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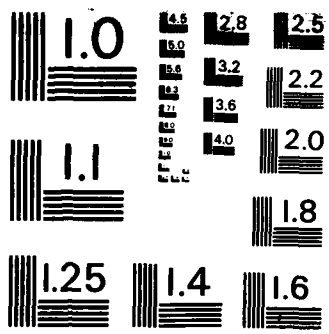

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ANALYSIS OF THE ACQUISITION COSTS OF UNIQUELY-BUILT SPACECRAFT VERSUS MULTI-MISSION MODULAR SPACECRAFT SURROGATES FOR THE MILITARY SPACE PROGRAM OF THE 1970'S

THESIS

Lawrence M. Cole
Major, USAF

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THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Space Operations

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December 1983

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Preface

The purpose of this study was to examine the financial feasibility of using a standard spacecraft exclusively for the military space program of the 1970's. The Multimission Modular Spacecraft (MMS) was the design chosen to make surrogate programs for the uniquely-built spacecraft of the 1970's.

Extensive research and study of Space Division's _Unmanned Spacecraft Cost Model_ was necessary to estimate the costs of the uniquely-built spacecraft used in the study. For their help and advice, I wish to thank Mr. Mike Koscielski and Mr. Gerry Heydinger from the Directorate of Cost Analysis at Space Division. For their help in learning about about the costs and capabilities of the MMS, I wish to thank the MMS subsystem contractors: Mr. M. Edmund Ellion of the Hughes Aircraft Corporation; Mr. Earl Knox of General Electric Space Division; Ms. Christi Gilbert of the Fairchild Space Company; and, Mr. W. Dean Purdy of the McDonnell Douglas Astronautics Company. For their encouragement, advice and willingness to answer all questions, I thank Mr. F. Mike Logan, Jr. Frank Cepollina, and Mr. Robert E. Davis of the MMS project at Goddard Space Flight Center.

In performing the analysis and writing the thesis, I am deeply indebted to my advisor, Dr. Joseph P. Cain, and especially my reader, Commander Joseph S. Stewart II, USN. Finally, and most heartfelt, I wish to thank my wife, Linda, whose love, concern, and encouragement have been especially appreciated during the writing of this thesis.

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Abstract

The purpose of the analysis was to determine and compare the costs of certain uniquely-built spacecraft of the 1970's with surrogate programs using the Multimission Modular Spacecraft. Using the Unmanned Spacecraft Cost Model, costs were developed for the unique satellites. After the feasibility of using the cost model was determined, the costs of the MMS were estimated from the cost model. Mission unique item costs such as, solar arrays, batteries, and communications equipment were also determined.

The surrogate MMS program costs were simulated varying the quantity of modules built and the slope of the learning curve in building the modules. These costs compared with the estimated costs of the uniquely-built satellites, both aggregate and program, enabled a cost comparison of the 1970's military space program had the U.S. used the MMS exclusively. The analysis concludes with the determination that the MMS is a highly cost effective method of decreasing the cost of utilizing space when it is employed within its design criteria.

Glossary

A & RC	Attitude & Reaction Control
ACS	Attitude Control System
AGE	Aerospace Ground Equipment
A.H.	Ampere - Hour
BOL	Beginning-of-Life
C & DH	Communications & Data Hand ng
CER	Cost Estimating Relations p
COMM	Communications
COMSATS	Communications Satellites
D.C.	Direct Current
DMSP	Defense Meteorological Satellite Program
DSCS	Defense Satellite Communications System
DSP	Defense Satellite Program
ELV	Expendable Launch Vehicle
EPS	Electrical Power System
FLTSAT	Fleet Satellite Communications
FU	First Unit
GEO	Geosynchronous Orbit
GPS	Global Positioning System
KG/KW	Kilograms Per Kilowatt
LBS/WATT	Pounds Per Watt
LEO	Low Earth Orbit
MACS	Modular Attit ontrol System
MAX	Maximum
MIN	Minimum
ML	Most Likely

MMS	Multimission Modular Spacecraft
MPS	Modular Power System
MSS	Module Support Subsystem
NASA	National Aeronautics and Space Administration
OBC	Onboard Computer
PM	Propulsion Module
PRU	Power Regulator Unit
R & D	Research & Development
RIU	Remote Interface Unit
SC & CU	Signal Conditioning & Control Unit
S, TC & I	Structure, Thermal Control & Interstage
STP	Space Test Program
STPSS	Space Test Program Standard Satellite
TA	Transition Adaptor
TT & C	Telemetry, Tracking & Control
USCM	Unmanned Spacecraft Cost Model
V.	Volts

ANALYSIS OF THE ACQUISITION COSTS OF UNIQUELY-BUILT SPACECRAFT VERSUS MULTIMISSION MODULAR SPACECRAFT SURROGATES FOR THE MILITARY SPACE PROGRAM OF THE 1970'S

I Introduction

Background

In our lifetime, the use of space vehicles has evolved from experimental concepts to practical operating systems which are highly useful and dependable. With this evolution has come the expansion into new fields of application with increased numbers of spacecraft and increasing costs. With near earth space travel an assured reality, we have time to reflect on the costs of historic programs and to learn what we can for the future. The preservation of our national monetary resources in a cost effective space program is a worthwhile goal. Historically, spacecraft have been built to the specifications of a particular mission or need. (A spacecraft for the purposes of this study is defined as that part of the satellite providing all the necessary housekeeping functions. It gathers and supplies electrical power to the equipment, maintains attitude and control, communicates and handles data, and provides propulsion. The sensors or payload rests on and receives support from the spacecraft.) Initially, the mission to be accomplished was identified, and then the satellite to do the job was built from the ground up. These uniquely-built satellites maximized a particular mission's potential, i.e., they were: built for the specific mission, designed for a particular orbit, engineered to a certain reliability standard and design life, and built to minimize weight and maximize payload. Because the spacecraft authorized in each satellite program were generally small in number, the uniquely-built satellites were handcrafted. Very little benefit could be derived from modern automated or repetitive manufacturing techniques to decrease costs. As could be expected, the costs of the space program were very high.

The development of a standard spacecraft has been a proposal of interest to cost conscious managers for years. A standard spacecraft is one which will support a wide variety of payloads over many different mission scenarios. There were two factors behind the desire to develop the standard spacecraft. One was looking towards the future servicing and repair of satellites in-orbit and the other was a basic cost saving philosophy aimed at taking advantage of repetition in manufacturing of identical vehicles.

Modularity

Although a standard spacecraft does not necessarily have to be modular to achieve its stated goal of supporting many missions with varying payloads, it is easier to achieve an on-orbit maintenance capability if the satellite is modular. This is due to the fact that in a weightless environment, a medium size module with cannon plugs and several bolts is easier to service than a panel with many small screws and intricate wiring. This fact coupled with the ability to swap out complete housekeeping functions, such as the electrical power system, make modularity very important for on-orbit maintenance. Modularity may also contribute to the basic cost philosophy.

Cost Reduction

The basic cost philosophy behind the standard satellite is that R & D costs can be saved for varied satellite programs and per unit cost for each satellite will be lower if a standard type of construction will fulfill numerous space missions. It was expected that the costs would be lower due to the standard spacecraft's ability to take advantage of the learning curve effect when many programs were using it for their missions. The importance of combining programs cannot be discounted. The economics of scale, the buying of many units to decrease the average cost of each unit, is a well known economic principle that can be applied to satellite systems. For example, Cost Implications of Methods of Satellite Procurement to the Air Force (1) shows the unit price of $2.41 million for three satellites decreasing to a unit price of $1.87 million for twelve satellites. In that study, the increased buy constituted a decrease in cost of 32% for each satellite (1:17). Besides total systems procurement, the buying of components in bulk brings just as much benefit. Buying from one to four components has been shown to decrease the unit cost by 25.8%

(1:16). These statistics are taken from examples of unique satellite systems and components. However, because the numbers of standardized systems and components could be greater than twelve or four, even greater savings should be expected to accrue to the procurement of standardized systems and parts.

Standard Spacecraft Development

Since the beginning of the last decade, both NASA and certain segments of the Air Force have been increasingly interested in standard spacecraft design and modularity. The Air Force's design to develop such standardized spacecraft was driven in the mid-1970's by the Air Force Space Test Program (STP). Managed in Los Angeles by the A.F. Systems Command (AFSC), Space Division (SD), this Air Force led tri-service activity is the focal point for all Department of Defense (DOD) experimental payloads. To increase the number of funds available for Research & Development (R & D), STP continually sought out low cost strategies and innovative ideas (12:32). This desire to conserve costs caused the STP to contract for a design of a modularized standard spacecraft, the STP Standard Satellite (STPSS) (12:34). The STPSS was specifically designed to handle the payloads of the STP. As such, it was an expendable, modular spacecraft designed to handle a payload from 1000 lbs. to a maximum of 1500 lbs. It had a mission duration of one year in orbits from Low Earth Orbit (LEO) up to and including geosynchronous orbit (GEO).

During the same period, NASA, persuing an objective to increase the sophistication of unmanned spacecraft, was developing the Multimission Modular Spacecraft (MMS). The MMS design, as well as being modular, was much more sophisticated and capable. Looking ahead to on-orbit servicing and maintenance, NASA engineered it to carry large payloads from LEO through GEO. Political and financial restrictions on the parallel development of a similar concept by both NASA and the Air Force caused the Air Force to drop their research in favor of NASA development of a standard spacecraft. The NASA research and development resulted in the attrition of the STPSS, as well as, several other proposed designs. At the present time, the MMS is the only developed standard spacecraft the author has found.

This research and development of a sole standardized spacecraft has resulted in a craft capable of a multitude of missions. The following is a listing of general MMS performance capabilities (29:12).

Payload Weight Capability

4000 lbs. with Delta 3910 launch vehicle: Greater than 10,000 lbs. with shuttle and limited by payload configuration.

Type of Missions

Stellar, solar, earth pointed, or special purpose missions: low earth or geosynchronous orbits: inertially pointed or payload pointed.

Operation Orbital Altitudes

All altitudes and inclinations

Reliability

Baseline configuration fully redundant; has no single point of failure to prevent resupply or retrieval by shuttle.

Launch Vehicle

Fully Delta, Atlas, Titan, and Shuttle compatible. Also IUS launched, shuttle in-orbit serviced and shuttle retrieved.

Problem

The reason for buying small numbers of uniquely-built satellites in the past was the wide variety of missions being performed. Each mission could be accomplished by a few satellites. When building only a few spacecraft, however, the learning for each lot of spacecraft procured did not continue for long. With the development of the MMS came the possibility of allowing us to choose to take advantage of the efficiencies of the learning curve on a grand scale. This ability to choose has sparked several studies on the use of standard spacecraft.

NASA and other agencies have done mission capture studies on both individual (21,36) and groups of several (4,27,15) satellite programs. The studies on individual programs have been concerned only with the ability of the MMS to fulfill the particular mission under study. The studies done on several different programs have been concerned primarily with the total number of missions the MMS could capture and have all concentrated on civilian satellite programs.

To the author's knowledge, the only studies done by the Air Force, mostly from STP, are those that compare specific individual programs (21) for MMS capture ability. Few, if any, studies have concentrated on using the MMS for operational military space missions. To be sure, when the word "operational" and "military space" are used in the same context, many of the aspects of the programs are classified. Herein lies one of the major problems with comparing costs of the standardized spacecraft with those of uniquely-built satellites assuming the MMS would be able to perform the missions in the military arena. Because of this, there has been no Air Force study to determine if money may have been saved had a standardized spacecraft, been used over many programs over a long period of time.

Future programs are especially difficult to assess. Their technical aspects may change as the program matures. There is also no assurance that future programs will survive the budget process. Contractor information is proprietary to the extreme. Essentially, there is very little open information to be found on future military space programs. Past military programs are available, however, for study. Most military programs of the 1970's have been launched and completed and much of their information is available. The actual costs of the past military programs, while not available for public release, can be estimated reasonably accurately from the information available. From the study of past programs, we may gain an insight to the future.

Research Objective

The overall research objective of this thesis is to attempt to determine, had the MMS been developed and been used exclusively for the military space program during the 1970's, if the overall program would have been cheaper than designing, building, and procuring uniquely-built spacecraft?

Research Questions

There are two sets of research questions that are addressed in this thesis. The first set deals with the use of the Unmanned Spacecraft Cost Model (34) (henceforth referred to as the model or the USCM) to estimate costs. The issue involves such questions as: What are the costs of acquisition of the uniquely-built satellite programs during the 1970's?; What was the total outlay for all the programs and for each individual program?; and, Are these estimates of both Research and Development (R & D) and First Unit (FU) production costs of the MMS feasible? This last point is extremely important due to the way the MMS was developed. R & D costs for the MMS have been blurred due to the use of in-house government labor, the use of fixed-fee contracts with contractors, option fees for future module buys, etc.

The second set of research questions deals with the learning curve effect of mass producing multiple MMS modules: What would the learning curve of the MMS have had to be to have cost less than the overall cost of the uniquely-built satellite programs? Just how important is quantity to the study? Using the MMS, which, if any, of the unique satellite programs would be the largest savers?

Scope

In order to achieve the objective of the thesis and have realistic cost estimates, the scope has been limited to estimating the cost of those military satellite programs that are contained in the Unmanned Spacecraft Cost Model (34). The following uniquely-built military satellites which have been included have met this criteria: DSP-1, DSP-2, GPS-1, DMSP, P72-2, S-3, P78-1, P78-2, DSCS-II, NATO 3, and FLTSATCOM. The programs, DSP-1, DSP-2 (Defense Satellite Program), and GPS-1 (Global Positioning System), are military mission satellites. DMSP (Defense Meteorological Satellite Program) is a weather satellite. P72-3, S-3, P78-1, and P78-2 are experimental satellites. DSCS-II (Defense Satellite Communications System), NATO 3, and FLTSATCOM are communications satellites. The use of this criteris is based on the implicit assumption that if the CERs for the model were derived from the actual data of the uniquely-built spacecraft; then estimating the costs of the programs from the model will give a very close approximation. Classified satellites launched from 1971 to 1980 and meeting certain requirements, while their costs were not estimated, were considered in increasing the number of satellites which could accept MMS surrogates.

Furthermore, only the acquisition costs of the satellite programs were compared. The launch costs, to include the expendable launch vehicles (ELV), mating of spacecraft to ELV, initial on-orbit checkout, etc., have not been considered.

Methodology Summary

The first step was to use the Unmanned Spacecraft Cost Model to calculate the R & D and FU production costs of the uniquely-built satellites produced and launched during the 1970's. This was done using the normalized CERs from the model to insure the best "point" cost estimate.

Next, the price quotes that had been received from several of the MMS module contractors for their modules were compared with the estimated price calculated from the model. This was done by first determining the normalization factors for the MMS modules using available technical data and literature. Then, the model was used to calculate an estimate for the FU production cost for each of the MMS modules with a quoted price. If the estimated FU production was feasible, then it was assumed that the model may indeed be used for the comparison. With this assumption, the R & D costs and the remaining FU production costs were then estimated for each of the MMS modules.

Thirdly, from the unique satellites' specifications, the different type of mission specific items that would have been used for each surrogate program were determined. The solar array cost, a mission specific item even for the MMS, was estimated from the specifications of the unique satellites. The cost of the particular MMS battery configuration and comm (if needed) was also determined from the unique programs.

The fourth step was to determine the actual number of satellites that were procured for each program. This figure enabled the individual and total program costs to be figured for all the unique satellite programs. It also facilitated the calculation of the number of MMS modules that would have had to be built to satisfy the need during the last decade.

To compare the costs of the two different philosophies, the uniquely-built satellites' program costs were calculated using a 95% cumulative average learning curve (34:VII-ii). Both individual program and overall decade acquisition costs were calculated. The type of MMS modules that would have been needed to accomplish the specific mission of each of the uniquely-built spacecraft were then determined. To estimate the cost of each of the space programs had the MMS been used, the average module costs, which make up each surrogate satellite, were added together with the battery and estimated solar array costs. The total number of satellites needed for each program determined the composite production cost. The R & D costs for MMS modules was prorated over all the surrogate MMS programs. The MMS module average costs were varied by changing the number of modules built (using design life and adding classified satellites) and the slope of the learning curve on these modules from 95% down to 80%. By this technique, each individual program, as well as the overall space program cost, displayed its sensitivity to the learning curve and the number of modules built.

II MMS Description

The Multimission Modular Spacecraft is a 3-axis stabilized spacecraft capable of performing all of the housekeeping chores needed by the average satellite. By its capabilities shown in Chapter I, it is shown to be extremely flexible and has the ability to take on many diversified missions. Much of this flexibility and capability is due to the separate parts that make up the MMS; and, within this section, a more specific description of each of the MMS's modules and functions will be accomplished. The Multimissions Modular Spacecraft (MMS) External Interface Specification and User's Guide (24) describes the MMS in terms of three spacecraft systems and four modular subsystems. The three spacecraft systems are the mechanical, thermal, and electrical systems. The four modular subsystems are the Modular Power Subsystem (MPS), the Attitude Control Subsystem (MACS), the Command and Data Handling Subsystem (C&DH), and the Propulsion Module (PM) (24:3-1). See Figure 1.

The author has combined some of the spacecraft systems of the MMS to correspond more closely with the cost model categories. To accomplish this action, some of the names have been changed to reflect the cost model category. The mechanical and thermal systems have been combined and renamed Structure, Thermal Control, and Interstage (S,TC&I). The electrical system will henceforth be referred to as the

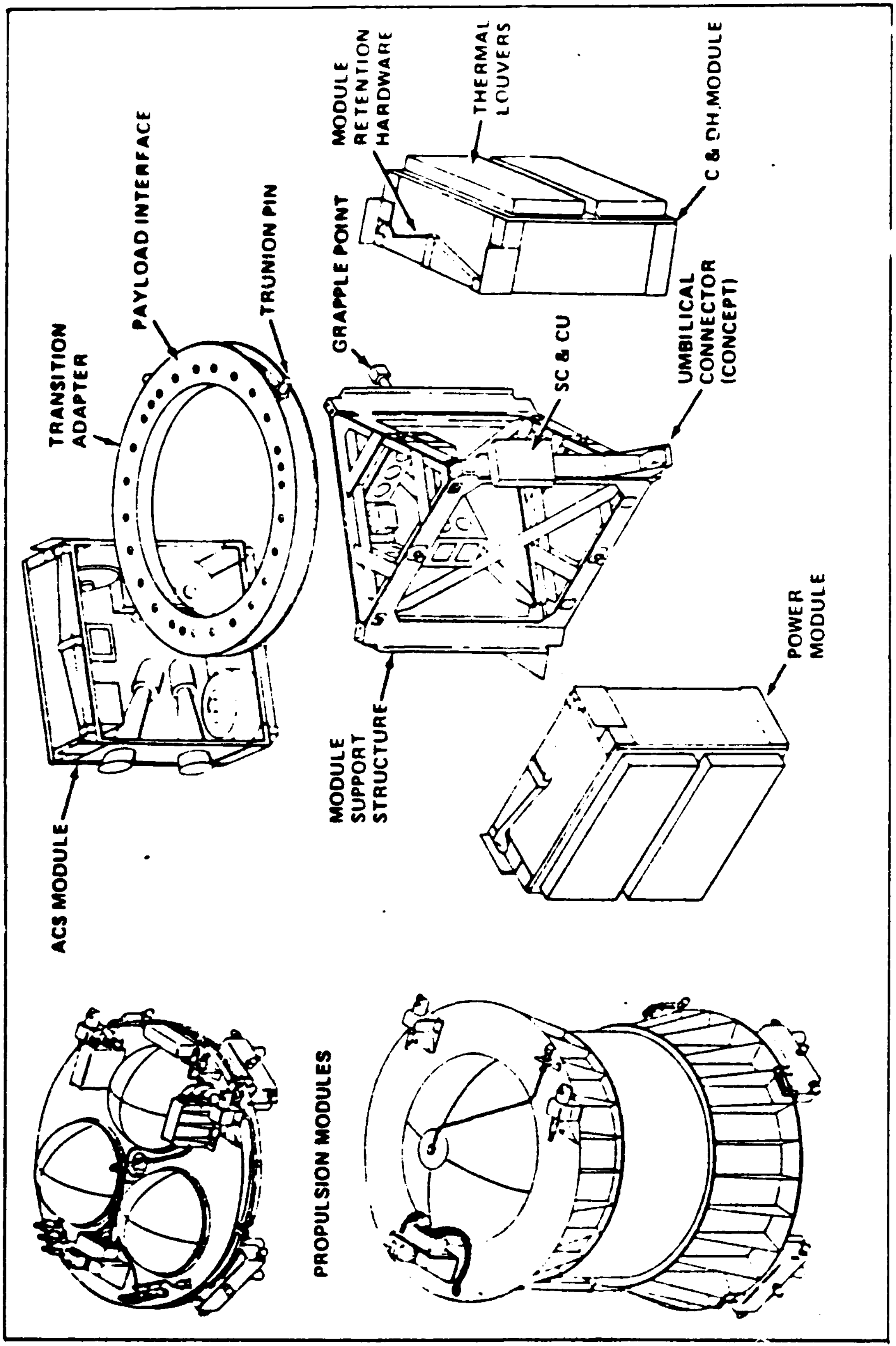


Fig. 1 Multimission Modular Spacecraft

Signal Conditioning and Control Unit (SC & CU) since, other than the wiring harness, clips and tiedowns, it is the primary module within the system. No changes were necessary on the four modular subsystems.

The discussion of each of the modules and systems include a description of the functions performed, some of the options capabilities of the system/subsystem, its weight and, if applicable, a price quote from the contractor. The discussion order will be S, TC & I; MPS; C & DH; PM; and SC & CU.

Structure, Thermal Control & Interstage

The S, TC & I is made up of the MMS's mechanical and thermal spacecraft system, as well as, the vehicle adapter. Included in the mechanical system are the module support structure (MSS), the transition adapter (TA) and the supporting structures that house the subsystem modules of the MPS, C & DH, and MACS. The MSS is the prime skeleton of the MMS and, as such, provides the main frame for all other parts to attach themselves (Fig. 1). It supports the stress loads generated during launch and on-orbit. The top and bottom faces of the MSS are triangular. On the top face, the TA is bolted to allow payload interface. Each of its three sides accepts one of the supporting structures housing the subsystem modules. Its bottom face accepts either the vehicle adapter or a propulsion module. The MSS also provides the standardized electrical connectors and a harness for each of the three subsystems.

The TA is a ring structure attached to the top face of the MSS. It serves as the mechanical, power, and C & DH interface between the MMS and the payload package. The TA supports the payload either by hardmounting the payload to the TA or by attaching the payload first to a mission unique adapter. The mission unique adapter is then attached to the TA. This universal-type of mating allows the payload to be developed, tested and integrated independently of the spacecraft (37:2-5). The TA also supports the solar array launch restraint, deployment mechanism, and drive motors (37:2-1).

The thermal system is designed to achieve "two major objectives: (1) it maintains the spacecraft components within acceptable temperature limits for all phases of flight, and (2) it accommodates all the required missions with a single design concept which requires little or no change to the thermal configuration" (24:3-7). These objectives are accomplished through the use of louvers and radiator covers on the MPS, C & DH, and MACS; thermal insulation material, and, heaters where needed.

The vehicle adapter is needed to mate the spacecraft with an ELV. Its purpose is to lessen the launch loads on the spacecraft and to achieve separation between spacecraft and ELV at the proper moment in the trajectory. It is not needed for a shuttle orbiter launch. For this thesis, the vehicle adapter used to estimate the costs of the S, TC & I was developed for the Delta 2910 ELV.

The latest weight figures for the S, TC & I were found in the Low Cost Modular Spacecraft Description (37). The

MSS, TA, module structures, and miscellaneous items were 403.0 lbs. The thermal control equipment weighed a total of 62.1 lbs. Lastly, the vehicle adapter with related equipment was 66.0 lbs. The total weight of the S, TC & I was calculated to be 531.1 lbs.

Modular Power System

The MPS is the modular unit containing the equipment that stores electrical energy and distributes 28 +/ - 7 V. DC power. The power supplied to the other modules and payload is unregulated; it is regulated internally by the modules and payload. The design allows the power to be stored in up to three 50 Ampere-Hour (A.H.) batteries for use during periods of darkness. The orbital average load that can be attained is 1200 watts in any orbit from 500 to 1665 km and geosynchronous orbit with 350 watts needed for the spacecraft itself. It also can attain a peak of 3 KW day or night (30:15).

Features which make the MPS very flexible are its ability to receive external power, the Power Regulator Unit (PRU), and its capability to handle different battery requirements. The MPS can receive external power throughout all mission phases - from ground checkout operations through on-orbit retrieval and resupply.

The heart of the MPS is the PRU. It accepts and processes all power from the solar array, transforms it to approximately 28 V. DC, supplies it to the spacecraft, and controls the battery charging currents. It is designed to be able to charge from one to three batteries without changing the battery charger. It is the PRU which actually limits the output power for use in orbit. The power is constrained to the 1200 watts mentioned above by thermal considerations of the PRU (21:3-16).

