"	"		↓	↓
METEOROLOGY						
OPERATIONAL MET. SAT.	500	830	14	?	0	0
SPACE TRANSPORTATION						
SHUTTLE	100	185-1110	14-16	14-16	0	0
TMS	"	1000	14	13	↓	↓
HLLV	"	200-500	15-16	1-2 x 16++	↓	↓
OTV	>1000*	LEO-GEO	-	?	?	↓
MANNED GEO-SORTIE	100	"	-	"	"	↓
PLATFORMS						
SOC	15-30	400	16	2 x 16++	0	0
PVP	10-30	"	"	"	"	"

\+ 5 MINUTES PER CONTACT FOR TRACKING DATA

++ INDICATES 2 CONTACTS PER ORBIT

* ST ACCURACY REQTS. (200m-10% OF TIME; >1000m-90% OF TIME); ALSO USED FOR ANALOGOUS MISSIONS

** INDICATES ACCURACY REQUIREMENT FOR MISSION SUPPORT ONLY (NO EXPERIMENT REQT. EXISTS TO-DATE)

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SECTION 4

COMMUNICATION REQUIREMENTS

The major requirement for TDAS is to provide forward and/or return link services to a diverse user community with a high probability of successful access and support. In order to help size the candidate TDAS architecture (Task 5) the potential communication requirements to support data communication services need to be estimated. This section presents the data volume distribution and resulting contact time estimates with respect to the four scenarios of mission models presented in Section 2.

Potential tradeoffs between the communication requirements and various design parameters are identified. These design parameters include the use of mass storage on the user spacecraft, the use of data compression on the user spacecraft, and the scheduling inefficiencies and acquisition time of the TDAS system. The tradeoff results are presented as a series of curves illustrating the impact of the design parameter on the communication requirements.

4.1 WORST CASE SCENARIOS

The mission models presented in Section 2 of this report formed the basis for constructing worst case scenarios for the years 1995, 2000 and 2005. Table 4.1-1 presents this worst case scenario for scenario of mission models A1 for 1995*. In this year, it has been assumed that two shuttles are being supported simultaneously at their maximum data rate, that three Teleoperator Maneuvering System are active and that an OTV mission is being supported. Thus this worst case scenario would represent the maximum stress on the TDAS system. Additional assumptions for this scenario include that the shuttle TV is not active and that the SOC optional forward link TV will not be implemented.

* These results have been updated to reflect the SOC implementation vice PUP for years 1995 and 2000 and are in Tables 4.1-1a and 4.1-2a respectively.

TABLE 4.1-1

WORST CASE SCENARIO - 1995 - SCENARIO A1

MISSION	SCIENCE DATA VOL. (BITS/DAY)	SCIENCE COMMANDS (BITS/DAY)	ENGINEERING DATA (REAL TIME)	SPACECRAFT COMMANDS (BITS/DAY)	NOTES
SPACE TELESCOPE	10^{10}	3×10^{6}	4 kbps	6×10^{6}	
AXAF	10^{11}	3×10^{6}	4 kbps	6×10^{6}	
EG-2	7×10^{8}	1.4×10^{7}	2 kbps	3×10^{7}	
SOIL MOISTURE	1×10^{7}	1×10^{7}	2 kbps	2×10^{7}	
OSAR	2×10^{12}	3×10^{7}	2 kbps	3×10^{7}	
METEOROLOGY (2)	6×10^{10}	9×10^{6}	8.32 kbps	8×10^{7}	
SHUTTLE (2)	50 Mbps RT	6×10^{9}	192 kbps*	72 kbps-RT	* Also TV-RT-intermittant
TMS (3)	-	-	[illegible]5 Mbps*	4 kbps-RT*	* Duration of mission
[illegible] V	-	-	6 Mbps*	4×10^{7}	* 0.75 hours every 2 hours
SOC	$\leq 10^{13}$	2.5×10^{10}	50 Mbps	1 Mbps-RT*	* Option for 22 Mbps TV
PUP 1A	$\leq 10^{13}$	2.5×10^{10}	50 kbps	-	

TABLE 4.1-1A

WORST CASE SCENARIO - 1995 - SCENARIO A1

15 min/orb

MISSION	SCIENCE DATA VOL. (BITS/DAY)	SCIENCE COMMANDS BITS/DAY	ENGINEERING DATA (REAL TIME)	SPACECRAFT COMMANDS (BITS/DAY)	NOTES	ENGINEERING SA	ENGINEERING MA	SCIENCE SA CONTACT TIME	SCIENCE MA CONTACT TIME
SPACE TELESCOPE	10^{10}	3×10^6	4kbps	6×10^6		-	24	3.6	-
AXAF	10^{11}	3×10^6	4kbps	6×10^6		-	24	5.3	-
EG-2	7×10^8	1.4×10^7	2kbps	3×10^7		-	24	-	5.3
SOIL MOISTURE	1×10^7	1×10^7	2kbps	2×10^7		-	24	-	5.3
OSAR	2×10^{12}	3×10^7	2kbps	3×10^7		-	24	2.5	-
METEOROLOGY (2)	6×10^{10}	9×10^6	8.32 kbps	8 X 10[illegible]		-	24	3.6	-
SHUTTLE (2)	50Mbps	6×10^9	192 kbps*	72kbps-RT	* Also TV-RT-intermittant	24	-	-	-
TMS (1)	-	-	15Mbps*	4kbps-RT*	* Duration of Mission	24	-	-	-
OTV	-	-	6Mbps*	4×10^7	0.75 Hours Every 2 Hours	9	-	-	-
SOC	$< 10^{13}$	2.5×10^{10}	50Mbps	1Mbps-RT*	Option for 22 Mbps TV	24		-	-
LARGE OPT/OV TELE.	10^{10}	3×10^6	2kbps	6×10^6		-	24	5.3	-
AG-2	5×10^8	3×10^6	2kbps	6×10^6		-	24	-	5.3

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TABLE 4.1-2A

NASA CONTACT TIME REQUIREMENTS - YEAR 2000, BUSY DAY

MISSIONS	SCIENCE DATA			ENGINEERING DATA	
	VOLUME (BITS/DAY)	DUMP RATE	CONTACT HOURS*	DUMP RATE	CONTACT HOURS (REAL TIME)
AG-3	5×10^8	35 Kbps	5.3	2 kbps	24
EG-5	7×10^8	48	5.3	2	↓
ADV. TM	3×10^9	200	5.3	2	↓
SG-1	5×10^9	350	5.3	2	↓
METEOROLOGY (2)	6×10^{10}	665	3.6 x 2	8.3	↓
LARGE OPT/UV	10^{10}	700	5.3	2	↓
AXAF	10^{11}	7 Mbps	5.3	4	↓
COSMIC/100-m	10^{11}	7	5.3	2	↓
SHUTTLE	—	50	24	192	**
EG-3	2×10^{12}	300	2.4	2	24
SG-2	3×10^{12}	300	3.6	2	↓
RG-1	1.5×10^{13}	300	5.3	2	↓
HLLV				15	↓
SHUTTLE				192	↓
OTV				6 Mbps	↓
TMS				15	↓
MOTV				15	↓
SPACE STATION/ PLATFORM	10^{13}	300	4	50	↓

* ASSUMES 16 CONTACTS/DAY, 15 MINS/CONTACT AND 75% SHCEDULING EFFICIENCY. EXCEPTIONS: SG-2 AND METEOROLOGY ARE BASED ON 10 MINS/CONTACT AND EG-3 ON 7 MINS/CONTACT.

** ENGINEERING DATA ASSUMED TO BE MULTIPLEXED WITH SCIENCE DATA.

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Tables 4.1-2 through 4.1-12 present the remaining worst case scenarios for the years 1995, 2000 and 2005 and scenarios of mission models A1, A2, B1* and B2.

4.2 DISTRIBUTION OF DATA VOLUMES*

The data to be communicated between the user spacecraft and the user ground system has been classified as:

- Science data - thc data from the experiment
- Science commands - data controlling the experiment from the ground
- Spacecraft commands - data controlling the spacecraft from the ground
- Engineering data - data on the health and well-being of the spacecraft.

Each of these classifications has a different distribution of data volumes as identified below.

4.2.1 Science Data

Figures 4.2.1-1 through 4.2.1-4 present the distribution of data volumes for scenarios of mission models A1, A2, B1 and B2, respectively. The various missions have been grouped into order of magnitude increases in the data volume. The first grouping labelled 10^{-6} represents the number of missions having data volumes $\geq 10^{-6}$ and $< 10^{-7}$ bits per day for the years 1995, 2000 and 2005. It can be seen that few missions have a data volume $< 4 \times 10^{-9}$ bits/day (50 kbps real-time rate). The majority of the missions have data volumes in excess of 10^{-11} bits per day (1 Mbps real-time rate).

* This section not revised.

TABLE 4.1-2

WORST CASE SCENARIO - 2000 - SCENARIO A1

MISSION	SCIENCE DATA VOL. (BITS/DAY)	SCIENCE COMMANDS (BITS/DAY)	ENGINEERING DATA (REAL TIME)	SPACECRAFT COMMANDS (BITS/DAY)	NOTES
AXAF	10^{11}	3×10^{6}	4 kbps	6×10^{6}	
COSMIC/100-M	10^{11}	3×10^{6}	2 kbps	6×10^{6}	
SG-2	3×10^{12}	3×10^{6}	2 kbps	6×10^{6}	
EG-5	7×10^{8}	1.4×10^{7}	2 kbps	3×10^{7}	
RG-1	1.5×10^{13}	1.5×10^{7}	2 kbps	3×10^{7}	
ADV. THERMAL MAPPER	3×10^{9}	1.7×10^{7}	2 kbps	3.5×10^{7}	
EG-3	2×10^{12}	3×10^{7}	2 kbps	3×10^{7}	
METEOROLOGY (2)	6×10^{10}	9×10^{6}	8.32 kbps	8×10^{7}	
SHUTTLE (2)	50 Mbps RT	6×10^{9}	192 kbps	72 kbps-RT	
TMS (3)	-	-	15 Mbps	4 kbps-RT	
OTV	-	-	6 Mbps	4×10^{7}	
HLLV	-	-	16 kbps	3 kbps-RT	
MOTV	-	-	15 Mbps	20 kbps-RT	
SOC	$\leq 10^{13}$	2.5×10^{10}	50 Mbps	1 Mbps-RT	
PUP 1A	$\leq 10^{13}$	2.5×10^{10}	50 kbps	-	

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TABLE 4.1-3
WORST CASE SCENARIO - 2005 - SCENARIO A1

MISSION	SCIENCE DATA VOL. (BITS/DAY)	SCIENCE COMMANDS (BITS/DAY)	ENGINEERING DATA (REAL TIME)	SPACECRAFT COMMANDS (BITS/DAY)	NOTES
COSMIC/100-M	10^{11}	3×10^6	2 kbps	6×10^6	
INFRARED INTER.	10^{11}	3×10^6	2 kbps	6×10^6	
ORBITING SUBMM TELE	10^6	3×10^6	2 kbps	6×10^6	
GRAVITY WAVE INT.	10^{11}	3×10^6	2 kbps	6×10^6	
RG-3	1.5×10^{13}	1.5×10^7	2 kbps	3×10^7	
EG-4	2×10^{12}	3×10^7	2 kbps	3×10^7	
METEOROLOGY (2)	6×10^{10}	9×10^6	8.32 kbps	8×10^7	
SHUTTLE (2)	50 Mbps-RT	6×10^9	192 kbps	72 kbps-RT	
TMS (3)	-	-	15 Mbps	4 kbps-RT	
OTV	-	-	6 Mbps	4×10^7	
HLLV	-	-	16 kbps	3 kbps-RT	
MOTV	-	-	15 Mbps	20 kbps-RT	
SOC	$\leq 10^{13}$	2.5×10^{10}	50 Mbps	1 Mbps-RT	
PUP 1A	$\leq 10^{13}$	2.5×10^{10}	50 kbps	-	

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TABLE 4.1-4

WORST CASE SCENARIO - 1995 - SCENARIO A2

MISSION	SCIENCE DATA VOL. (BITS/DAY)	SCIENCE COMMANDS (BITS/DAY)	ENGINEERING DATA (REAL TIME)	SPACECRAFT COMMANDS (BITS/DAY)	NOTES
SPACE TELESCOPE	10^{10}	3×10^{6}	4 kbps	6×10^{6}	
AXAF	10^{11}	3×10^{6}	4 kbps	6×10^{6}	
EG-2	7×10^{8}	1.4×10^{7}	2 kbps	3×10^{7}	
SHUTTLE (2)	50 Mbps-RT	6×10^{9}	192 kbps*	72 kbps-RT	* Also TV-RT-Intermittant
TMS (3)	-	-	15 Mbps*	4 kbps-RT*	* Duration of Mission
OTV	-	-	6 Mbps*	4×10^{7}	* 0.75 Hours Every 2 Hours
SOC	$\leq 10^{13}$	2.5×10^{10}	50 Mbps	1 Mbps-RT*	* Option for 22 Mbps TV
PUP 1A	$\leq 10^{13}$	2.5×10^{10}	50 kbps	-	
PUP 2A	2×10^{13}	2.5×10^{10}	50 kbps	-	

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TABLE 4.1-5

WORST CASE SCENARIO - 2000 - SCENARIO A2

MISSION	SCIENCE DATA VOL. (BITS/DAY)	SCIENCE COMMANDS (BITS/DAY)	ENGINEERING DATA (REAL TIME)	SPACECRAFT COMMANDS (BITS/DAY)	NOTES
AXAF	10^{11}	3×10^{6}	4 kbps	6×10^{6}	
COSMIC/100-M	10^{11}	3×10^{6}	2 kbps	6×10^{6}	
SG-2	3×10^{12}	3×10^{6}	2 kbps	6×10^{6}	
EG-5	7×10^{8}	1.4×10^{7}	2 kbps	3×10^{7}	
SHUTTLE (2)	50 Mbps-RT	6×10^{9}	192 kbps	72 kbps-RT	
TMS (3)	-	-	15 Mbps	4 kbps-RT	
OTV	-	-	6 Mbps	4×10^{7}	
HLLV	-	-	16 kbps	3 kbps-RT	
MOTV	-	-	15 Mbps	20 kbps-RT	
SOC	$\leq 10^{13}$	2.5×10^{10}	50 Mbps	1 Mbps-RT	
PUP 1A	$\leq 10^{13}$	2.5×10^{10}	50 kbps	-	
PUP 2A	2×10^{13}	2.5×10^{10}	50 kbps	-	

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TABLE 4.1-6

WORST CASE SCENARIO - 2005 - SCENARIO A2

MISSION	SCIENCE DATA VOL. (BITS/DAY)	SCIENCE COMMANDS (BITS/DAY)	ENGINEERING DATA (REAL TIME)	SPACECRAFT COMMANDS (BITS/DAY)	NOTES
COSMIC/100-M	10^{11}	3×10^6	2 kbps	6×10^6	
INFRARED INTER.	10^{11}	3×10^6	2 kbps	6×10^6	
ORBITING SUBMM TELE.	10^6	3×10^6	2 kbps	6×10^6	
GRAVITY WAVE INT.	10^{11}	3×10^6	2 kbps	6×10^6	
SHUTTLE (2)	50 Mbps-RT	6×10^9	192 kbps	72 kbps-RT	
TMS (3)	-	-	15 Mbps	4 kbps-RT	
OTV	-	-	6 Mbps	4×10^7	
HLLV	-	-	16 kbps	3 kbps-RT	
MOTV	-	-	15 Mbps	20 kbps-RT	
SOC	$\leq 10^{13}$	2.5×10^{10}	50 Mbps	1 Mbps-RT	
PUP 1A	$\leq 10^{13}$	2.5×10^{10}	50 kbps	-	
PUP 2A	2×10^{13}	2.5×10^{10}	50 kbps	-	

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TABLE 4.1-7

WORST CASE SCENARIO - 1995 - SCENARIO B1

MISSION	SCIENCE DATA VOL. (BITS/DAY)	SCIENCE COMMANDS (BITS/DAY)	ENGINEERING DATA (REAL TIME)	SPACECRAFT COMMANDS (BITS/DAY)	NOTES
SPACE TELESCOPE	10^{10}	3×10^6	4 kbps	6×10^6	
AXAF	10^{11}	3×10^6	4 kbps	6×10^6	
EG-2	7×10^8	1.4×10^7	2 kbps	3×10^7	
SHUTTLE (3)	50 Mbps-RT	6×10^9	192 kbps	72 kbps-RT	
TMS (4)	-	-	15 Mbps	4 kbps-RT	
OTV	-	-	6 Mbps	4×10^7	
SOC	$\leq 10^{13}$	2.5×10^{10}	50 Mbps	1 Mbps-RT	
PUP 1	$\leq 10^{13}$	2.5×10^{10}	50 kbps	-	
PUP 2	2×10^{13}	2.5×10^{10}	50 kbps	-	

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TABLE 4.1-8

WORST CASE SCENARIO - 2000 - SCENARIO B1

MISSION	SCIENCE DATA VOL. (BITS/DAY)	SCIENCE COMMANDS (BITS/DAY)	ENGINEERING DATA (REAL TIME)	SPACECRAFT COMMANDS (BITS/DAY)	NOTES
AXAF	10^{11}	3×10^{6}	4 kbps	6×10^{6}	
COSMIC/100-M	10^{11}	3×10^{6}	2 kbps	6×10^{6}	
EG-5	7×10^{8}	1.4×10^{7}	2 kbps	3×10^{7}	
SHUTTLE (3)	50 Mbps-RT	6×10^{9}	192 kbps	72 kbps-RT	
TMS (4)	-	-	15 Mbps	4 kbps-RT	
OTV	-	-	6 Mbps	4×10^{7}	
HLLV	-	-	16 kbps	3 kbps-RT	
MOTV	-	-	15 Mbps	20 kbps-RT	
SOC	$\leq 10^{13}$	2.5×10^{10}	50 Mbps	1 Mbps-RT	
PUP 1	$\leq 10^{13}$	2.5×10^{10}	50 kbps	-	
PUP 2	2×10^{13}	2.5×10^{10}	50 kbps	-	

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TABLE 4.1-9

WORST CASE SCENARIO - 2005 - SCENARIO B1

MISSION	SCIENCE DATA VOL. (BITS/DAY)	SCIENCE COMMANDS (BITS/DAY)	ENGINEERING DATA (REAL TIME)	SPACECRAFT COMMANDS (BITS/DAY)	NOTES
COSMIC/100-M	10^{11}	3×10^6	2 kbps	6×10^6	
INFRARED INT.	10^{11}	3×10^6	2 kbps	6×10^6	
ORBITING SUBMM TELE	10^6	3×10^6	2 kbps	6×10^6	
GRAVITY WAVE INT.	10^{11}	3×10^6	2 kbps	6×10^6	
EG-6	7×10^8	1.4×10^7	2 kbps	3×10^7	
AG-7	7×10^8	3×10^6	2 kbps	6×10^6	
SG-4	3×10^{12}	3×10^6	2 kbps	6×10^6	
SHUTTLE (3)	50 Mbps-RT	6×10^9	192 kbps	72 kbps-RT	
TMS (4)	-	-	15 Mbps	4 kbps-RT	
OTV	-	-	6 Mbps	4×10^7	
HLLV	-	-	16 kbps	3 kbps-RT	
MOTV	-	-	15 Mbps	20 kbps-RT	
SOC	$\leq 10^{13}$	2.5×10^{10}	50 Mbps	1 Mbps-RT	
PUP 1	$\leq 10^{13}$	2.5×10^{10}	50 kbps	-	
PUP 2	2×10^{13}	2.5×10^{10}	50 kbps	-	

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TABLE 4.1-10

WORST CASE SCENARIO - 1995 - SCENARIO B2

MISSION	SCIENCE DATA VOL. (BITS/DAY)	SCIENCE COMMANDS (BITS/DAY)	ENGINEERING DATA (REAL TIME)	SPACECRAFT COMMANDS (BITS/DAY)	NOTES
SPACE TELESCOPE	10^{10}	3×10^6	4 kbps	6×10^6	
AXAF	10^{11}	3×10^6	4 kbps	6×10^6	
SHUTTLE (3)	50 Mbps-RT	6×10^9	192 kbps	72 kbps-RT	
TMS (4)	-	-	15 Mbps	4 kbps-RT	
OTV	-	-	6 Mbps	4×10^7	
SOC	$\leq 10^{13}$	2.5×10^{10}	50 Mbps	1 Mbps-RT	
PUP 1	$\leq 10^{13}$	2.5×10^{10}	50 kbps	-	
PUP 2	2×10^{13}	2.5×10^{10}	50 kbps	-	
PUP 3	7×10^8	2.5×10^{10}	50 kbps	-	

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TABLE 4.1-11

WORST CASE SCENARIO - 2000 - SCENARIO B2

MISSION	SCIENCE DATA VOL. (BITS/DAY)	SCIENCE COMMANDS (BITS/DAY)	ENGINEERING DATA (REAL TIME)	SPACECRAFT COMMANDS (BITS/DAY)	NOTES
AXAF	10^{11}	3×10^6	4 kbps	6×10^6	
COSMIC/100-M	10^{11}	3×10^6	2 kbps	6×10^6	
SHUTTLE (3)	50 Mbps-RT	6×10^9	192 kbps	72 kbps-RT	
TMS (4)	-	-	15 Mbps	4 kbps-RT	
OTV	-	-	6 Mbps	4×10^7	
HLLV	-	-	16 kbps	3 kbps-RT	
MOTV	-	-	15 Mbps	20 kbps-RT	
SOC	$\leq 10^{13}$	2.5×10^{10}	50 Mbps	1 Mbps-RT	
PUP 1	$\leq 10^{13}$	2.5×10^{10}	50 kbps	-	
PUP 2	2×10^{13}	2.5×10^{10}	50 kbps	-	
PUP 3	7×10^8	2.5×10^{10}	50 kbps	-	

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TABLE 4.1-12

MISSION	SCIENCE DATA VOL. (BITS/DAY)	SCIENCE COMMANDS (BITS/DAY)	ENGINEERING DATA (REAL TIME)	SPACECPAFT COMMANDS (BITS/DAY)	NOTES
COSMIC/100-M	10^{11}	3×10^6	2 kbps	6×10^6	
INFRARED INT.	10^{11}	3×10^6	2 kbps	6×10^6	
ORBITING SUBMM TELE.	10^6	3×10^6	2 kbps	6×10^6	
GRAVITY WAVE INT.	10^{11}	3×10^6	2 kbps	6×10^6	
AG-7	7×10^8	3×10^6	2 kbps	6×10^6	
SG-4	3×10^{12}	3×10^6	2 kbps	6×10^6	
SHUTTLE (3)	50 Mbps-RT	6×10^9	192 kbps	72 kbps-RT	
TMS (4)	-	-	15 Mbps	4 kbps-RT	
OTV	-	-	6 Mbps	4×10^7	
HLLV	-	-	16 kbps	3 kbps-RT	
MOTV	-	-	15 Mbps	20 kbps-RT	
SOC	$\leq 10^{13}$	2.5×10^{10}	50 Mbps	1 Mbps-RT	
PUP 1	$\leq 10^{13}$	2.5×10^{10}	50 kbps	-	
PUP 2	2×10^{13}	2.5×10^{10}	50 kbps	-	
PUP 3	7×10^8	2.5×10^{10}	50 kbps	-	