One to three nickel-cadmium batteries can be contained within the MPS. The power storage capacity of the batteries can be either 20 or 50 A.H. The baseline capability contains two 20 A.H. batteries and the configuration with the most power storage and redundancy contains three 50 A.H. In between are the three 20 A.H. configuration and the two 50 A.H. configuration (30:28, Part 2). They can be added to or removed from the module with relative ease without requiring a harness redesign or addition of equipment. A unique feature of the battery design is that cells from various manufacturers can be used for battery assembly without modification. Depending on temperature and depth of battery discharge, the operating design life for the batteries is 4 years in LEO and 7 years in GEO (17:1638, 39).

The weight of the functional portion of the MPS without batteries is approximately 165 lbs (37:2-10). Each 20 A.H. and 50 A.H. battery weighs approximately 53 lbs. and 112 lbs., respectively (17:1639). The current quoted price of the MPS, in 1983 dollars, without batteries is $4,469,000 (20). Each battery configuration also has a different cost: two 20 A.H. - $277,000; three 20 A.H. - $379,000; two 50 A.H. - $312,000; and, three 50 A.H. - $434,000 (20).

Attitude Control System

The MACS is capable of performing stellar, solar and earth-pointing missions. Its primary concern is with attitude determination, orientation, and stabilization of the spacecraft, with respect to a given target, during all phases of orbital operations. These operations are accomplished through its sensors, the onboard computer (OBC) in the C & DH module, and its reaction control devices. Information provided from the sensors to the OBC is processed and commands given to the reaction control devices (52:16). In the event of OBC failure, the MACS has a safe hold mode in which the MACS orients the spacecraft in a power and thermally safe attitude (5:322).

All MACS equipment, with the exception of the course sun sensors and mission unique payload sensors, are located within the module. The principal sensoring mechanisms used with the MACS are the course sun sensor, an inertial reference unit, a 3-axis magnetometer, two fixed head star trackers, and a fine sun sensor. The course sun sensor and the magnetometer with the inertial reference unit perform the initial acquisition function. In all other modes, the inertial reference unit is updated by the fine sun sensor and the star trackers. A mission unique payload fine error sensor may be added to improve the accuracy of the system. The MACS is accurate to within +/- 10^{-2} degrees for all missions. With a payload sensor, it is accurate to +/- 10^{-5} degrees (24:3-24).

The reaction control devices located within the MACS are reaction-wheels and magnetic-torquers. The reaction-wheels are the primary devices. In low earth orbit, they are unloaded by the magnetic-torques. In geosynchronous orbit, where earth's magnetic field is weaker, the magnetic-torquers may be deleted and a propulsion module added to provide momentum-wheel unloading through mass expulsion (24:3-22).

The weight of the MACS is 450 lbs. and its quoted price is 14-15 million 1983 dollars (13).

Communications & Data Handling

The C & DH module provides for communications and tracking, the command of all spacecraft and instrument functions from either stored memory or real time, and the processing of all housekeeping tasks.

Within the C & DH, there are two groups of equipment: the communications equipment and the Data Handling equipment. Besides some miscellaneous equipment, the communications portion, is primarily composed of transponders and mission unique antennas. As mission unique equipment, the antenna specification is determined by user desires and requirements. The transponder is compatible with many different types of antennas; and, its function is to provide ranging, transmission of narrowband sensor and housekeeping telemetry, and receive commands from the ground. Transponder output power is selectable by the user according to his particular needs (24:3-14,18). Transponders are available that are compatible with the NASA Satellite Tracking and Data Network, the Tracking and Data Relay Satellite System, and the military's Space Ground Link System (31:20).

The Data Handling equipment consists of three groups: command, telemetry, and the onboard computer. The command group simply decodes commands and either processes them, if real time, or stores them for future use in the OBC. The telemetry group is primarily concerned with telemetry format. The OBC performs nearly all the decision-making and processing functions onboard the spacecraft. Some of these functions are attitude control, power management, thermal control, command storage and processing, and data dumping (24:3-18,19). The command and telemetry rates, within certain specifications, may be determined by the user (30:14).

Data handling between the C & DH and other modules, including the instrument packages in the payload, is accomplished by putting telemetered data on a data bus to be recognized and read by the specific Remote Interface Unit (RIU) to which it is addressed. Each function that needs to communicate with the C & DH has one or more RIUs acting as its interpreter between itself and the data bus.

Within the C & DH module, there has been provided 6 ft^2 and/or 60 lbs. of space for mission unique optional equipment. The following equipment is optional and may be selected by the user: tape recorders - up to three units with each having a 4.5×10^8 bit storage capacity or two units with each having a 10^9 bit capacity; a Global Positioning System (GPS) terminal - to provide precision location determination through GPS; additional computer memory - up to 64K maximum in 8K word increments; Ultra Stable Oscillator - needed for missions with precise clock/accuracy requirements; and, a power amplifier - needed for missions requiring greater than 5 watts of transponder power (41:18). In addition to the above equipment, up to 27 more RIUs may be added for experiments and propulsion (24:3-17).

The weight of the C & DH module without any additional optional equipment is 210 lbs. If additional equipment is added by the user, the module weight may vary up to 270 lbs. maximum (31:18). The quoted price of the C & DH was $8,900,000 in 1983 dollars (10).

Propulsion Module

The propulsion module provides the spacecraft with the many functions required for reaction and attitude control and orbit adjustments. Some of these being to provide the specific impulse to offset drag and to correct injection errors during launch. The module serves as a mechanism to unload the momentum wheels by mass expulsion. It also serves as a backup to the momentum wheels in case of their failure. Finally, in the event the reaction control devices within the MACS are too small, the PM can accommodate larger reaction wheels and magnetic torquers (37:7-1).

There are two classes of propulsion modules for the MMS: The Mark I and the Mark II. The Mark I class is composed of the PM-I, the PM-IA, and the PM-II. The Mark I class is limited to less than 1060 lbs. of hydrazine propellent. The Mark II class is composed of the Mark II module with different propellent tank configurations all of which contain a greater propellent capacity than the Mark I class.

Of both classes, only the PM-I and PM-IA are available for flight today (16).

The initial design philosophy behind the PM-I stressed system growth: ". . . requirements were taken into account so that basic elements of the PM such as the mechanical retention interface, the thruster modules, control electronics and propellent feed concepts can be utilized in modules with larger propellent requirements" (8:1). Components were selected based on low cost and weight, reliability, and proven flight performance. An effort was also made to include as many NASA standard parts within the design as possible. They were included as long as they were competitive in the technical performance and price areas.

This philosophy can best be illustrated by a description of the Mark I class. The PM-I contains three propellent tanks carrying a maximum of 167 lbs. of hydrazine. It's dry weight is 165 lbs. The PM-IA extends the performance of the PM-I by adding a 28 inch tank within the MMS supporting structure while using the same propulsion system. This action increases the propellent capacity to 550 lbs. The PM-IA dry weight was derived to be 235 lbs. (16:3,5). The PM-II design concept merely replaces the three tanks of the PM-I with a large bladder tank with a maximum capacity of 1060 lbs. of hydrazine (24:3-29,31a).

The Mark II class, while not building on the Mark I class, will give the MMS a genuine orbital transfer capability in the future. Although not available at present, it is in the final development to be available in the late 1980's.

It has one, two, or four propellent tank configurations whose propellent capacity can be varied from two to more than six thousand pounds (11:1) depending on the mission.

The only price quote available was for the PM-I. It was quoted at "slightly over 1 million" (6) in 1977 dollars.

Signal Conditioning and Control Unit

Within this category, previously described as the MMS electrical system, are the electrical wiring harness and the SC & CU. It has been renamed because, even though the harness is important (it provides power and signal distribution throughout the spacecraft and a central ground), the functions of the SC & CU are what makes it unique.

The functions of the SC & CU are many. It controls structural heating and monitors the temperature of both the solar array and the structure. It provides the command, telemetry, and power interface for all mission unique equipment not interfaced with either the main subsystem modules or the payload. This ability simplifies electrical interfacing since structural and appendage control do not have to be routed through any of the major subsystems. It commands all pyrotechnic arming circuitry and their subordinate firing circuitry used for appendage release, dust cover release, etc. It also has control of all the actuator circuitry for electro-mechanical devices, such as, restowable appendages and antenna control (24:3-15,15, 4-10).

The weight of the SC & CU itself is 25 lbs.; the weight of the system all together is 73 lbs. (37:2-11).

III Methodology

Discussion

This chapter first describes the cost estimating relationships (CERs) available within the Unmanned Spacecraft Cost Model (USCM) and then defines the different categories of cost estimation that characterize the model. Secondly, some of the general assumptions which were used are listed. Thirdly, the Research and Development (R & D) and First Unit (FU) production costs of the uniquely-built satellite programs are determined. Next, the feasibility of estimating the costs for the MMS modules using the model is investigated. The costs for the MMS modules and the needed mission unique equipment are then estimated. Following a development of learning curve theory, the number of satellites actually built is examined. Ultimately, mission capable MMS surrogates, which could have been substituted for the unique satellites, are developed and compared to the actual spacecraft to form decision criteria. For the reader's convenience, a methodology flowchart, Fig. 2., has been provided to help follow the development of method and the analysis.

Definitions

The Unmanned Spacecraft Cost Model has different categories for estimating the various types of hardware and non-hardware costs. Within each hardware category, there are two different types of CERs: The regular and the normalized CER. The regular CER is designed to give the user a "ball

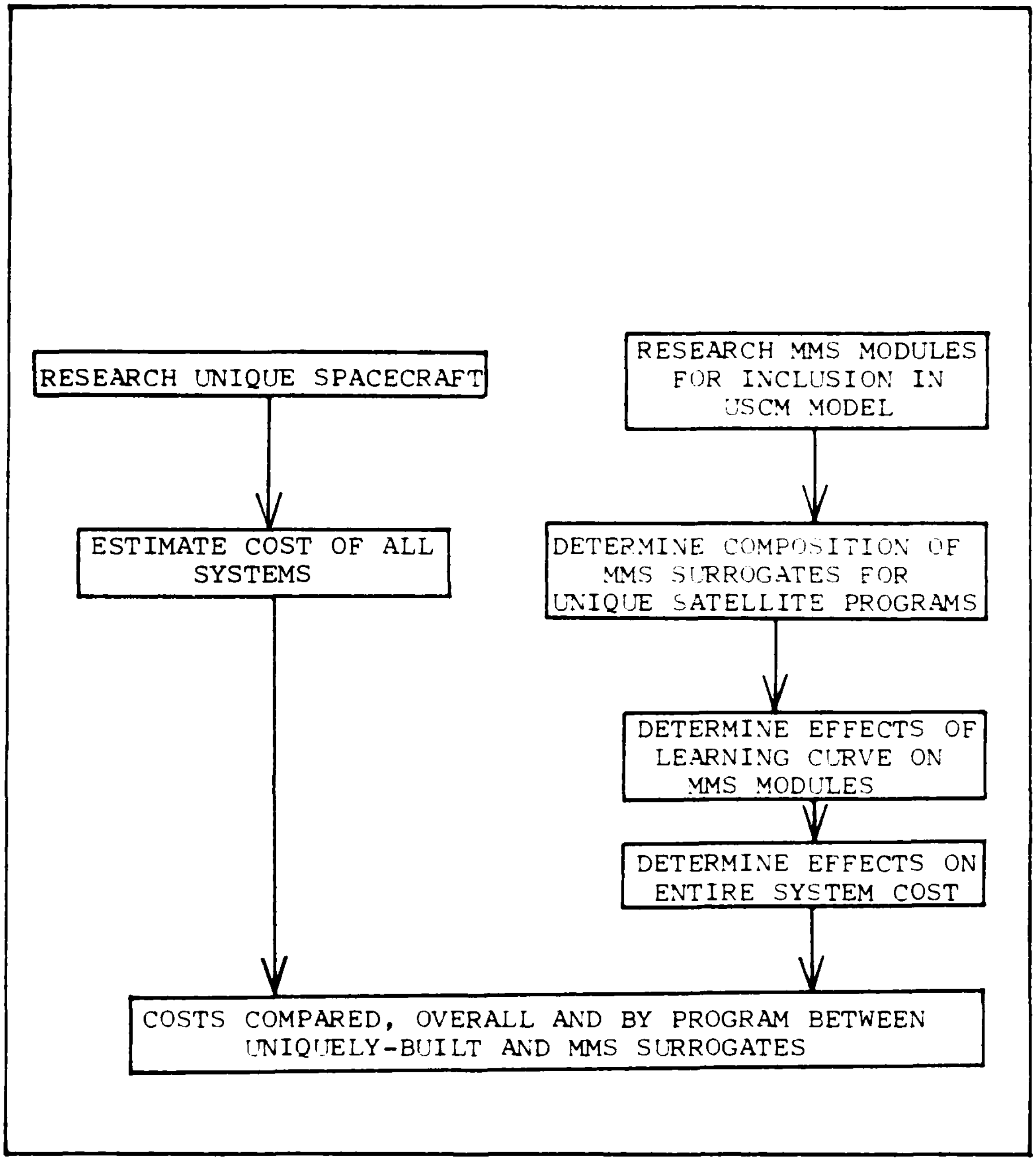


Fig. 2. Methodology Flow Chart

park" figure. It takes an independent variable, normally weight in the case of hardware estimation, and introduces it into an equation in order to generally estimate a research and development or first unit production cost. The normalized CER is an entirely different equation and with its normalization factor provides much more of a "point" estimate. It multiplies the calculated cost estimate by the normalization factor. The normalization factor is based on the complexity of the technology, the technological carry-over of the engineering associated with the date of the program, and other factors. The resulting estimate is more definitive of the hardware cost for a specific program. Appendix A contains a sample calculation of the normalization factor for the Attitude Control System of GPS-I and the normalization criteria used to calculate the factors for this thesis (34:V-1,6). Nonhardware costs are restricted in the USCM to the use of the regular CERs. The CERs from the USCM used in this thesis are contained in Appendix B. They are referenced in the text by their equation number within the appendix, i.e., B.2.

Each of the two different types of CERs, regular and normalized, estimate both an R & D and a FU production cost for each estimation category. R & D costs, a type of non-recurring costs, are those costs that are incurred in the development, design, testing, and manufacturing of a space vehicle prior to qualification. The cost of support equipment procured only once during the lifetime of a program, such as Aerospace Ground Equipment (AGE), is also considered non-recurring cost. FU production costs identify those costs that will be recurring each time a spacecraft is built. These costs are associated with the manufacture, test, assembly, integration, etc., of all space hardware.

Within the USCM are different categories of cost estimation. When estimating the hardware cost, the specific category, and hence the specific CER used, depends upon the attributes of that particular piece of equipment. For instance, within the hardware area, the categories are: the Structure, Thermal Control, & Interstage (S,TC&I); Telemetry, Tracking and Command (TT&C); Communications (Comm); Attitude Control System (ACS), which includes Attitude Determination and Attitude and Reaction Control (A & RC); the Electrical Power Supply (EPS); and Aerospace Ground Equipment (AGE). The nonhardware area consists of the Program Level costs (34). A brief description of the categories follow in subsequent paragraphs.

The Structure, Thermal Control & Interstage combines three different areas into one. The structure includes all support and mounting surfaces that bear the majority of the dynamic stress and to which other equipment is attached. Examples of structure are metal braces and supports, solar panel supports, and antenna supports (34:III-8). The thermal Control portion includes all equipment whose function is to maintain the spacecraft within the prescribed temperature limits. This category include both passive and active thermal control devices, such as, reflective paint, insulation, heaters, and louvers (34:III-9). The Interstage consists of that part of the spacecraft whose job it is to separate the spacecraft from its launch vehicle when achieving the proper trajectory (34:III-7).

The Telemetry, Tracking and Command category includes any type of equipment that communicates with the ground, receives commands and initiates their execution, processes information, and contains a tracking capability. Equipment contained within this category include computers, analog and digital converters, switching relays, tape recorders, amplifiers, clocks, and transponders (34:III-10).

The Communications category specifically applies to those satellites which are designed to have a large comm capability because of mission requirements. The only satellites within this study that use this category are the communications satellites and the navigation satellite, GPS-1. Comm equipment typically function as transmission repeaters and signal conditioners. They retransmit signals from the ground after their amplification or reconfiguration. Equipment normally found in this category include traveling wave tubes, receivers and their antennas, transmitters and their antennas, amplifiers, and solid state electronics (34:III-11).

The Attitude Control System may be broken into two different areas: the equipment that determines what attitude the spacecraft is in and the equipment that controls the attitude movement of the spacecraft. The cost model has CERs for both Attitude Determination and Attitude & Reaction Control. If the two areas cannot be broken out, the two are simply lumped together and the general ACS CER is used. Examples of equipment performing the attitude determination function would be star trackers, fine and coarse sun sensors, and inertial reference units. Some examples of equipment controlling the attitude of the spacecraft are magnetic torquers, momentum wheels, gravity booms, mass expulsion systems, and nutation dampers (34:III-13).

The Electrical Power Supply category is concerned with all equipment whose function is to generate, store, distribute, and regulate power between the spacecraft subsystems. The model contains CERs for spacecraft in subsynchronous and in geosynchronous orbits. Equipment typical of this category would be power regulators, solar cells, batteries and wire harnesses (34:III-12).

Aerospace Ground Equipment is that equipment, although not a homogeneous part of the spacecraft, which must be designed and built to perform on-the-ground checkout and integration of the satellite. Special tools, in-plane equipment, and electrical and mechanical ground equipment fall into this category. Since the equipment is only bought once, all AGE is considered a non-recurring cost in the model (34:III-14).

Program level costs are all nonhardware costs that cannot be fitted into any other categories. Program costs are both non-recurring and recurring. They include areas, such as, program management, systems engineering and analysis, test and evaluation, and quality control (34:III-15).

Assumptions

Many of the assumptions made within this chapter are section specific and can be understood only in context; and as such, are explained in their particular subsection. However, the following assumptions are applicable to the cost estimation methodology in general:

1. The cost model can predict the costs of the uniquely-built satellites since the CERs were derived from their physical characteristics.

2. The MMS can perform all missions accomplished by the uniquely-built satellites with minimum engineering changes and costs.

3. Apogee kick motor costs were considered equal for both types of satellites and were not used in cost comparisons.

4. Launch and Orbital Operations Support were considered equal for both types of satellites and were not used in cost comparisons.

5. AGE equipment is considered a one time cost for the entire MMS program but a cost incurred for each different uniquely-built satellite program.

Normalization Factors of Unique Satellites

Most of the normalization factors were provided as numerical values by the Directorate of Cost Analysis/Space Division (26). The only two that needed hand computation were the ACS and the Comm subsystems. The ACS needed to be computed due to the fact that, although the normalization factors were available for attitude determination and Attitude & Reaction Control, the weights needed to estimate the costs with the CER were not available. The weight for the overall ACS subsystems were available, however, and so the overall normalization factor was computed and used.

The comm system had the same problem as the ACS. It also had two separate breakdown areas for the normalization factors. The only weight available to be used as an independent variable was the overall comm weight. Additionally, when computing the normalization factor from a table of normalization criteria (25), one of the operational criteria, Operational Frequency and Transmitter Output Power, was unable to be determined. Since this was the case, it was assumed to take on the lowest possible degree of complexity, a value of 1.0. Although this assumption will skew the value of the communications subsystem to a value slightly lower than might have been originally expected, it should not have a significant effect on the comparison.

The operational criteria used to determine the ACS and Comm normalization factors may be found in Appendix A. The values of the normalization factors for both R & D and FU production for each unique satellite subsystem may be found in Table I below (26).

Unique Satellite R & D and FU Production Cost

This subsection displays a table of independent variables; discusses the model's CERs in conjunction with cost estimation of the unique satellite programs; illustrates a

TABLE I

Uniquely-Built Satellite Normalization Factors

PROGRAM	STRUCTURE, THERMAL & INTERSTAGE R & D	STRUCTURE, THERMAL & INTERSTAGE FU PROD.	TELEMETRY, TRACKING & CONTROL R & D	TELEMETRY, TRACKING & CONTROL FU PROD.
DPS-1	1.138	1.165	1.197	1.176
DSCS-II	1.164	1.184	1.182	1.164
P72-2	1.122	1.148	1.198	1.263
S-3	1.119	1.138	1.152	1.182
NATO 3	1.082	1.088	1.147	1.160
P78-1	1.105	1.115	1.105	1.173
P78-2	1.030	1.036	1.096	1.153
GPS-1	1.098	1.115	1.106	1.103
DSP-2	1.090	1.108	1.205	1.220
DMSP	1.147	1.180	1.204	1.266
FLTSAT	1.109	1.125	1.147	1.142

PROGRAM	ATTITUDE CONTROL SYSTEM R & D	ATTITUDE CONTROL SYSTEM FU PROD.	ELECTRICAL POWER SYSTEM R & D	ELECTRICAL POWER SYSTEM FU PROD.
DSP-1	1.205	1.233	1.141	1.269
DSCS-II	1.177	1.197	1.112	1.246
P72-2	1.151	1.146	1.062	1.156
S-3	1.138	1.139	1.059	1.045
NATO 3	1.189	1.173	1.075	1.223
P78-1	1.132	1.104	1.046	1.149
P78-2	1.085	1.067	1.023	1.126
GPS-1	1.156	1.144	1.088	1.237
DSP-2	1.162	1.155	1.101	1.262
DMSP	1.228	1.187	1.103	1.266
FLTSAT	1.161	1.156	1.165	1.529

PROGRAM	COMMUNICATIONS R & D	COMMUNICATIONS FU PROD.
DSCS-II	1.146	1.171
NATO 3	1.104	1.124
GPS-1	1.180	1.206
FLTSAT	1.268	1.277

sample calculation (with explanation); and finally, displays a table of estimated costs for the satellite programs.

With the exception of the EPS, AGE, and Program, the CERs within the model use weight as an independent variable. The EPS uses the product of the subsystem weight and Beginning-of-Life (BOL) electrical power as the independent variable. The independent variable for AGE is the sum of non-recurring and FU production cost. Program level uses as an independent variable the non-recurring hardware cost for its non-recurring program cost and FU production for its recurring program costs. Table II depicts the weights and BOL power which make up many of the independent variables for the CERs.

The use of each of the CERs resulted in a "most likely" (ML) cost of the subsystem. By applying the standard error of the estimate (Appendix B), one can obtain the minimum and the maximum values of the estimate. Since it was assumed the CERs would provide reasonable costs for the unique programs, only the ML cost estimate was carried forward throughout the calculations. The R & D and FU production costs are always columned separately. The hardware subsystem costs are multiplied by their respective normalization factors and the results summed. Nonhardware costs are then estimated. The sum of all the estimates, results in a no profit R & D and FU production cost. To obtain the full price paid, one must multiply the no profit costs by the contractor fee. Throughout this thesis, this fee has been

TABLE II

Uniquely-Built Satellite Weight Table (56)
(All weight in lbs. BOL Power in Watts)

PROGRAM	STRUCTURE WT.	TT&C WT.	COMM WT.
DSP-1	289.30	99.00	174.20
DSCS-II	231.00	79.50	236.9
P72-2	538.00	119.00	.00
S-3	190.60	44.00	.00
NATO 3	179.40	65.06	132.98
P78-1	489.90	172.80	.00
P78-2	222.90	110.10	.00
GPS-1	262.70	62.20	124.30
DSP-2	319.00	82.80	.00
DMSP	214.40	129.10	.00
FLTSAT	615.40	46.40	443.90

PROGRAM	ACS WT.	EPS WT.	TOTAL WT.	BOL POWER
DSP-1	174.20	511.10	1073.60	670.0
DSCS-II	153.20	312.30	1012.90	535.0
P72-2	172.00	235.00	1064.00	260.0
S-3	22.50	68.20	325.30	100.0
NATO 3	61.30	257.98	696.72	533.0
P78-1	99.50	194.60	956.80	330.0
P78-2	48.10	198.50	579.60	310.0
GPS-1	100.20	353.70	903.10	515.0
DSP-2	199.40	540.50	1141.70	865.0
DMSP	132.80	229.30	705.60	900.0
FLTSAT	196.70	556.60	1859.00	1640.0

assumed to be 12.5% (14). Since non-recurring and FU production costs are calculated similarly, Table III depicts as a sample, the calculation of the nonrecurring costs of FLTSAT.

TABLE III

FLTSAT 1979 Thousands of Dollars

(1) MODULE	(2) WEIGHT	(3) NON-RECURRING COST (NORMALIZED)	EQUATION NUMBER
STRUCTURE	615.4	7823.751	(B.1)
TT & C	46.4	2319.95	(B.3)
ACS	196.7	12694.62	(B.7)
EPS (SYCHRONOUS)	556.6	13977.586	(B.13)
COMMUNICATIONS	443.9	15129.33	(B.5)
SUBTOTALS	1859.00	51945.237	

MODULE	(4) R & D NORM. FACTOR	(5) R & D HARDWARE COST		
STRUCTURE	1.109	86766.650		
TT & C	1.147	2660.983		
ACS	1.161	14738.454		
EPS (SYNCHRONOUS)	1.165	16283.888		
COMMUNICATIONS	1.268	19183.990		
SUBTOTALS OF NON-RECURRING HARDWARE COST		61543.855		
AGE		9443.277		(B.19)
PROGRAM LEVEL FOR COMSATS		21958.847		(B.17)
SUBTOTAL COMPOSITE COSTS			92945.980	
CONTRACTOR FEE (SUBTOTAL TIMES .125)			11618.248	
NONRECURRING AGGREGATE COST			104564.227	

The first step in estimating the cost of the satellite program is to determine the nature of the subsystems onboard the satellite. This identification will determine the particular CERs used in the estimation process. In the example, FLTSAT is a communications satellite in geosynchronous orbit. In addition to the common S, TC & I, TT & C, and ACS CERs, FLTSAT necessitates the use of mission specific CERs for Comm and EPS. The CER equation numbers needed for the estimation are shown in the right-hand margin. The second is to determine the values of the initial independent variables, weight and BOL power. The weights of the subsystems, extracted from Table II are referenced in column (2) of the table. BOL power for FLTSAT is 1640 watts.

The normalized cost estimates are simply obtained. Two examples will illustrate this simplicity. First, to obtain the normalized cost of the S, TC & I, replace the independent variable of the CER with the weight of the subsystem. In this case, entering 615.4 into the equation $Y = 1098.18 + 90.99\ X^{.67}$ (B.1) yields a normalized cost of \$7823.751 in thousands of 1979 dollars. The EPS uses a different independent variable. The weight of the subsystem, 556.6 lbs., and the BOL power, 1640 watts, are multiplied together and the resulting product, 912824 lbs-watts, is the independent variable. When entered into the CER for normalized EPS at geosynchronous altitude, $Y = 2098.5 + .03401\ X^{.93}$ (B.13) , the result is \$15129.33 in thousands of 1979 dollars. The remainder of the normalized costs are calculated in similar fashion.

The normalization factors, referenced from Table I, are depicted in column (4). Each normalization factor multiplies the normalized cost of its respective subsystem to obtain a more certain point estimate. These costs are shown under column (5) as R & D HARDWARE COSTS. All subsystem costs are then summed to obtain a subtotal of hardware costs. In our example, the figure $61543.855 represents the subtotal of non-recurring hardware cost for FLTSAT.

From the hardware costs, the AGE and nonhardware expenses are obtained. The CER for AGE uses the sum of the total non-recurring hardware and FU production costs as the independent variable. The FU production costs was previously calculated as $21951.081. This figure added to the total non-recurring costs gives a figure of $83494.936 to be entered into $Y = .1131\ X$ (B.19) . The AGE cost for the program is then $9443.277. The Program level cost is determined using the CER for comsats, $Y = .3561\ X$ (B.17) , with the subtotal of non-recurring hardware costs of $61543.855 as the independent variable.

These costs (hardware cost, AGE cost, and Program cost) are summed to obtain a composite cost subtotal. This subtotal includes all the costs to design and develop the spacecraft but does not include a fee for the contractor. The cost to the buyer is obtained by adding the contractor's fee to this subtotal. This has been assumed to be 12.5% of the program cost. The estimated non-recurring aggregate cost to the government to develop FLTSAT then was $104564.227 ('79 K).

To calculate the recurring, or FU production, one must merely mirror the example. To obtain proper results, however, the use of the CERs and normalization factors dealing with FU production is essential.

All of the unique satellites use the same equations for S, TC & I (equations B.1, B.2); TT & C (equations B.3, B.4); ACS (equations B.7, B.8); and, AGE (equation B.19). For estimating the EPS cost, those satellites in geosynchronous orbit, DSP-I, DSP-II, DSCS-II, NATO3 and FLTSAT use equations B.13 and B.14. The remainder of the spacecraft use equations B.11 and B.12 to estimate their EPS cost. Those programs with Comm missions, DSCS-II, NATO 3, FLTSAT, and GPS-1 use equations B.5 and B.6 to estimate the cost of their comm equipment. The comsats program level CERs are also different. They use equations B.17 and B.18 to estimate their program costs and those satellites with no comm function use equations B.15 and B.16.

Table IV depicts the calculated NR and FU costs for each of the uniquely-built satellite programs.

TABLE IV

NR and FU Costs for Uniquely Built Satellites
1979 Dollars in Thousands

PROGRAM	NR $	FU $
DSP-I	32336.230	16897.001
DSCS-II	65430.013	21227.537
P72-2	51153.212	15950.261
S-3	18370.210	5086.940
NATO 3	44868.664	13852.058
P78-1	43883.494	14836.038
P78-2	27225.967	9635.558
GPS-1	48563.145	16249.369
DSP-II	62568.299	17248.823
DMSP	47530.312	17323.510
FLTSAT	104564.227	32822.080

Normalization Factors for MMS Subsystems

In order to calculate point estimates for any of the MMS modules, the normalization factors first had to be determined. When determining these factors, it had to be assumed that each module could have its' most sophisticated capabilities. Therefore, the general rule, when selecting normalization criteria to determine the factors, was to always select the most sophisticated criteria in each category that the module could possess. The specific criteria used for each module can be found in Appendix A.

With very little change, the MMS modules fit into categories prescribed by the USCM to determine the normalization factors. The MPS used the EPS table, the C & DH used the TT & C table, and the MMS composite S, TC & I used the S, TC & I table. The SC & CU used the TT & C table due to the significant amount of command and telemetry functions within the module. The MACS, due to it having both attitude determination and reaction control devices within the module, used the overall ACS table. The propulsion module, both PM-1 and PM-1A, used the Attitude & Reaction Control table due to these modules containing only reaction control devices. Table V contains the R & D and FU production normalization factors for the MMS modules. No R & D normalization factor was determined for the PM-1A under the assumption that the R & D for it was collateral with the PM-1.

TABLE V

MMS Subsystem Normalization Factors

SUBSYSTEM MODULE	R & D	FU PROD.
MPS	1.116	1.459
C & DH	1.143	1.209
PM-1	1.118	1.119
MACS	1.201	1.153
S, TC & I	1.168	1.171
SC & CU	1.068	1.075
PM-1A		1.119

Feasibility of Cost Model for MMS Estimation

To determine if the cost model could be assumed to provide a reasonable estimate of the MMS module costs, some comparison with the real costs of the MMS modules needed to be accomplished. To do this, price quotes were first solicited from the manufacturers of the modules. Current quotes were returned for the MPS, C & DH, PM-1, and the MACS. These quotes were then deflated/inflated to 1979 dollars to provide a valid comparison with the cost model. Secondly, the FU production costs of each of the quoted modules was determined using both regular and normalized CERs. Thirdly, the price quote and the estimated prices were compared for closeness.

Table VI depicts the inflated/deflated quotes. References for the inflation factor and the deflation factor were the cost model (34:A-4) and Mr. Koscielski (14), Resource Analyst in Space Division's Directorate of Cost Analysis. Mr. Koscielski's factors were provided by Data Resources Inc., an econometrics firm specializing in such data. Additionally, Mr. Ellison's quote for the PM-1A of "slightly over" was assumed to be $1,250,000. This assumption was within a few thousand dollars of a corresponding quotation on an MMS project internal budget memo (19). The price quote for the MACS was averaged out to 14.5 million dollars.

Table VI

Inflated/Deflated MMS Price Quotes (in K $)

SUBSYSTEM	PRICE QUOTE (YEAR)	INFLATE/DEFLATE FACTOR	1979 PRICE
MPS	4469 ('83)	1.417	3150.000
BATTERIES			
2 - 20 A.H.	277	1.417	195
3 - 20 A.H.	379	1.417	267
2 - 50 A.H.	312	1.417	220
3 - 50 A.H.	434	1.417	306
C & DH	8900 ('83)	1.417	6280.000
PM-1	1250 ('78)	1.089	1361.000
MACS	1450 ('83)	1.417	10232.886

The next step, to estimate the FU costs of the quoted modules, was done using both types of CERs. This procedure allowed a comparison of which CER was the most accurate in estimating the MMS subsystem cost. In addition to calculating the most likely (ML) cost for each of the CERs, the standard error of the estimate was applied to see the minimum and maximum estimates. A 12.5% contractor's fee was applied to each of the estimates. Some required assumptions for each module are explained in the following paragraphs prior to Table VII, a table of price estimations.

To estimate the MPS cost, the cost driver, or independent variable, X, had to be determined. The cost driver (lbs.-watts) is the product of the BOL power and the weight of the module. The BOL power was assumed to be the maximum regulating capability of the PRU; 1200 watts. The weight of the MPS module, without batteries, of 165 lbs. was used. This assumption was made due to the fact that the batteries make up a small percentage of the cost of the module but a substantial percentage of the weight. The cost driver for the CERs was calculated to be 198,000 lbs.-watts.

Four EPS CERs were used to determine which one estimated the MPS price most closely. They were: Regular - Subsynchronous (B.23); Regular - Geosynchronous (B.24); Normalized - Subsynchronous (B.12); and, Normalized - Geosynchronous (B.14). It should be noted that the power factor assumed for the MPS is outside the allowable range of 900 watts for both CERs estimating the subsynchronous EPS costs. The resulting price estimations are tabulated in Table VII.

Cost estimation of the remaining subsystems, the C & DH, PM-1 and MACS, were calculated in a manner similar to the MPS. The cost driver used for the C & DH module was 210 lbs., its weight without mission unique equipment. The CERs for TT & C, both regular (B.20) and normalized (B.4), were used to estimate the price of the C & DH. The cost driver used for the PM-1 was its dry weight of 165 lbs. The Attitude and Reaction Control CERs, both regular (B.22) and normalized (B.10) were the equations used to estimate the PM-1. The cost driver used to determine the MACS estimated price was its most recently quoted weight of 450 lbs. (13). Although this weight is outside the range of the independent variable, this should not present a problem since the ACS CER correlates very closely with the data (14). The MACS price was estimated using both the regular (B.21) and normalized (B.8) overall ACS CERs. The price estimations from the cost model of all MMS subsystems with quoted prices are in the following table.

TABLE VII

MMS FU Price Estimation (in '79 K $)

MODULE/CER	MIN	ML	MAX
MPS			
REGULAR:			
SUBSYNCHRONOUS	2831.327	3555.624	4279.922
GEOSYNCHRONOUS	1411.348	2568.118	3724.888
NORMALIZED:			
SUBSYNCHRONOUS	3342.453	4235.000	5127.547
GEOSYNCHRONOUS	1997.992	3200.118	4402.245
C & DH			
REGULAR	5082.725	5885.863	6689.000
NORMALIZED	5044.456	5851.472	6658.489
PM-1			
REGULAR	1538.842	2051.730	2564.617
NORMALIZED	1511.424	2000.560	2489.696
MACS			
REGULAR	9520.512	10846.730	12172.947
NORMALIZED	9153.141	10399.483	11645.825

With the quoted module prices adjusted to 1979 dollars and the prices of the modules estimated from the model, one can readily determine which of the CERs proved the closest.

Table VIII depicts the subsystem, its quoted price, the closest calculated price, the CER used, and the percentage difference of the two prices.

TABLE VIII

Quoted Versus Estimated Price Comparison (in 1979 K $)

MODULE	QUOTED PRICE	CALCULATED PRICE	CER USED	PERCENT DIFFERENCE
MPS	3150	3200.118	NORMALIZED/ SYNCHRONOUS/ MOST LIKELY	1.56
C & DH	6280	5885.863	REGULAR/ MOST LIKELY	6.69
PM-1	1361	1511.424	NORMALIZED/ MINIMUM	9.95
MACS	10232.886	10399.483	NORMALIZED/ MOST LIKELY	1.60

Since all the estimates are within ten percent of the quoted price of the module, it would appear to be feasible to use the Unmanned Spacecraft Cost Model to determine the costs of the MMS modules. The normalized most likely estimates, with the exception of the PM-1 and C & DH, are the closest estimates. However, the normalized most likely estimate for the C & DH was only a small percentage away from the regular estimate. Its estimate was 5851.472 (K $) for a percent difference of 7.34. Since there is such a small difference and to maintain uniformity, it would appear feasible to estimate the MMS modules, with the exception of the PM modules, with the normalized most likely prices. The PM modules should be estimated using the standard error for the minimum cost of the module.

MMS R & D and FU Production Costs

Since the conclusion was reached that the cost model is a suitable tool for calculating the cost for the MMS, both R & D and FU production costs for all the modules can be determined. The normalized CERs, then will be used to determine the hardware costs of the MMS. These CERs correspond to those used for the normalization factors: the MPS uses the EPS (Geosynchronous) (B.13, B.14); and C & DH uses the TT & C (B.3, B.4); the PM-1 and PM-1A use the A & RC (B.9, B.10); the MACS uses the overall ACS (B.7, B.8); the S, TC & I uses the S, TC & I (B.1, B.2); and, the SC & CU uses the TT & C (B.3, B.4).

A few assumptions about the modules and their cost drivers must be stated prior to displaying their R & D and FU cost in Table IX. R & D costs were not figured for the PM-1A on the assumption that the R & D costs for the PM-1 included the design of the PM-1A. The cost driver for the R & D cost for the C & DH was considered to be its total weight complement of 270 lbs. The assumption was made due to the feeling that the designers planned for and considered all the options that could be put in the module. The FU production estimate for the C & DH was based on a module weight of 210 lbs., the weight without the added optional equipment.

Mission Unique Items for MMS Substitution

In order to substitute the MMS for the uniquely-built satellite systems, the costs for the solar arrays, the

TABLE IX

MMS R & D and FU Production Prices (in 1979 K $)

SUBSYSTEM	COST DRIVER	R & D	FU PROD.
MPS	198,000 lbs.-watts	6235.393	3200.118
C & DH	270/210 lbs.	12988.919	5851.47
PM-1	165 lbs.	5331.565	1511.424
PM-1A	235 lbs.		2168.344
MACS	450 lbs.	37789.088	10399.483
S, TC & I	531.1 lbs.	9449.775	1605.756
SC & CU	73 lbs.	3899.624	1999.617
SUMMED COSTS		75694.364	23736.212

battery complements, and communications payload packages (if applicable) needed to be added to the module costs. This subsection deals with these determinations.

Solar Arrays. Solar arrays for the MMS are mission unique items, and as such, are sized for each mission. Because of the way the MMS is built, the solar arrays are necessarily paddle-type, either roll-out or rigid, rather than the body-mounted type. Although the size and the beginning-of-life (BOL) power were available for the solar arrays of the uniquely built satellites, the independent variable for the CER, weight, was not. It was therefore necessary to estimate the weight of the unique system satellite solar arrays in order to arrive at an estimated cost for paddle-type solar arrays for the surrogate MMSs. The ratio of .14 lbs/watt or 65 Kg/KW (2:68) was considered the most appropriate due to it being current for the period and its closeness to reality. The ratio is used on the BOL power for the applicable solar array. For instance, this ratio differs from the FLTSAT ratio of .1369 lbs/watt by only .0031 lbs/watt (2:68).

The solar array is normally considered part of, and its weight added to the weight of, Electrical Power Supply when used within the cost model. In order to point estimate the cost of each solar array that must be added to the MMS to achieve the appropriate mission, the Normalized Electrical Power Supply, Synchronous Altitude or Above CERs (B.13, B.14) were used.

The cost driver, X, used to calculate the costs of each of the MMS solar arrays was the estimated weight of the array times the actual BOL power of the unique satellite system (34:II-6,7) for the program. The normalization factors used were those previously calculated for the MPS: 1.116 for R & D and 1.459 for first unit production. Finally, to this normalized estimate was added the contractor fee of 12.5%. The following table depicts each unique program and the solar array cost had the MMS been used.

TABLE X

Solar Array Price Estimate

PROGRAM	BOL POWER (WATTS)	ESTIMATED WEIGHT (LBS)	X (BOL X WT) (WATTS-LBS)	R&D COST (1979 K $)	FU COST (1979 K $)
DSP-1	670.0	93.8	62846.00	3873.519	2347.477
DSCS-II	535.0	74.9	40071.50	3450.049	2078.892
P72-2	260.0	36.4	9464.00	2848.130	1408.012
S3	100.0	14.0	1400.00	2671.233	840.467
NATO 3	533.0	74.6	39761.80	3444.191	2074.540
P78-1	330.0	46.2	15246.00	2966.942	1601.469
P78-2	310.0	43.4	13454.00	2930.536	1548.304
GPS-1	515.0	72.1	37131.50	3394.305	2036.558
DSP-II	865.0	121.1	104751.50	4626.695	2694.695
DMSP	900.0	126.0	113400.00	4779.176	2753.036
FLTSAT	1640.0	229.6	376544.00	9180.568	3806.594

Batteries. Of the eleven unique satellite programs studied, in only four were the battery complements readily available: P78-2 (three 8 A.H.) (28:8); DSP-I (three 15 A.H.) (9:282); DSCS-II (three 15 A.H.) (9:282); and FLTSAT (three 24 A.H.) (33:1). The MMS currently has two types of batteries, the 20 and the 50 Ampere-Hour (A.H.), that may be used in any one of four redundant configurations within the MPS. MMS battery redundant configurations were matched as close as possible with these satellites. The MMS battery complements that could substitute for the other unique satellites had to be assumed depending on orbit and design life. The following table indicates the MMS configuration used when costing out each surrogate program.

TABLE XI

MMS Battery Configurations

PROGRAM	BATTERY COMPLEMENT	WEIGHT (LBS)	COST (1979 K $)
DSP-I	3-20 A.H.	159	267
DSCS-II	3-20 A.H.	159	267
P72-2	2-20 A.H.	106	195
S-3	2-20 A.H.	106	195
NATO 3	3-20 A.H.	159	267
P78-1	3-20 A.H.	159	267
P78-2	2-20 A.H.	106	195
GPS-1	3-20 A.H.	159	267
DSP-II	2-50 A.H.	224	220
DMSP	2-50 A.H.	224	220
FLTSAT	2-50 A.H.	224	220

Communications. The communications package costs when added to the MMS were assumed to be the normalized costs of the communications packages of the uniquely-built satellites plus a 12.5% contractor fee. The weight of the comm module remained the same between the two systems. Table XII shows the R & D and FU production prices, by program, of the comm packages when used with the substituted MMS.

TABLE XII

Communications Package Prices for MMS Substitution
(in 1979 K $)

PROGRAM	R & D PRICE	FU PROD. PRICE
DSCS-II	13636.609	6288.929
NATO 3	9452.505	3652.650
GPS-1	9721.880	3695.604
FLTSAT	21581.989	11843.421

Learning Curve Development

The aerospace industry has for many years used the concept of learning in order to predict the reduction in costs of items as the number produced increased. This decrease was typically attributed to learning or experience. The most commonly cited sources for the learning were job familiarization, improvement in organizational management and liaison, and the development of more efficient tools and subassemblies (3:1,3). The learning curve theory basically states that as the number of units produced is doubled, the cost is reduced by some constant percentage of the previous cost. For instance, if the marginal cost of the 50th item produced is 90 percent of the 25th item, and the marginal cost of the 100th item is 90 percent of the 50th item, then the production process is said to follow a 90 percent unit learning curve. However, if the average cost of producing the 100 items is 90 percent of the average cost of the first

50 items, the production process is said to follow a 90 percent cumulative average learning curve (3:1).

The spacecraft industry generally supports the assumption that uniquely-built spacecraft follow a 95 percent cumulative average learning curve (34:III-18, VII-11). In using the cumulative average learning curve, there are two different types of equations. One is primarily concerned with first lots of items and the second is concerned with follow on lots after the first initial production run. To simplify the comparison, the unique satellites, the MMS modules, and the MMS mission specific equipment have been assumed to be all of the first lot type regardless of number built or time period. The equations used in this thesis for the cumulative average learning curve for first lots are as follows (3:13):

AVERAGE COST PER UNIT (Y) AT QUANTITY N UNITS:

$$Y = AN^{B} \qquad \text{(III.1)}$$

TOTAL COST (T) OF QUANTITY N UNITS:

$$T = AN^{B+1} \qquad \text{(III.2)}$$

where

A = FU COST

N = NUMBER OF UNITS PRODUCED

B = LOG (LEARNING CURVE SLOPE) / LOG (2)

and B = LEARNING CURVE EXPONENT ($-1 < B < 0$)

Number of Spacecraft Built

In order to determine the cost of a program, it is first essential to determine the number of spacecraft built. A preliminary number of spacecraft was obtained from the Unmanned Spacecraft Cost Model, pages II-6 and 7. The figures obtained were then compared to those of other sources (33, 22, 23). The cost model when compared with these other sources included the same total number of satellites for each program with the exception of DSP-I, DSP-II, DSCS-II and DMSP. DSP-I and DSP-II being classified programs could not be verified. The model had included six DSCS-II spacecraft in their model and the 1980 IRW Space Log (33) had a record of 14 DSCS-IIs being launched. The model also included only four DMSP spacecraft. The Space Log had recorded 2 DMSPs launched for concept development and 5 DMSPs launched as part of the DMSP 5D-1 program. Five approved DMSP spacecraft for the DMSP 5D-2 program were also counted in the Report on Active and Planned Spacecraft and Experiments (23). The DMSP count came to a total of 12 spacecraft.

Additionally, a count of all classified spacecraft launched from 1971 to 1980 was made. The purpose of this count was to determine the number of classified spacecraft that may have been able to use the MMS during that time frame. Identification of those classified satellites able to use the MMS was done through an analysis of their launch vehicle. The 1980 TRW Space Log (33) was used in conjunction with section five of U.S. Space Launch Systems (18). The criteria used for selection was that if the booster was able to launch the MMS and a payload (from 2000 to 12000 lbs) into LEO or geosynchronous orbits, it was counted. If it was too large, like a Titan IIIC launching 29000 lbs. into LEO, or too small, such as using a Thor-Burner II or Scout, it was not counted. This count resulted in a total of 82 classified satellites. Of this 82, 33 were considered too small or too large, leaving 49 in the MMS regime. Of the remaining 49, 12 would have to be either DSP-I or DSP-II. Subtracting the DSP spacecraft leaves a total of 37 classified MMS capable spacecraft. Although unable to determine the costs of these classified programs, this number can be used in the analysis to amortize the non-recurring costs of the MMS and increase the number of MMS modules built by 37. In this fashion, the potential effects on the cost model programs can be assessed.

Table XIII presents a summation of the number of uniquely-built spacecraft counted and used in this analysis.

TABLE XIII

Unique Satellites Production

PROGRAM	NUMBER OF SATELLITES
DSP-I	4
DSCS-II	14
P72-2	1
S-3	3
NATO 3	3
P78-1	1
P78-2	1
GPS-1	7
DSP-II	8
DMSP	12
FLTSAT	5
TOTAL	59
WITH CLASSIFIED	37
TOTAL	96

MMS Module Substitution

In order to make a comparison between the unique satellites and the MMS, it is necessary to determine which specific modules of the MMS are needed for each type of unique satellite. All of the unique satellites, including the classified ones, were assumed to need the S, TC & I, C & DH, MACS, SC & CU, and MPS (without batteries). They also required certain mission specific equipment, such as, solar arrays, batteries, and communications equipment (if needed). The mission specific equipment to be used for each of the unique programs were developed in Tables X, XI, and XII, respectively.

The MMS propulsion module was the only module that was changed according to the specific unique program. The PM-1 or PM-1A was assigned to the specific programs using the following quote as a guideline: "The 7-year life propellant requirements vary between 133 pounds for a DSCS-II and 203 pounds for a DSP. If a 10-year life and N-S stationkeeping were required, the propellant requirements would vary between 258 and 400 pounds" (7:3-48). With this information all modules with the exception of DSP-I, DSP-II, NATO 3, DMSP, FLTSAT and the classified satellites, were assumed to use the PM-I. DSP-I, DSP-II, NATO 3, FLTSAT, and the classified satellites were assumed to use the PM-IA; NATO 3 and FLTSAT because of their long life and the classified programs because of their mass expulsion requirements in LEO. DMSP did not require a propulsion module (32:9).

Decision Criteria

In making a logical comparison, besides knowing which modules would have been needed to simulate each unique satellite program, it was necessary to determine the total number of each type of MMS module that would have been built. The total number of modules built was varied in the analysis depending on three different criteria: the design life of the MMS; whether classified satellites were included in the total; and whether the comsats (DSCS-II, NATO 3, FLTSAT) and GPS-1 were included.

Within the design life criteria, two categories were used: the normal design life of the MMS (48 months or less), and an assumed design life of greater than 48 months. The normal design life category was further subdivided into two parts, one containing the comsats and GPS-1 and one not. This differentiation was made due to the long lives of the comsats and GPS-1. The design life of the MMS being years shorter than the comsats and GPS-1. When analyzed in the normal design life category, the number of MMS modules used for those programs were doubled. The reason for making an analysis without the comsats and GPS was that the doubling of the number of comsats and GPS-1 produced a fear that the costs associated with the doubling would significantly affect the results. Each of these two parts were then analyzed with and without the inclusion of the classified satellites.