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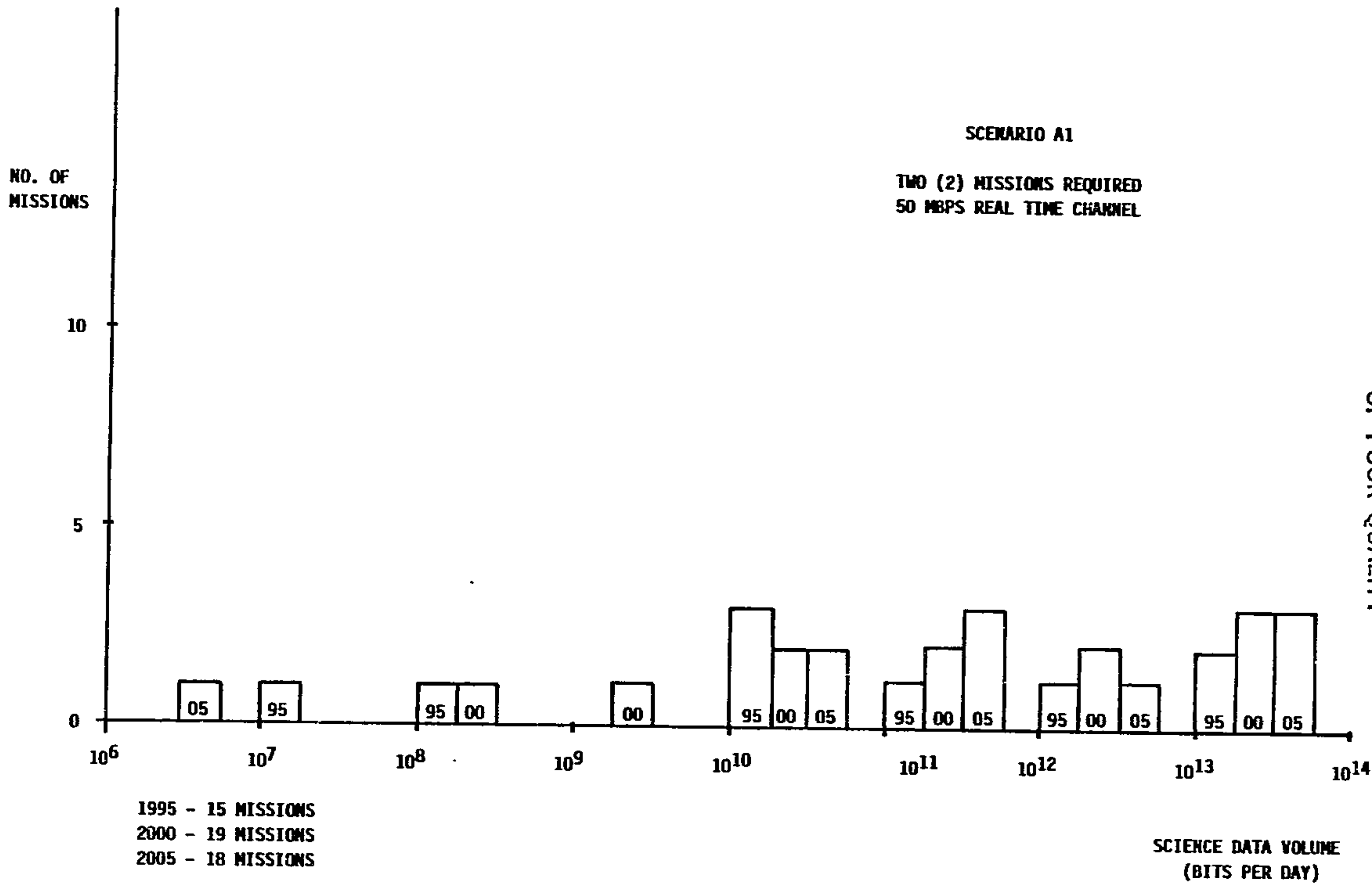

FIGURE 4.2.1-1: DISTRIBUTION OF SCIENCE DATA VOLUME, SCENARIO A1

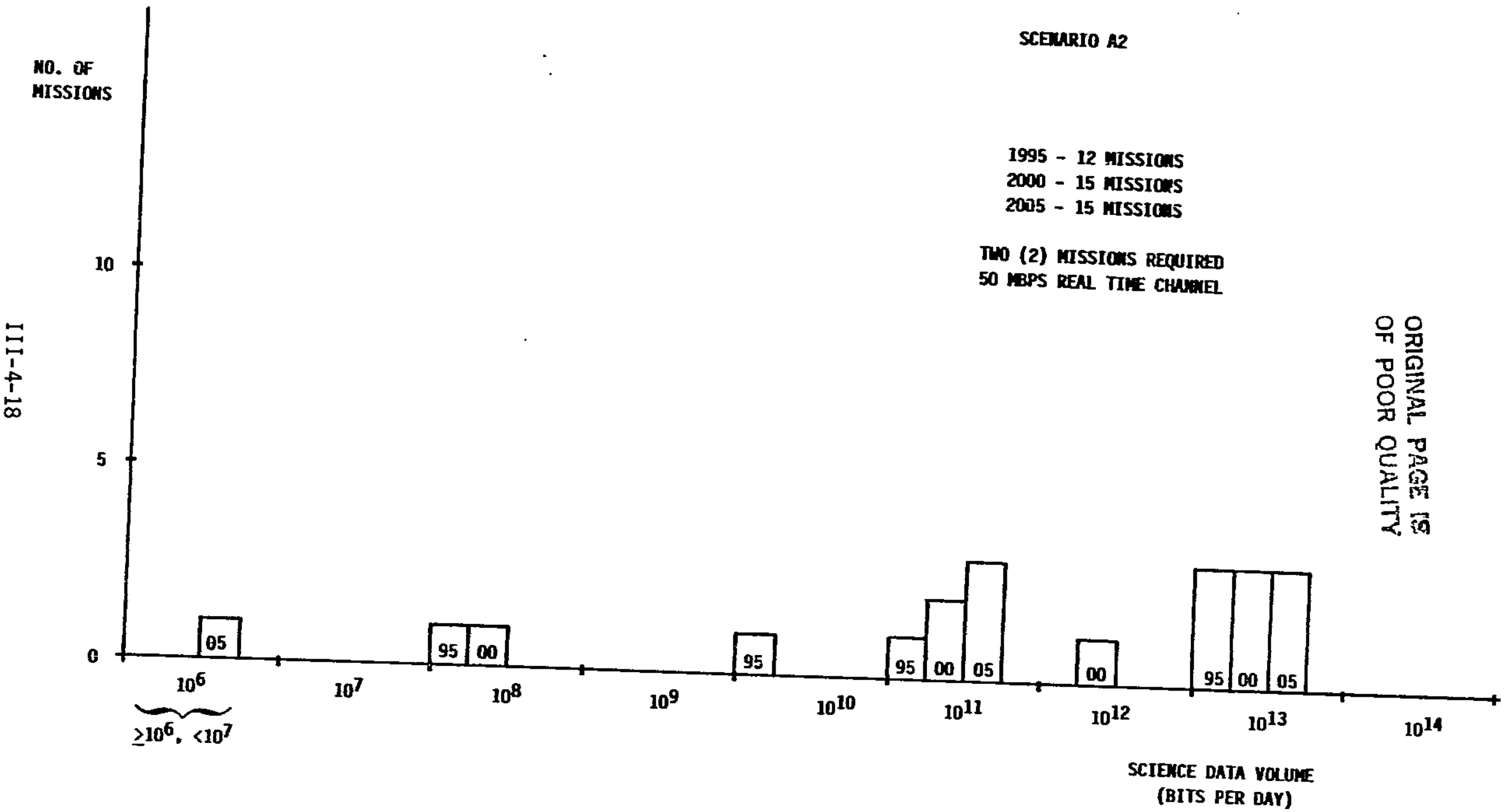

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FIGURE 4.2.1-2: DISTRIBUTION OF SCIENCE DATA VOLUME, SCENARIO A2

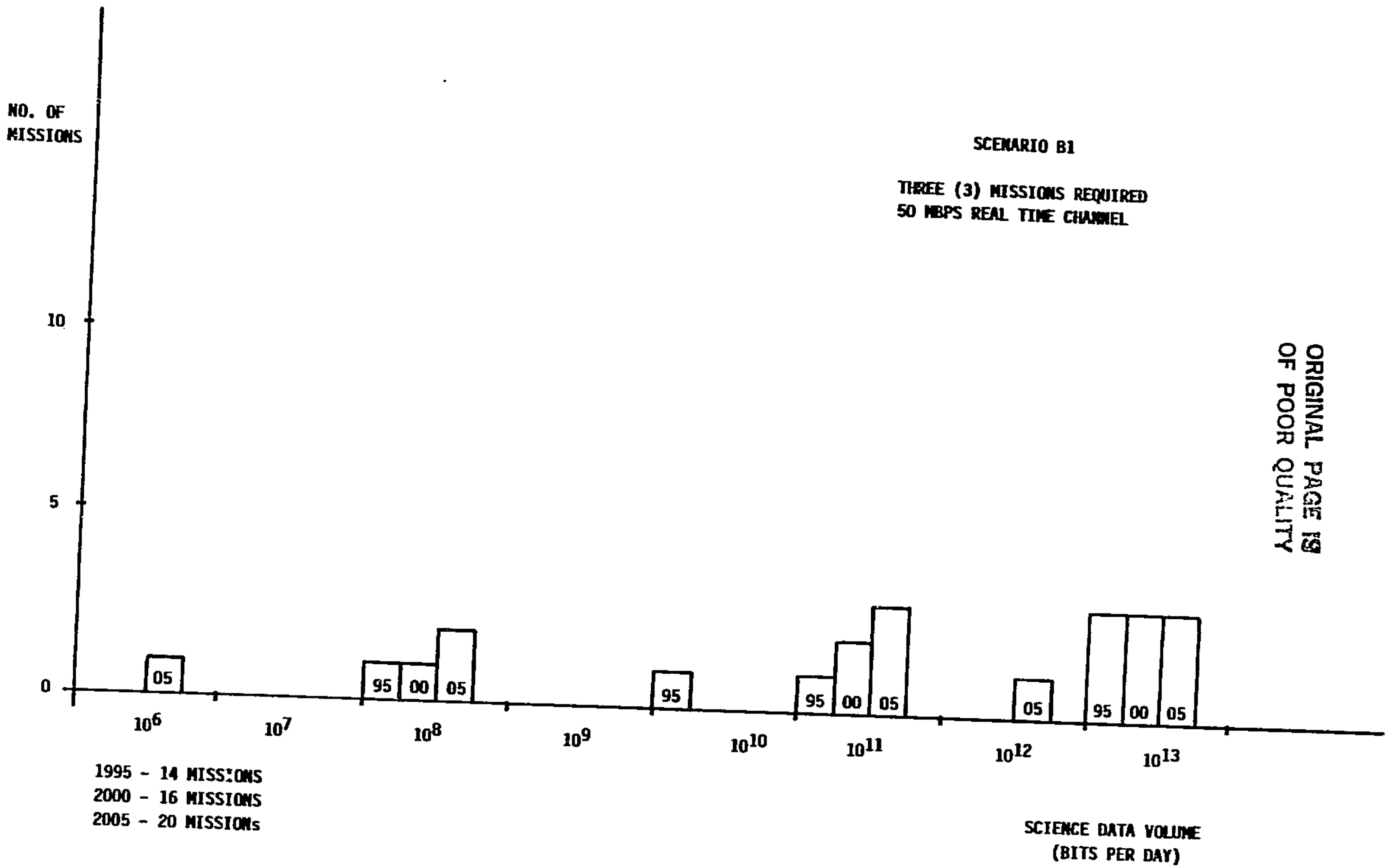

FIGURE 4.2.1-3: DISTRIBUTION OF SCIENCE DATA VOLUME, SCENARIO B1

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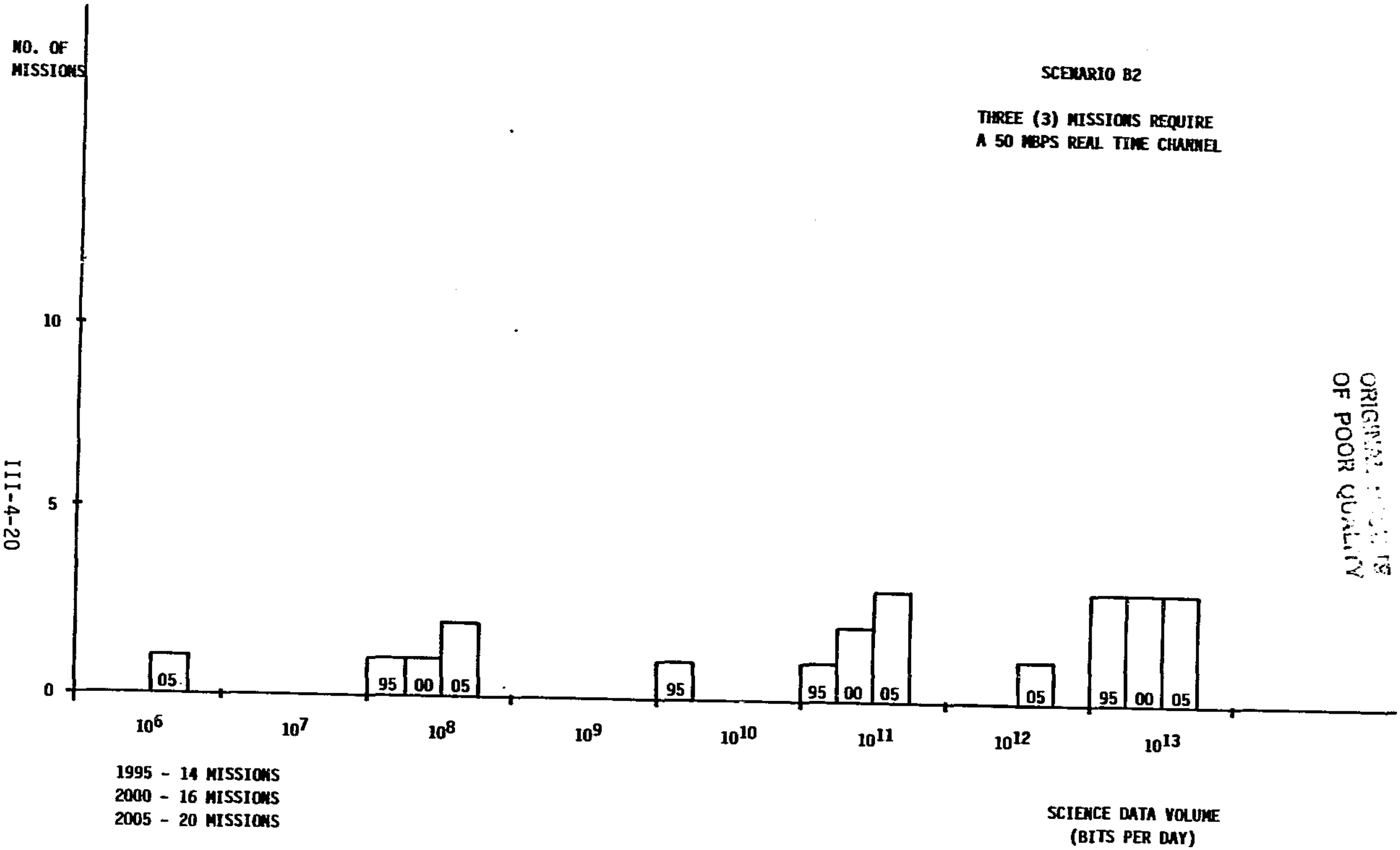

FIGURE 4.2.1-4: DISTRIBUTION OF SCIENCE DATA VOLUME, SCENARIO B2

4.2.2 Science Commands

Figures 4.2.2-1 through 4.2.2-4 present the destribution of science commands data volumes for scenario of mission models A1, A2, B1 and B2, respectively. As before, the various missions have been grouped into order of magnitude increases in the data volume.

4.2.3 Spacecraft Commands

Figures 4.2.3-1 through 4.2.3-4 present the distribution of spacecraft commands data volumes and real-time data rates for scenarios of mission models A1, A2, B1 and B2, respectively.

4.2.4 Engineering Data

Figures 4.2.4-1 through 4.2.4-4 present the distribution of engineering data rates for scenario of mission models A1, A2, B1 and B2, respectively.

4.3 CONTACT TIME REQUIREMENTS*

The contact time requirements for the TDAS system are presented parametrically as a function of data rate and data volume. The resulting values represent the amount of time required to transmit the science data and does not include acquisition times or other delays. Also included herein is the impact of military missions on the TDAS communication requirements.

4.3.1 Contact Time Per Mission

Figure 4.3.1-1 presents the contact time per mission as a function of data rate (called dump rate) and data volume. The parametric curves end at 24 hours of contact time since this is the equivalent real-time data rate corresponding to the data volume.

* This section not revised.

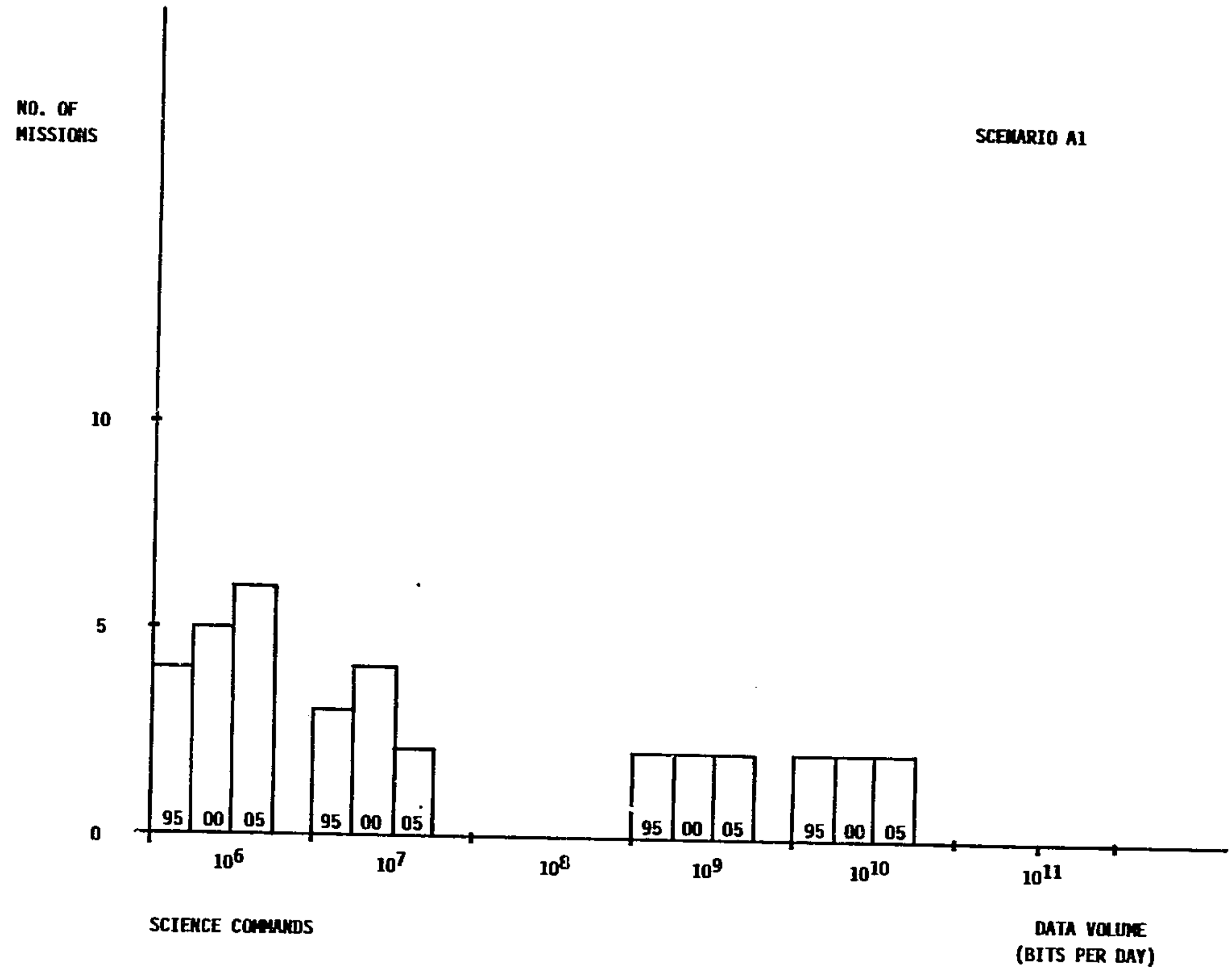

FIGURE 4.2.2-1: DISTRIBUTION OF SCIENCE COMMANDS DATA VOLUME, SCENARIO A1

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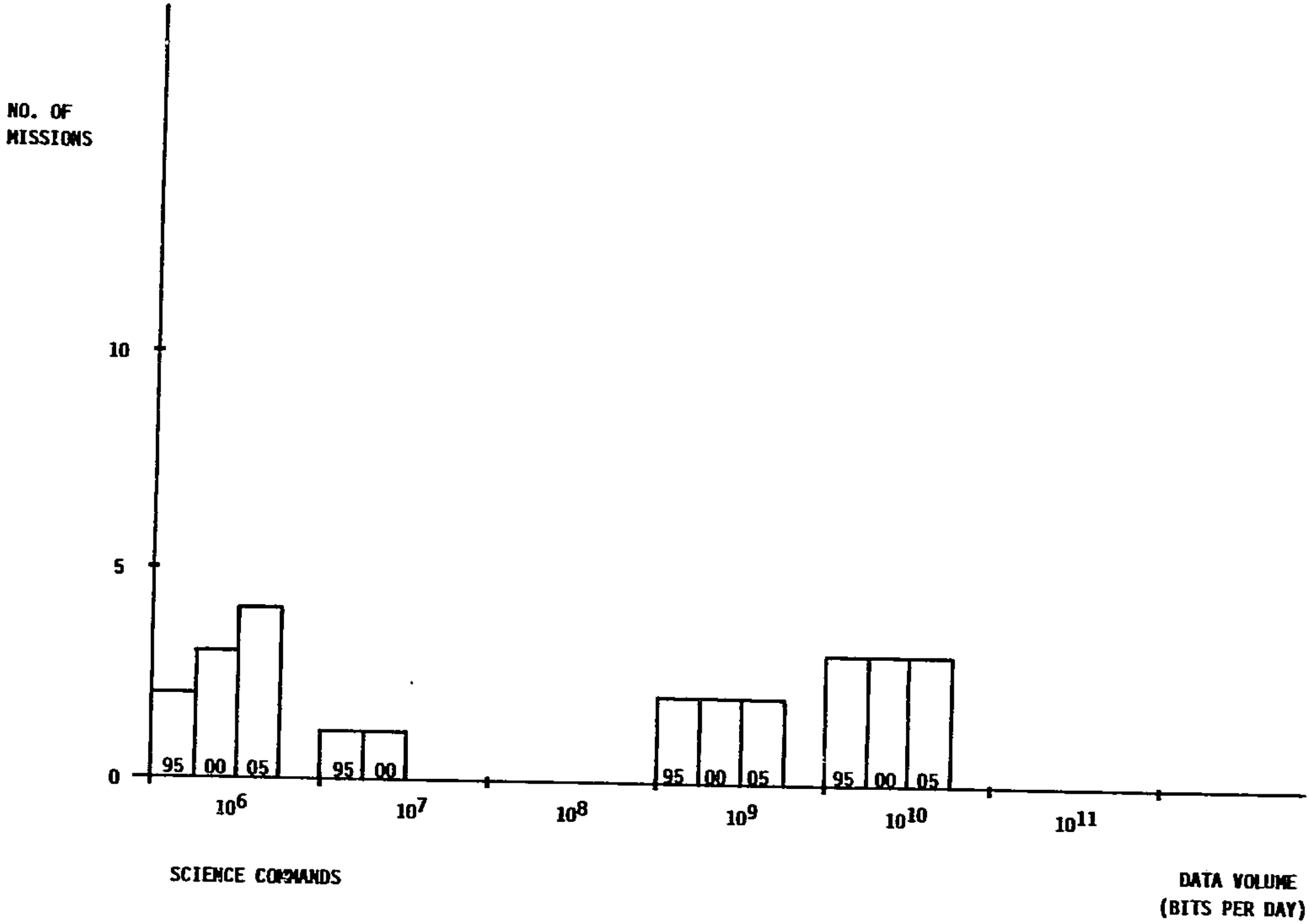