The second category, the assumption of a greater than 48 month design life for the MMS, was done with and without classified satellites. The primary assumption within this category is that the MMS could be engineered to achieve the design lives of the comsats and GPS-1 without significant costs. Table XIV gives the total number of MMS modules used within each subdivision of the categories.

TABLE XIV

Number of MMS Modules Used for Analysis

CATEGORY	NUMBER OF MPS, SC & CU, C & DH, MACS, AND S, TC & I	NUMBER OF PM-1	NUMBER OF PM-1A
LESS THAN 48 MONTHS DESIGN LIFE:			
W/COMM & GPS-			
(1) W/O CLASSIFIED	88	48	28
(2) W/ CLASSIFIED	125	48	65
W/COMM & GPS-			
(3) W/O CLASSIFIED	30	6	12
(4) W/ CLASSIFIED	67	6	49
GREATER THAN 48 MONTHS DESIGN LIFE:			
(5) W/O CLASSIFIED	59	27	20
(6) W/ CLASSIFIED	96	27	57

For each of the above six subdivisions, computer runs were made varying the learning curve from 95 percent down to 80 percent in five percent increments.

IV Analysis

Discussion

This chapter builds on the cost estimates calculated in Chapter III and details a logical method of analysis needed to compare the two different types of philosophies of building spacecraft - building twos and threes with a design towards the mission or building a common spacecraft capable of many missions to take advantage of the manufacturing process. In order to develop and perform the analysis, this chapter develops the analysis as follows:

(1) the costs of the uniquely-built satellites, both total and program, are calculated;

(2) the composite costs of the MMS surrogate for R & D and production are developed and a sample calculation provided;

(3) the costs of the different philosophies are gathered together and compared graphically.

Total Production and Program Costs for Unique Satellites

By using the figures contained in Table IV and Table XIII with equations IV.1 and IV.2, the average cost per satellite, composite production costs, and aggregate acquisition costs (non-recurring and production) for each program may be estimated for any learning curve slope for the unique satellites. This thesis assumed that the learning curve for these satellites has a 95 percent slope (34:VII-11). Table XV depicts the results of applying the learning curve equations with the aforementioned tables to determine the costs of the programs.

TABLE XV

Unique Satellites Estimated Acquisition and Production Costs
(Thousands of 1979 Dollars)

PROGRAM	AVERAGE COST PER SATELLITE (1)	COMPOSITE PRODUCTION COST (2)	AGGREGATE ACQUISITION COST (3) = (2) + NR $
DSP-I	15249.543	60998.174	93334.404
DSCS-II	17461-657	244463.205	309893.218
P72-2	15950.261	15950.261	67103.473
S-3	4689.746	14069.239	32439.449
NATO 3	12770.475	38311.425	83180.089
P78-1	14836.038	14836.038	58719.532
P78-2	9625.558	9635.558	35861.525
GPS-1	14070.151	98491.056	147054.201
DSP-II	14788.710	118309.677	180877.976
DMSP	14413.712	172964.548	220494.860
FLTSAT	29136.804	145684.020	250248.247
SUMMATION OF INDIVIDUAL PROGRAM COSTS			933713.202

Composite Costs of MMS Surrogate Spacecraft

The cost of each program with MMS substitution can be broken up into R & D and production or recurring costs. The R & D and FU hardware costs for the MMS subsystems were found in Table IX. Equations B.15 and B.19 were used to estimate the nonrecurring program level cost and the AGE cost. These costs were added together to obtain the estimated composite MMS nonrecurring cost of $126373.766 (1979 K dollars). These composite nonrecurring costs, including program development and AGE costs, were considered a one time expense regardless of how many programs the MMS serviced. The estimated composite nonrecurring costs were prorated among the programs according to the number of major MMS modules they used out of the total number produced within the subdivision. An estimated composite nonrecurring costs for each surrogate program was determined by adding the estimated MMS nonrecurring composite costs to the estimated R & D costs of the solar arrays (Table X) and communications (Table XII), if needed.

The recurring or production costs for an MMS surrogate was a composite cost based on the total number of modules produced and the slope of the learning curve. Using equation III.1 and the needed input data, the average cost of each MMS subsystem was determined. The mission unique equipment, solar arrays and the communications equipment, were always assumed to have a learning curve of 95 percent since they were generally made in small numbers. Using equation III.1, Table X, Table XII, a 95 percent learning curve, and the number of mission specific items needed for the surrogate program, the average cost of the solar arrays and the comm equipment (if needed) was determined. The batteries were considered to be a fixed cost (Table XI). The estimated MMS subsystem average cost and the mission unique hardware average costs were totaled to determine an estimated composite hardware cost. From this summation, an estimated recurring program cost (B.16 or B.18) could be calculated. The estimated recurring program cost and the hardware cost summed to a composite cost for each surrogate spacecraft. The total number of MMS substitute spacecraft used for each program multiplied by the composite cost per surrogate spacecraft resulted in a composite production cost. This cost plus the prorated nonrecurring composite cost resulted in the aggregate acquisition cost for that specific program. This procedure was accomplished for each uniquely-built satellite program for each subdivision of criteria (Table XIV).

To better illustrate this procedure, an example of how the NATO 3 substitution costs were determined for subdivision two - design life less than 48 months, without including classified - is reviewed in Table XVI. A learning curve of 95 percent was used for the mission unique items and a curve of 80 percent was used for the MMS modules.

Interpretation of Graphs

The computer runs made of each subdivision of criteria are contained in Appendix C. The data from these runs were developed into graph form to facilitate the comparison between the uniquely-built satellite programs and the MMS substitution programs. Figure 3 depicts how the overall uniquely-built space program, both with and without the comm satellites, would have compared with a program of MMS surrogates. Figures 3 through 14 show how each specific uniquely-built program costs would have faired had the MMS been available for their substitution.

Some explanation of the figures may be needed. In all of the graphs, the vertical axis depicts estimated costs in constant 1979 dollars and the horizontal axis relates to the learning curve slope used in computing the composite costs of the MMS surrogate spacecraft. For instance, in

TABLE XVI

Estimated Program Costs for MMS Substitution of NATO 3
(in Thousands of 1979 Dollars)

NONRECURRING COSTS:	
ESTIMATED COMPOSITE NONRECURRING COST Prorated for 6 of 88 (satellites doubled due to long life)	8618.690
SOLAR ARRAY	3444.191
COMMUNICATIONS PACKAGE	9452.505
PRORATED NONRECURRING COMPOSITE COST	21515.386
AVERAGE COSTS:	
S, TC, & I	379.923
C & DH	1384.463
MACS	2460.527
MPS (W/O BATTERIES)	757.151
SC & CU	473.111
PM-IA	741.733
SOLAR ARRAY	1816.930
COMMUNICATIONS PACKAGE	3199.075
BATTERIES	267.000
ESTIMATED COMPOSITE HARDWARE COSTS	11479.913
ESTIMATED PROGRAM LEVEL COST (B.18)	3778.039
COMPOSITE COST PER SURROGATE MMS	15257.952
COMPOSITE PRODUCTION COST (Number of satellites (6) times Composite Cost per Surrogate MMS)	91547.713
AGGREGATE ACQUISITION COSTS (Prorated Nonrecurring Composite Costs + Composite Production Costs)	113063.100

Fig. 3, the summation of the estimated costs of the uniquely-built satellite programs, both with and without comsats and GPS-1, are represented by the horizontal dashed line. The upper dashed line represents the inclusion of the comsats and GPS-1. The solid horizontal lines running parallel to the summation of estimated costs line represents error estimation by +/- ten percent of the total.

The curves, 1 through 6, relate to the analysis criteria subdivisions (Table XIV):

1 - less than 48 months MMS design life, with comsats and GPS-1, without classified.

2 - less than 48 months MMS design life, with comsats and GPS-1, with classified.

3 - less than 48 months MMS design life, without comsats and GPS-1, without classified.

4 - less than 48 months MMS design life, without comsats and GPS-1, with classified.

5 - greater than 48 months MMS design life, with comsats and GPS-1, without classified.

6 - greater than 48 months MMS design life, with comsats and GPS-1, without classified.

The learning curve slope for the production of the MMS modular subsystems was varied from 80 to 95 percent and the aggregate acquisition costs for each individual program estimated. In Fig. 3, the summation of the aggregate acquisition costs of the MMS surrogate programs are plotted against the learning curve slope used to produce the MMS modular subsystems for each of the above subdivisions. The curve representing subdivision 4 for example, crosses the summed costs of the uniquely-built programs, excluding comsats and GPS-1, (lower dashed line) at approximately 88.5%. Therefore, for the MMS surrogates to have saved money within this criteria, a constant learning rate of 11.5% or better for production of the MMS modular subsystems would have had to have been achieved.

Figures 4 through 14 are representations of the individual uniquely-built satellite programs. The estimated aggregate acquisition cost for each of the uniquely-built programs is depicted by the horizontal dashed line. Curves 1 through 6 are plotted similarly to Fig. 3. The curves in these figures represent estimated aggregate acquisition costs of each specific MMS surrogate program.

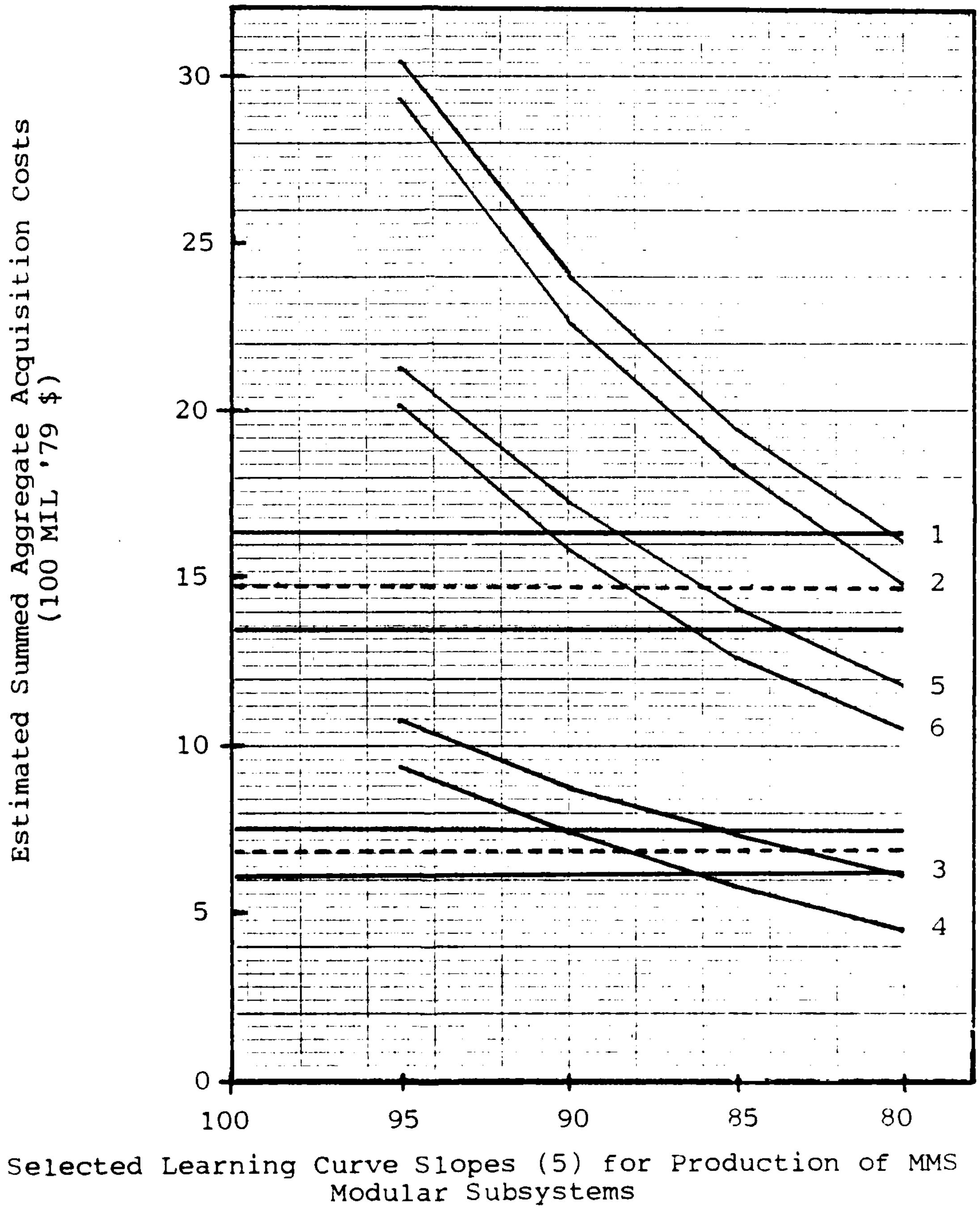


Fig. 3 The Effect of Increased Learning on Summed Aggregate Acquisition Costs for MMS Surrogate Satellite Programs

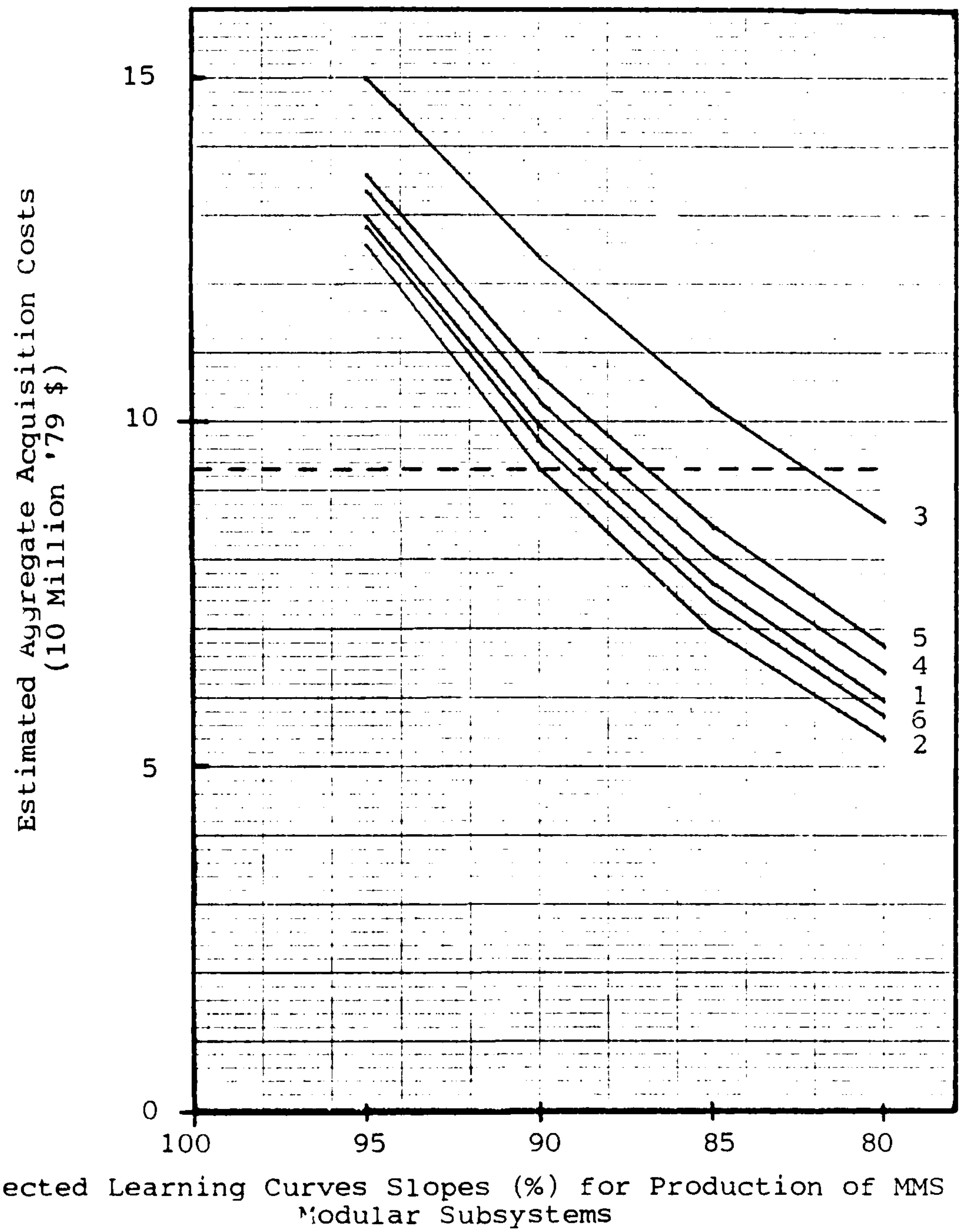
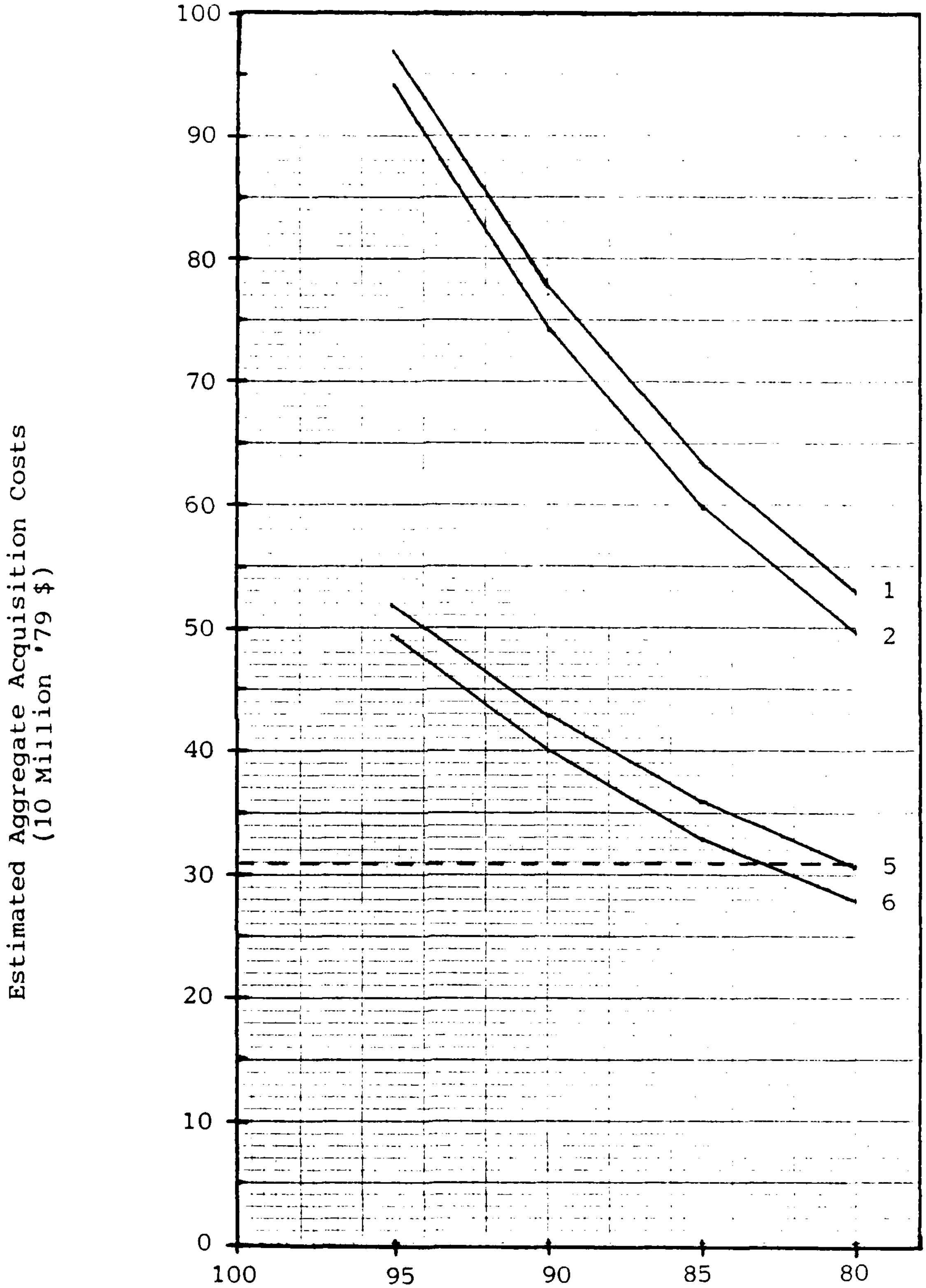


Fig. 4 The Effect of Increased Learning on Aggregate Acquisition Costs for MMS Surrogate DPS-1 Program