FIGURE 4.2.2-2: DISTRIBUTION OF SCIENCE COMMANDS DATA VOLUME, SCENARIO A2

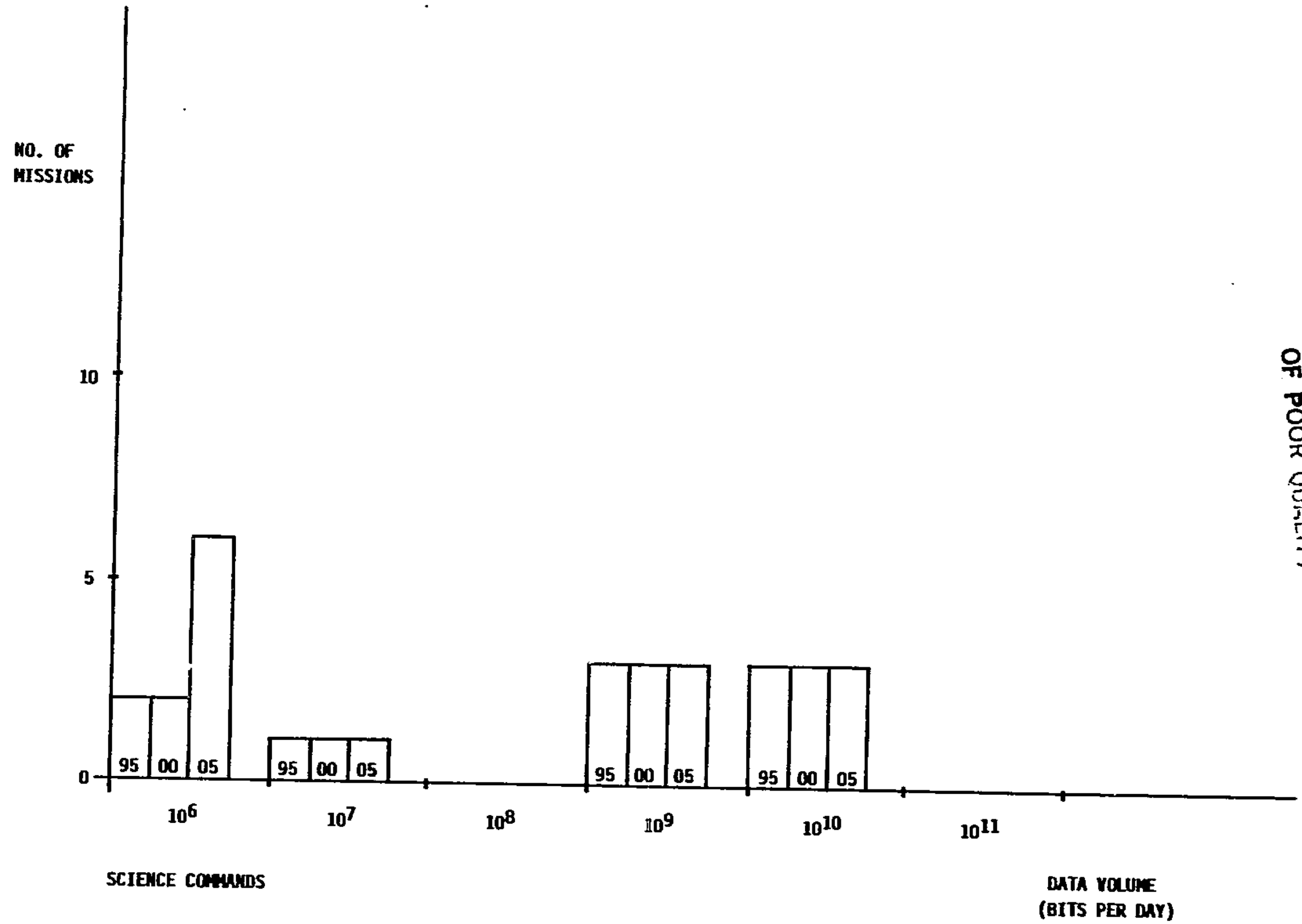

FIGURE 4.2.2-3: DISTRIBUTION OF SCIENCE COMMANDS DATA VOLUME, SCENARIO B1

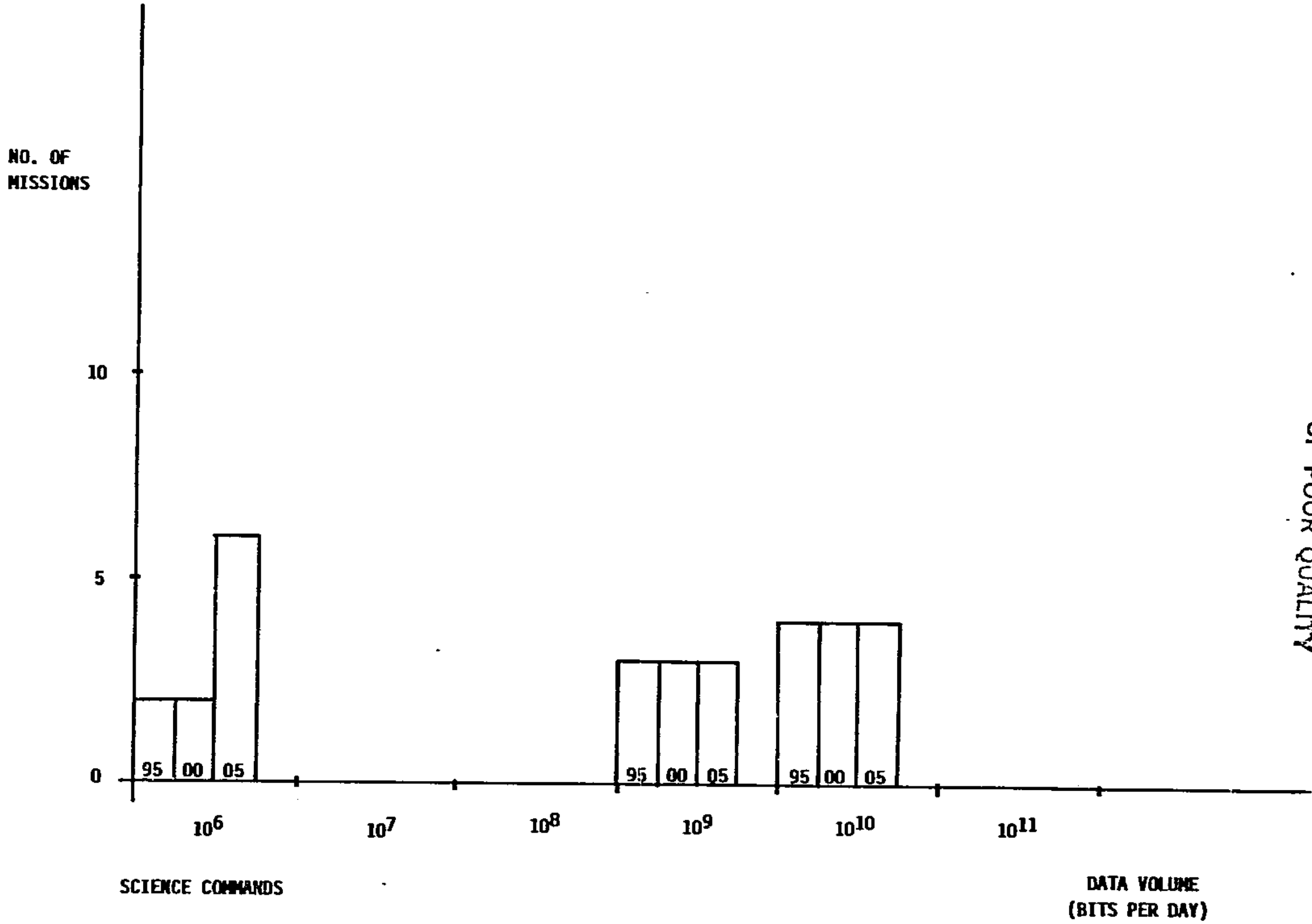

FIGURE 4.2.2-4: DISTRIBUTION OF SCIENCE COMMANDS DATA VOLUME, SCENARIO B2

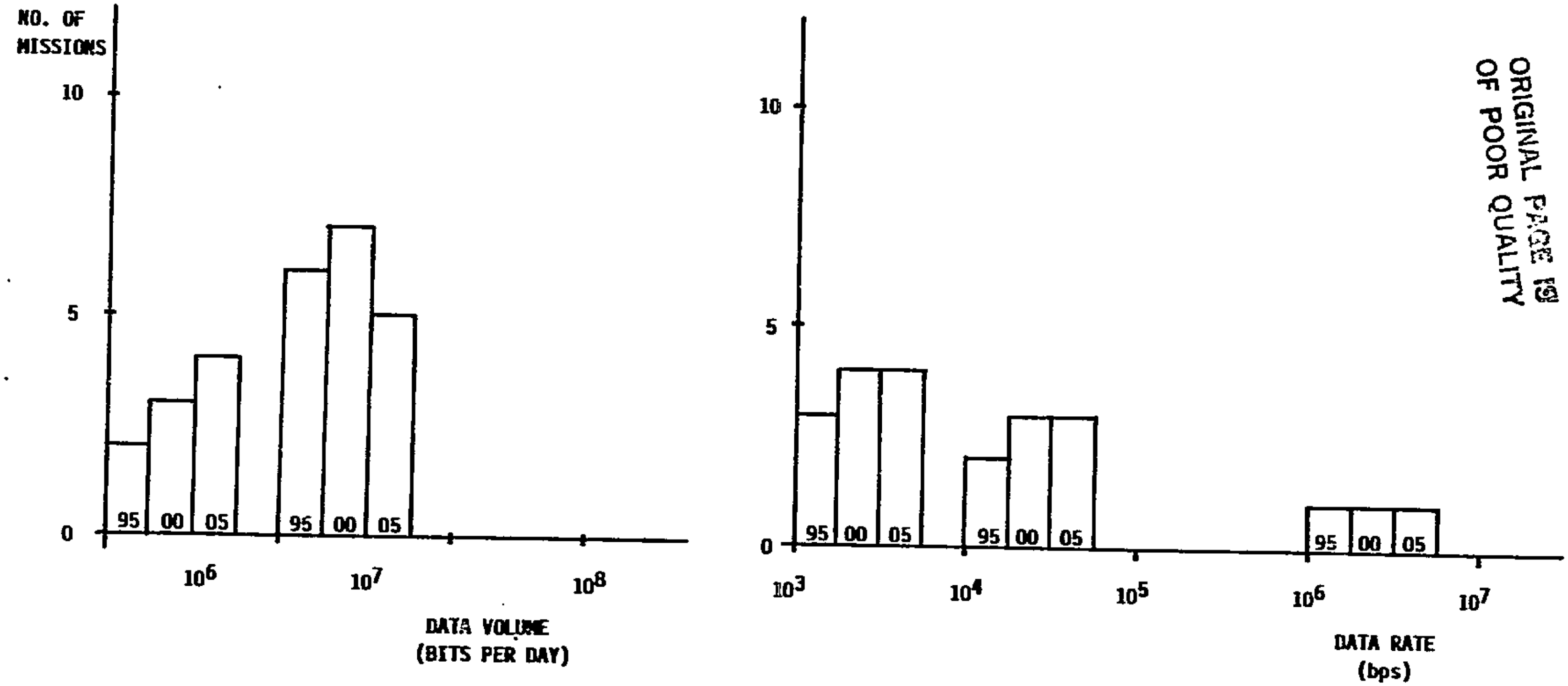

FIGURE 4.2.3-1: DISTRIBUTION OF SPACECRAFT COMMANDS, SCENARIO A1

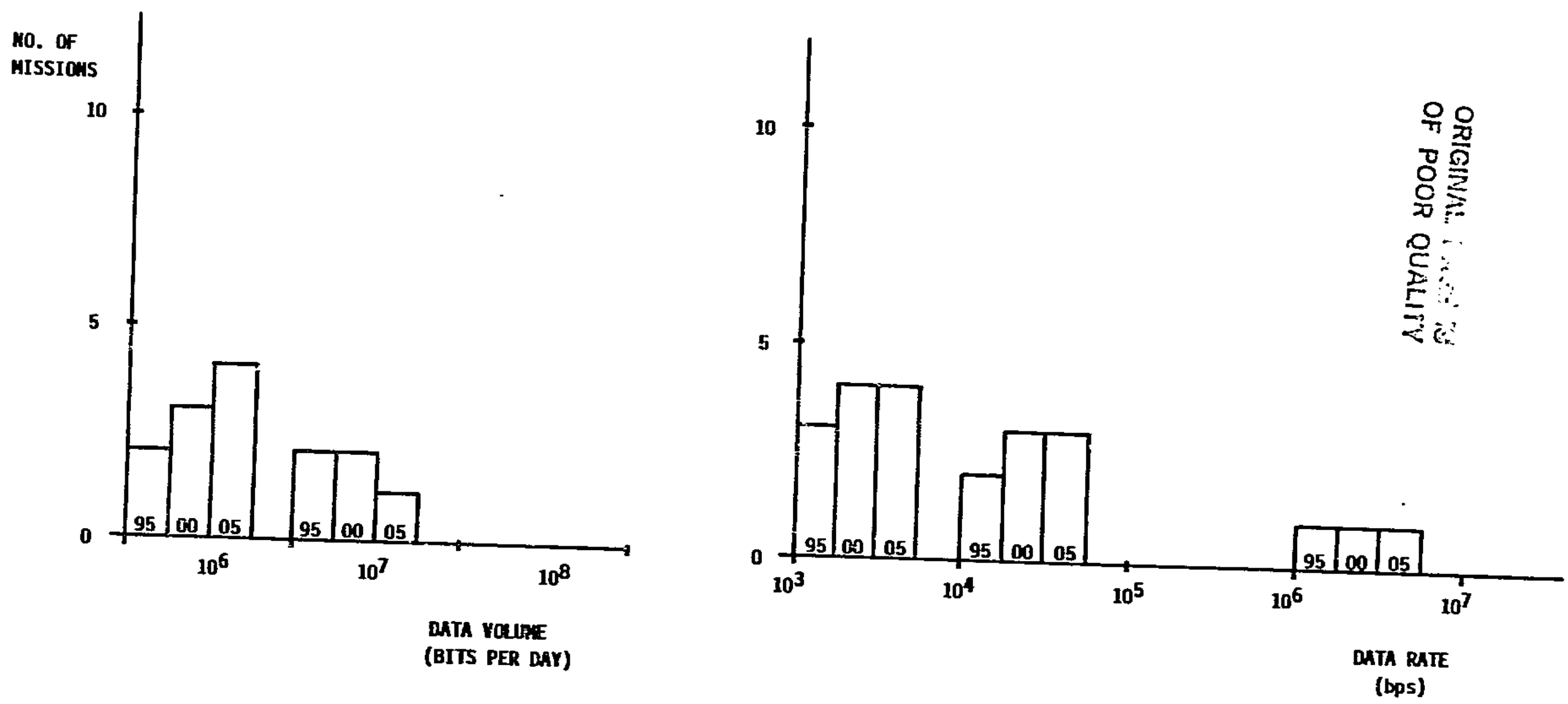

FIGURE 4.2.3-2: DISTRIBUTION OF SPACECRAFT COMMANDS, SCENARIO A2

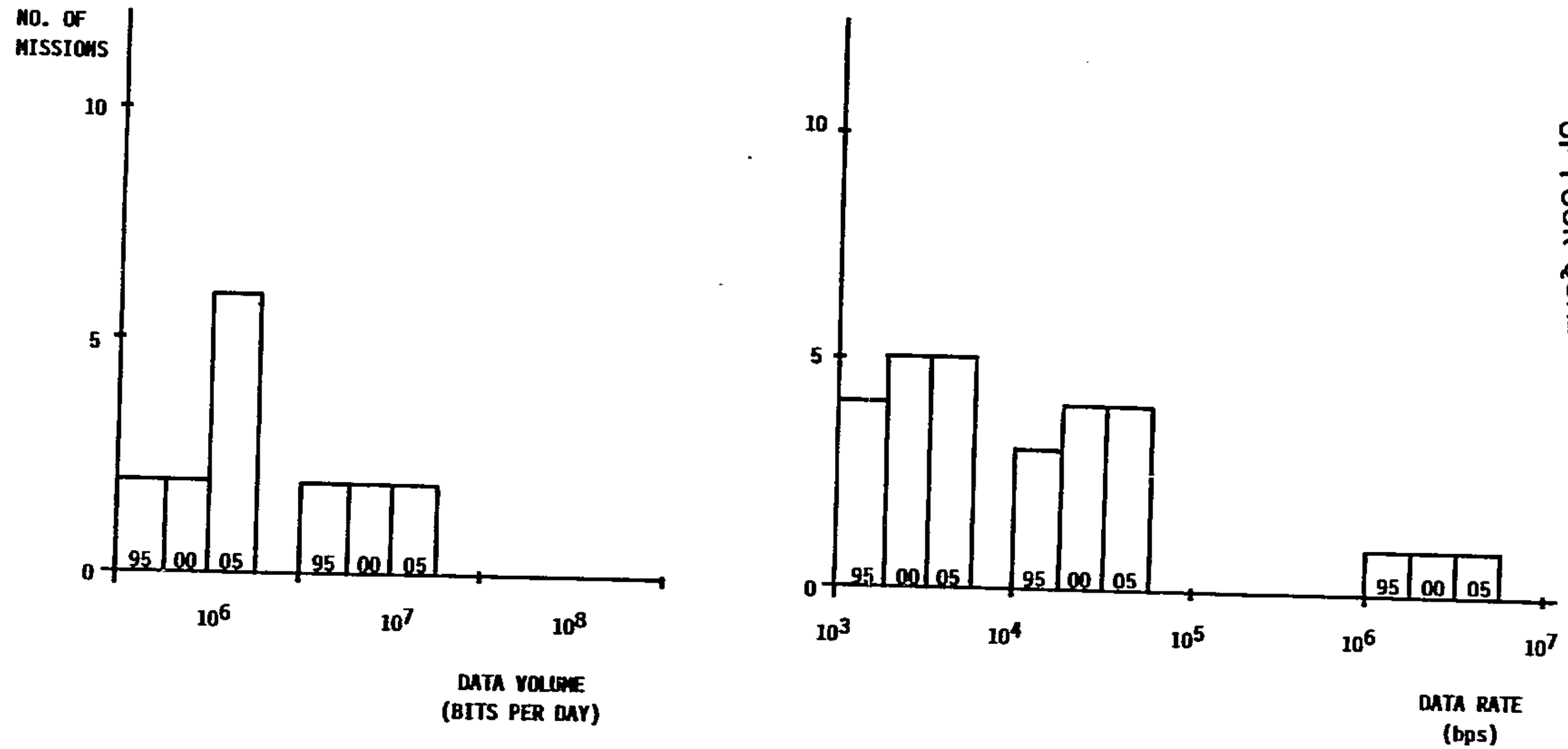

FIGURE 4.2.3-3: DISTRIBUTION OF SPACECRAFT COMMANDS, SCENARIO B1

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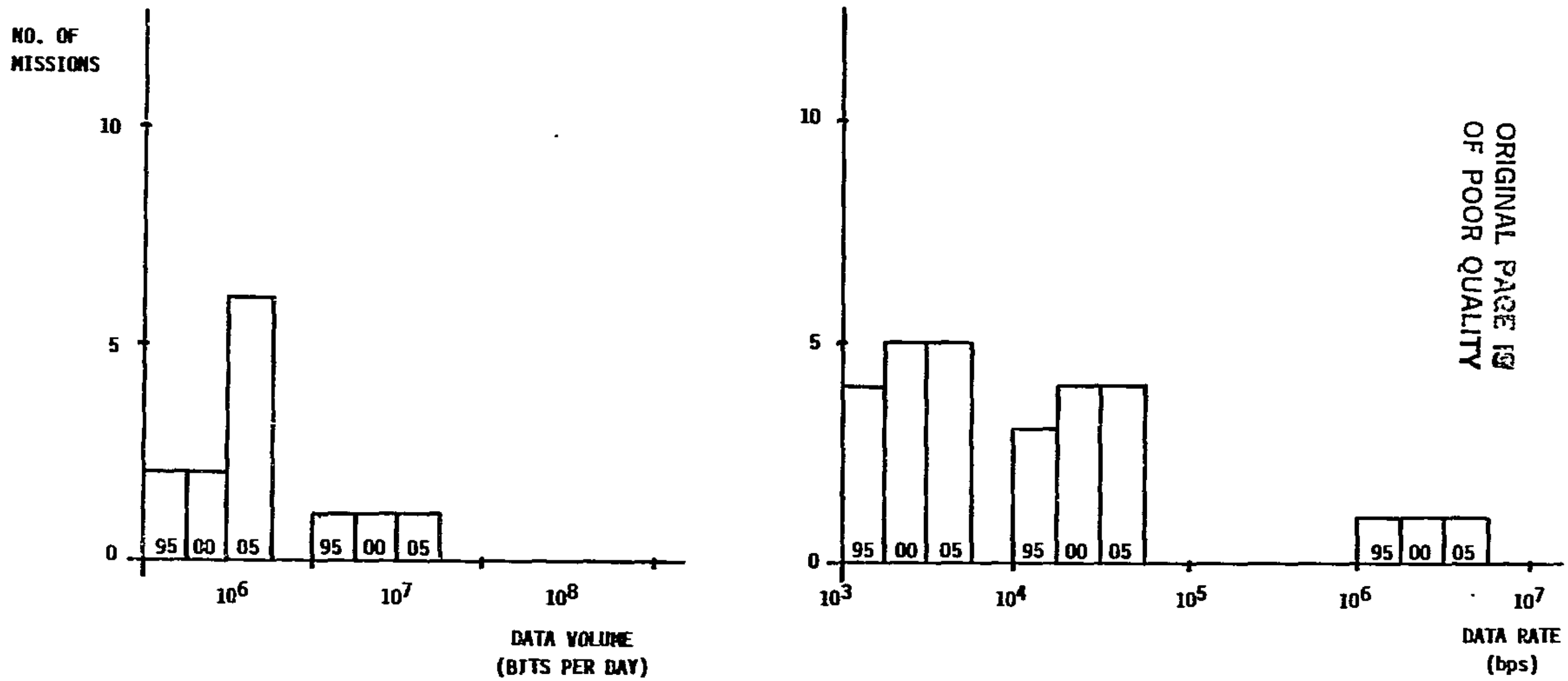