Selected Learning Curve Slopes (%) for Production of MMS Modular Subsystems

Fig. 5 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate DSCS-II Program

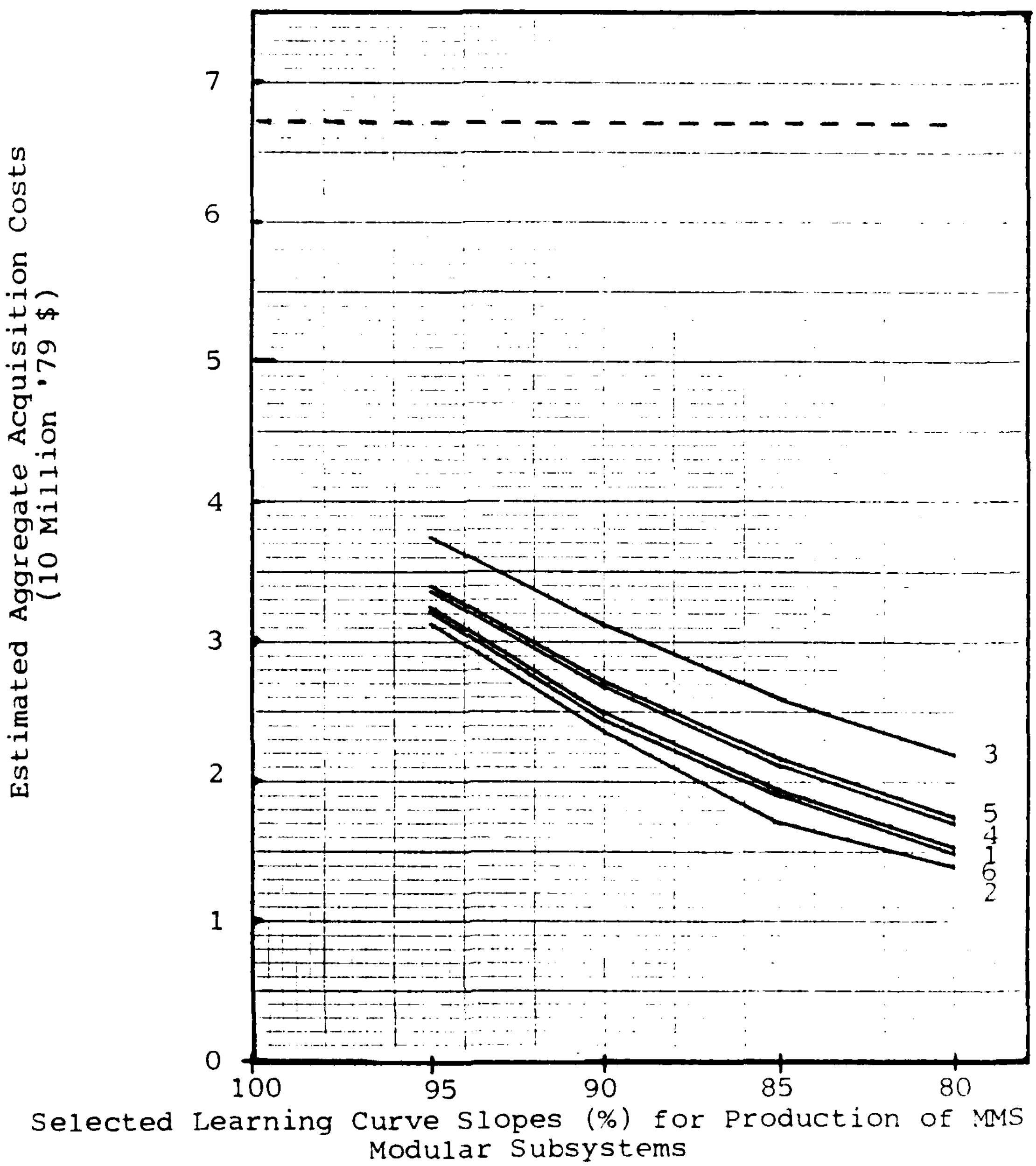


Fig. 6 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate P72-2 Program

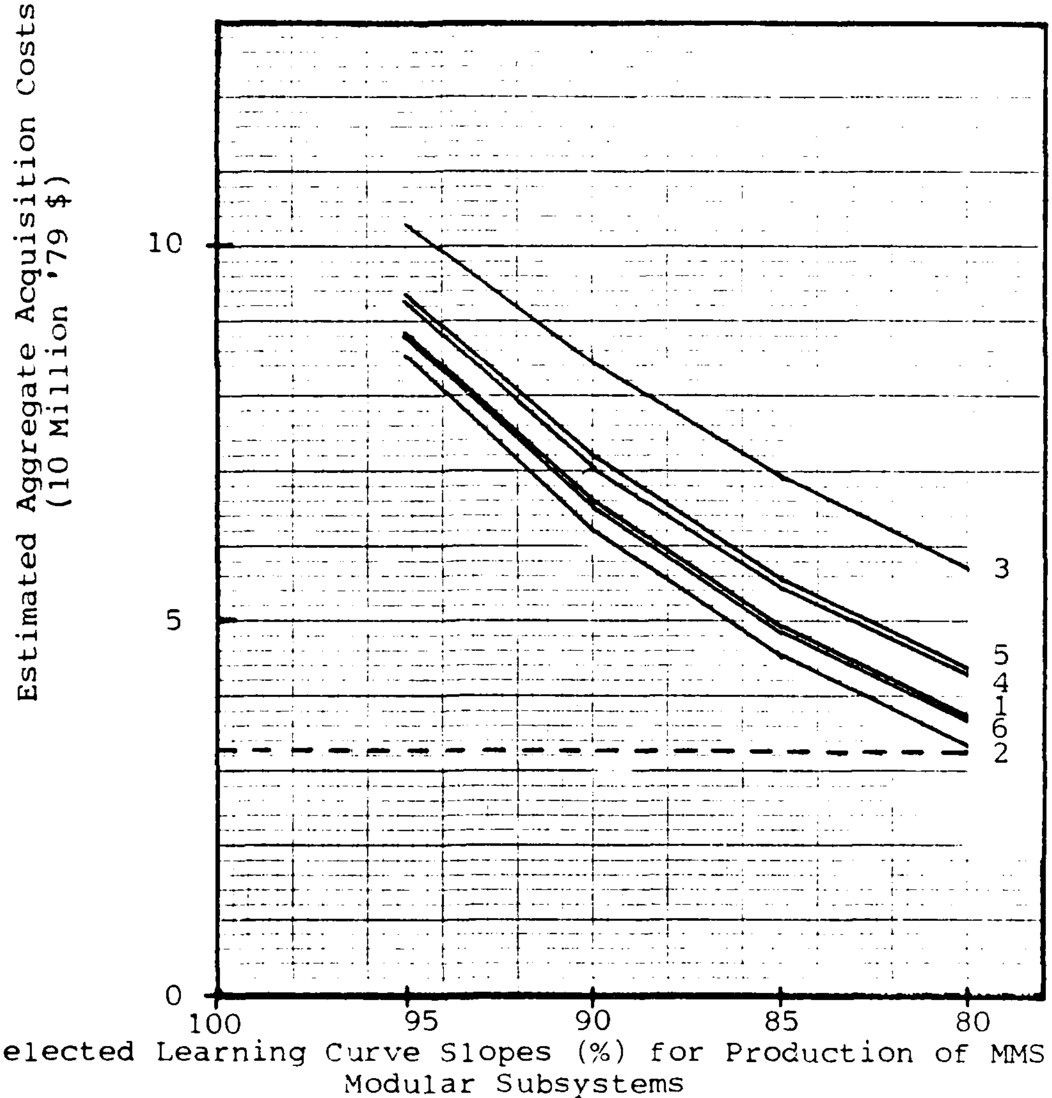


Fig. 7 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate S-3 Program

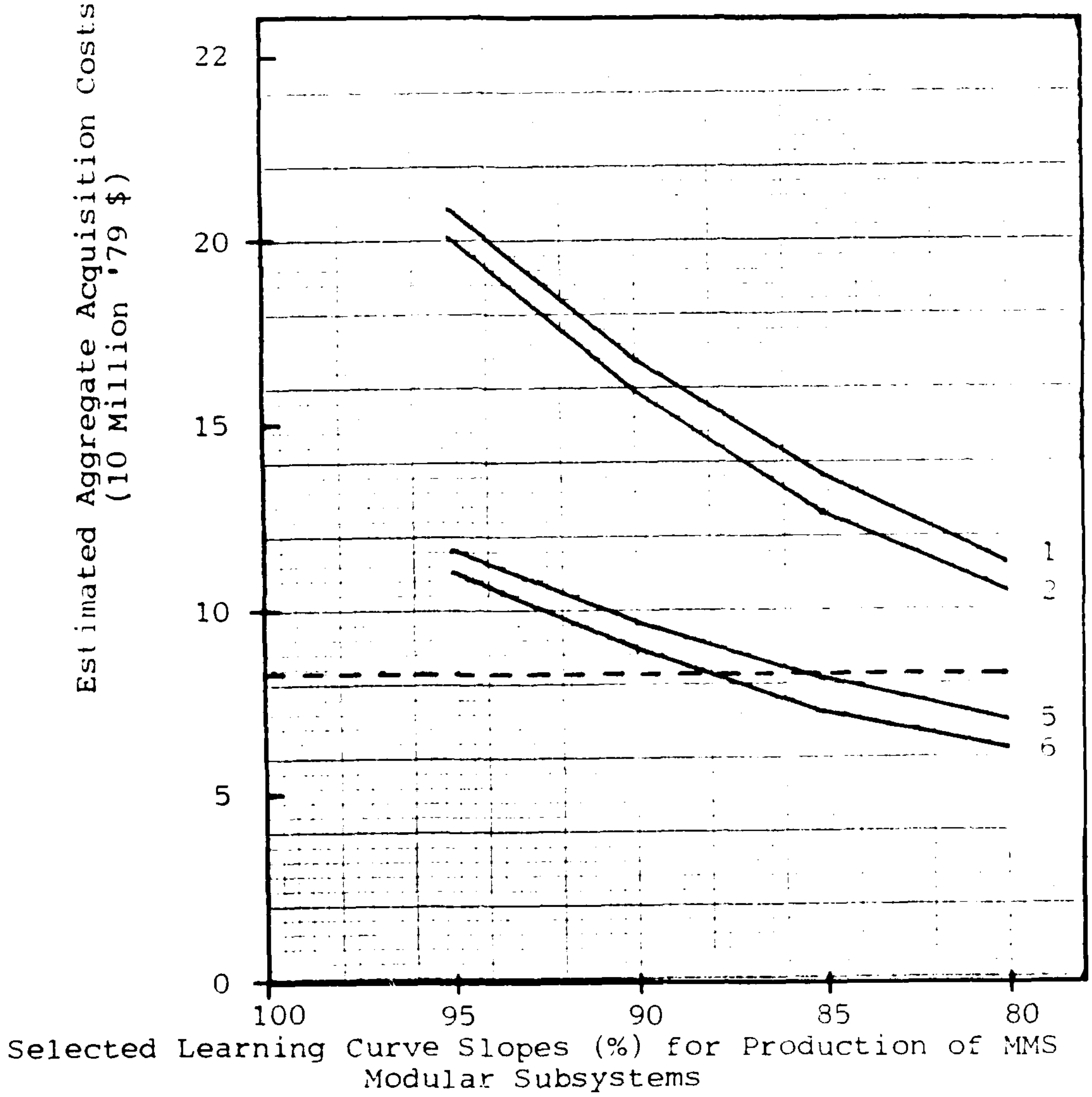


Fig. 8 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate NATO 3 Program

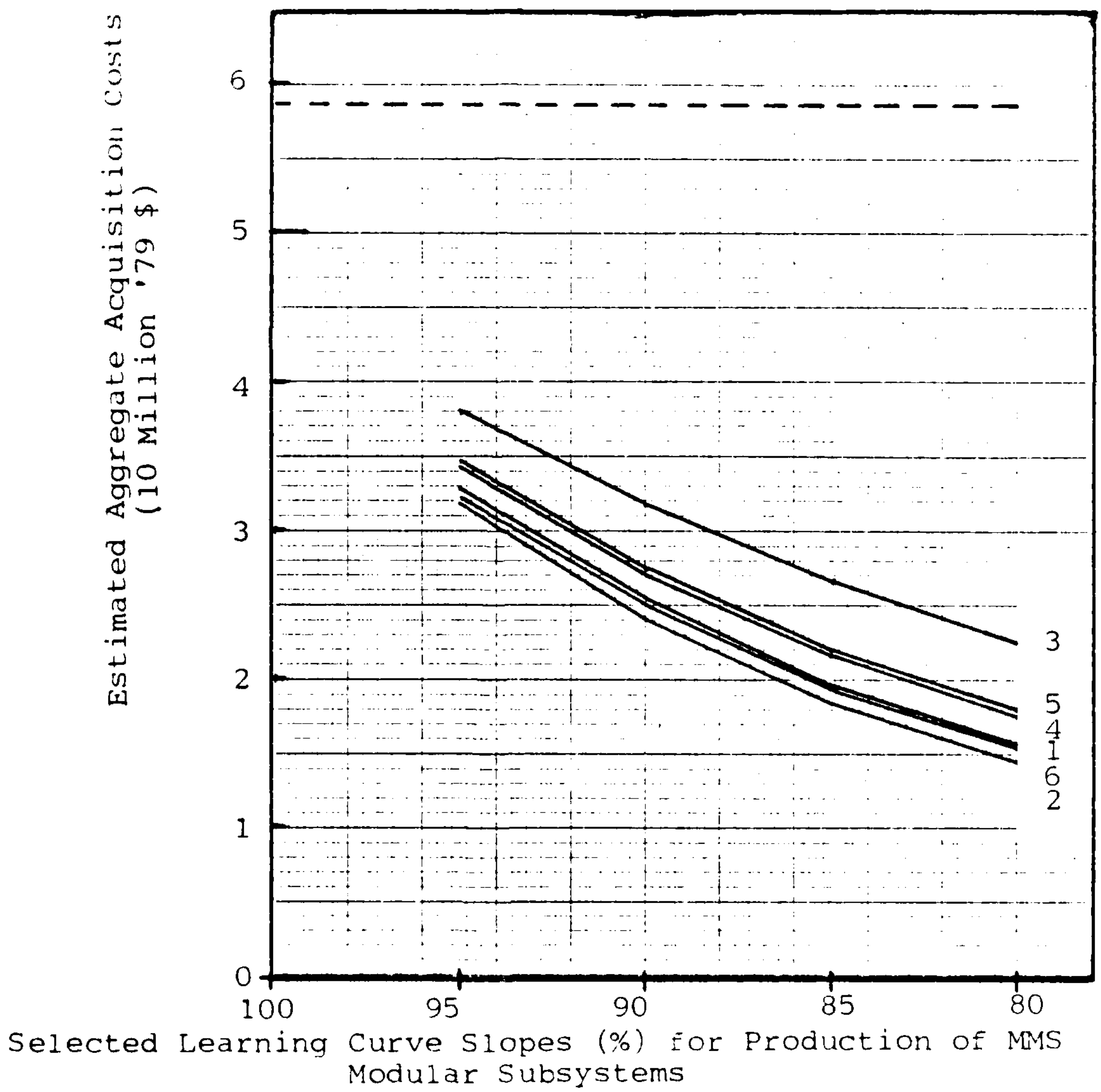


Fig. 9 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate P78-1 Program

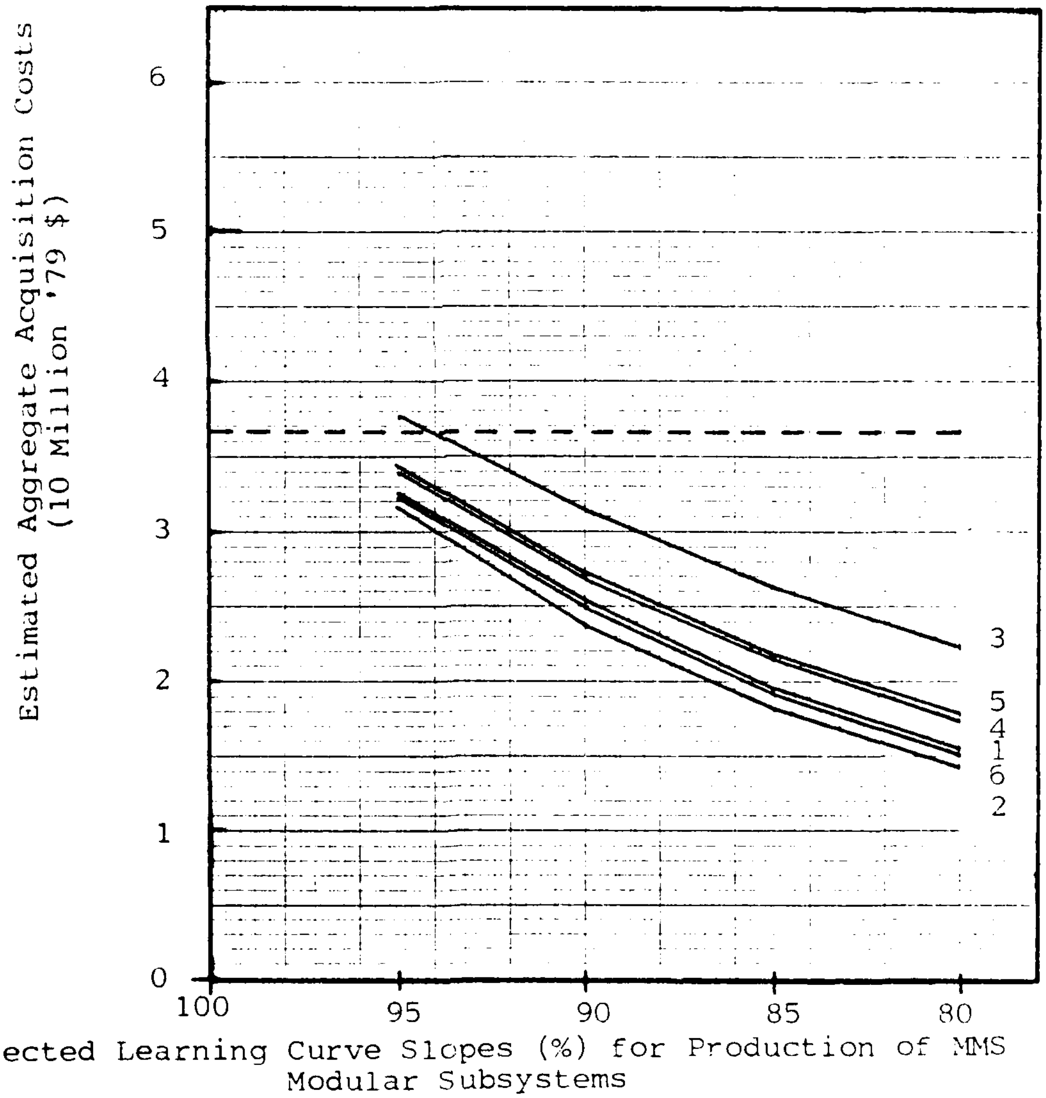


Fig. 10 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate P78-2 Program

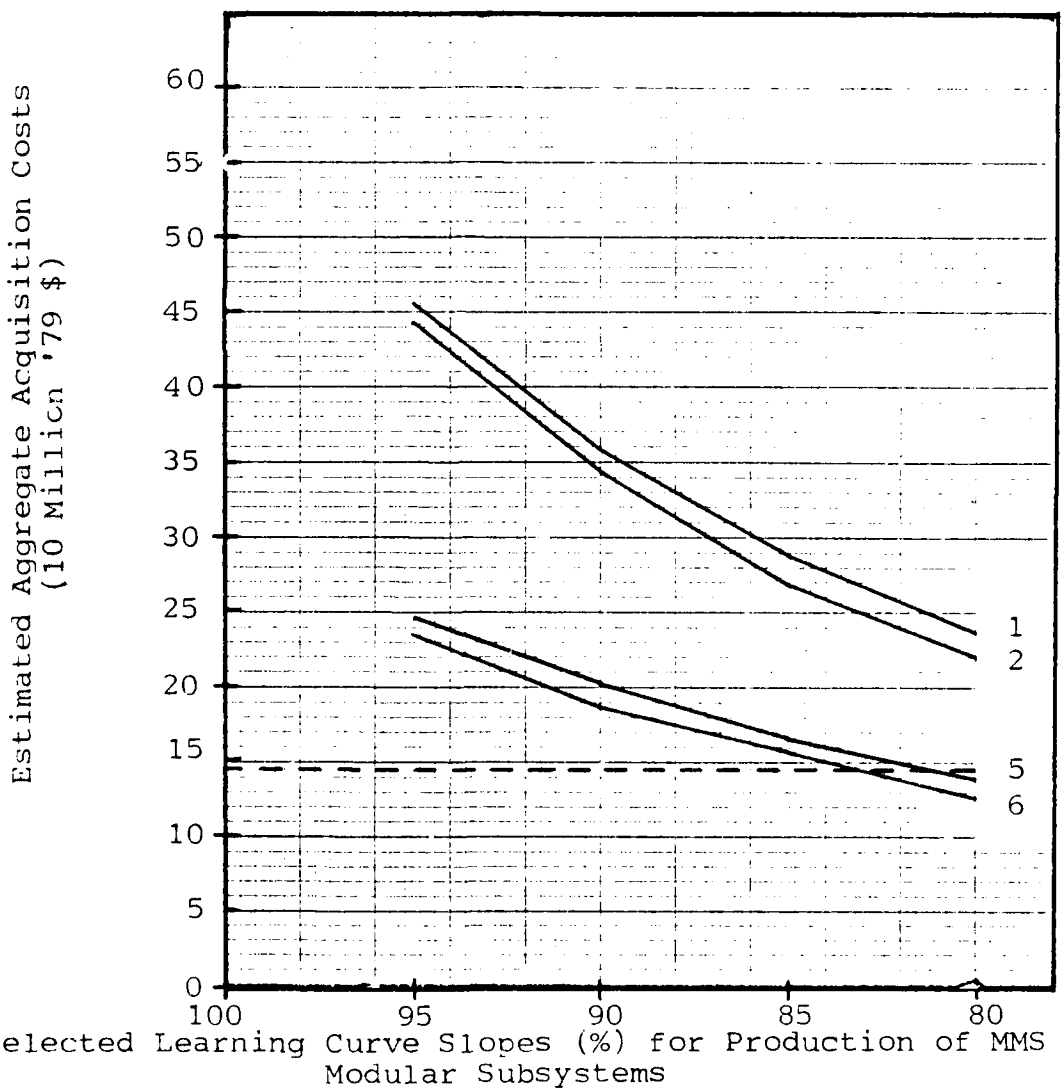


Fig. 11 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate GPS-1 Program

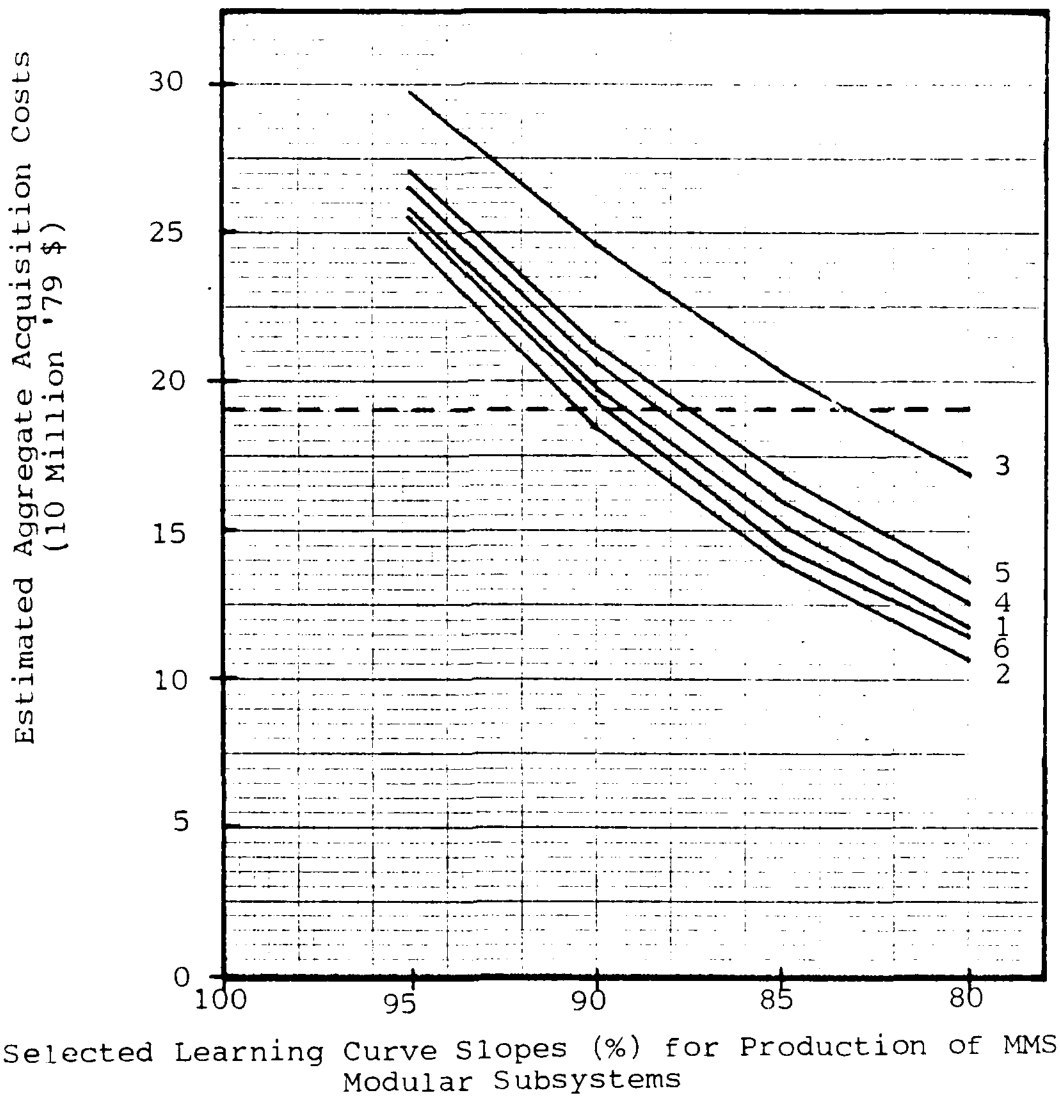


Fig. 12 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate DPS-II Program

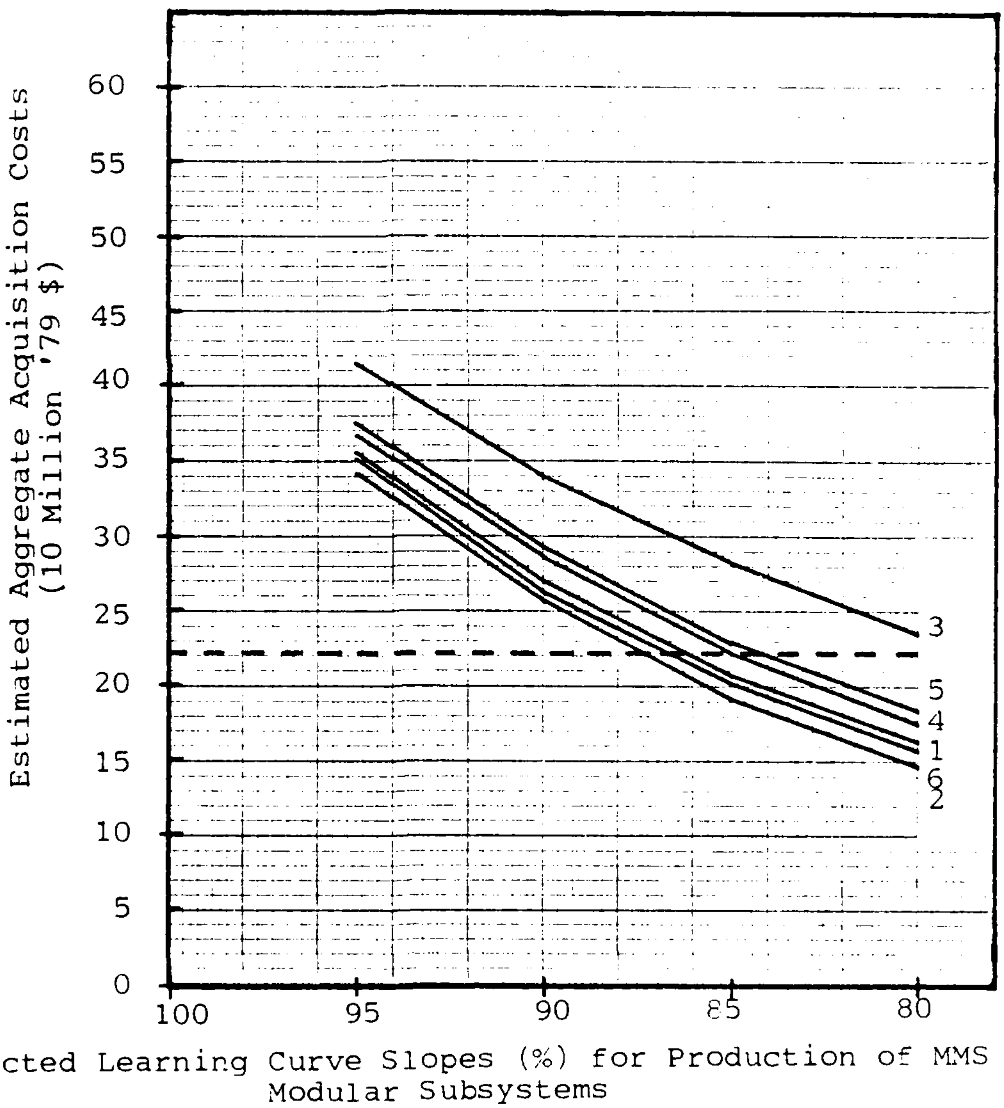
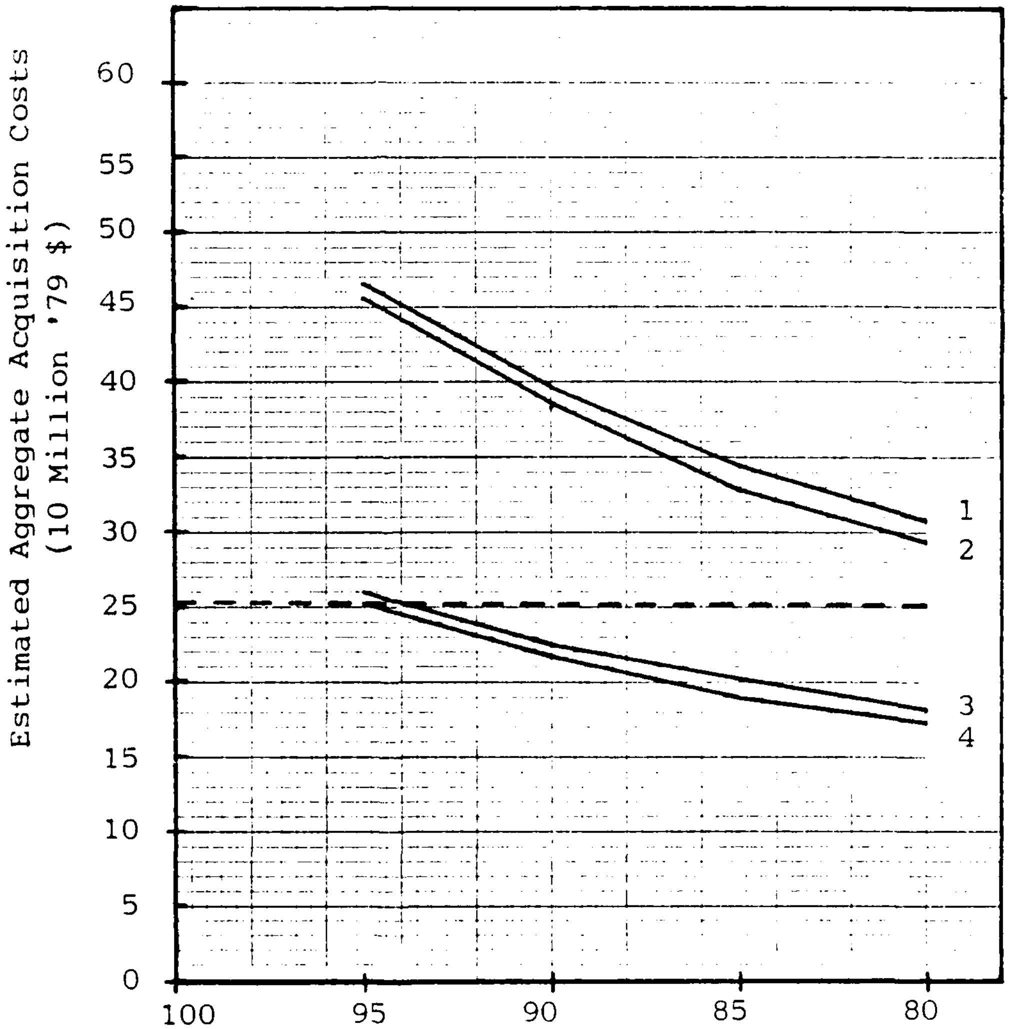


Fig. 13 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate DMSP Program



Selected Learning Curve Slopes (%) for Production of MMS Modular Subsystems

Fig. 14 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate FLTSAT Program

V Conclusions and Recommendations

Discussion

This chapter determines if our research questions and objectives have or could have been answered by the thesis. Both sets of research questions have been addressed and are followed by comments on the major research objectives. Additional conclusions, mostly collateral to the study found during research, are discussed. Following the additional conclusions, recommendations for future research and analysis are presented. A final concluding comment on the MMS and Air Force use is stated.

Research Questions and Objectives

The first set of research questions dealt with determining the costs, both by program and total outlay, of the uniquely-built satellite programs of the 1970's and the feasibility of using the model to estimate the costs of the MMS. The non-recurring and first unit recurring costs of the uniquely-built programs were calculated and depicted in Table IV. Total and individual program outlay for these programs was depicted in Table XV. The feasibility and reasonableness of these costs were examined. Within the model itself, some of the studied satellite programs were deleted from its CER regression analysis due to various factors. The S-3 program was deleted from several due to its short design life of six months or less (34:V-20). FLTSAT was deleted from some CERs due to technical problems resulting in higher costs (34:V-22).

However, the model does state it is designed and considered "to yield a 'starting point estimate' which represents the 'average' cost for a program with 'average' problems, 'average' technology, 'average' schedule, 'average' engineering changes, etc." (34:III-18). So, even with these problems, the costs calculated and depicted are believed to be a reasonable and feasible representation of the 1970's space programs. The main assumption of the thesis, that the model could predict the costs of the uniquely-built satellite programs, is reasonable. The feasibility of estimating the MMS costs, both R & D and FU, when using the cost model was developed in Chapter III with the conclusion that the results from the cost model were reasonably accurate.

The second set of research questions dealt with the learning curve and the quantity of MMS modules produced. What would the learning curve parameters have had to have been for the MMS program to have been less costly than the actual uniquely-built space program? How important was quantity to the study? And which, if any, of the uniquely-built satellites would have benefited the most had they been replaced at the outset with the MMS? The answers to these research questions depended heavily on the criteria subdivision used (Table XIV) when comparing the programs.

Decision Criteria

The design life of the MMS turned out to be a critical cost factor in determining overall and individual program costs and in determining the intersection of the curves and the expenditure lines when the comsats and GPS-1 was included in the analysis. This was true because the shorter design life of the MMS (48 months or less) required the total number of substitutions for the long-lived comsats and GPS-1 to be double the number of the originals. Although, the acquisition cost of the individual MMS surrogate was significantly less in some cases than the cost of the uniquely-built program, the requirement to use double the number of substitutes more than offset the savings incurred by using the MMS. For instance, the acquisition cost of FLTSAT for the uniquely-built program was $50049.649 ('79 K). When using an 80% learning curve for the MMS in category one (less than 48 months design life, with comsats and GPS-1, without classified), the acquisition cost of an MMS substitute for FLTSAT costed out at $30582.740 ('79 K). The doubling of the MMS substitutes more than offset the savings the MMS brought to the program.

To have saved money using the MMS with its original design life and considering replacement assumptions for the comsats the GPS-1, the learning curve slope for the MMS would have had to have been 80% or below. If the MMS design life could have been increased to achieve a one-for-one replacement with the long-lived satellites, the cost savings would have started when the MMS modular subsystems had a learning curve slope of 86%. If the classified subset was added the savings start with a learning curve slope of 88% (Fig. 3).

If the comsats and GPS-1 were not included in the analysis due to the infeasibility of using the MMS because of its design life, the cost savings for the other programs would have begun when the MMS modules had a learning curve slope of 83%. When the classified satellites were included in the analysis, the savings began with a learning curve slope of 89% (Fig. 3).

<u>Quantity Considerations as a Cost Driver</u>

Quantity of MMS substitutes appeared to be important in the study. Quantity affected both the total outlay and individual program costs. As far as the total program categories were concerned, the addition of the classified satellites to the different subdivisions was significant. Adding the classified satellites to subdivisions 1, 3, 5 resulted in subdivisions 2, 4, 6 respectively (Table XIV). The inclusion of the classified satellites caused a downward shift of the previous curves resulting in an overall savings of approximately 100 million ('79 $) over those categories that did not include the classified programs. The shift also reflected that less learning needed to be accomplished in order to start cost savings.

For individual programs, as well, a downward shift of the curves was the typical result as the quantity of MMS substitutions were made. While the comsats and GPS-1 do not appear to reflect this statement, it should be noted that the curves in Chapter IV plot the learning curve slope of the MMS subsystem modules versus aggregate acquisition cost.

The doubling of the number of substitutions resulted in a lower acquisition cost per satellite but higher aggregate acquisition costs for the comsat and the GPS-1 programs. A better graphical display of this phenomenem can be seen in the DSP-II graph, Fig. 12. Those noncomsat programs continued to depict a downward shift of the curve as the numbers increased due to the amortization of R & D cost and additional benefits from the effect of the learning curve.

Even when the comsats and GPS-1 were deleted from consideration in the study, the summed aggregate acquisition costs and individual aggregate acquisition costs of the other satellite programs could have shown a cost savings. Without inclusion of the classified satellites, P72-2 and P78-1 showed a savings immediately when using the MMS. P78-2 started saving at a slope of 93.5% and DSP-I and II at 82%. DMSP and S-3 as individual programs never showed a savings down to an 80% slope. With the inclusion of the classified satellites, these satellite programs, with the exception of DMSP, DSP-I, DSP-II, and S-3, started saving immediately regardless of learning curve slope of the MMS modular subsystems. DSP-I and II started saving with a slope of 87.5% and DMSP at 85%. The S-3 program never saved.

The research objective to determine if the overall program cost for the military space program of the 1970's could have been cheaper had the MMS been developed and been used exclusively, rather than building unique spacecraft, can now be addressed. Given the design life of the MMS of four years or less, the MMS may not have saved total program cost had it been used exclusively to replace the uniquely-built satellite programs of the 1970's. It may have cost more than the total overall program had the MMS been substituted for the comsats and GPS-1. However, overall program costs could have been saved in the 1970's had the MMS been able to be used within its design life capabilities for other than those long-lived spacecraft. Without including the classified program, the learning curve slope of the MMS subsystems had to be only 83% to effect a cost savings for the noncomsat spacecraft. With the classified, the learning curve slope had to be a mere 88.5% to effect a cost savings of the overall program. Mr. Earl Knox stated that his learning curve slope for the MACS would be approximately 90% once full production was under way (13). For the MMS, this slope should be readily achievable and savings accrued for those programs within the design life capability of the MMS.

Additional Conclusions

Some additional comments must be directed regarding the MMS on the topics of solar arrays, integration costs, and modularity. P80-3/MMS Compatibility Study (21) mentions two different types of solar arrays which could be compatible with the MMS (21:1-5). It would therefore seem feasible that the estimated R & D costs within this study for solar arrays may have been much less for each of the surrogate programs. A standard type of array that could be sized as needed would appear to be appropriate. If this is indeed within the capability of the various programs, then the cost for the solar arrays would have been less than those estimated.

Another cost for the MMS that may have been overestimated was the recurring program cost of which spacecraft integration is a subset. The MMS integration costs may prove to be much lower than the uniquely-built spacecraft integration costs. This is due to the ability of the MMS to test the modules without the requirement for them to be physically mated to one another. This is done through computer simulation of those modules not yet completed. The payload may also be integrated without it being physically attached to the MMS. This feature could produce tremendous labor savings when trouble shooting the spacecraft.

One factor that would have affected the costs of boosting to orbit was the effect of modularity on the different space programs. Modularity normally results in a weight increase. This was true when the MMS was substituted for the uniquely-built programs. The most startling was that of the S-3 program. When uniquely-built, it weighed only 325.3 lbs. When the MMS was substituted for it, the substitute weighed in at 1714.1 lbs. If the MMS had been used in the 1970's, the type of boosters may have had to have been changed resulting in an increase to on-orbit costs.

Recommendations

Due to time constraints, the author was not able to fully explore all areas which could pertain to the use and effects of using the MMS for military purposes. Because this was the case, the following areas are recommended for further study:

1) Because of the increase in weight due to modularity, a study could be accomplished for the costs to orbit had the MMS been used for the 1970's. This study would have to determine which of the programs would have required different boosters and their costs had the MMS been used.

2) If the information can be found for the 1980's military space program, a study should be accomplished to determine the number of different programs that could result in acquisition cost savings if the MMS is used in the future.

3) A study to determine the cost to orbit for those satellite programs capable of using the MMS in the 1980's could be undertaken. Shuttle launch, as well as, ELV boosting could be explored.

4) Finally, the costs of different maintenance concepts using the capabilities of the MMS for Air Force satellites could be explored for the future. These would include programs like on-orbit module replacement versus expendable satellites and on-orbit retrieval and ground refurbishment versus expendable satellites.

Final Comment

Although this study took a "what if" approach when studying the costs of the 1970's space program, it is felt that considerable insight can be gained from it for the future. The MMS showed itself to be a competitor for all military space missions that were within its capabilities.

Short-lived (less than four years) satellites, especially the programs with only a few spacecraft, should be considered potential candidates for using the MMS. This fact may be even more attractive for the Air Force since the R & D costs are already sunk and are not being amortized over each program as the study purported to do.

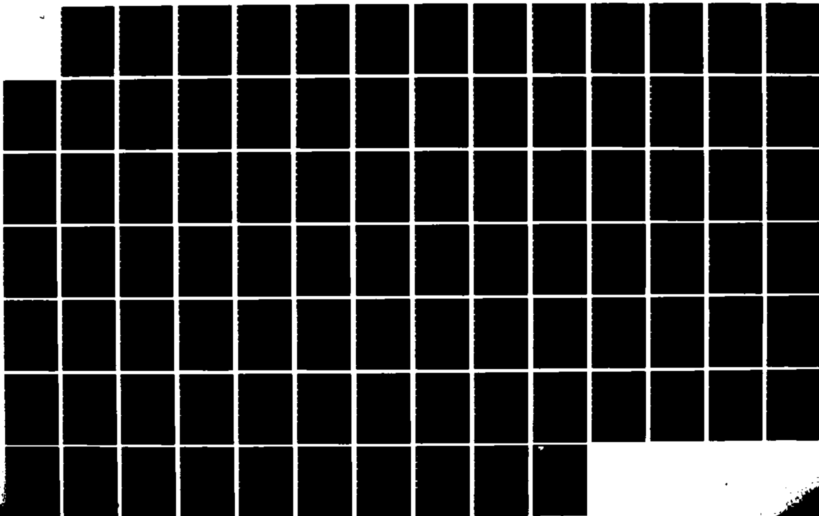
Appendix A: Normalization Factors - Calculations and Criteria

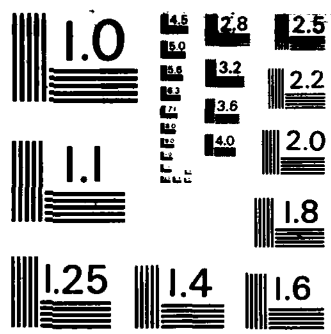
Calculations

To determine the normalization factor that applies to the specific subsystem, one enters into the USCM tables in Appendix B (34:B-1, 28) with the appropriate criteria from the subsystem. Under each subheading of "operational criteria" are several descriptors/parameters with corresponding values for degrees of complexity and rank of the subsystem operational criteria. The degree of complexity and the rank are multiplied together. All of the resulting products are then summed to obtain complexity factors for both R & D and FU production. The complexity factors are then multiplied by a weighting different for each subsystem (34:B-28). The technological carryover factor is then taken from the table of Technological Indices (34:B-1) and multiplied by its weighting. The other category, "those influences not related to either technological carryover or complexity of design (34:V-10)", are then multiplied by their weighting. Finally, the resulting multiplications are summed together to achieve two final normalization factors - one for R & D and one for FU production. The following table helps illustrate the method for calculating the normalization factor for the attitude control system of the Global Positioning System (GPS-1). Following the Operational Criteria within the same heading are the systems' descriptors (25:2).

AD-A141 120 ANALYSIS OF THE ACQUISITION COSTS OF UNIQUELY-BUILT SPACECRAFT VERSUS MUL..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. L M COLE 2/2

UNCLASSIFIED DEC 83 AFIT/GSO/OS/83D-2 F/G 5/1 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE A.1

Attitude Control System - GPS-1

CRITERIA	DEG OF COMPLEX RDT & E	DEG OF COMPLEX PROD	RANK RDT & E	RANK PROD	PRODUCT RDT & E	PRODUCT PROD
determination (sensors) - sun & horizon	1.360	1.270	0.150	0.170	0.204	0.216
logic Special purpose computer - single redundancy	1.230	1.150	0.140	0.120	0.172	0.138
antenna or sensor steering-point sens/antenna w/closed loop	1.270	1.270	0.060	0.070	0.076	0.089
degree of autonomy - Manual (ground control)	1.000	1.000	0.070	0.070	0.070	0.070
attitude control - momentum wheel - nagnetics - gas	1.300	1.300	0.040	0.050	0.052	0.065
station keeping - monopropellent	1.000	1.000	0.050	0.060	0.050	0.060
pointing accuracy of spacecraft - +/-1.0 to +/- .	1.180	1.130	0.230	0.180	0.271	0.203
stabilization -3 axis	1.250	1.220	0.100	0.090	0.125	0.110
operational design life (mths) - 47-72	1.170	1.150	0.080	0.110	0.094	0.126
hardening - natural + nuclear in Low Earth Orbit	1.170	1.130	0.080	0.080	0.094	0.090
				COMPLEXITY FACTOR =	1.208	1.268

COMPLEXITY	FACTOR	WEIGHT	RDT & E	PROD
RDT & E	1.208	0.620	0.749	
PROD.	1.168	0.570		0.666
TECHNOLOGY CARRYOVER				
RDT & E	1.085	0.320	0.347	
YEAR-1974				
PROD	1.118	0.410		0.458
OTHER				
RDT & E	1.000	0.060	0.060	
PROD	1.000	0.020		0.020

NORMALIZATION FACTOR RDT & E 1.156

PROD. 1.144

Criteria

The following tables detail which descriptors/parameters apply for each system under each subheading of the Operational Criteria. The uniquely-built satellite data was provided by Space Divison (25).

TABLE A.2

Attitude Control System-Unique Satellites

OPERATIONAL CRITERIA: DESCRIPTOR	PROGRAM
ATTITUDE DETERMINATION (SENSORS):	
EARTH AND GYROCOMPASS	P72-2
SUN AND HORIZON	ALL OTHERS
SUN-HORIZON-NAGNETOMETER	S-3
ANY OF ABOVE PLUS STAR	DMSP
LOGIC:	
SPECIAL PURPOSE COMPUTER-NONREDUNDANT	P78-1
SPECIAL PURPOSE COMPUTER-SINGLE REDUNDANCY	DSP-1, P72-2, S-3, P78-2, GPS-1, DSP-2, FLTSAT, DSCS-II
SPECIAL PURPOSE COMPUTER-GREATER THAN SINGLE REDUNDANCY	NATO 3
CENTRAL PROCESSING UNIT	DMSP
ANTENNA OR SENSOR STEERING:	
POINT SPACECRAFT ONLY	ALL OTHERS
POINT & STABILIZE SENSOR/ ANTENNA WITH CLOSED LOOP CONTROL SYSTEM	GPS-1, P78-1, NATO 3
DEGREE OF AUTONOMY:	
MANUAL (GROUND CONTROL)	P78-2, GPS-1
AUTOMATIC MOMENTUM DUMP	DSP-1, DSCS-II, P72-2, S-3
VELOCITY ADJUSTMENT	NATO 3, DSP-2, DMSP, FLTSAT
ATTITUDE CONTROL:	
WHEEL-GAS/GAS TYPE	
BI-PROPELLENT	B78-1
MONO-PROPELLENT	DSP-1, DSP-2, DMSP
HYDRAZINE	DSCS-II, SP78-2, FLTSAT
WHEEL-MAGNETICS-GAS	S-3, NATO 3, GPS-1
STATIONKEEPING:	
MONOPROPELLENT	ALL

TABLE A.2 CONTINUED

OPERATIONAL CRITERIA: DESCRIPTOR	PROGRAM
POINTING ACCURACY OF SPACECRAFT (DEGS):	
+/- 2.0 - +/- 1.0	P78-2
+/- 1.0 - +/- 0.1	ALL OTHERS
+/- 0.1 - +/- .01	DSP-1, DSP-2, P78-1
STABILIZATION:	
SPIN	DSP-2, P78-2, S-3
SPIN WITH DESPUN PLATFORM	DSCS-II
3-AXIS	ALL OTHERS
OPERATIONAL DESIGN LIFE (MONTHS):	
0-18	P72-2, S-3, P78-1, P78-2
19-48	DSP-1, DSP-2, DSMP
49-72	DSCS-II, GPS-1, FLTSAT
73-96	NATO 3
HARDENING:	
NATURAL ENVIRONMENT	
SYNCHRONOUS ORBIT	DSP-1, DSCS-II, NATO 3, P78-2
LOW EARTH ORBIT	P78-1
NATURAL + NUCLEAR TEST ENVIRONMENT	
SYNCHRONOUS	DSP-2
LOW EARTH ORBIT	S-3, P72-2, GPS-1, DMSP
HOSTILE ENVIRONMENT SURVIVING TO JCS REQUIREMENTS	FLTSAT

TABLE A.3

Communications Subsystem - Uniquely Built Satellites

OPERATIONAL CRITERIA: DESCRIPTOR	PROGRAM
OPERATIONAL FREQUENCY (MHZ) AND TRANSMITTER POWER (WATTS): TRAVELING WAVE TUBE ASSEMBLY OR SOLID STATE	ALL ASSUMED TO HAVE A VALUE OF 1.0 - THE LOWEST COMPLEXITY FACTOR
NUMBER OF TRANSMITTERS:	
1 - 2	NATO 3, GPS-1
2 - 10	DSCS-II
OVER 10	FLTSAT
MODULATION METHOD:	
PHASE SHIFT	DSCS-II
BI-PHASE SHIFT	NATO 3
QUAD PHASE SHIFT	GPS-1
FREQUENCY SHIFT	FLTSAT

TABLE A.3 CONTINUED

OPERATIONAL CRITERIA:

DESCRIPTOR	PROGRAM
MULTIPLEXING:	
FREQUENCY DIVISION-SINGLE CARRIER	GPS-1, FLTSAT
FREQUENCY DIVISION-MULTIPLE ACCESS	DSCS-II, NATO 3
REDUNDANCY OF COMMUNICATIONS:	
MORE THAN SINGLE REDUNDANCY	ALL
ON-BOARD SIGNAL PROCESSING:	
TRANSLATION ONLY	ALL OTHERS
DEMOD/REMOD/DECODE & MESSAGE SWITCH	FLTSAT
DATA RATE (BITS/SECOND):	
NON-DIGITIZED	ALL OTHERS
0 - 75	GPS-1
BIT ERROR RATE:	
10^{-2}	ALL
ENCRYTION LEVEL:	
NONE	ALL
TYPES OF ANTENNA:	
EARTH COVERAGE - 11 - 20db GAIN	DSCS-II (.15), FLTSAT
SPOT BEAM	DSCS-II (.85), NATO 3
SHAPED BEAM	GPS-1
ANTENNA DESIGN:	
HORN	DSCS-II (.15), NATO 3, FLTSAT (.03)
REFLECTOR - DISH-CENTER FED	DSCS-II (.85), FLTSAT (.91)
HELICAL	DPS-1. F:TSAT (.06)
POWER HANDLING CAPABILITY (MILLIWATTS):	
10000 - 250000	ALL
ANTI-JAM CAPABILITY:	
NONE	ALL
OPERATIONAL DESIGN LIFE (MONTHS):	
49 - 72	ALL
HARDENING:	
NATURAL ENVIRONMENT - SYNCHRONOUS ORBIT	DSCS-II, NATO 3
NATURAL + NUCLEAR TEST - LOW EARTH ORBIT	GPS-1
HOSTILE ENVIRONMENT SURVIVING TO JCS REQUIREMENTS	FLTSAT

The descriptors/parameters for the MMS were gleaned from many sources. The overall assumption in determining the MMS descriptors was that since the MMS modules were designed to do many different tasks, the best capability that the MMS could achieve must be used in determining each module's normalization factor. For instance, in some cases, the complexity factors for hardening at geosynchronous altitude were larger than those at LEO. In these cases, the higher value was taken under the assumption that the MMS's designers' would have had to plan for all orbits and conditions. Specific assumptions pertaining to each of the MMS modules will be discussed with their table. Within the following tables, if a specific reference is not made, for a descriptor/parameter, then it should be considered the best assumption the author could make from the literature available for the MMS.

TABLE A.4

MPS Normalization Criteria

The category within the cost model used to calculate the MPS normalization factor was the Electrical Power Supply table (34:B-26).