FIGURE 4.2.3-4: DISTRIBUTION OF SPACECRAFT COMMANDS, SCENARIO B2

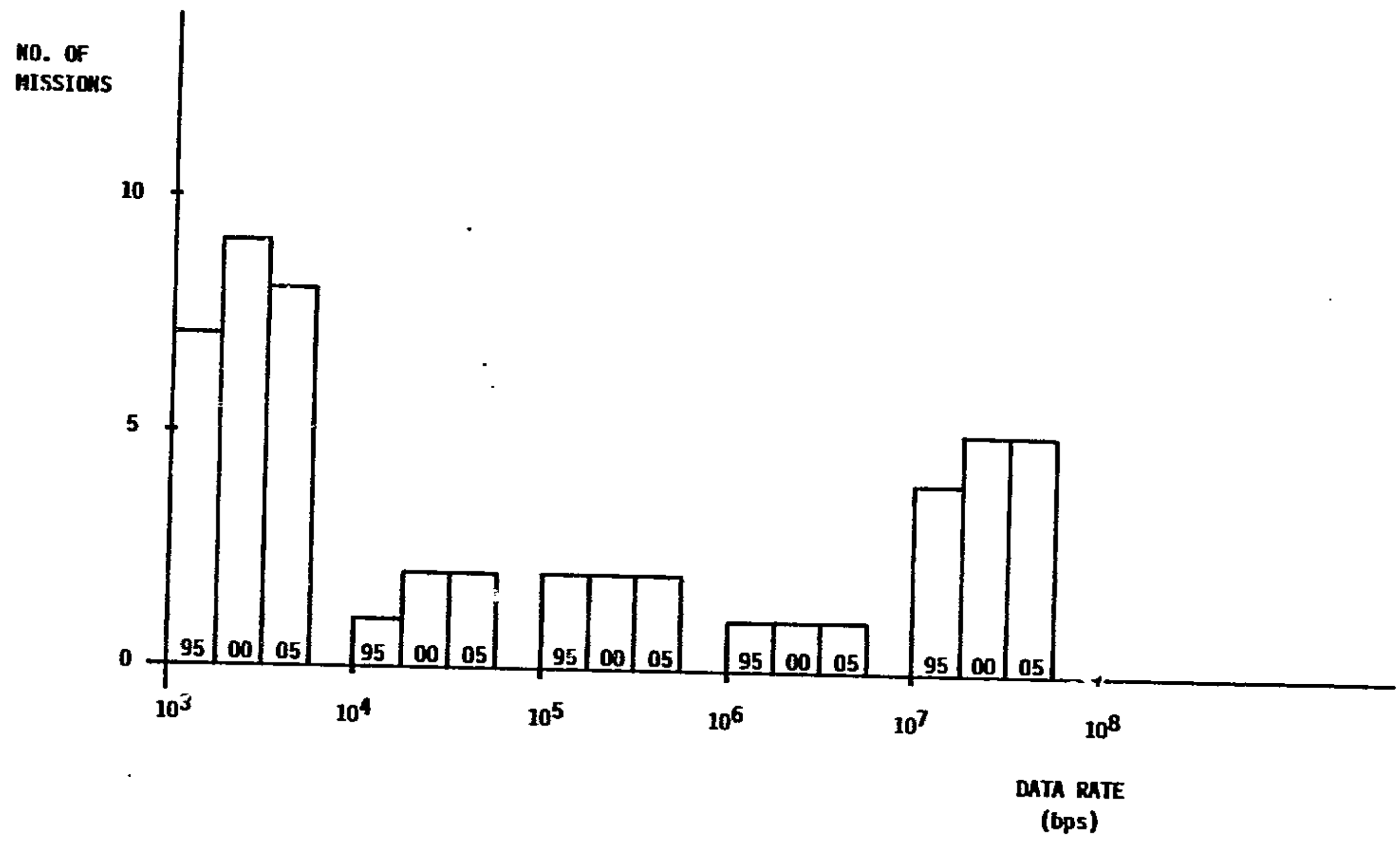

FIGURE 4.2.4-1: DISTRIBUTION OF ENGINEERING DATA RATES, SCENARIO A1

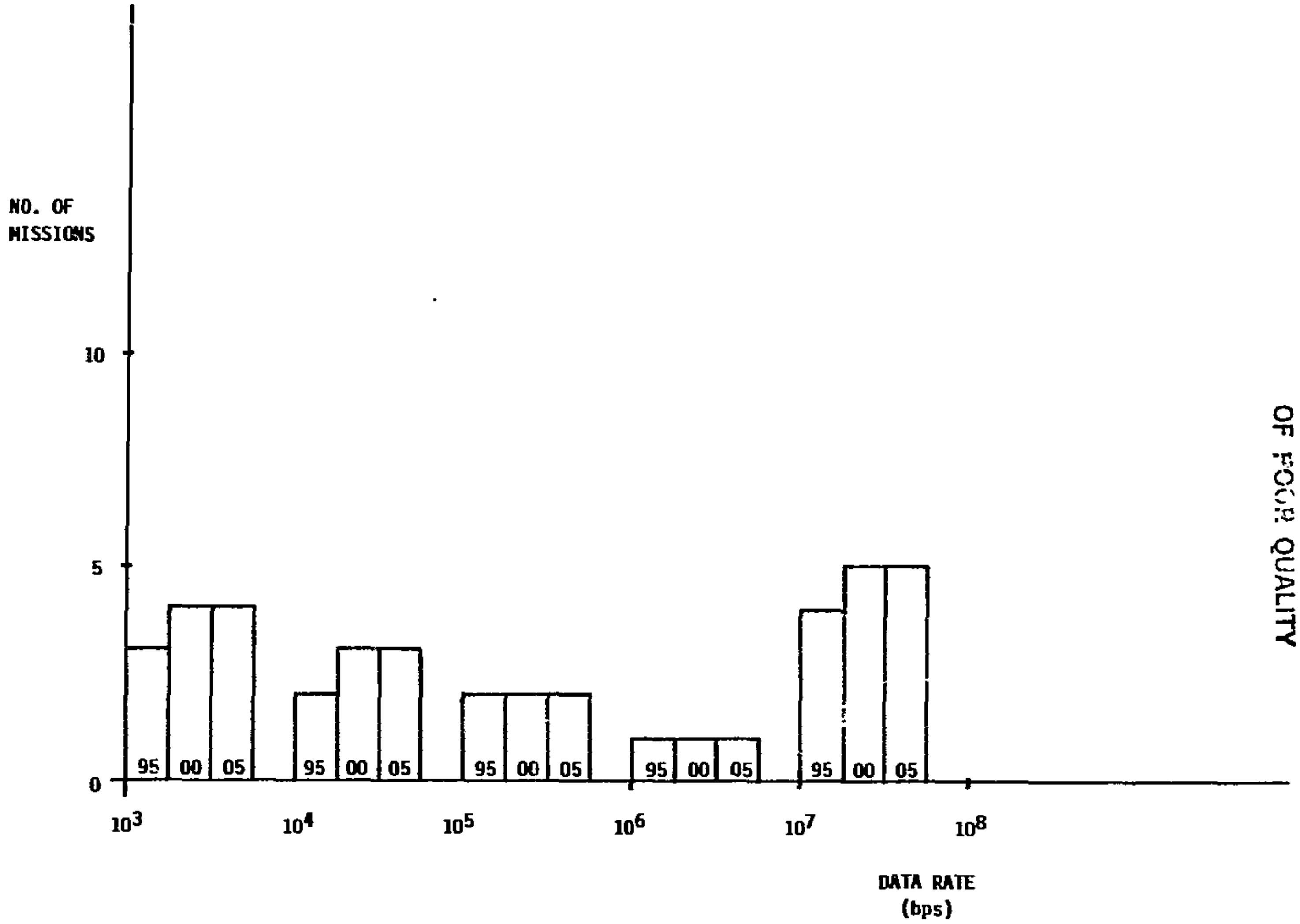

FIGURE 4.2.4-2: DISTRIBUITON OF ENGINEERING DATA RATES, SCENARIO A2

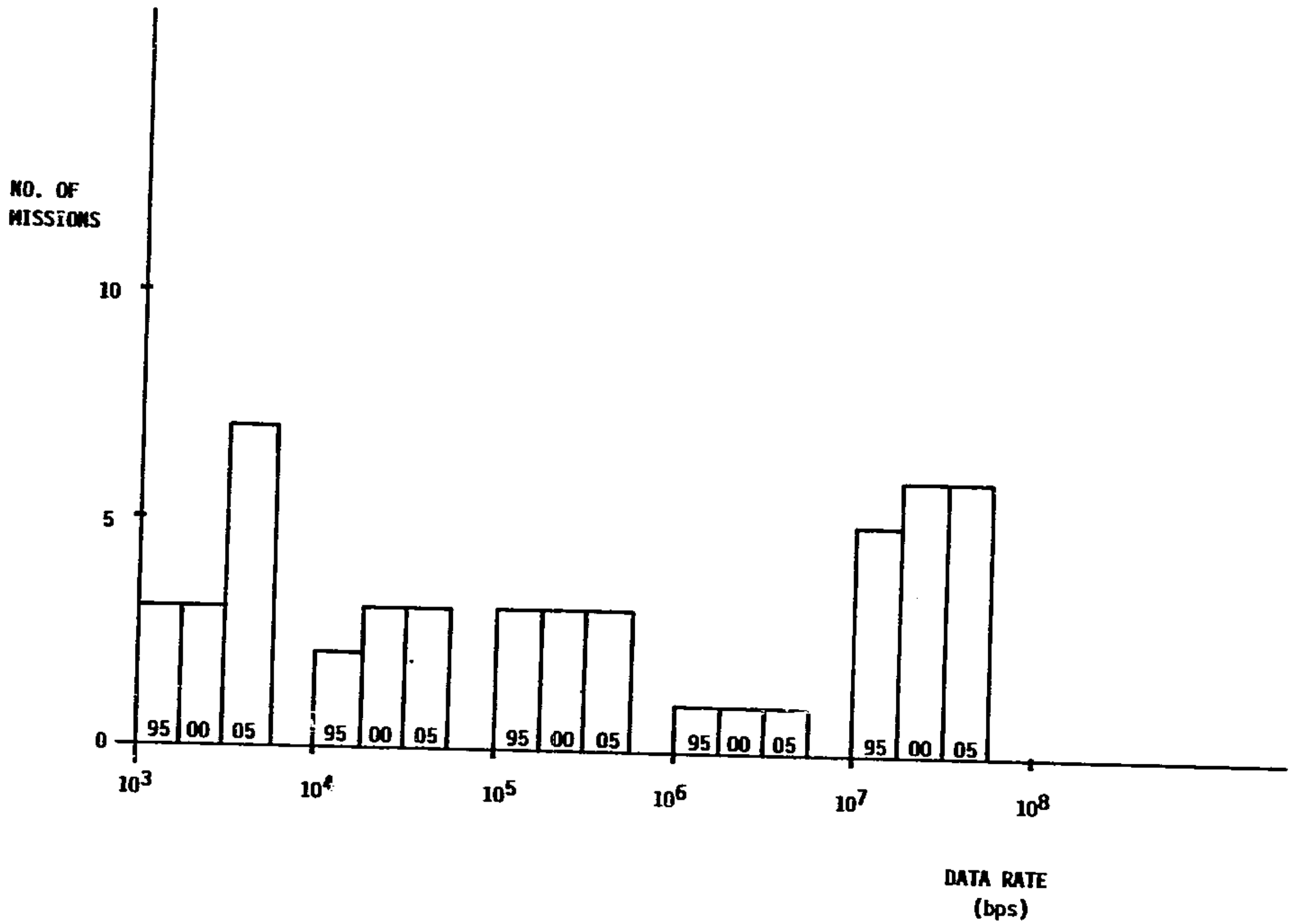

FIGURE 4.2.4-3: DISTRIBUTION OF ENGINEERING DATA RATES, SCENARIO B1

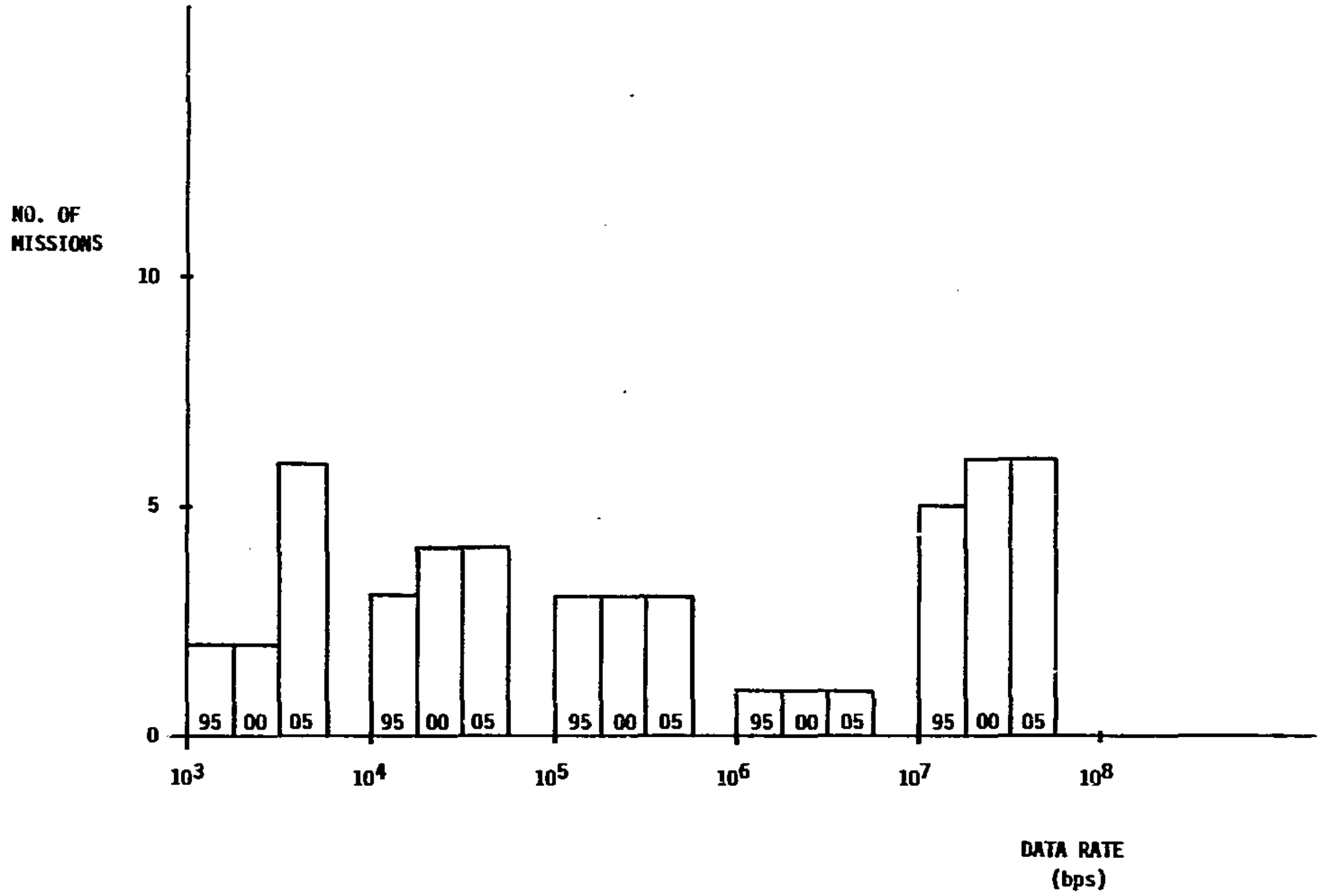

FIGURE 4.2.4-4: DISTRIBUTION OF ENGINEERING DATA RATES, SCENARIO B1

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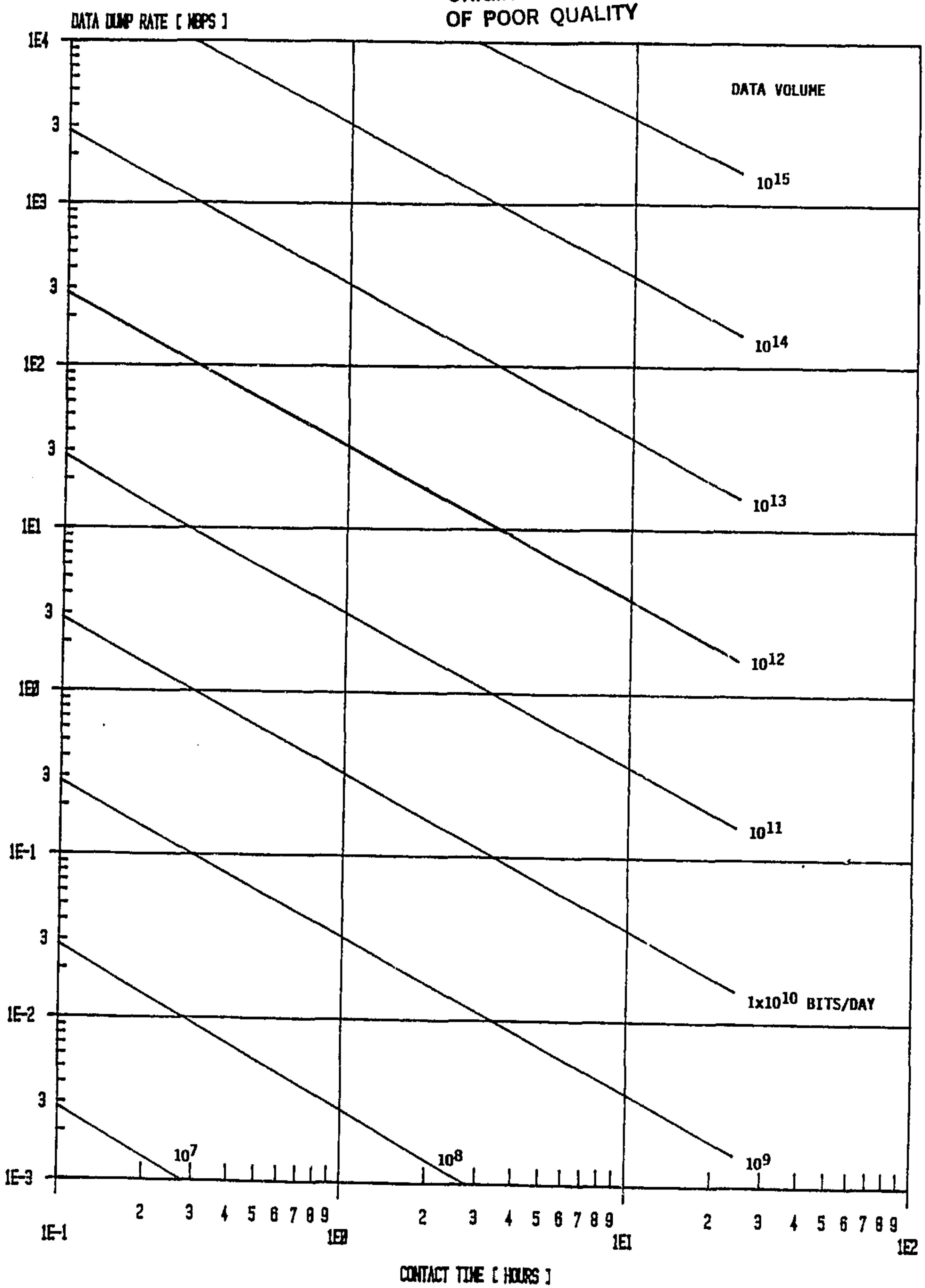

FIGURE 4.3.1-1: CONTACT TIME

The equation relating the parameters is

$$T = \frac{V}{R} \cdot \frac{1}{3600}$$

where: T = contact time hours

V = data volume, bits per day

R = dump rate, bits per second

The data volume can range from 10^6 to 10^{14} bits per day.

4.3.2 Total Contact Time

The contact time per mission was combined with the distribution of data volumes to obtain the total contact time for each group of missions. The missions were grouped in order of magnitude increases in data volume with the average data volume used for each group. Figures 4.3.2-1 through 4.3.2-4 present the total contact time for scenarios of mission models A1, A2, B1 and B2, respectively. As before, the contact time shown is strictly for communication and does not include acquisition times or other delays. Real- time science data requirements are not included.

4.3.3 Impact of Military Requirements

The military mission model (SCS-A) was added to scenario A1. The distribution of science data volumes is shown in Figure 4.3.3-1 for the combined models. The number of military missions is more than double the number of NASA missions. The total contact time for the combined models is shown in Figure 4.3.3-2.

4.4 IMPACT OF MASS STORAGE*

If mass storage is used on-board the user spacecraft to implement a dump mode of data communications, the storage volume of the mass storage as well as the maximum tranfer rate will impact the communication requirements. The equations describing the mass storage are:

* This section is not revised.