OPERATIONAL CRITERIA	DESCRIPTOR/PARAMETERS
ELECTRICAL POWER DESIGN SHAPE (ASSUMES DEPLOYMENT MECHANISM INCLUDED IN STRUCTURE SUBSYSTEM)	ROLL OUT TYPE
MECHANICAL INTERFACE (THE MOVEMENT OF PADDLES)	ONE DEGREE OF FREEDOM
POWER REQUIREMENTS (WATTS)	1101 - 1500 (24:3-27)
TYPE OF BATTERIES	NICKEL-CADMIUM (17:1638)
OPERATIONAL DESIGN LIFE	19 - 48 MONTHS
HARDENING	NATURAL - LOW EARTH ORBIT

TABLE A.5

C & DH Normalization Criteria

The category within the cost model used to calculate the C & DH normalization factor was the Telemetry, Tracking & Command table (34:B-5).

OPERATIONAL CRITERIA	DESCRIPTOR/PARAMETERS
ON-BOARD DATA PROCESSING	MEDIUM STORAGE - 10^4 - 10^6 (31:19)
DATA HANDLING RATE (BITS/SECOND)	10^6 - 10^9 (31:20)
NUMBER OF DISCRETE COMMANDS	GREATER THAN 1000 (37:5-22)
TYPE OF ELECTRONICS	INTEGRATED - SINGLE REDUNDANCY (31:14)
ENCRYPTION LEVEL	NONE
DEGREE OF AUTONOMY	MANUAL (GROUND CONTROL) (37:5-24)
TYPE OF MEMORY	TAPE - SINGLE REDUNDANCY (31:19)
OPERATING DESIGN LIFE	19 - 48 MONTHS
HARDENING	NATURAL - LEO

TABLE A.6

PM-1 Normalization Criteria

The category within the cost model used to calculate the PM-1 normalization factor was the Attitude & Reaction Control System table (34:B-21). Due to its similarity with the PM-1, the PM-1A was assumed to have no R & D normalization factor and its FU Production normalization factor was considered to be the same.

OPERATIONAL CRITERIA	DESCRIPTOR/PARAMETERS
ATTITUDE CONTROL	WHEEL - NAGNETICS - GAS (30:21)
STATION KEEPING	MONO-PROPELLENT (8:1)
POINTING ACCURACY OF SPACECRAFT	+/- 0.1 - +/- .01 (24:3-4)
STABILIZATION	3 - AXIS (24:3-4)
OPERATIONAL DESIGN LIFE	19 - 48 MONTHS
HARDENING	NATURAL ENVIRONMENT - ALL ORBITS

TABLE A.7

MACS Normalization Criteria

The category within the cost model used to calculate the MACS normalization factor was the Attitude Control Systems table (34:B-24).

OPERATIONAL CRITERIA	DESCRIPTOR/PARAMETERS
ATTITUDE DETERMINATION (SENSORS)	ANY OTHERS PLUS STAR (5:316)
LOGIC	CENTRAL PROCESSING UNIT - SINGLE REDUNDANCY (31:14)
ANTENNA OR SENSOR STEERING	POINT & STABILIZE SENSOR/ ANTENNA WITH CLOSED LOOP CONTROL SENSOR (24:3-4)
DEGREE OF AUTONOMY	AUTOMATIC MOMENTUM DUMP (24:3-22)
ATTITUDE CONTROL	WHEEL - MAGNETICS - GAS (30:21)
STATION KEEPING	MONO-PROPELLENT (8:1)
POINTING ACCURACY OF SPACE-CRAFT	+/- 0.1 - +/- .01 (24:3-4)
STABILIZATION	3 - AXIS (24:3-4)
OPERATIONAL DESIGN LIFE	19 - 48 MONTHS
HARDENING	NATURAL - LEO

TABLE A.8

Structure, Thermal Control & Interstage

The category within the cost model used to calculate the Structure, Thermal Control, and Interstage normalization factor for the MMS was the Structure, Thermal Control, and Interstage table (34:B-2).

OPERATIONAL CRITERIA	DESCRIPTOR/PARAMETERS
STRUCTURAL MATERIAL COMPOSITION	HONEYCOMB (37:2-3)
STRUCTURAL DESIGN SHAPE	POLYHEDRON WITH DEPLOYMENT MECHANISMS (37:3-1)
THERMAL CONTROL	LOUVERS (37:3-1)
STABILIZATION/MECHANICAL INTERFACE	WHEEL - MAGNETICS - GAS (30:21)
OPERATIONAL DESIGN LIFE	19 - 48 MONTHS
HARDENING	NATURAL ENVIRONMENT - SYNCHRONOUS ORBIT
LAUNCH METHOD	BOTH ELV & STS COMPATIBLE - NON-STANDARD STS ORBIT (24:3-4)

TABLE A.9

SC & CU Normalization Criteria

The SC & CU module exhibits traits similar to the C & DH module. It "provides control and monitoring functions for the MMS and the payload which are not directly related to the major subsystem modules" (24:4-10). Because of the similarity with the C & DH module, the TT & C normalization table (34:B-5) was used. Many of the criteria could not be substantiated by research but had to be assumed and deduced by study of the SC & CU functional diagram (24:3-15).

OPERATIONAL CRITERIA	DESCRIPTOR/PARAMETERS
ON-BOARD DATA PROCESSING	ALL REAL TIME TRANSMISSIONS
DATA HANDLING RATE (BITS/SECOND)	$0 - 10^3$
NUMBER OF DISCRETE COMMANDS	0 - 100
TYPE OF ELECTRONICS	SOLID STATE - SINGLE REDUNDANCY
ENCRYPTION LEVEL	NONE
DEGREE OF AUTONOMY	MANUAL
TYPE OF MEMORY	MAGNETIC CORE - NON-REDUNDANT
OPERATIONAL DESIGN LIFE	19 - 48 MONTHS
HARDENING	NATURAL ENVIRONMENT - SYNCHRONOUS OR LEO

Appendix B: <u>Parametric Cost Estimating Relationships</u>

The following CERS have been taken directly from the <u>Unmanned Spacecraft Cost Model</u> (55) and were the ones used in the analysis.

<u>Normalized Structure, Thermal Control and Interstage</u>

NONRECURRING COST CER

1. Equation: $Y = 1098.18 + 90.99\, X^{.67}$ (B.1)

   where Y = Nonrecurring FY 79 \$ in Thousands

   X = Subsystem Weight (lbs)

2. Sample Size: 19

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .63

   Standard Error of the Estimate (SE): 1178.68

   F Statistic: 28.77

4. Range of the Independent Variable:

   $$15.40 <= X <= 941.85$$

FIRST UNIT COST CER

1. Equation: $Y = 19.38\, X^{.66}$ (B.2)

   where: Y = First Unit FY 79 \$ in Thousands

   X = Subsystem Weight (lbs)

2. Sample Size: 31

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .64

   Standard Error of the Estimate (SE): 500.79

   F Statistic: 33.30

4. Range of the Independent Variable:

   $$15.40 <= X <= 1710.0$$

Normalized TT & C

NONRECURRING COST CER

1. Equation: $Y = 705.23 + 34.8\ X$ (B.3)

   where: Y = Nonrecurring FY79 $ in Thousands

   X = Subsystem Weight (lbs)

2. Sample Size: 20

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .81

   Standard Error of the Estimate (SE): 1113.94

   F Statistic: 75.27

4. Range of the Independent Variable:

   $8.50 <= X <= 246.40$

FIRST UNIT COST CER

1. Equation: $Y = 1411 + 33.04\ X^{.91}$ (B.4)

   where: Y = First Unit FY79 $ in Thousands

   X = Subsystem Weight (lbs)

2. Sample Size: 29

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .80

   Standard Error of the Estimate (SE): 593.34

   F Statistic: 105.47

4. Range of the Independent Variable:

   $8.50 <= X <= 246.40$

Normalized Communications

NONRECURRING COST CER

1. Equation: $Y = 468.67 X^{.57}$ (B.5)

   where: Y = Nonrecurring FY79 $ in Thousands

   X = Subsystem Weight (lbs)

2. Sample Size: 13

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .63

   Standard Error of the Estimate (SE): 2926.80

   F Statistic: 12.42

4. Range of the Independent Variable:

   $12.88 <= X <= 507.80$

FIRST UNIT COST CER

1. Equation: $Y = 41.02 X^{.87}$ (B.6)

   where: Y = First Unit FY79 $ in Thousands

   X = Subsystem Weight (lbs)

2. Sample Size: 15

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .75

   Standard Error of the Estimate (SE): 3120.78

   F Statistic: 11.96

4. Range of the Independent Variable:

   $12.88 <= X <= 507.80$

Normalized Attitude Control

NONRECURRING COST CER

1. Equation: $Y = 833.61 + 60.3\ X$ (B.7)

   where: Y = Nonrecurring FY79 $ in Thousands

   X = Subsystem Dry Weight (lbs)

2. Sample Size: 18

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .82

   Standard Error of the Estimate (SE): 2274.10

   F Statistic: 73.49

4. Range of the Independent Variable:

   $3.00 < = X < = 308.20$

FIRST UNIT COST CER

1. Equation: $Y = 21.40\ X^{.97}$ (B.8)

   where: Y = First Unit FY79 $ in Thousands

   X = Subsystem Dry Weight (lbs)

2. Sample Size: 30

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .83

   Standard Error of the Estimate (SE): 960.85

   F Statistic: 66.62

4. Range of the Independent Variable:

   $3.00 < = X < = 308.20$

Normalized Attitude and Reaction Control

NONRECURRING COST CER

1. Equation: $Y = 372.82 + 27.92\,X$ (B.9)

   where: Y = Nonrecurring FY79 $ in Thousands

   X = Subsystem Dry Weight (lbs)

2. Sample Size: 9

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .79

   Standard Error of the Estimate (SE): 740.65

   F Statistic: 26.28

4. Range of the Independent Variable:

   $24.57 <= X <= 170.24$

FIRST UNIT COST CER

1. Equation: $Y = -103.17 + 34.93\,X^{.76}$ (B.10)

   where: Y = First Unit FY79 $ in Thousands

   X = Subsystem Dry Weight (lbs)

2. Sample Size: 16

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .77

   Standard Error of the Estimate (SE): 388.55

   F Statistic: 46.03

4. Range of the Independent Variable:

   $18.70 <= X <= 368.30$

Normalized Electrical Power Supply - Subsynchronous Altitude

NONRECURRING COST CER

1. Equation: $Y = 273.03 + .01559 X$ (B.11)

   where: Y = Nonrecurring FY79 $ in Thousands

   X = Subsystem Weight (lbs) X BOL Power (watts)

2. Sample Size: 11

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .62

   Standard Error of the Estimate (SE): 1478.93

   F Statistic: 14.86

4. Range of the Independent Variable:

   6820.00 < = X < = 362500.00

   68.20 < = weight < = 725.00

   100.00 < = power < = 900.00

FIRST UNIT COST CER

1. Equation: $Y = 521.73 + .05075 X^{.87}$ (B.12)

   where: Y = First Unit FY79 $ in Thousands

   X = Subsystem Weight (lbs) X BOL Power (watts)

2. Sample Size: 11

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .82

   Standard Error of the Estimate (SE): 543.78

   F Statistic: 40.53

4. Range of the Independent Variable:

   6820.00 < = X < = 362500.00

   68.20 < = weight < = 725.00

   100.00 < = power < = 900.00

Normalized Electrical Power Supply - Synchronous Altitude or Above

NONRECURRING COST CER

1. Equation: $Y = 2098.95 + .03401\ X^{.93}$ (B.13)

   where: Y = Nonrecurring FY79 $ in Thousands

   X = Subsystem Weight (lbs) X BOL Power (watts)

2. Sample Size: 17

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .66

   Standard Error of the Estimate (SE): 2285.72

   F Statistic: 28.65

4. Range of the Independent Variable:

   228.40 < = X < = 912824.00 (lbs-watts)
   9.10 < = weight < = 619.60
   25.10 < = power < = 1640.00

FIRST UNIT COST CER

1. Equation: $Y = 72.42\ X^{.27}$ (B.14)

   where: Y = First Unit FY79 $ in Thousands

   X = Subsystem Weight (lbs) X BOL Power (watts)

2. Sample Size: 19

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .69
   Standard Error of the Estimate (SE): 732.39
   F Statistic: <6.78

4. Range of the Independent Variable:

   228.40 < = X < = 912824.00 (lbs-watts)
   9.10 < = weight < = 619.60
   25.10 < = power < = 1640.00

Program Level as a Function of Platform

NONRECURRING COST CER

1. Equation: $Y = .464\ X$ (B.15)

   where: Y = Nonrecurring FY79 $ in Thousands

   X = Nonrecurring Platform Cost - FY79 $ in Thousands

2. Sample Size: 30

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .85

   Standard Error of the Estimate (SE): 5307.00

   F Statistic: 168.47

4. Range of the Independent Variable:

   $3529.02 <= X <= 85331.1$ ($ 1000's)

FIRST UNIT COST CER

1. Equation: $Y = .4568\ X$ (B.16)

   where: Y = First Unit FY79 $ in Thousands

   X = First Unit Platform Cost - FY79 $ in Thousands

2. Sample Size: 30

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .84

   Standard Error of the Estimate (SE): 1950.70

   F Statistic: 147.24

4. Range of the Independent Variable:

   $763.51 <= X <= 18994.00$

Program Level = Communications Satellites

NONRECURRING COST CER

1. Equation: $Y = .3568\ X$ (B.17)

   where: Y = Nonrecurring FY79 $ in Thousands

   X = Nonrecurring Comm Satellite Hardware cost - FY79 $ in Thousands

2. Sample Size: 15

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .94

   Standard Error of the Estimate (SE): 3753.20

   F Statistic: 262.48

4. Range of the Independent Variable:

   $14535.06 <= X <= 114251.32$

FIRST UNIT COST CER

1. Equation: $Y = .3291\ X$ (B.18)

   where: Y = First Unit FY79 $ in Thousands

   X = First Unit Comm Satellite Hardware Cost - FY79 $ in Thousands

2. Sample Size: 15

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .93

   Standard Error of the Estimate (SE): 1465.10

   F Statistic: 179.13

4. Range of the Independent Variable:

   $1110.13 <= X <= 40321.79$

Aerospace Ground Equipment

NONRECURRING COST CER

1. Equation: $Y = .1131\ X$ (B.19)

   where: Y = Nonrecurring FY79 $ in Thousands

   X = Nonrecurring plus First Unit Cost ($ in Thousands)

2. Sample Size: 26

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .88

   Standard Error of the Estimate (SE): 1943.70

   F Statistic: 196.68

4. Range of the Independent Variable:

   $10056.09 < = X < = 122041.48$

Regular TT & C

FIRST UNIT COST CER

1. Equation: $Y = 42.43 + 35.93\ X^{.93}$ (B.20)

   where: Y = First Unit FY79 $ in Thousands

   X = Subsystem Weight (lbs)

2. Sample Size: 29

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .80

   Standard Error of the Estimate (SE): 713.90

   F Statistic: 107.72

4. Range of the Independent Variable:

   $850 < = X < = 246.40$

Regular Attitude Control

FIRST UNIT COST CER

1. Equation: $Y = 29.08\ X^{.95}$ (B.21)

   where: Y = First Unit FY79 $ in Thousands

   X = Subsystem Dry Weight (lbs)

2. Sample Size: 30

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square); .81

   Standard Error of the Estimate (SE): 1178.86

   F Statistic: 60.33

4. Range of the Independent Variable:

   $3.00 <= X <= 308.20$

Regular Attitude and Reaction Control

FIRST UNIT COST CER

1. Equation: $Y = 166.12 + 47.87^{.73}$ (B.22)

   where: Y = First Unit FY79 $ in Thousands

   X = Subsystem Dry Weight (lbs)

2. Sample Size: 16

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .76

   Standard Error of the Estimate (SE): 455.90

   F Statistic: 43.23

4. Range of the Independent Variable:

   $18.70 <= X <= 368.30$

Regular Electrical Power Supply - Subsynchronous Altitude

FIRST UNIT COST CER

1. Equation: $Y = 381.3 + .3345\ X^{.74}$ (B.23)

   where: Y = First Unit FY79 $ in Thousands

   X = Subsystem Weight (lbs) X BOL Power (watts)

2. Sample Size: 11

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .83

   Standard Error of the Estimate (SE): 643.82

   F Statistic: 42.75

4. Range of the Independent Variable:

   6820.00 < = X < = 362500.00

   68.20 < = weight < = 725.00

   100.00 < = power < = 900.00

Regular Electrical Power Supply = Synchronous Altitude or Above

FIRST UNIT COST CER

1. Equation: $Y = 66.44\ X^{.29}$ (B.24)

   where: Y = First Unit FY79 $ in Thousands

   X = Subsystem Weight (lbs) X BOL Power (watts)

2. Sample Size: 19

3. Measure of Statistical Fit:

   Coefficient of Determination (R - square): .71

   Standard Error of the Estimate (SE): 1028.24

   F Statistic: 15.62

4. Range of the Independent Variable:

   228.40 < = X < = 912824.00 (lbs-watts)

   9.10 < = weight < = 619.60

   25.10 < = power < = 1640.00

Appendix C: MMS Surrogate Program Calculations

PROGRAM	RATIO MMS/ UNIQUE	# OF UNIQUE	# OF MMS(MPS/ SC&CU/C&DH/MACS S,TC&I	WT (LBS)	# OF PM-1	WT (LBS)	# OF PM-1A	WT (LBS)	PRORATED RATIO MMS/TOTAL
DSP-I	1	4	4	1429.100		165	4	235	0.0455
DSCS-II	2	14	28		28				0.3182
P72-2	1	1	1		1				0.0114
S-3	1	3	3		3				0.0341
NATO 3	2	3	6				6		0.0682
P78-1	1	1	1		1				0.0114
P78-2	1	1	1		1				0.0114
GPS-1	2	7	14		14				0.1591
DSP-II	1	8	8				8		0.0909
DMSP	1	12	12		0		0		0.1364
FLTSAT	2	5	10				10		0.1136
CLASSIF	1	0	0				0		0.0000
		59	88		48		28		1.0000

LEARNING CURVE FACTORS:

FORMULAS: CUMULATIVE AVG COST AT QUATITY n Y = a n where

TOTAL COST OF n UNITS
T = a n

Y = cumulative avg. cost for n items
a = cost of 1st item
n = quantity produced
T = total cost of n item
b = log(learning curve) /log(2)

UNIQUE & MMS MSN SPECIFIC LEARNING CURVE SLOPE 0.950 b = -0.0740

b+1= 0.9260

check DSCS-II 0.823
11.516

MMS MODULES LEARNING CURVE SLOPE 0.950 b = -0.0740

b+1= 0.9260

check PM-1 0.751
36.044

UNIQUE SATELLITE COSTS('79 K $)

LEARNING CURVE SLOPE	0.950	b=	-0.074
		b + 1 =	0.926

PROGRAM	WEIGHT	# OF SATS	NR $	FU $	AVERAGE COST	COMPOSITE PRODUCTION COST
DSP-I	1073.60	4	32336.230	16897.001	15249.543	60998.174
DSCS-II	1012.90	14	65430.013	21227.537	17461.657	244463.205
P72-2	1064.00	1	51153.212	15950.261	15950.261	15950.261
S-3	325.30	3	18370.210	5086.940	4689.746	14069.239
NATO 3	696.72	3	44868.664	13852.058	12770.475	38311.425
P78-1	956.80	1	43883.494	14836.038	14836.038	14836.038
P78-2	579.60	1	27225.967	9635.558	9635.558	9635.558
GPS-1	903.10	7	48563.145	16249.369	14070.151	98491.056
DSP-II	1141.70	8	62568.299	17248.823	14788.710	118309.677
DMSP	705.60	12	47530.312	17323.510	14413.712	172964.548
FLTSAT	1859.00	5	104564.227	32822.080	29136.804	145684.020
CLASSIF						
TOTALS		59	546493.773			933713.202

PROGRAM	AGGREGATE ACQUISITION COST(NR$+RC$)	ACQUISITION COST/SAT
DSP-I	93334.404	23333.601
DSCS-II	309893.218	22135.230
P72-2	67103.473	67103.473
S-3	32439.449	10813.150
NATO 3	83180.089	27726.696
P78-1	58719.532	58719.532
P78-2	36861.525	36861.525
GPS-1	147054.201	21007.743
DSP-II	180877.976	22609.747
DMSP	220494.860	18374.572
FLTSAT	250248.247	50049.649
CLASSIF	0.000	0.000
TOTALS	1480206.975	25088.254

MMS MISSION SPECIFIC ITEMS('79 K $)

PROGRAM	# OF ITEM	NR $	FU $	WEIGHT	AVERAGE COST
SOLAR ARRAYS					
DSP-I	4	3873.519	2347.477	93.80	2118.598
DSCS-II	28	3450.049	2078.892	74.90	1624.581
P72-2	1	2848.130	1408.012	36.40	1408.012
S-3	3	2671.233	840.467	14.00	774.842
NATO 3	6	3444.191	2074.540	74.60	1816.930
P78-1	1	2966.942	1601.469	46.20	1601.469
P78-2	1	2930.536	1548.304	43.40	1548.304
GPS-1	14	3394.305	2036.558	72.10	1675.262
DSP-II	8	4626.695	2694.695	121.10	2310.364
DMSP	12	4779.176	2753.036	126.00	2290.614
FLTSAT	10	9180.568	3806.594	229.60	3210.229
CLASSIF	0	0.000	0.000	0.00	
COMMUNICATION PACKAGES					
DSP-I					
DSCS-II	28	13636.609	6288.929	236.90	4914.577
P72-2					
S-3					
NATO 3	6	9452.505	3652.650	132.98	3199.075
P78-1					
P78-2					
GPS-1	14	9721.880	3695.604	124.30	3039.984
DSP-II					
DMSP					
FLTSAT	10	21581.989	11843.421	443.90	9987.955
CLASSIF					

contractor fee of 12.5% added to comm packages

BATTERIES		WEIGHT	AVERAGE COST
DSP-I		159.00	267.000
DSCS-II	2 - 20 Ampere-Hour - 106 lbs.	159.00	267.000
P72-2		106.00	195.000
S-3	3 - 20 Ampere-Hour - 159 lbs.	106.00	195.000
NATO 3		159.00	267.000
P78-1	2 - 50 Ampere-Hour - 224 lbs.	159.00	267.000
P78-2		106.00	195.000
GPS-1	3 - 50 Ampere-Hour - 336 lbs.	159.00	267.000
DSP-II		224.00	220.000
DMSP		224.00	220.000
FLTSAT		224.00	220.000
CLASSIF			

BATTERIES HAVE A FIXED COST FOR A SPECIFIC CONFIGURATION.