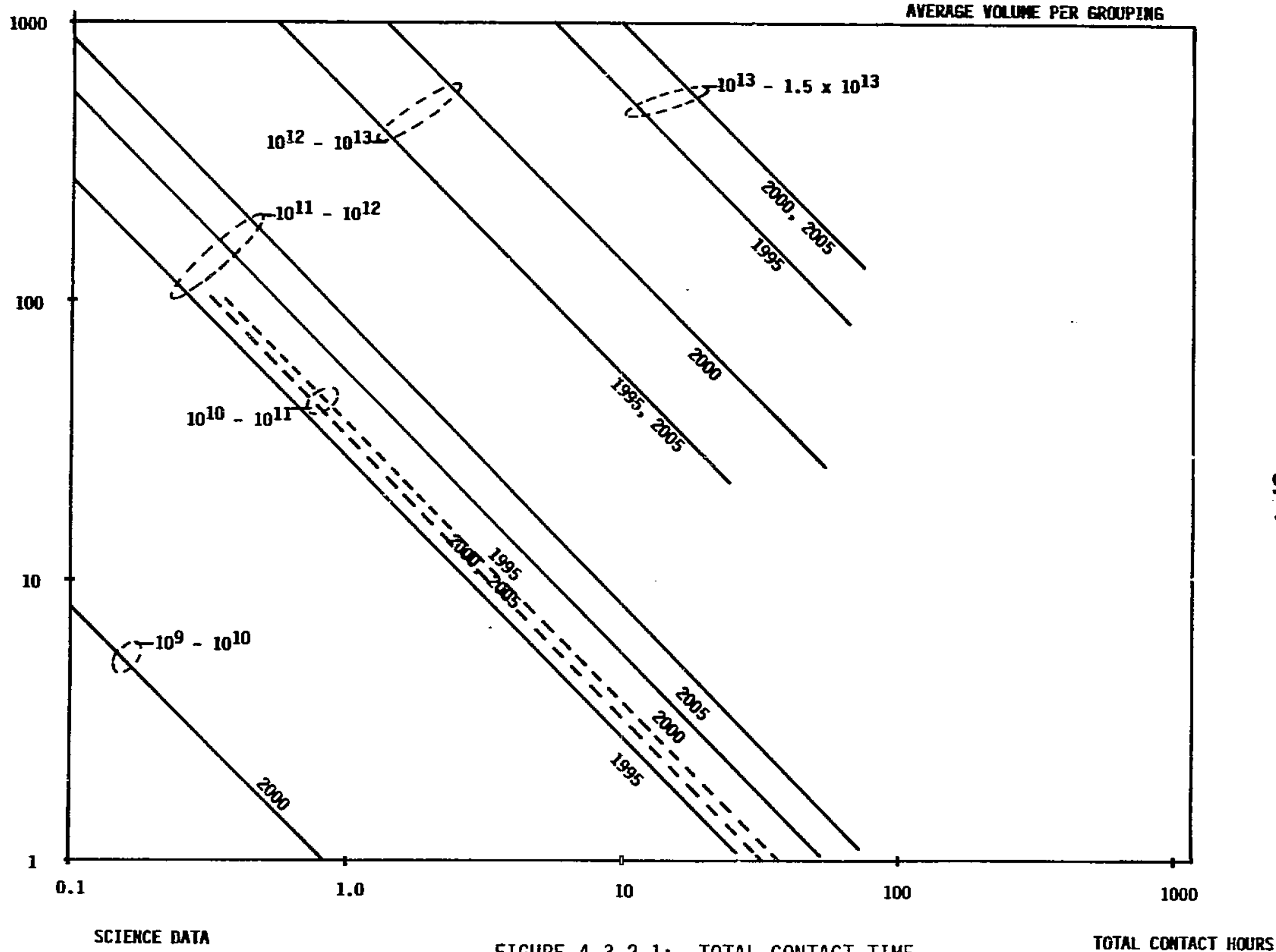

FIGURE 4.3.2-1: TOTAL CONTACT TIME, SCENARIO A1

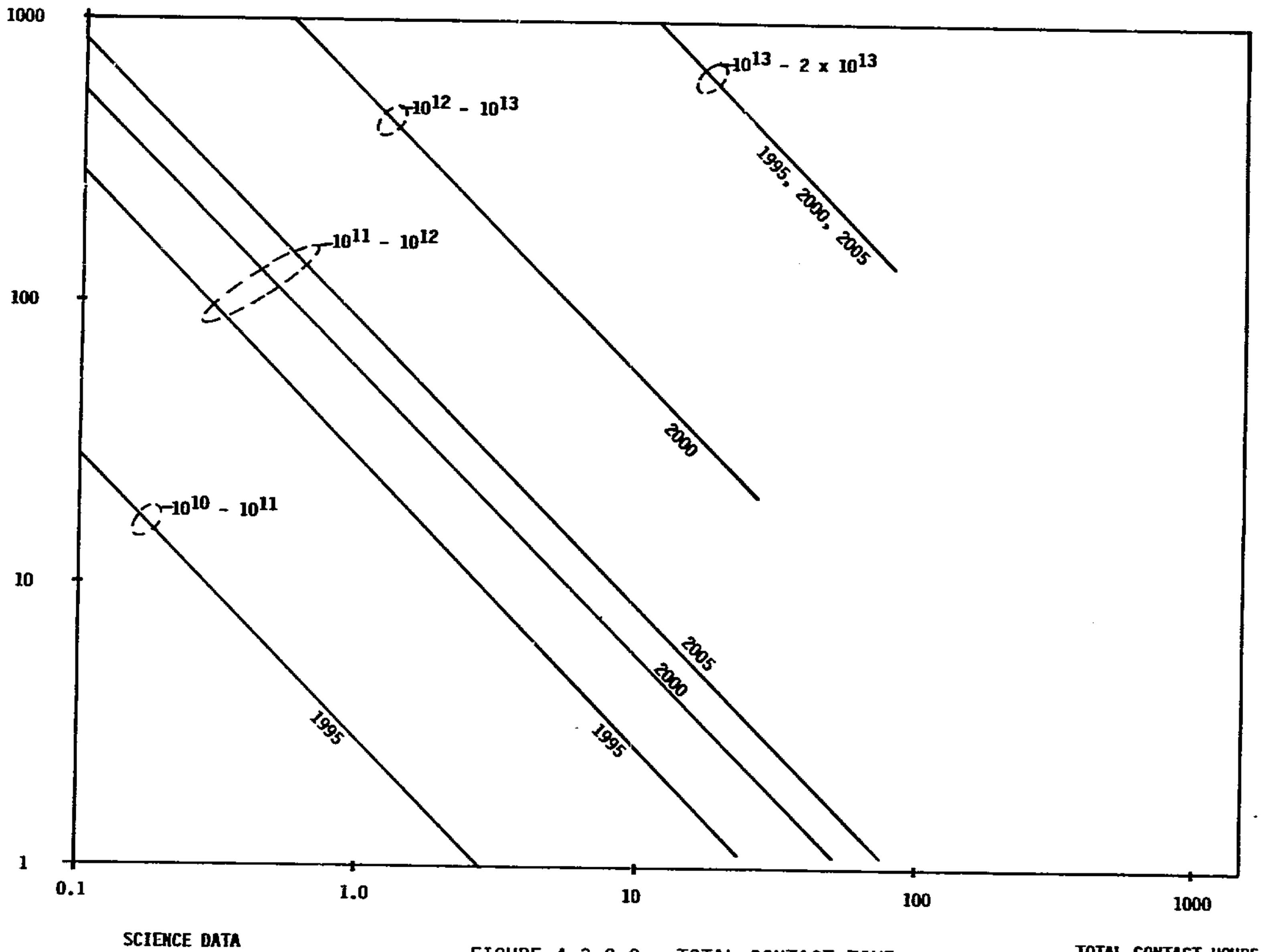

FIGURE 4.3.2-2: TOTAL CONTACT TIME, SCENARIO A2

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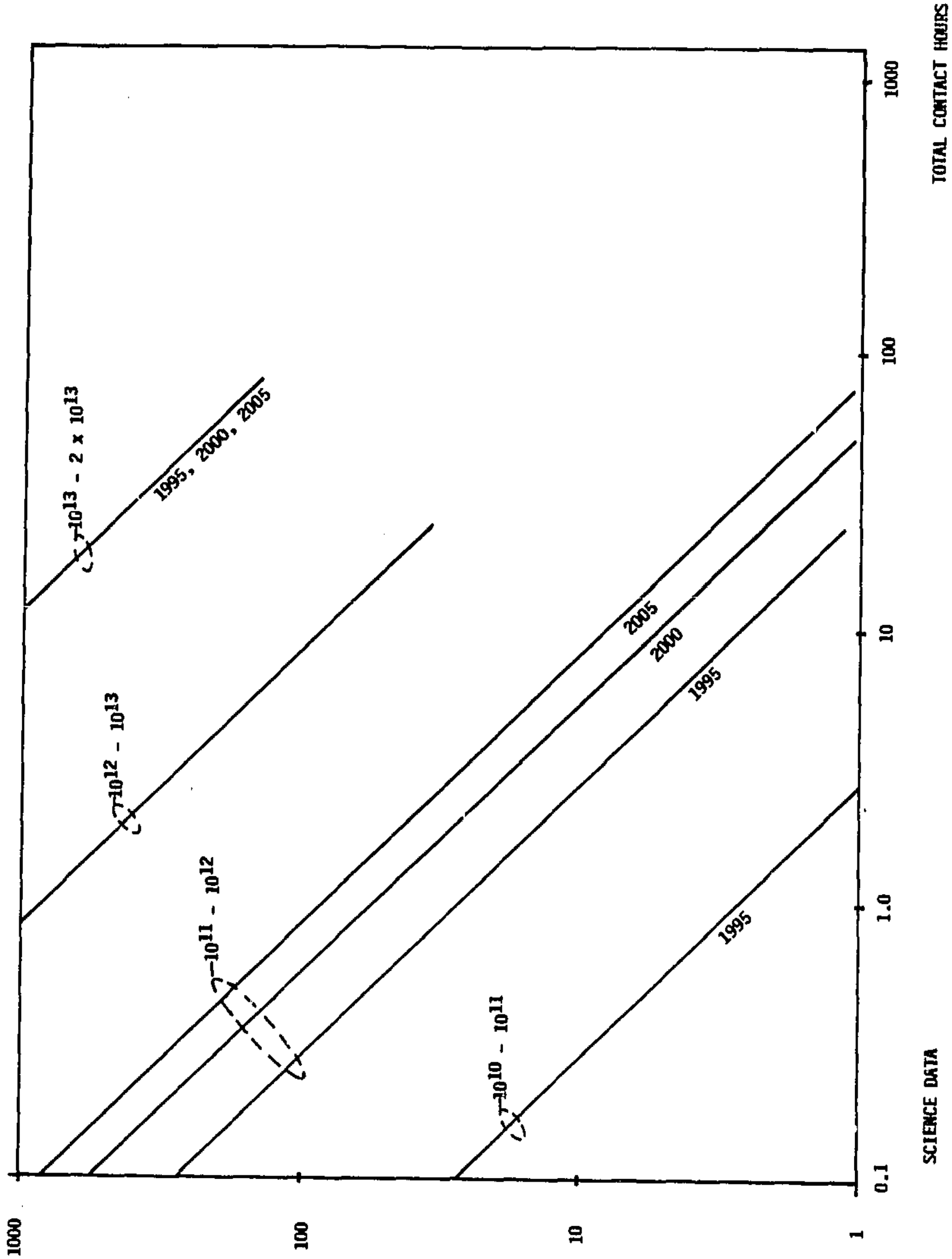

FIGURE 4.3.2-3: TOTAL CONTACT TIME, SCENARIO B1

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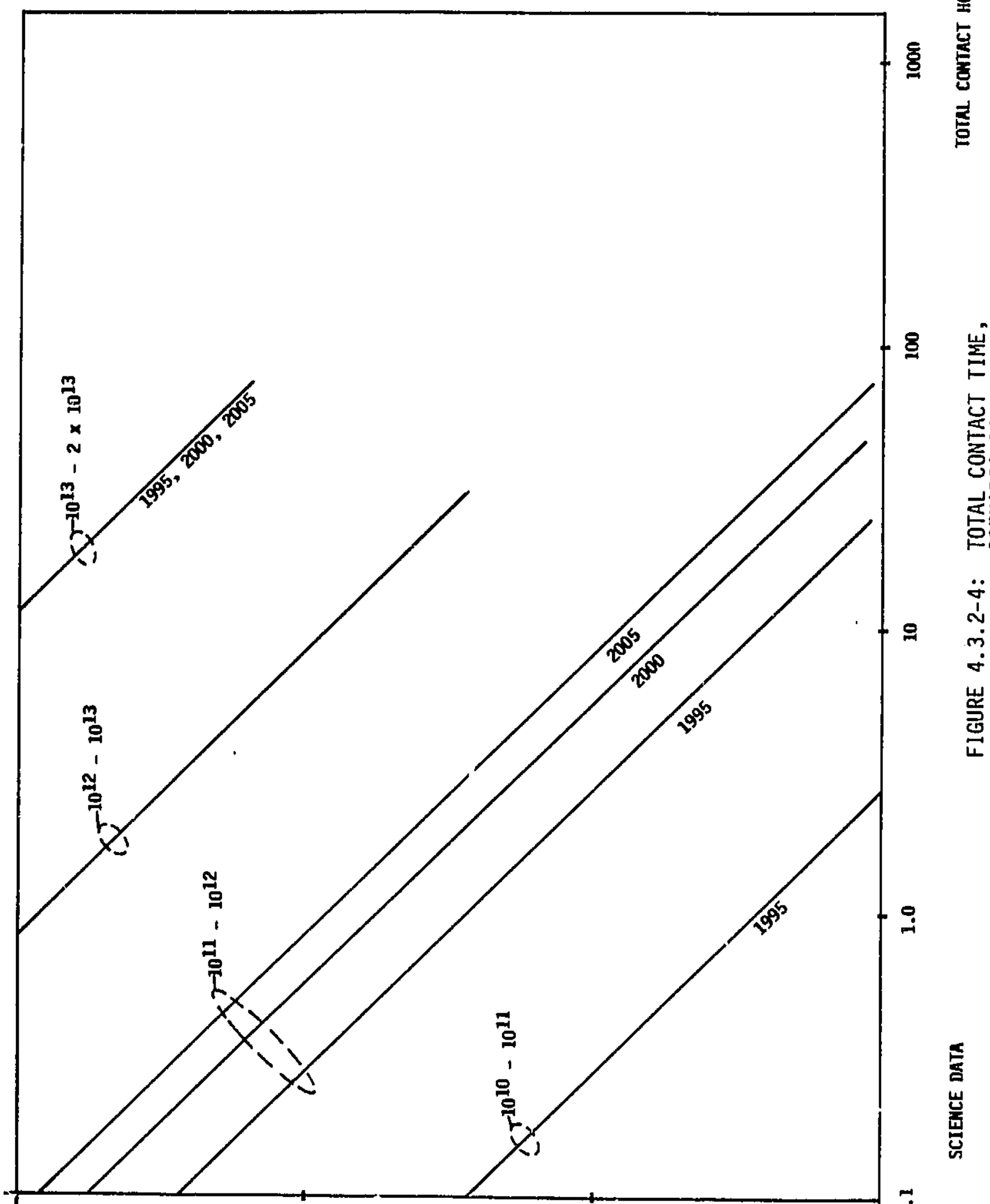

FIGURE 4.3.2-4: TOTAL CONTACT TIME,
SCENARIO B2

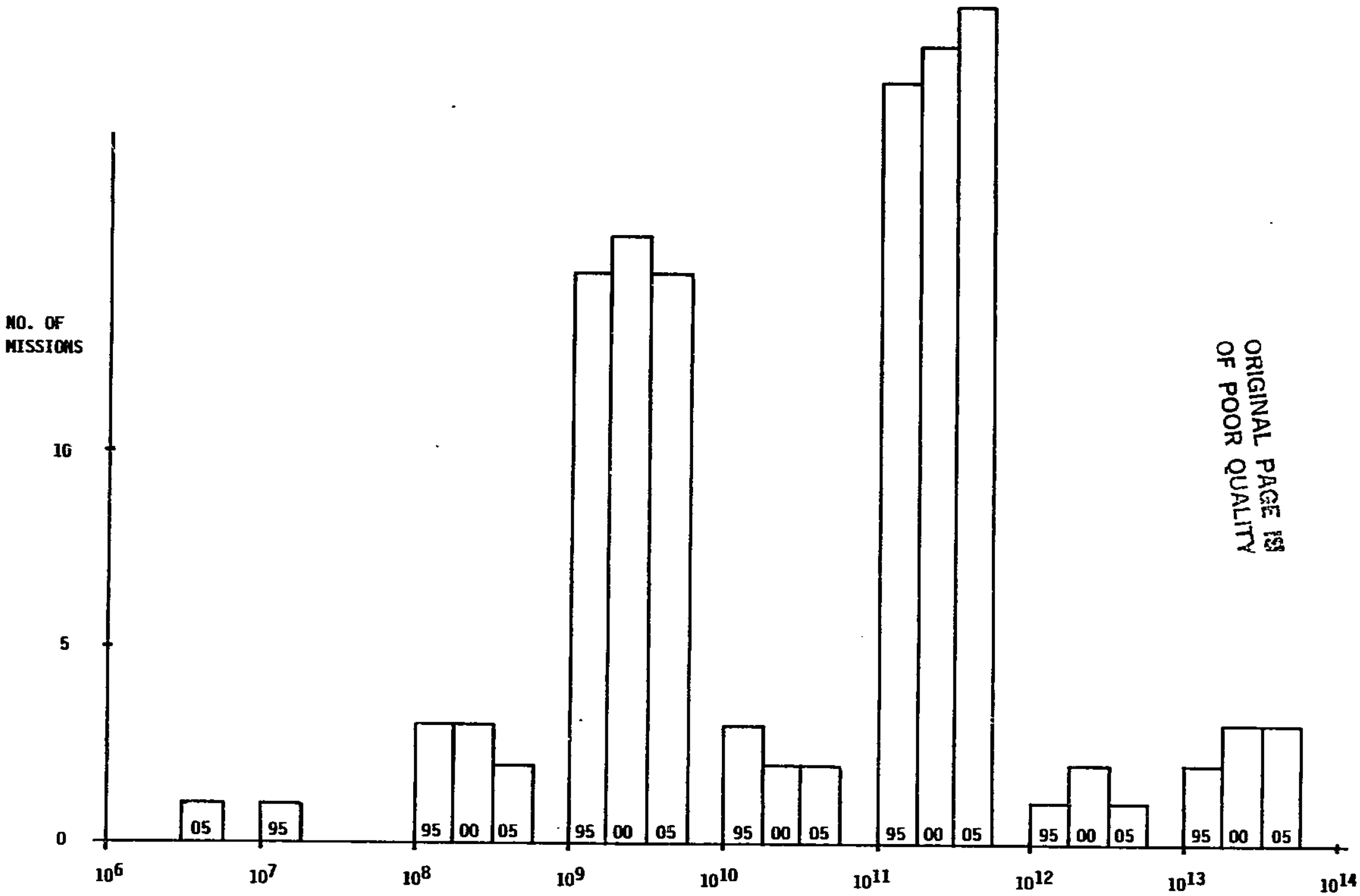

FIGURE 4.3.3-1: DISTRIBUTION OF SCIENCE DATA VOLUME, SCENARIO A1 PLUS SCS-A

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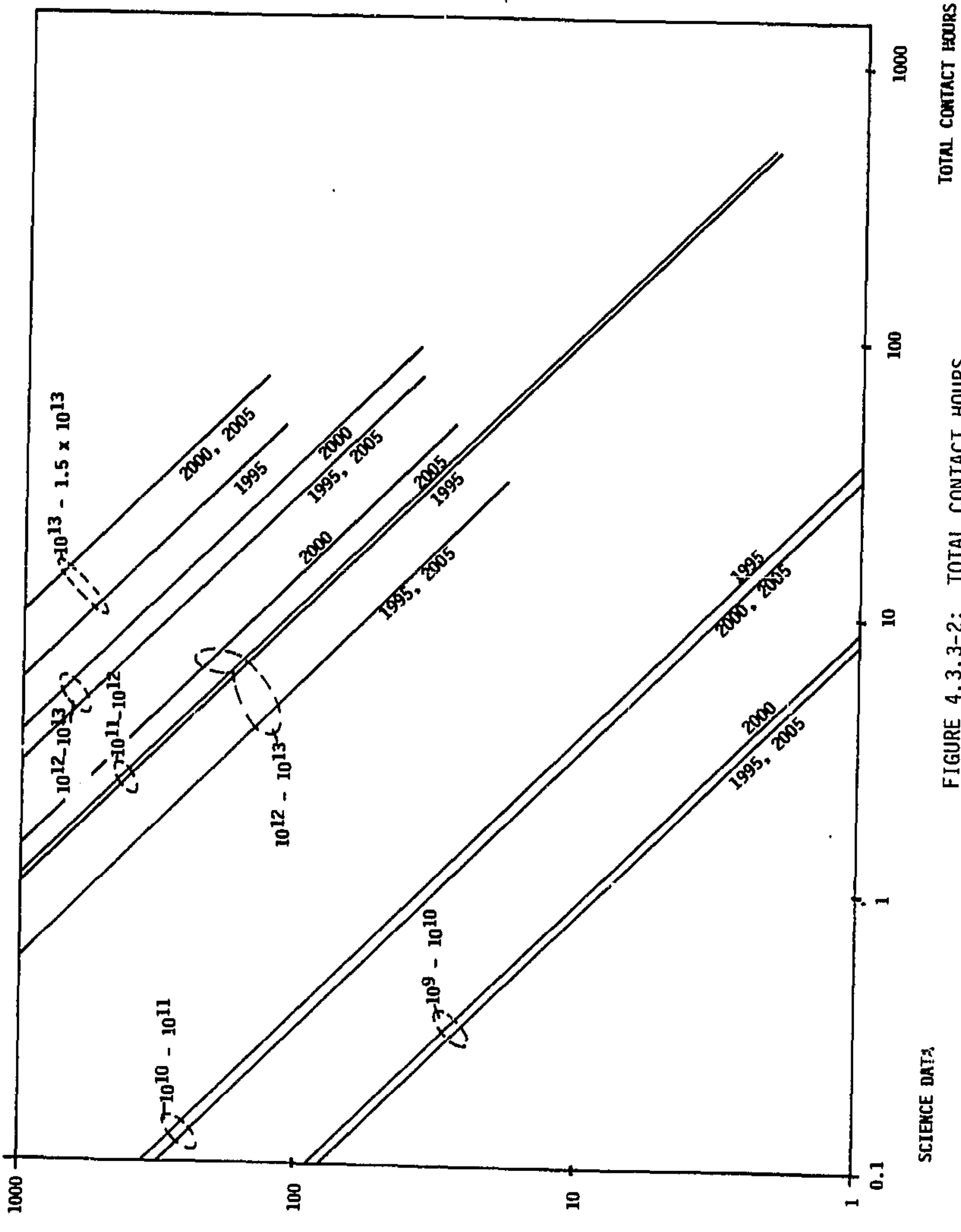

FIGURE 4.3.3-2: TOTAL CONTACT HOURS, SCENARIO A1 PLUS SCS-A

$$\text{Hours per Contact} = \frac{\text{Storage Volume}}{\text{Dump Rate}}$$

$$\text{No. of Contacts/Day} = \frac{\text{Data Volume}}{\text{Storage Volume}}$$

Figure 4.4-1 shows a plot of the hours per contact as a function of storage volume and dump rate. The maximum mass storage transfer rate projected for the year 2000 is shown as a technology limit related to mag tape. Also shown is the storage volume technology limit projected for the year 2000.

Figure 4.4-2 shows a plot of the number of contacts per day as a function of storage volume and data volume. Figure 4.4-3 shows a plot of the number of contacts per day as a function of the contact time per mission and storage volume for a dump rate of 10 Mbps.

Figure 4.4-4 shows the dump rate as a function of contact hours per mission and data volume. The technology limits for mag tape mass storage are also indicated.

4.5 IMPACT OF ON-BOARD PROCESSING*

The use of on-board processing for data compression by the user spacecraft will modify the distribution of science data volumes and consequently modify the contact time requirements. The effect of this on-board processing will be to reduce the science data volume by the data compression factor. One further assumption invoked was that all missions having a data volume of 10^{10} bits per day or greater will use data compression.

Figure 4.5-1 shows the resulting distribution of science data volume for scenario A1 assuming a data compression factor of 2. As expected the distribution is shifted to the left when comapred with Figure 4.2.1-1 which is the distribution without data compression. Figure 4.5-2 shows the associated total contact time as a function of dump rate for the various data volume groupings.

* This section not revised.

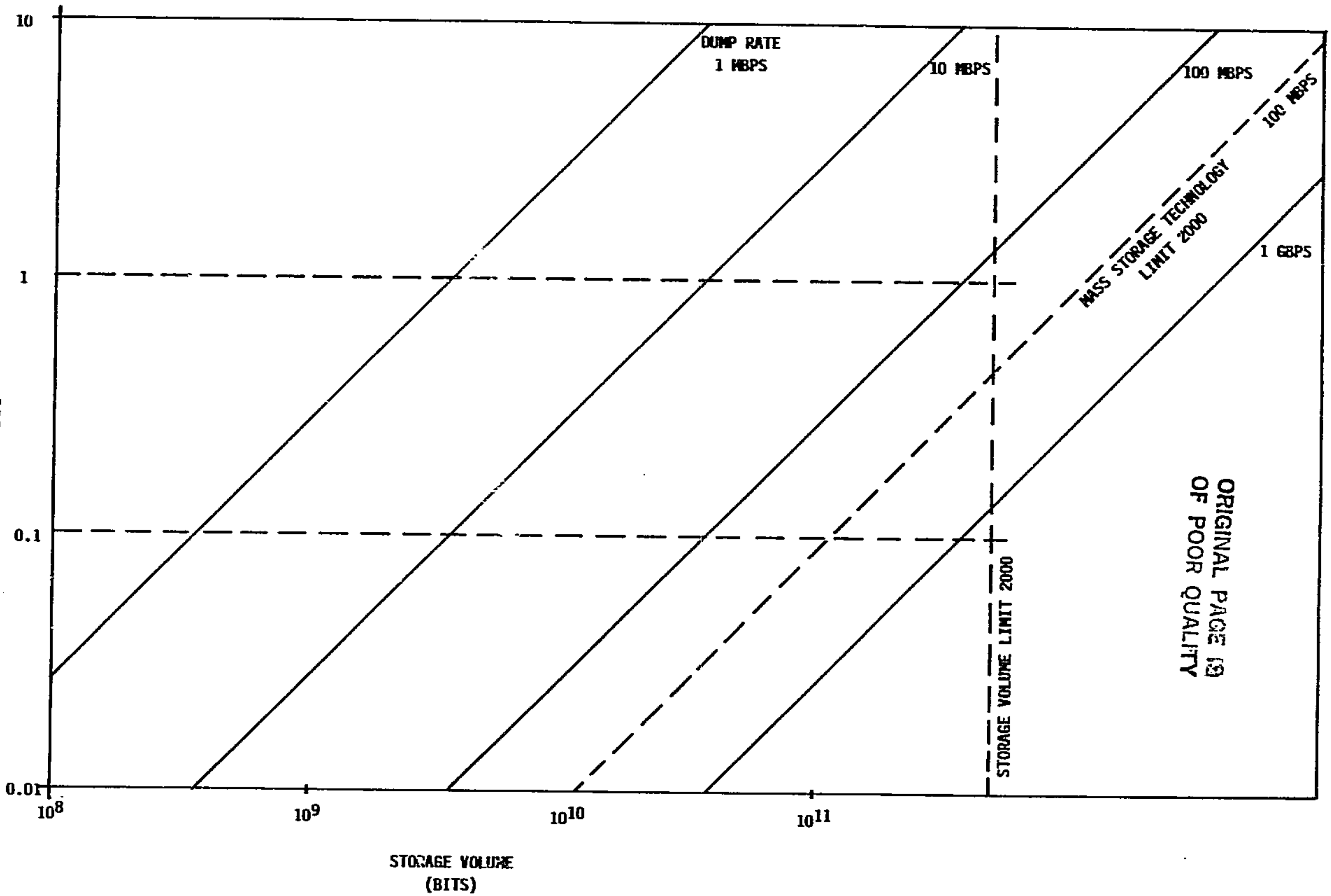

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FIGURE4.4-1: HOURS PER CONTACT

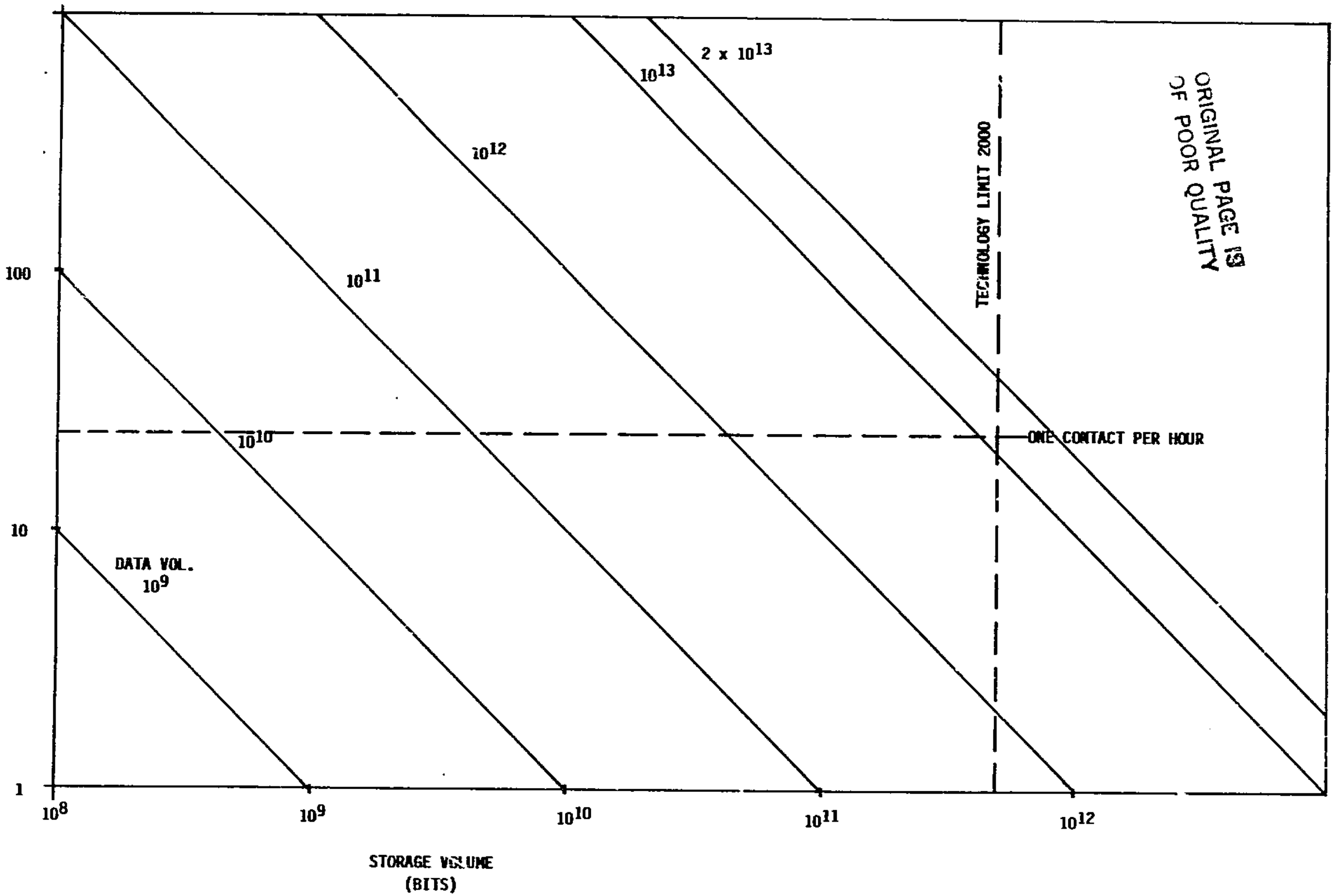

FIGURE 4.4-2: NUMBER OF CONTACTS PER DAY

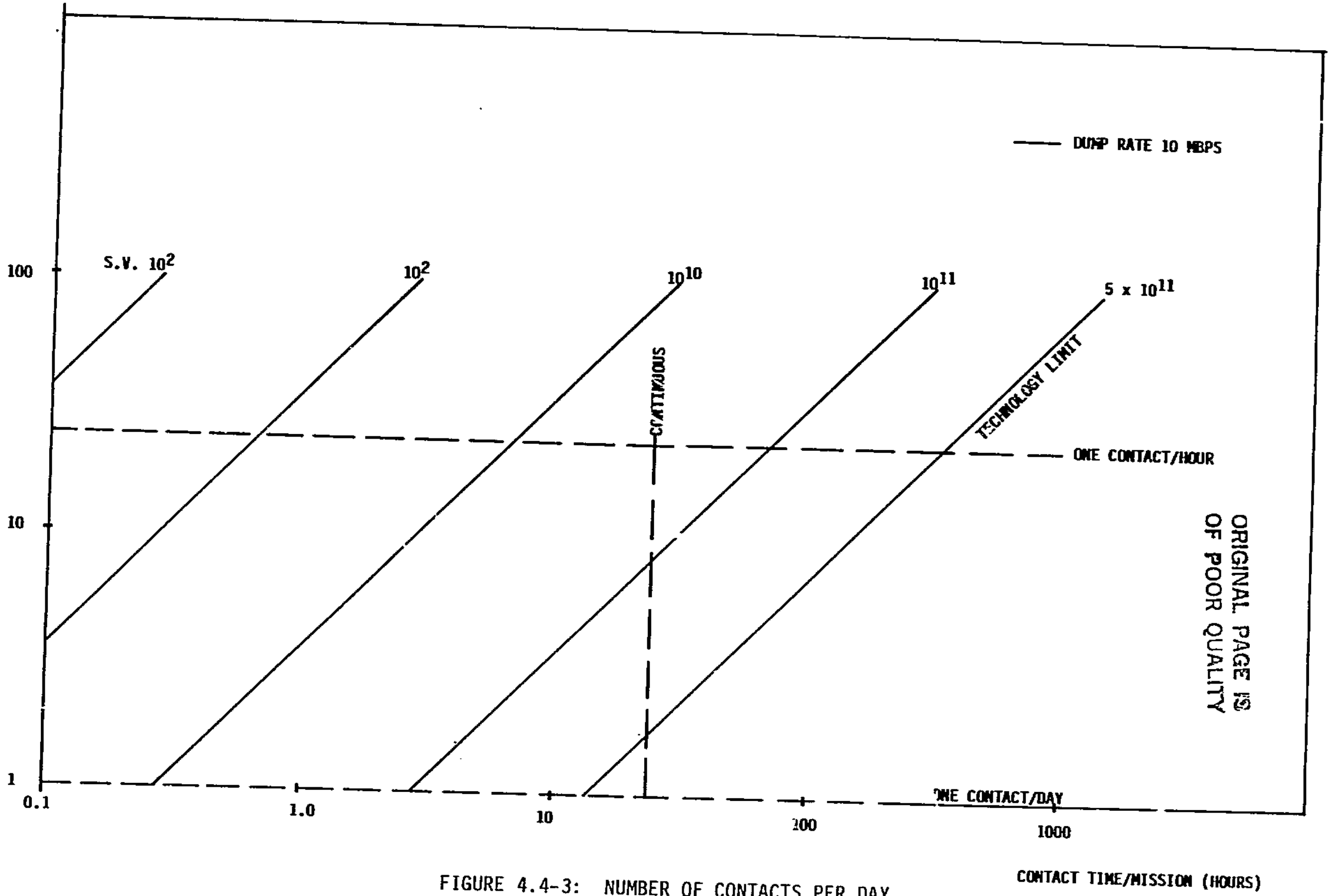

FIGURE 4.4-3: NUMBER OF CONTACTS PER DAY, DUMP RATE 10 MBPS

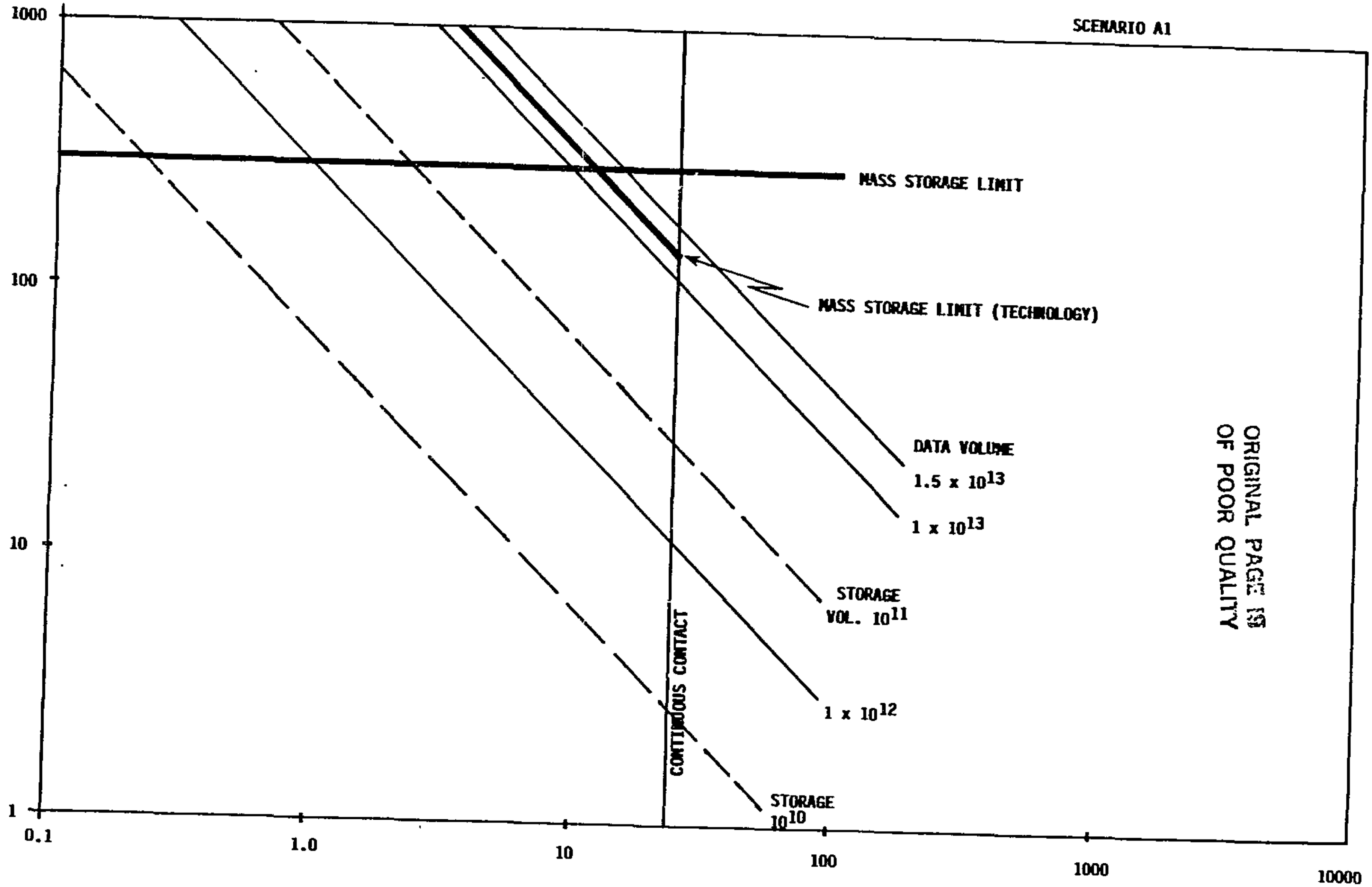

FIGURE 4.4-4: DUMP RATE

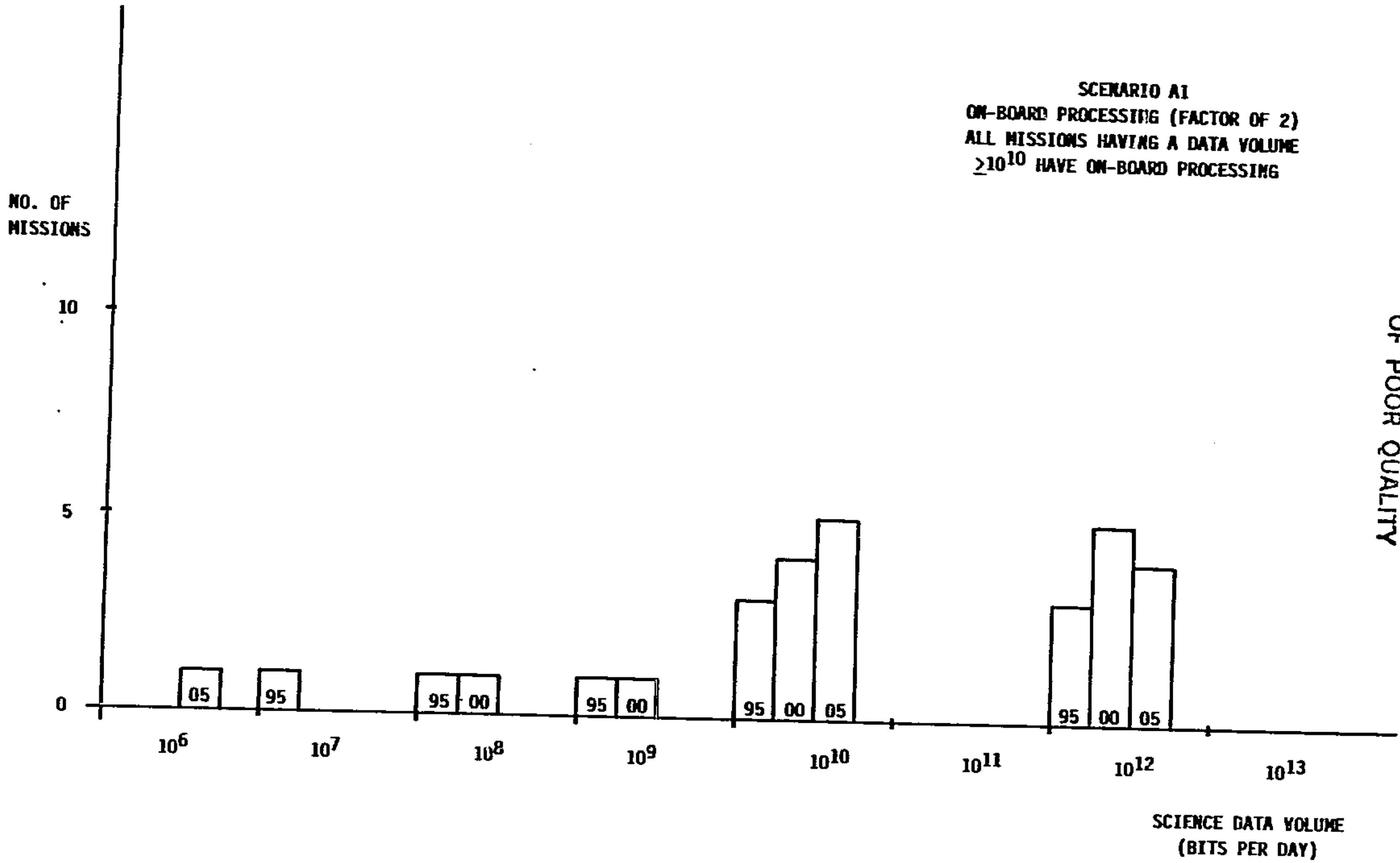

FIGURE 4.5-1: DISTRIBUTION OF SCIENCE DATA VOLUME, SCENARIO A1 DATA COMPRESSION

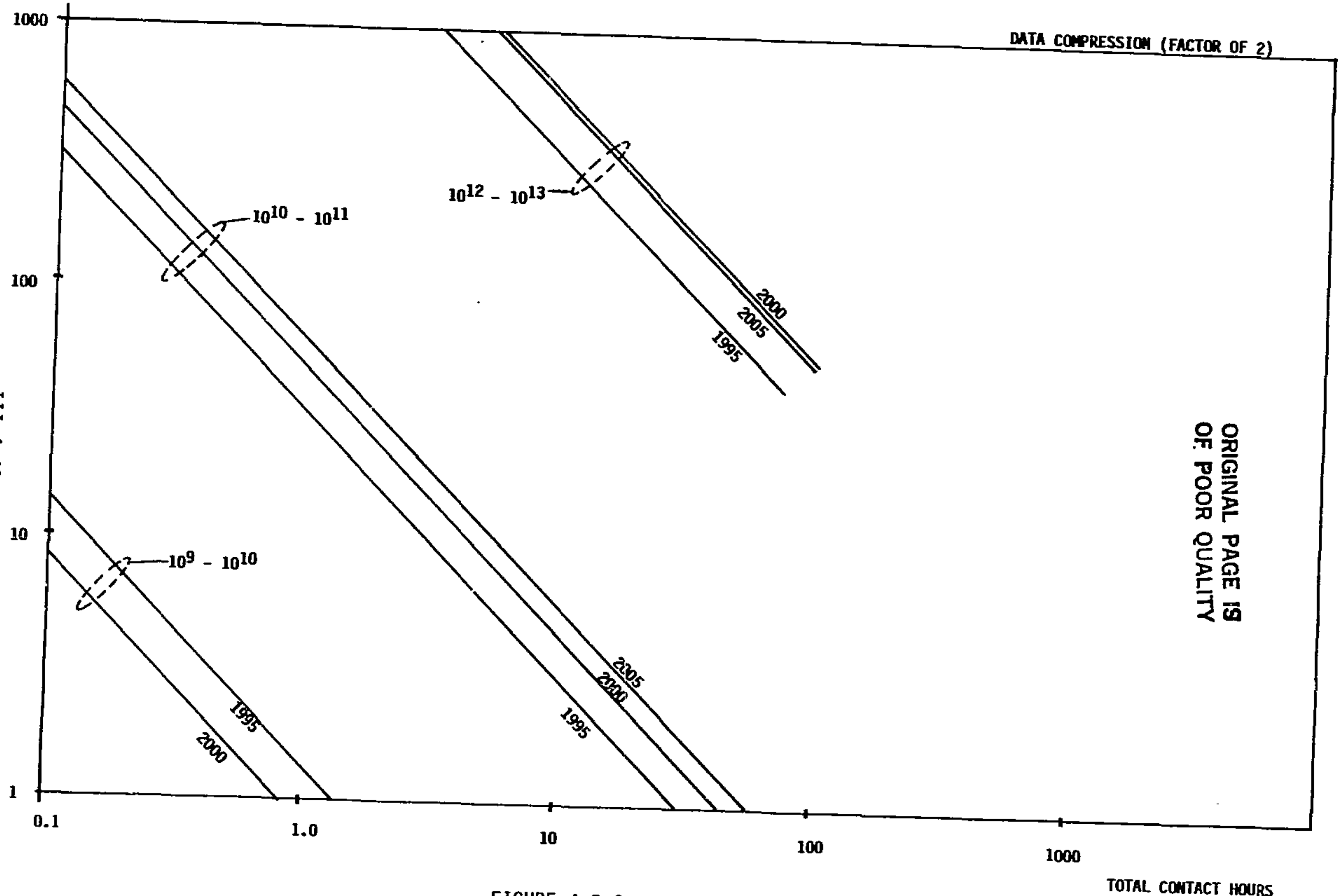

FIGURE 4.5-2: TOTAL CONTACT TIME, SCENARIO A1, DATA COMPRESSION

4.6 AN EXAMPLE*

As an example of the application of the above parametric curves, the problem of using TDRSS spacecraft in the year 2000 will be examined. The following assumptions will be invoked for illustrative purposes in this example:

- The scheduling will be assumed to be 75% efficient.
- The data compression factor will be 1, 2 or 3.
- Coding will not be used
- High data volume users ($\geq 10^{12}$) will dump at 300 Mbps and medium volume users ($\geq 10^{11}$) at 30 Mbps.
- Visibility problems are included in the scheduling efficiency.

Communication requirements to support projected NASA and military missions in the year 2000 are summarized in Table 4.7-1, 4.7-2 and 4.7-3. The first half of the Table 4.7-1 displays the number of equivalent TDRSS single access channels required to support future NASA activity, assuming that the current level of NASA activity is maintained, while the second half of the table displays the impact of adding military users to the constant level NASA activity. The military activity assumed here is characterized by a relatively large number of missions operating at moderate data rates. The assumed NASA and military missions conservatively estimate the potential activity that may occur in the year 2000.

Table 4.7-1 gives 3 different estimates of the number of required channels. On any given day the number of channels required will most likely exceed the "minimum" estimate, while it will never exceed the "maximum" estimate. The "busy day" estimate is the required number of channels to support a peak in the activity which is likely to occur at least once during the year.

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* This section has been updated reflecting the deletion of the PUP.

TABLE 4.7-1
SUMMARY OF TDRSS SA CHANNEL REQUIREMENTS FOR THE YEAR 2000

		NASA MISSIONS				NASA AND MILITARY* MISSIONS			
DATA COMPRESSION FACTOR	CHANNEL TYPE	MIN DAY	BUSY DAY	MAX DAY	NUMBER OF MISSIONS	MIN DAY	BUSY DAY	MAX DAY	NUMBER OF MISSIONS
1	R.T. ENG.	4	8	11		4	8	11	
	300 Mbps	3	3	3	7	3	3	3	7
	30 Mbps	1	1	1	4	4	4	4	39
	TOTAL	8	12	15	11	11	15	18	46
2**	R.T. ENG.	4	8	11		4	8	11	
	300 Mbps	2	2	2	7	2	2	2	7
	30 Mbps	1	1	1	4	2	2	2	39
	TOTAL	7	11	14	14	8	12	15	46

IN THE YEAR 2000 NASA AND MILITARY MISSIONS WILL REQUIRE A TOTAL OF 12 - 15 TDRSS SA CHANNELS TO SUPPORT BUSY-DAY TRAFFIC FOR 46 MISSIONS.

*INCLUDES ALL MISSIONS IN SATELLITE CONTROL SYSTEM STUDY (1979) EXCEPT THOSE WITH DATA RATES EXCEEDING 1 GBPS.
**APPLIES TO MISSIONS WITH NON-REAL TIME REQUIREMENTS.

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TABLE 4.7-2

NASA AND MILITARY MISSIONS*

DATA COMP FACTOR	CHANNEL TYPE	MIN DAY	BUSY DAY	MAX DAY	NUMBER OF MISSIONS
1	R.T. ENGINEERING	4	8	11	
	300 Mbps	6	6	6	9
	30 Mbps	4	4	4	39
	TOTAL	14	14	21	48
2	R.T. ENGINEERING	4	8	11	
	300 Mbps	3	3	3	9
	30 Mbps	2	2	2	39
	TOTAL	9	13	16	48

IN THE YEAR 2000 NASA AND MILITARY MISSIONS WILL REQUIRE A TOTAL OF 13 -18 TDRSS SA CHANNELS TO SUPPORT A BUSY-DAY TRAFFIC FOR 48 MISSIONS INCLUDING MISSION S13 OF SCENARIO SCS-B. THE BUSY-DAY CHANNEL REQUIREMENTS ARE SUMMARIZED IN TABLE FOR THE DIFFERENT ASSUMPTIONS REGARDING MILITARY TRAFFIC.

*INCLUDES MISSION S13 OF MILITARY SCENARIO SCB-B.

TABLE 4.7-3

BUSY-DAY SA CHANNEL REQUIREMENTS
FOR THE YEAR 2000

DATA COMPRESSION FACTOR	NASA MISSIONS	NASA AND MILITARY SCS-A	NASA AND MILITARY SCS-A & S13
1	12	15	18
2	11	12	13

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Figure 4.5-3 shows the distribution of science data volume for Scenario A1 assuming a data compression factor of 3. Figure 4.5-4 shows the associated total contact time as a function of dump rate for the various data volume groupings.

Figure 4.5-5 shows the distribution of engineering data rates when data compression is used. For this result, it has been assumed that only the TV data forming part of the engineering data will be compressed. The remaining portions of the engineering data was assumed to not be amenable to data compression.

4.7 IMPACT OF SCHEDULING INEFFICIENCIES AND ACQUISITION*

The efficient use of a particular channel will depend on scheduling efficiency and fixed overhead items. Since it is not possible to effectively schedule every minute of a 24 hours period, the total contact hours requirement will be increased by this scheduling inefficiency. Figure 4.6-1 shows the impact of scheduling inefficiencies on the total contact hours for Scenario A1 in the year 2000. From this figure, it is apparent that 50% efficient scheduling doubles the total contact hours required.

The fixed overhead time for each contact depends on the TDAS system design and will include such items as

- System setup (e.g., antenna slewing of required, commands, etc.)
- Signal Acquisition and Test
- Service Termination.

The equation describing the impact of this fixed overhead time on the contact hours per day is:

$$\text{Contact Hours/Day} = \frac{\text{Data Volume}}{\text{Dump Rate}} \quad \frac{1}{3600} \quad \frac{\text{Data Volume}}{\text{Storage Volume}} \text{(Overhead Time)}$$

This equation was computed for an overhead time of 0.1 hours with the results shown in Figure 4.6-2.

* This section not revised.

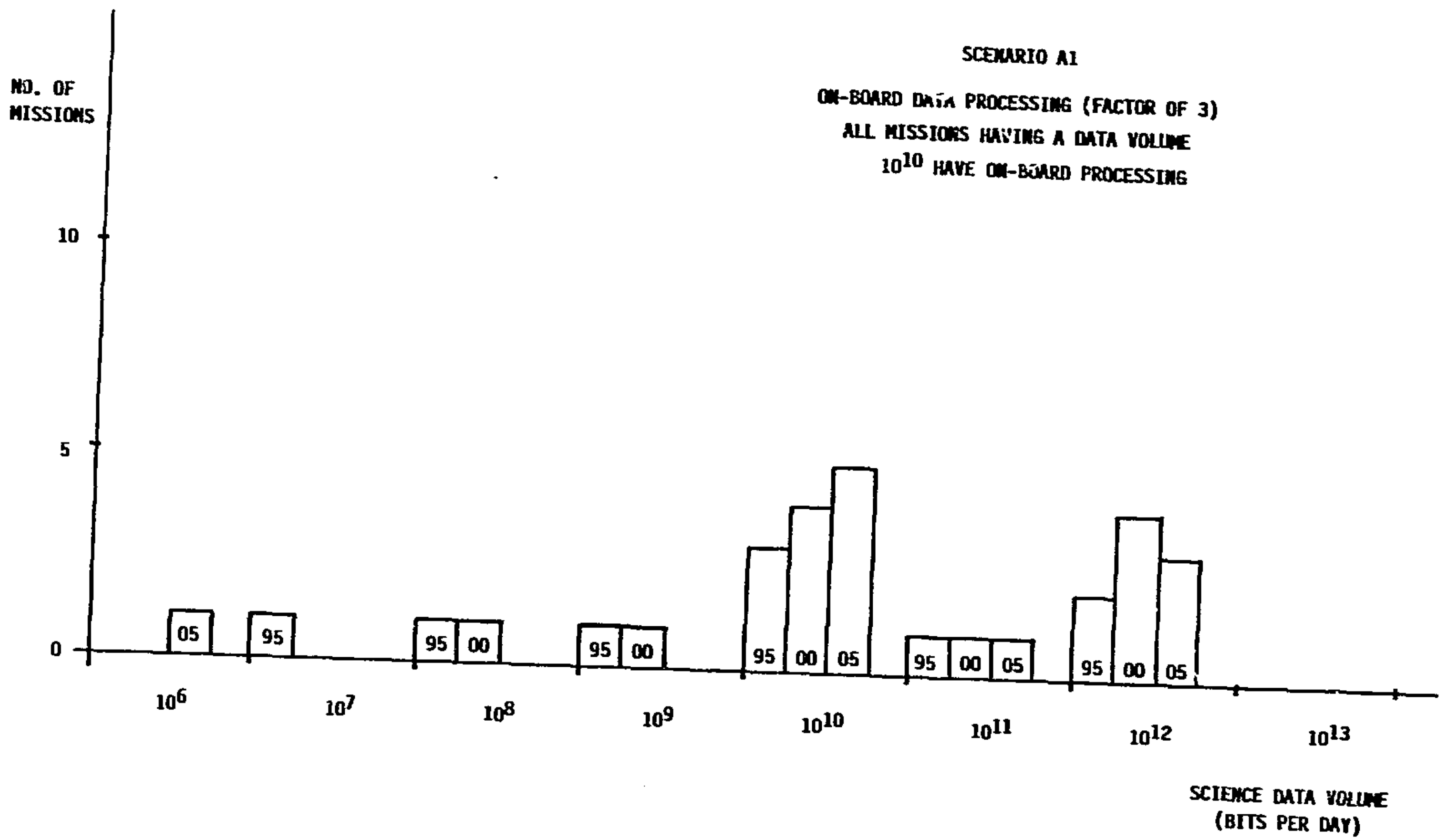

FIGURE 4.5-3: DISTRIBUTION OF SCIENCE DATA VOLUME, SCENARIO A1 DATA COMPRESSION

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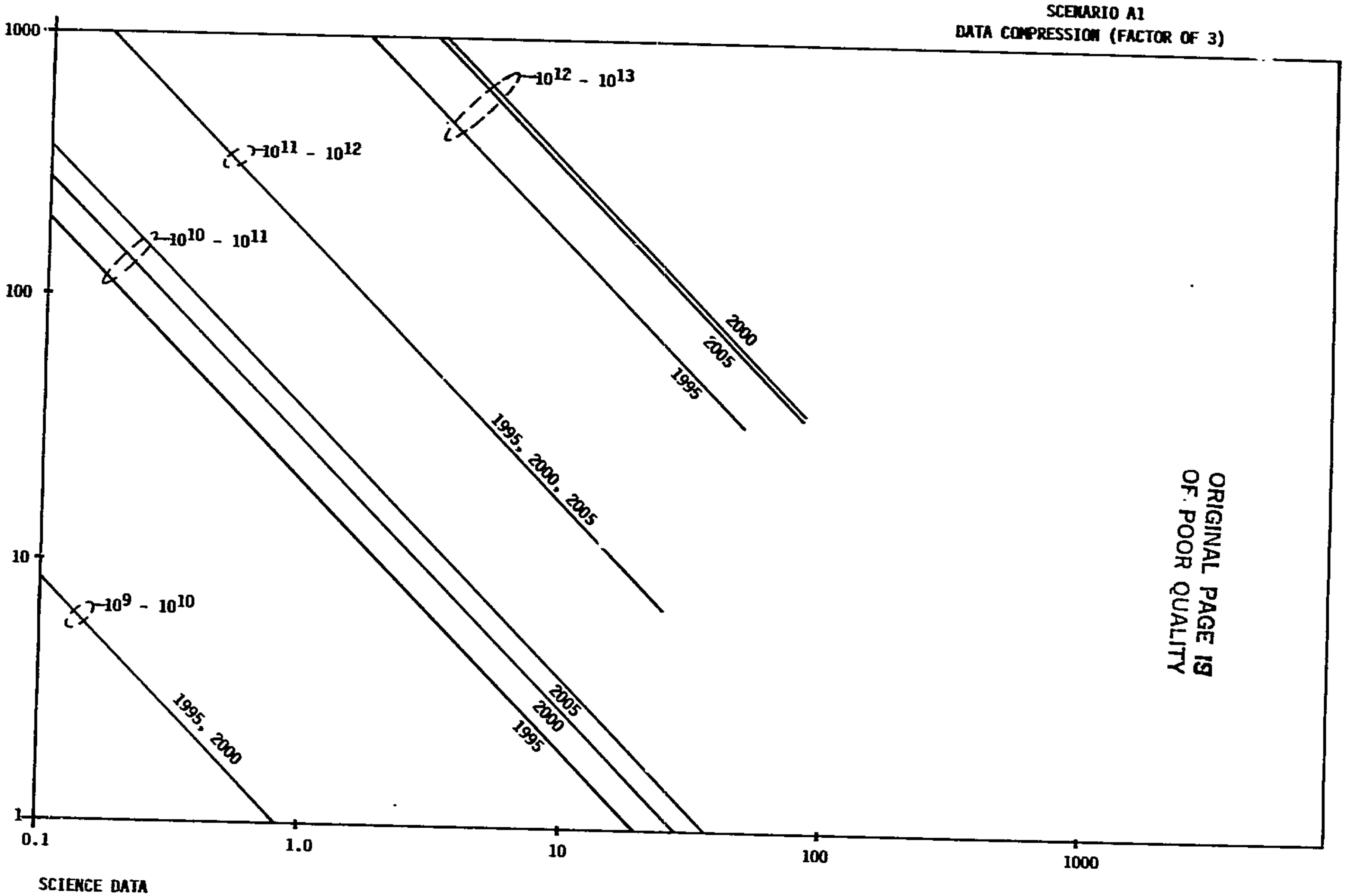

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FIGURE 4.5-4: TOTAL CONTACT TIME, SCENARIO A1, DATA COMPRESSION

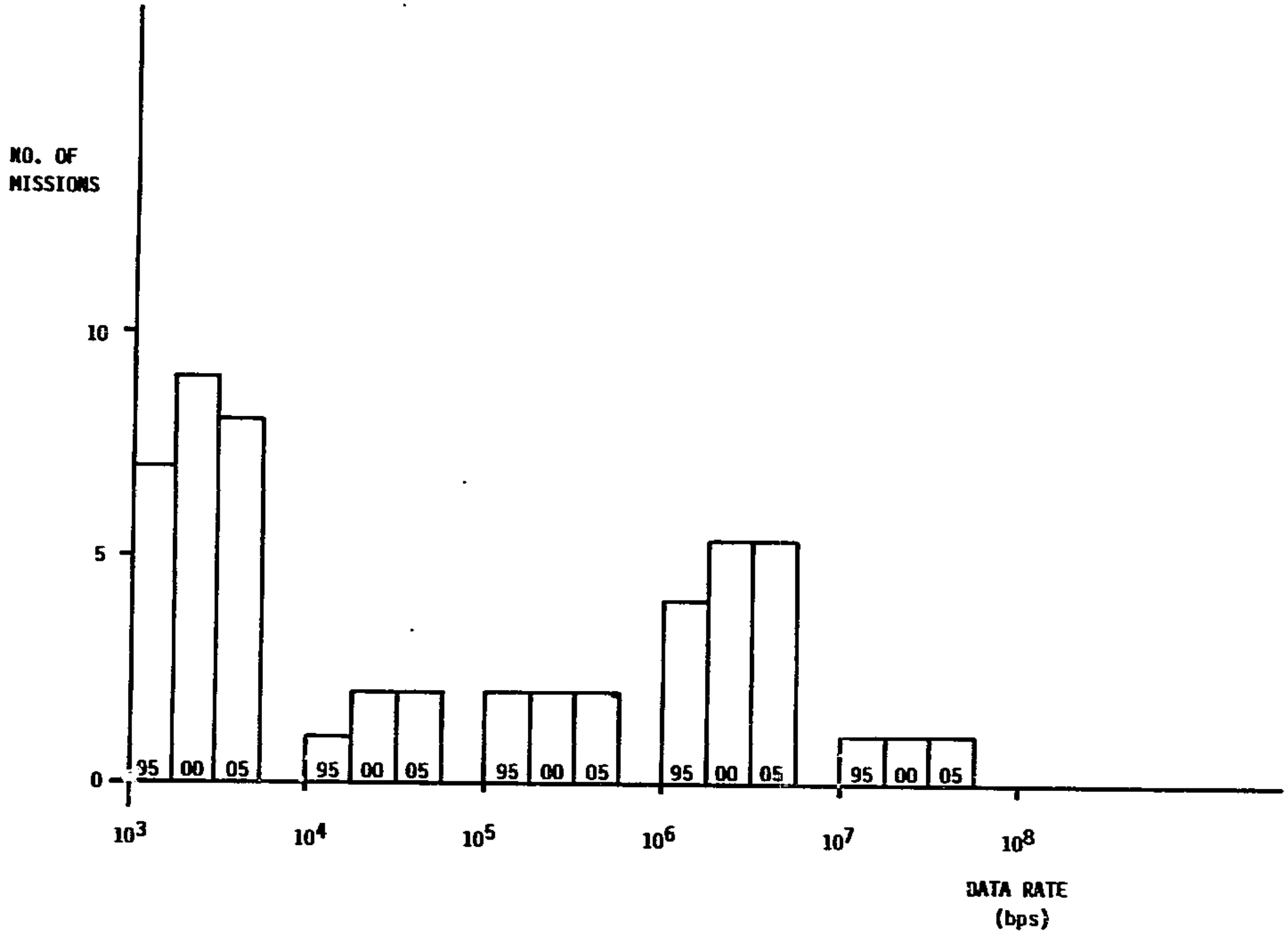

FIGURE 4.5-5: DISTRIBUTION OF ENGINEERING DATA RATES, SCENARIO A1 DATA COMPRESSION (FACTOR 2 OR 3)

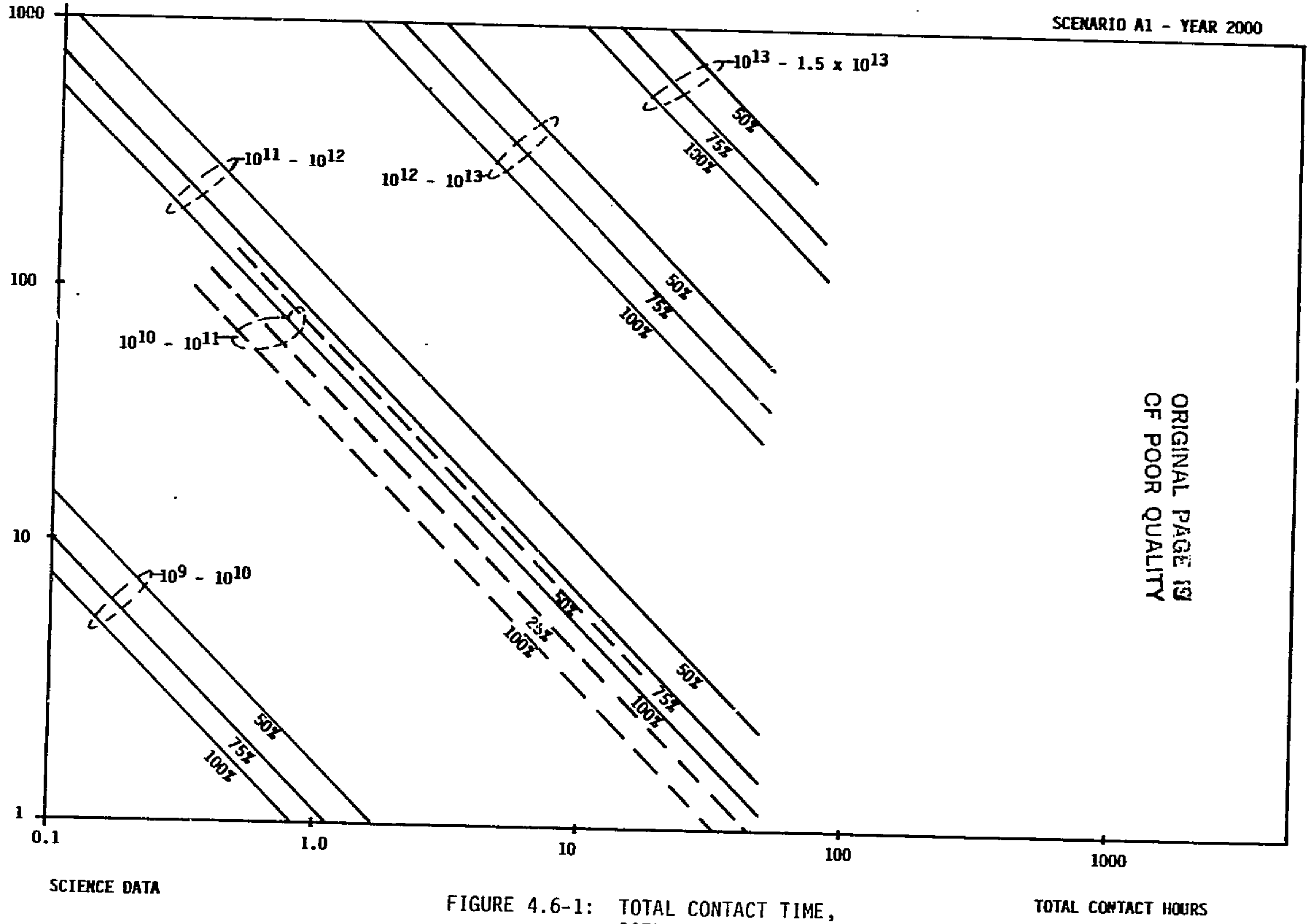

FIGURE 4.6-1: TOTAL CONTACT TIME, SCENARIO A1 WITH INEFFICIENCIES

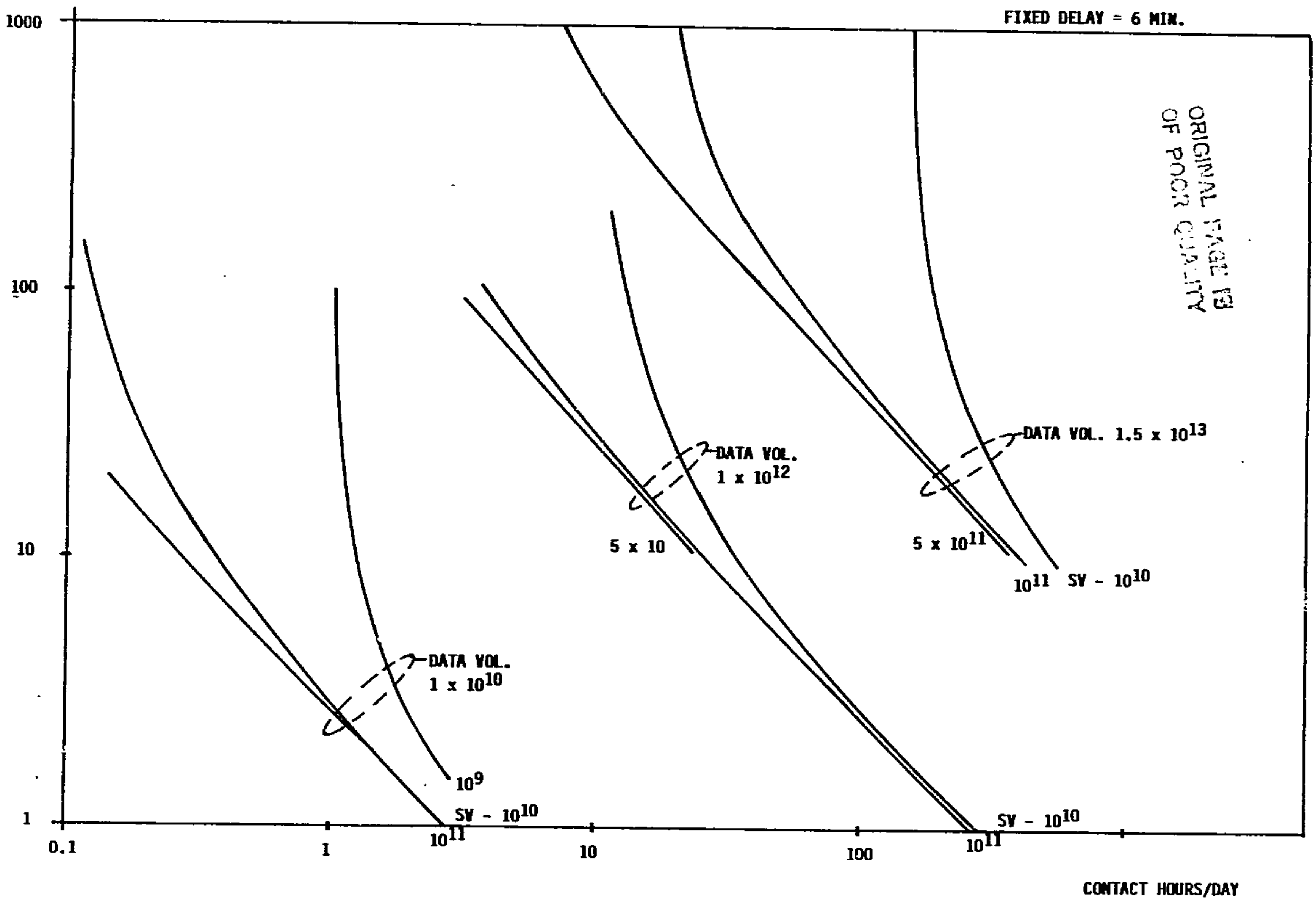

FIGURE 4.6-2: CONTACT HOURS PER DAY, FIXED OVERHEAD TIME

The impact of compressing the science data by a factor of 2 is also presented in the table.

This treatment of the requirements yields an estimate of 12-15 SA channels required to support both NASA and military missions under some rather conservative assumptions regarding mission activity in the year 2000. It is emphasized that the channel requirements are stated in terms of equivalent TDRSS SA channels at 300 or 30 Mbps for science data and dedicated real-time channels for the engineering data. The engineering data dominates the channel requirements as shown in Table 4.7-2. This dominance stems from the need to support several manned vehicles in space planned for this time period.

An alternative and less conservative projection of military requirements would add 1-3 more SA channels at 300 Mbps to the requirements stated for 30 Mbps SA channels. These SA channels would handle the data volume of mission S/3 in the military scenario SCS-B. The impact of adding this military mission is shown in Table 4.7-3.

APPENDIX A

SCENARIOS OF EXPERIMENTS

In Task 1 of the TDAS Study [1] screened baseline of NASA plans was used to generate two scenarios of experiments: one for a constant activity level and one for an increased activity level(20%). Various data were used to determine an estimated flight schedule for the potential experiments/missions. Assignment of experiments [to the schedule was accomplished by first assigning the planned experiments], then the candidate experiments and finally the opportunity experiments. Blanks were filled by adding generic experiments in various classifications: Astrophysics (AG), Solar Terrestrial (SG), Resource Observation (RG) and Environmental/Observation (EG). Scheduling of generic experiments was based on an analysis of historical launch rates in the respective category.

Figures A.1 and A.2 list the experiments/missions in each scenario and the estimated schedule. Numbers in the second column refer to sections in Appendix B of the Task 1 report [1] where more detailed information on each experiment/mission may be found.

FIGURE A.1

SCENARIOS OF EXPERIMENTS - CONSTANT BUDGET

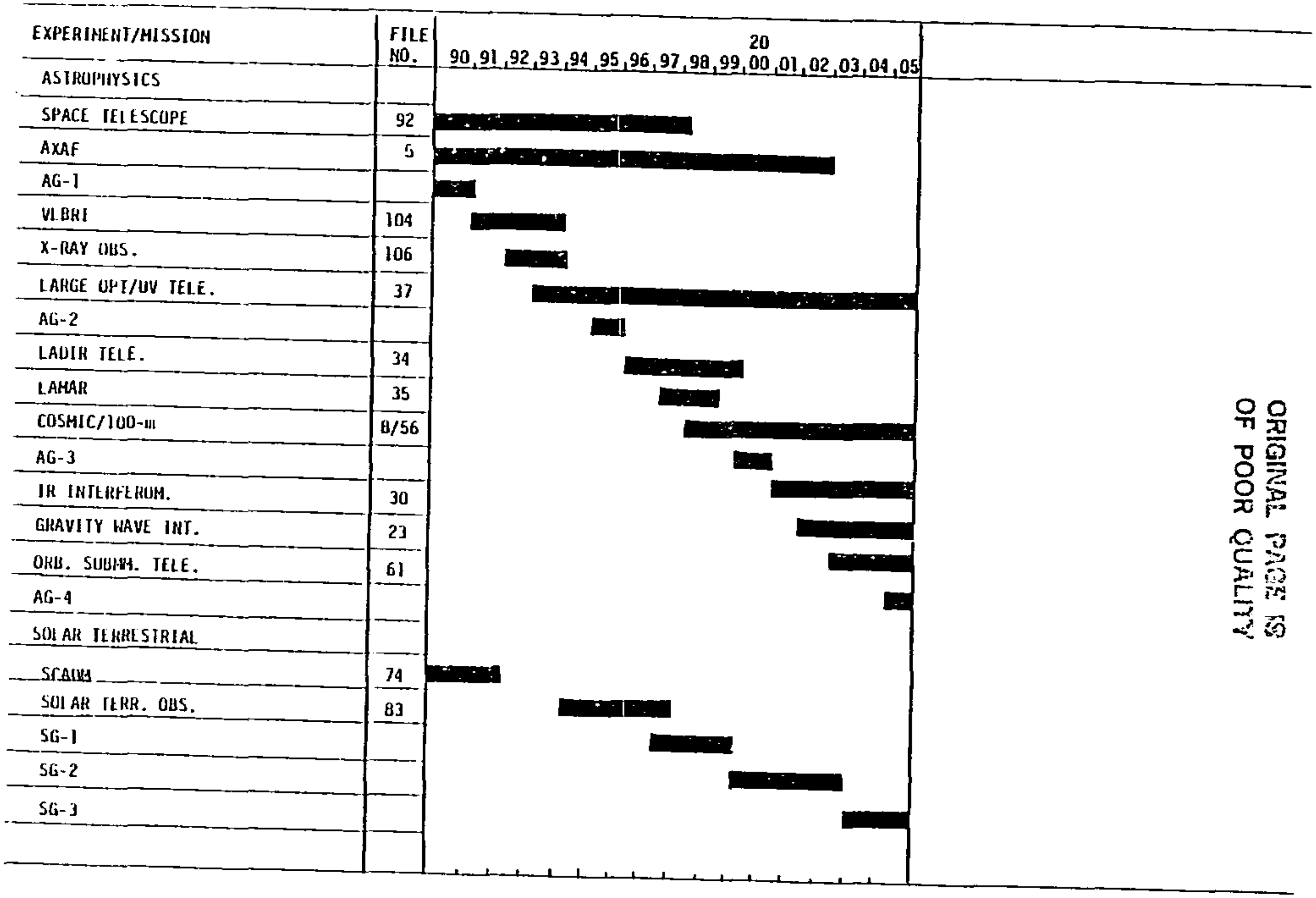

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FIGURE A.1 (CONT'D)

SCENARIOS OF EXPERIMENTS - CONSTANT BUDGET (CONT.D)

EXPERIMENT/MISSION	FILE NO.
RESOURCE OBS.	
MAG SAT B	40
OERS	57
SOIL MOISTURE	73
ADV. THER. MAP	4
RG-1	
RG-2	
RG-3	
GLOBAL ENVIRON.	
TOPEX	53
NOSS	47
OSAR	55
EG-1	
EG-2	
EG-3	
EG-4	
EG-5	
METEOROLOGY	58

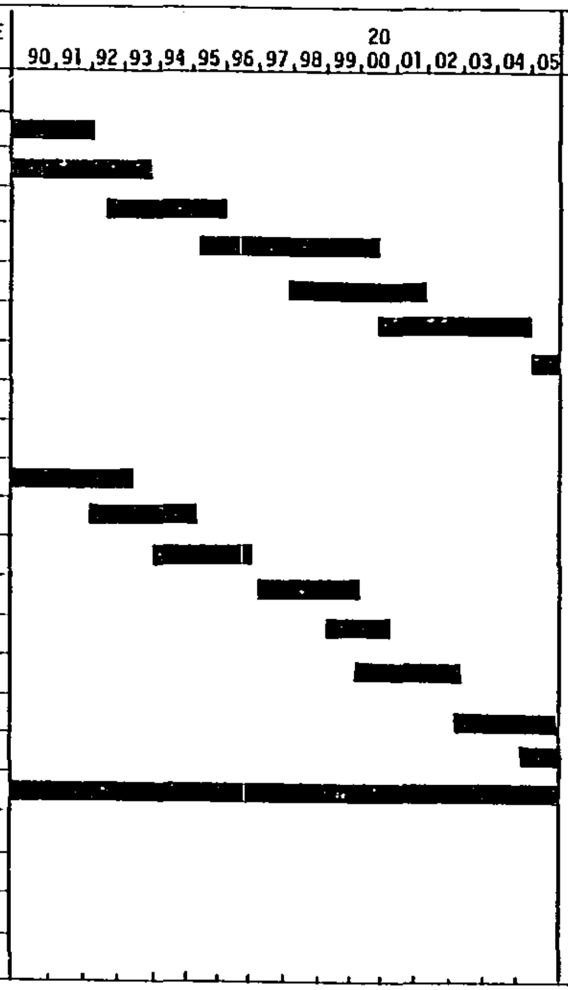

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FIGURE A.2

SCENARIO OF EXPERIMENTS - INCREASED BUDGET

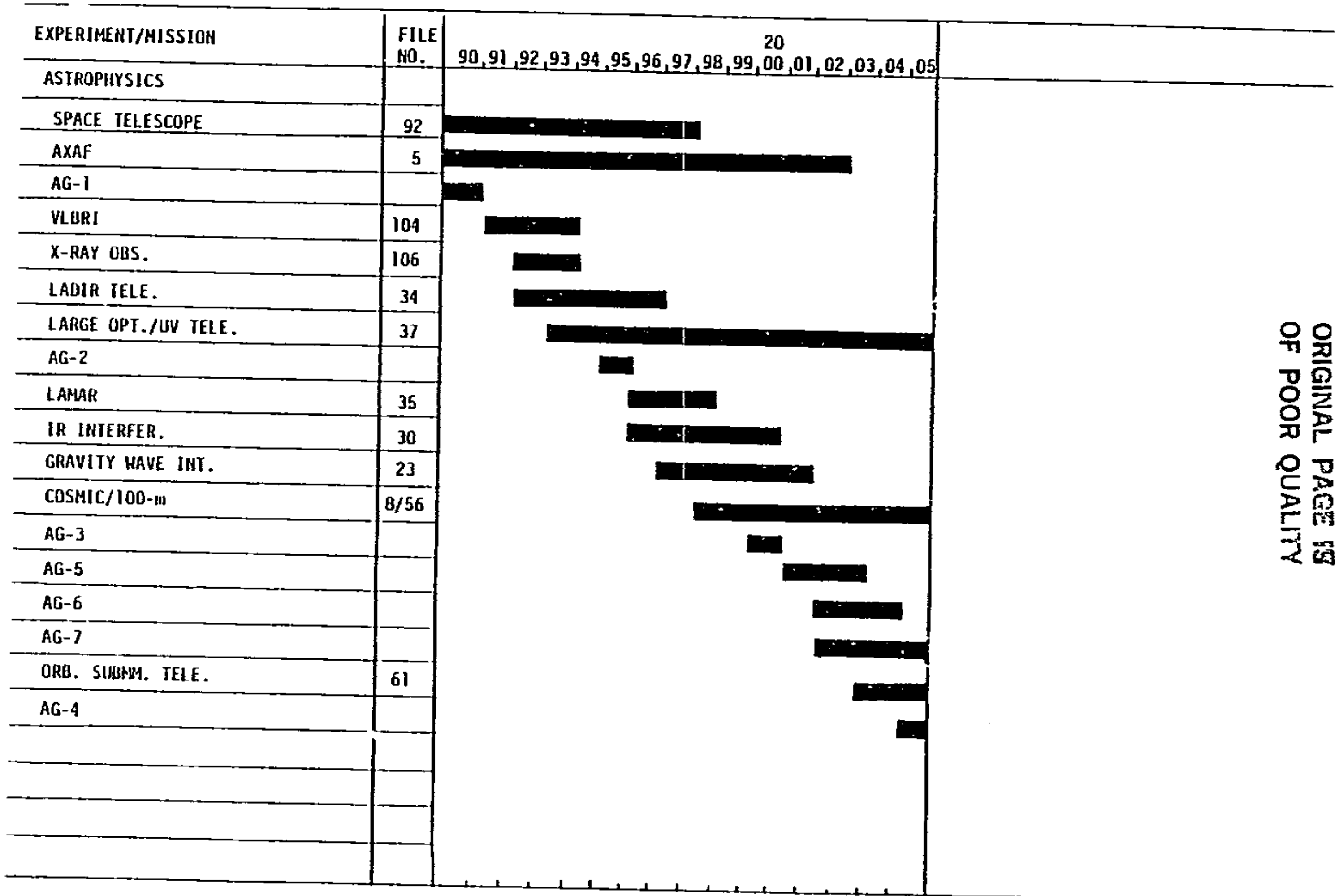

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FIGURE A.2 (CONT'D)

SCENARIOS OF EXPERIMENTS - INCREASED BUDGET (CONT'D)

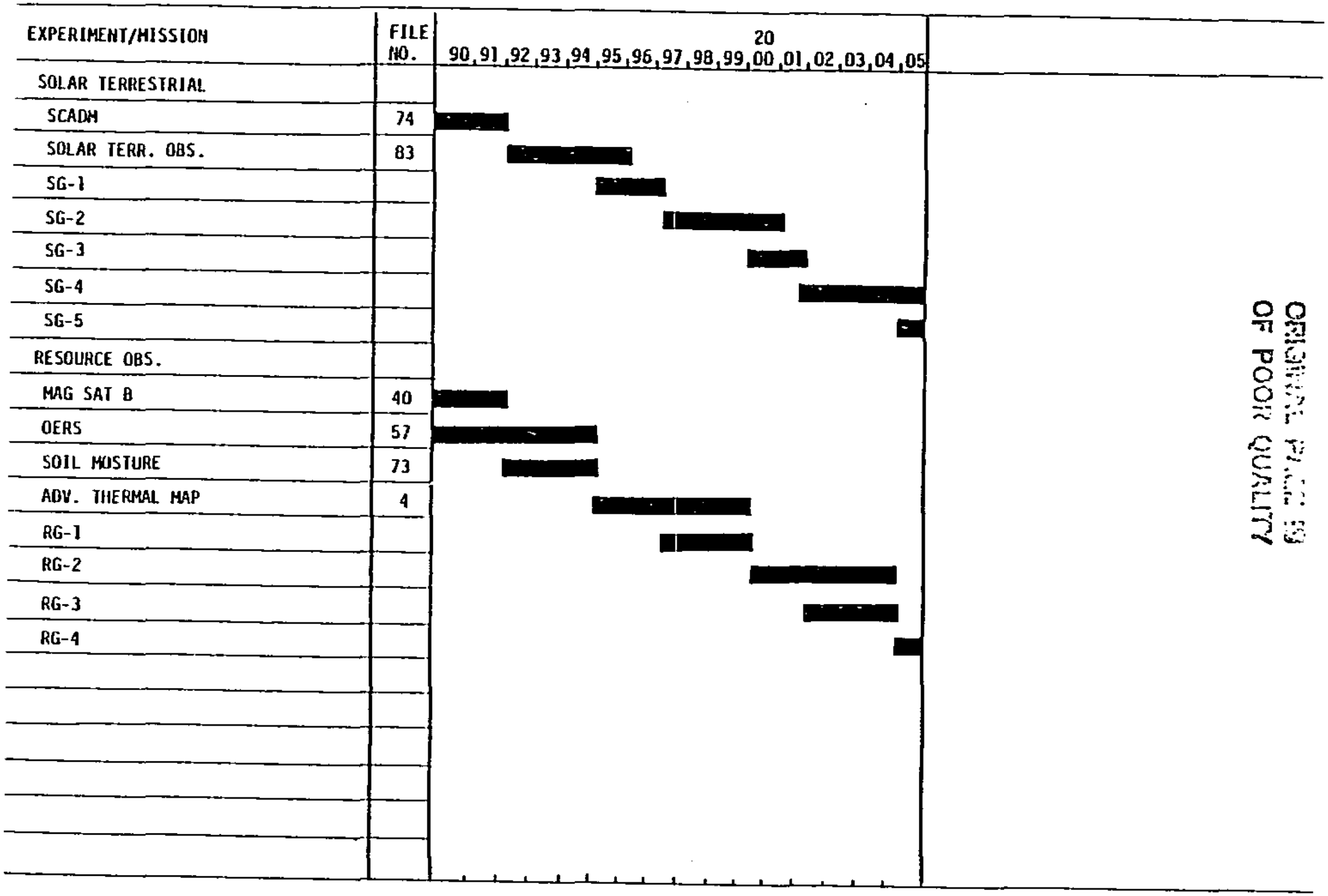

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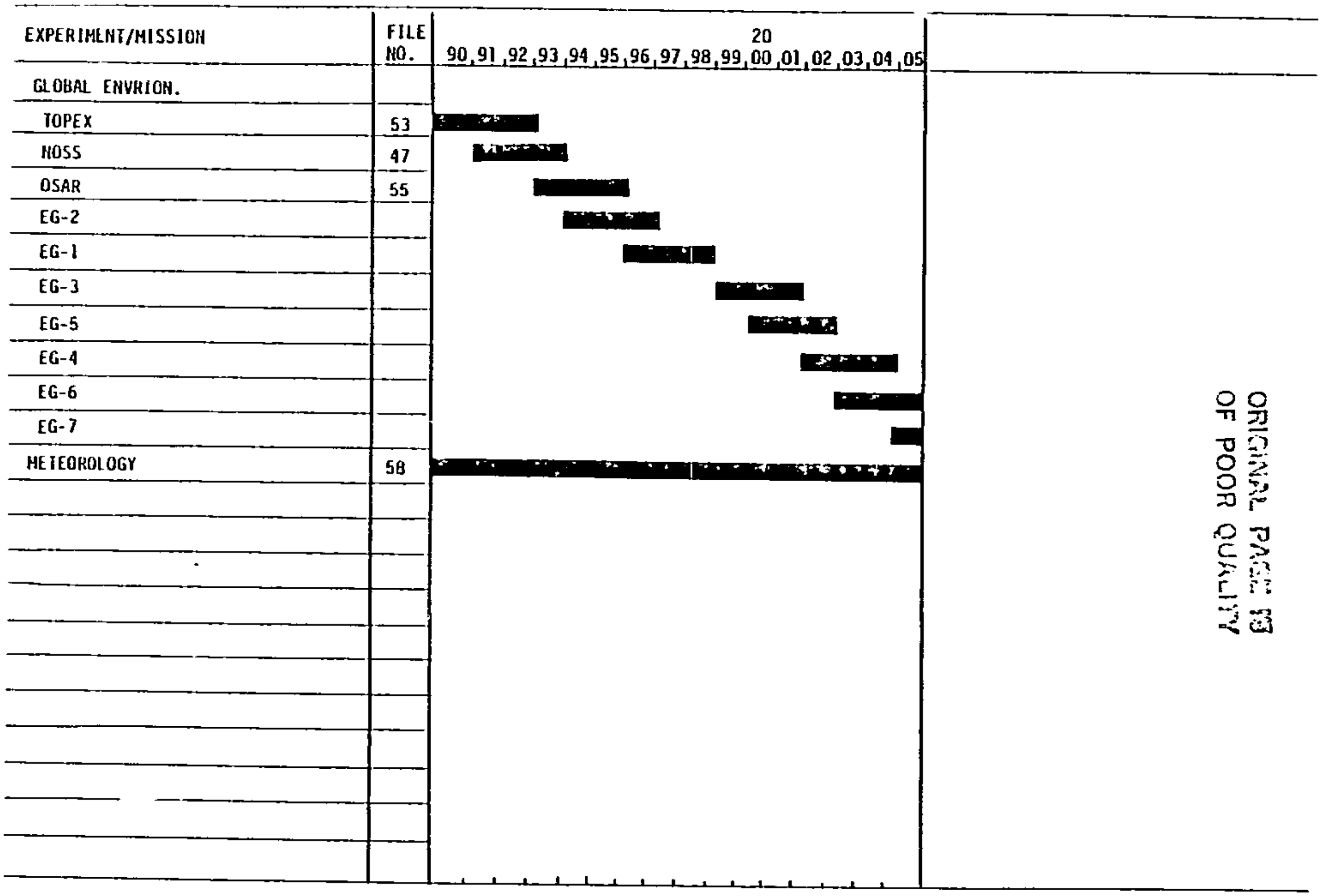
FIGURE A.2 (CONT'D)

SCENARIOS OF EXPERIMENTS - INCREASED BUDGET (CONT'D)



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