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.950

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	88	9449.775	1605.756	1152.887
COMMUNICATIONS & DATA HANDLING (C & DH)	88	12988.919	5851.470	4201.188
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	88	37789.088	10399.483	7466.531
MODULAR POWER SYSTEM(MPS)	38	6235.393	3200.118	2297.593
PROPULSION SYSTEM-1(PM-1)	48	5331.565	1511.424	1134.942
PROPULSION SYSTEM-1A(PM-1A)	28		2168.344	1694.485
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	88	3899.624	1999.617	1435.668
SUBTOTAL		75694.364	26736.212	19383.294
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			16553.868	
WITH PM-1			17688.809	
WITH PM-1A			18248.352	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.950

b= -0.074 b + 1 = 0.926

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	9617.781	20633.950	9425.589
DSCS-II	2	14.00	28	57296.493	24494.967	8061.294
P72-2	1	1.00	1	4284.196	19291.821	8812.504
S-3	1	3.00	3	6979.430	18658.652	8523.272
NATO 3	2	3.00	6	21513.089	23531.357	7744.170
P78-1	1	1.00	1	4403.008	19557.278	8933.765
P78-2	1	1.00	1	4366.602	19432.113	8876.589
GPS-1	2	7.00	14	33221.102	22671.055	7461.044
DSP-II	1	8.00	8	16115.219	20778.716	9491.718
DMSP	1	12.00	12	22011.962	19064.481	8708.655
FLTSAT	2	5.00	10	45123.212	31666.536	10421.457
CLASSIF	1	0.00	0	0.000		
TOTALS		59.00	88	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	30059.539	120238.155	129855.936
DSCS-II	2064.90	32556.261	911575.312	968871.805
P72-2	1736.50	28104.325	28104.325	32388.521
S-3	1714.10	27181.924	81545.771	88525.201
NATO 3	2030.68	31275.527	187653.161	209166.250
P78-1	1799.30	28491.043	28491.043	32894.050
P78-2	1743.50	28308.702	28308.702	32675.304
GPS-1	1949.50	30132.099	421849.384	455070.486
DSP-II	2009.20	30270.434	242163.473	258278.692
DMSP	1779.10	27773.136	333277.637	355289.599
FLTSAT	2561.60	42087.993	420879.933	466003.146
CLASSIF	6 to 8 K			
TOTALS			2804086.897	3029018.990

PROGRAM	ACQUISITION COST / SAT
DSP-I	32463.984
DSCS-II	34602.564
P72-2	32388.521
S-3	29508.400
NATO 3	34861.042
P78-1	32894.050
P78-2	32675.304
GPS-1	32505.035
DSP-II	32284.837
DMSP	29607.467
FLTSAT	46600.315
CLASSIF	

AVERAGE COST PER SAT 34420.670

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.900

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	88	9449.775	1605.756	813.040
COMMUNICATIONS & DATA HANDLING (C & DH)	88	12988.919	5851.470	2962.768
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	88	37789.088	10399.483	5265.558
MODULAR POWER SYSTEM(MPS)	88	6235.393	3200.118	1620.312
PROPULSION SYSTEM-1(PM-1)	48	5331.565	1511.424	839.136
PROPULSION SYSTEM-1A(PM-1A)	28		2168.344	1306.639
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	88	3899.624	1999.617	1012.464
SUBTOTAL		75694.364	26736.212	13819.917
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			11674.141	
WITH PM-1			12513.277	
WITH PM-1A			12980.781	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.900

b= -0.152 b + 1 = 0.848

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	9617.781	15366.378	7019.362
DSCS-II	2	14.00	28	57296.493	19319.436	6358.026
P72-2	1	1.00	1	4284.196	14116.289	6448.321
S-3	1	3.00	3	6979.430	13483.120	6159.089
NATO 3	2	3.00	6	21513.089	18263.785	6010.612
P78-1	1	1.00	1	4403.008	14381.746	6569.582
P78-2	1	1.00	1	4366.602	14256.581	6512.406
GPS-1	2	7.00	14	33221.102	17495.523	5757.777
DSP-II	1	8.00	8	16115.219	15511.145	7085.491
DMSP	1	12.00	12	22011.962	14184.755	6479.596
FLTSAT	2	5.00	10	45123.212	26398.964	8687.899
CLASSIF	1	0.00	0	0.000		
TOTALS		59.00	88	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	22385.740	89542.961	99160.742
DSCS-II	2064.90	25677.462	718968.936	776265.428
P72-2	1736.50	20564.611	20564.611	24848.806
S-3	1714.10	19642.209	58926.627	65906.057
NATO 3	2030.68	24274.397	145646.383	167159.472
P78-1	1799.30	20951.328	20951.328	25354.336
P78-2	1743.50	20768.988	20768.988	25135.589
GPS-1	1949.50	23253.300	325546.195	358767.298
DSP-II	2009.20	22596.635	180773.084	196888.303
DMSP	1779.10	20664.351	247972.213	269984.175
FLTSAT	2561.60	35086.864	350868.636	395991.849
CLASSIF	6 to 8 K			
TOTALS			2180529.961	2405462.054

PROGRAM	ACQUISITION COST / SAT
DSP-I	24790.185
DSCS-II	27723.765
P72-2	24848.806
S-3	21968.686
NATO 3	27859.912
P78-1	25354.336
P78-2	25135.589
GPS-1	25626.236
DSP-II	24611.038
DMSP	22498.681
FLTSAT	39599.185
CLASSIF	

AVERAGE COST PER SAT 27334.796

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.850

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	88	9449.775	1605.756	562.038
COMMUNICATIONS & DATA HANDLING (C & DH)	88	12988.919	5851.470	2048.101
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	88	37789.088	10399.483	3639.973
MODULAR POWER SYSTEM(MPS)	88	6235.393	3200.118	1120.089
PROPULSION SYSTEM-1(PM-1)	48	5331.565	1511.424	609.809
PROPULSION SYSTEM-1A(PM-1A)	28		2168.344	992.704
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	88	3899.624	1999.617	699.895
SUBTOTAL		75694.364	26736.212	9672.609
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			8070.096	
WITH PM-1			8679.905	
WITH PM-1A			9062.800	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.850

b= -0.234 b + 1 = 0.766

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	9617.781	11448.398	5229.628
DSCS-II	2	14.00	28	57296.493	15486.063	5096.463
P72-2	1	1.00	1	4284.196	10282.917	4697.236
S-3	1	3.00	3	6979.430	9649.747	4408.005
NATO 3	2	3.00	6	21513.089	14345.805	4721.204
P78-1	1	1.00	1	4403.008	10548.374	4818.497
P78-2	1	1.00	1	4366.602	10423.209	4761.322
GPS-1	2	7.00	14	33221.102	13662.150	4496.214
DSP-II	1	8.00	8	16115.219	11593.164	5295.758
DMSP	1	12.00	12	22011.962	10580.710	4833.268
FLTSAT	2	5.00	10	45123.212	22480.984	7398.492
CLASSIF	1	0.00	0	0.000		
TOTALS		59.00	88	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	16678.027	66712.107	76329.888
DSCS-II	2064.90	20582.526	576310.739	633607.231
P72-2	1736.50	14980.153	14980.153	19264.349
S-3	1714.10	14057.752	42173.256	49152.685
NATO 3	2030.68	19067.010	114402.058	135915.147
P78-1	1799.30	15366.871	15366.871	19769.878
P78-2	1743.50	15184.531	15184.531	19551.132
GPS-1	1949.50	18158.364	254217.097	287438.199
DSP-II	2009.20	16888.922	135111.376	151226.595
DMSP	1779.10	15413.978	184967.735	206979.698
FLTSAT	2561.60	29879.476	298794.762	343917.975
CLASSIF	6 to 8 K			
TOTALS			1718220.685	1943152.778

PROGRAM	ACQUISITION COST / SAT
DSP-I	19082.472
DSCS-II	22628.830
P72-2	19264.349
S-3	16384.228
NATO 3	22652.525
P78-1	19769.878
P78-2	19551.132
GPS-1	20531.300
DSP-II	18903.324
DMSP	17248.308
FLTSAT	34391.797
CLASSIF	

AVERAGE COST PER SAT 22081.282

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.800

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	88	9449.775	1605.756	379.923
COMMUNICATIONS & DATA HANDLING (C & DH)	88	12988.919	5851.470	1384.463
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	88	37789.088	10399.483	2460.527
MODULAR POWER SYSTEM(MPS)	88	6235.393	3200.118	757.151
PROPULSION SYSTEM-1(PM-1)	48	5331.565	1511.424	434.658
PROPULSION SYSTEM-1A(PM-1A)	28		2168.344	741.733
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	88	3899.624	1999.617	473.111
SUBTOTAL		75694.364	26736.212	6631.566
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			5455.175	
WITH PM-1			5889.833	
WITH PM-1A			6196.908	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.800

b= -0.322 b + 1 = 0.678

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	9617.781	8582.506	3920.489
DSCS-II	2	14.00	28	57296.493	12695.992	4178.251
P72-2	1	1.00	1	4284.196	7492.845	3422.732
S-3	1	3.00	3	6979.430	6859.676	3133.500
NATO 3	2	3.00	6	21513.089	11479.913	3778.039
P78-1	1	1.00	1	4403.008	7758.302	3543.992
P78-2	1	1.00	1	4366.602	7633.137	3486.817
GPS-1	2	7.00	14	33221.102	10872.079	3578.001
DSP-II	1	8.00	8	16115.219	8727.272	3986.618
DMSP	1	12.00	12	22011.962	7965.789	3638.772
FLTSAT	2	5.00	10	45123.212	19615.092	6455.327
CLASSIF	1	0.00	0	0.000		
TOTALS		59.00	88	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	12502.995	50011.979	59629.760
DSCS-II	2064.90	16874.242	472478.786	529775.279
P72-2	1736.50	10915.577	10915.577	15199.773
S-3	1714.10	9993.176	29979.527	36958.957
NATO 3	2030.68	15257.952	91547.713	113060.802
P78-1	1799.30	11302.295	11302.295	15705.302
P78-2	1743.50	11119.954	11119.954	15486.556
GPS-1	1949.50	14450.080	202301.121	235522.223
DSP-II	2009.20	12713.890	101711.121	117826.340
DMSP	1779.10	11604.562	139254.740	161266.702
FLTSAT	2561.60	26070.419	260704.188	305827.400
CLASSIF	6 to 8 K			
TOTALS			1381327.000	1606259.094

PROGRAM	ACQUISITION COST / SAT
DSP-I	14907.440
DSCS-II	18920.546
P72-2	15199.773
S-3	12319.652
NATO 3	18843.467
P78-1	15705.302
P78-2	15486.556
GPS-1	16823.016
DSP-II	14728.293
DMSP	13438.892
FLTSAT	30582.740
CLASSIF	

AVERAGE COST PER SAT 18252.944

PROGRAM	RATIO MMS/ UNIQUE	# OF UNIQUE	# OF MMS(MPS/ SC&CU/C&DH/MACS S,TC&I	WT (LBS)	# OF PM-1	WT (LBS)	# OF PM-1A	WT (LBS)	PRORATED RATIO MMS/TOTAL
DSP-I	1	4	4	1429.100		165	4	235	0.0320
DSCS-II	2	14	28		28				0.2240
P72-2	1	1	1		1				0.0080
S-3	1	3	3		3				0.0240
NATO 3	2	3	6				6		0.0480
P78-1	1	1	1		1				0.0080
P78-2	1	1	1		1				0.0080
GPS-1	2	7	14		14				0.1120
DSP-II	1	8	8				8		0.0640
DMSP	1	12	12		0		0		0.0960
FLTSAT	2	5	10				10		0.0800
CLASSIF	1	37	37				37		0.2960
		96	125		48		65		1.0000

LEARNING CURVE FACTORS:

FORMULAS: CUMULATIVE AVG COST AT QUATITY n Y = a n where

TOTAL COST OF n UNITS
T = a n

Y = cumulative avg. cost for n items
a = cost of 1st item
n = quantity produced
T = total cost of n item
b = log(learning curve) /log(2)

UNIQUE & MMS MSN SPECIFIC LEARNING CURVE SLOPE	0.950	b =	-0.0740
		b+1=	0.9260
check DSCS-II	0.823 11.516		
MMS MODULES LEARNING CURVE SLOPE	0.950	b =	-0.0740
		b+1=	0.9260
check PM-1	0.751 36.044		

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.950

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	125	9449.775	1605.756	1123.329
COMMUNICATIONS & DATA HANDLING (C & DH)	125	12988.919	5851.470	4093.478
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	125	37789.088	10399.483	7275.104
MODULAR POWER SYSTEM(MPS)	125	6235.393	3200.118	2238.687
PROPULSION SYSTEM-1(PM-1)	48	5331.565	1511.424	1134.942
PROPULSION SYSTEM-1A(PM-1A)	65		2168.344	1592.104
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	125	3899.624	1999.617	1398.860
SUBTOTAL		75694.364	26736.212	18856.504
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			16129.458	
WITH PM-1			17264.399	
WITH PM-1A			17721.562	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.950

b= -0.074 b + 1 = 0.926

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	7917.480	20107.160	9184.951
DSCS-II	2	14.00	28	45394.382	24070.557	7921.620
P72-2	1	1.00	1	3859.120	18867.411	8618.633
S-3	1	3.00	3	5704.203	18234.242	8329.402
NATO 3	2	3.00	6	18962.637	23004.567	7570.803
P78-1	1	1.00	1	3977.932	19132.868	8739.894
P78-2	1	1.00	1	3941.526	19007.703	8682.719
GPS-1	2	7.00	14	27270.047	22246.645	7321.371
DSP-II	1	8.00	8	12714.616	20251.926	9251.080
DMSP	1	12.00	12	16911.058	18640.071	8514.785
FLTSAT	2	5.00	10	40872.458	31139.746	10248.090
CLASSIF	1	37.00	37	37406.635		
TOTALS		96.00	125	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	29292.111	117168.443	125085.923
DSCS-II	2064.90	31992.178	895780.982	941175.364
P72-2	1736.50	27486.045	27486.045	31345.165
S-3	1714.10	26563.643	79690.930	85395.133
NATO 3	2030.68	30575.370	183452.220	202414.856
P78-1	1799.30	27872.762	27872.762	31850.695
P78-2	1743.50	27690.422	27690.422	31631.948
GPS-1	1949.50	29568.016	413952.219	441222.265
DSP-II	2009.20	29503.006	236024.049	248738.665
DMSP	1779.10	27154.856	325858.272	342769.330
FLTSAT	2561.60	41387.836	413878.365	454750.823
CLASSIF	6 to 8 K			
TOTALS			2748854.709	2936380.168

	ACQUISITION COST / SAT		
DSP-I	31271.481		
DSCS-II	33613.406		
P72-2	31345.165		
S-3	28465.044		
NATO 3	33735.809	AVERAGE COST	
P78-1	31850.695	PER SAT	23491.041
P78-2	31631.948		
GPS-1	31515.876		
DSP-II	31092.333		
DMSP	28564.111		
FLTSAT	45475.082		
CLASSIF			

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.900

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	125	9449.775	1605.756	770.802
COMMUNICATIONS & DATA HANDLING (C & DH)	125	12988.919	5851.470	2808.848
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	125	37789.088	10399.483	4992.004
MODULAR POWER SYSTEM(MPS)	125	6235.393	3200.118	1536.134
PROPULSION SYSTEM-1(PM-1)	48	5331.565	1511.424	839.136
PROPULSION SYSTEM-1A(PM-1A)	65		2168.344	1149.634
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	125	3899.624	1999.617	959.865
SUBTOTAL		75694.364	26736.212	13056.423
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			11067.653	
WITH PM-1			11906.789	
WITH PM-1A			12217.287	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.900

b= -0.152 b + 1 = 0.848

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	7917.480	14602.885	6670.598
DSCS-II	2	14.00	28	45394.382	18712.947	6158.431
P72-2	1	1.00	1	3859.120	13509.801	6171.277
S-3	1	3.00	3	5704.203	12876.631	5882.045
NATO 3	2	3.00	6	18962.637	17500.292	5759.346
P78-1	1	1.00	1	3977.932	13775.258	6292.538
P78-2	1	1.00	1	3941.526	13650.093	6235.362
GPS-1	2	7.00	14	27270.047	16889.034	5558.181
DSP-II	1	8.00	8	12714.616	14747.651	6736.727
DMSP	1	12.00	12	16911.058	13578.266	6202.552
FLTSAT	2	5.00	10	40872.458	25635.471	8436.633
CLASSIF	1	37.00	37	37406.635		
TOTALS		96.00	125	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	21273.483	85093.931	93011.411
DSCS-II	2064.90	24871.378	696398.579	741792.961
P72-2	1736.50	19681.078	19681.078	23540.198
S-3	1714.10	18758.676	56276.029	61980.233
NATO 3	2030.68	23259.638	139557.827	158520.464
P78-1	1799.30	20067.796	20067.796	24045.728
P78-2	1743.50	19885.455	19885.455	23826.981
GPS-1	1749.50	22447.216	314261.017	341531.064
DSP-II	2009.20	21484.378	171875.025	184589.641
DMSP	1779.10	19780.818	237369.820	254280.877
FLTSAT	2561.60	34072.104	340721.044	381593.502
CLASSIF	6 to 8 K			
TOTALS			2101187.601	2288713.059

PROGRAM	ACQUISITION COST / SAT
DSP-I	23252.853
DSCS-II	26[illegible]92.606
P72-2	23540.198
S-3	20660.078
NATO 3	26420.077
P78-1	24045.728
P78-2	23826.981
GPS-1	24395.076
DSP-II	23073.705
DMSP	21190.073
FLTSAT	38159.350
CLASSIF	

AVERAGE COST PER SAT 18309.704

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.850

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	125	9449.775	1605.756	517.639
COMMUNICATIONS & DATA HANDLING (C & DH)	125	12988.919	5851.470	1886.307
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	125	37789.088	10399.483	3352.426
MODULAR POWER SYSTEM(MPS)	125	6235.393	3200.118	1031.605
PROPULSION SYSTEM-1(PM-1)	48	5331.565	1511.424	609.809
PROPULSION SYSTEM-1A(PM-1A)	65		2168.344	814.822
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	125	3899.624	1999.617	644.606
SUBTOTAL		75694.364	26736.212	8857.215
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		

AVERAGE MMS HARDWARE COST:

WITHOUT PROPULSION MODULES	7432.583
WITH PM-1	8042.392
WITH PM-1A	8247.406

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.850

b= -0.234 b + 1 = 0.766

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	7917.480	10633.004	4857.156
DSCS-II	2	14.00	28	45394.382	14848.550	4886.658
P72-2	1	1.00	1	3859.120	9645.404	4406.021
S-3	1	3.00	3	5704.203	9012.235	4116.789
NATO 3	2	3.00	6	18962.637	13530.411	4452.858
P78-1	1	1.00	1	3977.932	9910.861	4527.281
P78-2	1	1.00	1	3941.526	9785.696	4470.106
GPS-1	2	7.00	14	27270.047	13024.638	4286.408
DSP-II	1	8.00	8	12714.616	10777.770	4923.285
DMSP	1	12.00	12	16911.058	9943.197	4542.052
FLTSAT	2	5.00	10	40872.458	21665.590	7130.146
CLASSIF	1	37.00	37	37406.635		
TOTALS		96.00	125	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	15490.160	61960.640	69878.119
DSCS-II	2064.90	19735.208	552585.831	597980.213
P72-2	1736.50	14051.425	14051.425	17910.545
S-3	1714.10	13129.023	39387.070	45091.273
NATO 3	2030.68	17983.269	107899.613	126862.250
P78-1	1799.30	14438.142	14438.142	18416.075
P78-2	1743.50	14255.802	14255.802	18197.328
GPS-1	1949.50	17311.046	242354.643	269624.690
DSP-II	2009.20	15701.055	125608.442	138323.058
DMSP	1779.10	14485.249	173822.993	190734.051
FLTSAT	2561.60	28795.735	287957.354	328829.812
CLASSIF	6 to 8 K			
TOTALS			1634321.956	1821847.414

	ACQUISITION COST / SAT
DSP-I	17469.530
DSCS-II	21356.436
P72-2	17910.545
S-3	15030.424
NATO 3	21143.708
P78-1	18416.075
P78-2	18197.328
GPS-1	19258.906
DSP-II	17290.382
DMSP	15894.504
FLTSAT	32882.981
CLASSIF	

AVERAGE COST PER SAT 14574.779

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.800

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	125	9449.775	1605.756	339.332
COMMUNICATIONS & DATA HANDLING (C & DH)	125	12988.919	5851.470	1236.547
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	125	37789.088	10399.483	2197.645
MODULAR POWER SYSTEM(MPS)	125	6235.393	3200.118	676.257
PROPULSION SYSTEM-1(PM-1)	48	5331.565	1511.424	434.658
PROPULSION SYSTEM-1A(PM-1A)	65		2168.344	565.588
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	125	3899.624	1999.617	422.564
SUBTOTAL		75694.364	26736.212	5872.592
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			4872.346	
WITH PM-1			5307.003	
WITH PM-1A			5437.934	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.800

b= -0.322 b + 1 = 0.678

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	7917.480	7823.532	3573.789
DSCS-II	2	14.00	28	45394.382	12113.162	3986.441
P72-2	1	1.00	1	3859.120	6910.015	3156.495
S-3	1	3.00	3	5704.203	6276.846	2867.263
NATO 3	2	3.00	6	18962.637	10720.939	3528.261
P78-1	1	1.00	1	3977.932	7175.472	3277.756
P78-2	1	1.00	1	3941.526	7050.307	3220.580
GPS-1	2	7.00	14	27270.047	10289.249	3386.192
DSP-II	1	8.00	8	12714.616	7968.298	3639.919
DMSP	1	12.00	12	16911.058	7382.959	3372.536
FLTSAT	2	5.00	10	40872.458	18856.118	6205.548
CLASSIF	1	37.00	37	37406.635		
TOTALS		96.00	125	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	11397.321	45589.285	53506.764
DSCS-II	2064.90	16099.603	450788.887	496183.269
P72-2	1736.50	10066.510	10066.510	13925.631
S-3	1714.10	9144.109	27432.327	33136.531
NATO 3	2030.68	14249.200	85495.198	104457.835
P78-1	1799.30	10453.228	10453.228	14431.160
P78-2	1743.50	10270.888	10270.888	14212.414
GPS-1	1949.50	13675.441	191456.171	218726.218
DSP-II	2009.20	11608.217	92865.732	105580.348
DMSP	1779.10	10755.495	129065.940	145976.998
FLTSAT	2561.60	25061.666	250616.662	291489.120
CLASSIF	6 to 8 K			
TOTALS			1304100.829	1491626.287

PROGRAM	ACQUISITION COST / SAT		
DSP-I	13376.691		
DSCS-II	17720.831		
P72-2	13925.631		
S-3	11045.510		
NATO 3	17409.639	AVERAGE COST	
P78-1	14431.160	PER SAT	11933.010
P78-2	14212.414		
GPS-1	15623.301		
DSP-II	13197.544		
DMSP	12164.750		
FLTSAT	29148.912		
CLASSIF			

PROGRAM	RATIO MMS/ UNIQUE	# OF UNIQUE	# OF MMS(MPS/ SC&CU/C&DH/MACS S,TC&I	WT (LBS)	# OF PM-1	WT (LBS)	# OF PM-1A	WT (LBS)	PRORATED RATIO MMS/TOTAL
DSP-I	1	4	4	1429.100		165	4	235	0.1333
P72-2	1	1	1		1				0.0333
S-3	1	3	3		3				0.1000
P78-1	1	1	1		1				0.0333
P78-2	1	1	1		1				0.0333
DSP-II	1	8	8				8		0.2667
DMSP	1	12	12		0		0		0.4000
CLASSIF	1	0	0				0		0.0000
		30	30		6		12		1.0000

LEARNING CURVE FACTORS:

FORMULAS: CUMULATIVE AVG COST AT QUATITY n   Y = a n where

TOTAL COST OF n UNITS
T = a n

Y = cumulative avg. cost for n items
a = cost of 1st item
n = quantity produced
T = total cost of n item
b = log(learning curve) /log(2)

UNIQUE & MMS MSN SPECIFIC LEARNING CURVE SLOPE	0.950		b =	-0.0740
check DSCS-II			b+1=	0.9260
MMS MODULES LEARNING CURVE SLOPE	0.950		b =	-0.0740
check PM-1	0.876 5.255		b+1=	0.9260

UNIQUE SATELLITE COSTS('79 K $)

LEARNING CURVE
SLOPE 0.950 b= -0.074
b + 1 = 0.926

PROGRAM	WEIGHT	# OF SATS	NR $	FU $	AVERAGE COST	COMPOSITE PRODUCTION COST
DSP-I	1073.60	4	32336.230	16897.001	15249.543	60998.174
P72-2	1064.00	1	51153.212	15950.261	15950.261	15950.261
S-3	325.30	3	18370.210	5086.940	4689.746	14069.239
P78-1	956.80	1	43883.494	14836.038	14836.038	14836.038
P78-2	579.60	1	27225.967	9635.558	9635.558	9635.558
DSP-II	1141.70	8	62568.299	17248.823	14788.710	118309.677
DMSP	705.60	12	47530.312	17323.510	14413.712	172964.548
CLASSIF						
TOTALS		30	283067.724			406763.495

PROGRAM	AGGREGATE ACQUISITION COST(NR$+RC$)	ACQUISITION COST/SAT
DSP-I	93334.404	23333.601
P72-2	67103.473	67103.473
S-3	32439.449	10813.150
P78-1	58719.532	58719.532
P78-2	36861.525	36861.525
DSP-II	180877.976	22609.747
DMSP	220494.860	18374.572
CLASSIF	0.000	0.000
TOTALS	689831.219	22994.374

MMS MISSION SPECIFIC ITEMS('79 K $)

PROGRAM	# OF ITEM	NR $	FU $	WEIGHT	AVERAGE COST
SOLAR ARRAYS					
DSP-I	4	3873.519	2347.477	93.80	2118.598
P72-2	1	2848.130	1408.012	36.40	1408.012
S-3	3	2671.233	840.467	14.00	774.842
P78-1	1	2966.942	1601.469	46.20	1601.469
P78-2	1	2930.536	1548.304	43.40	1548.304
DSP-II	8	4626.695	2694.695	121.10	2310.364
DMSP	12	4779.176	2753.036	126.00	2290.614
CLASSIF	37	0.000	0.000	0.00	

BATTERIES			
DSP-I		159.00	267.000
	2 - 20 Ampere-Hour - 106 lbs.		
P72-2		106.00	195.000
S-3	3 - 20 Ampere-Hour - 159 lbs.	106.00	195.000
P78-1	2 - 50 Ampere-Hour - 224 lbs.	159.00	267.000
P78-2		106.00	195.000
	3 - 50 Ampere-Hour - 336 lbs.		
DSP-II		224.00	220.000
DMSP		224.00	220.000
CLASSIF			

BATTERIES HAVE A FIXED COST FOR A SPECIFIC CONFIGURATION.

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.950

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COSTS
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	30	9449.775	1605.756	1248.452
COMMUNICATIONS & DATA HANDLING (C & DH)	30	12988.919	5851.470	4549.432
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	30	37789.088	10399.483	8085.445
MODULAR POWER SYSTEM(MPS)	30	6235.393	3200.118	2488.045
PROPULSION SYSTEM-1(PM-1)	6	5331.565	1511.424	1323.740
PROPULSION SYSTEM-1A(PM-1A)	12		2168.344	1804.131
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	30	3899.624	1999.617	1554.673
SUBTOTAL		75694.364	26736.212	21053.917
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			17926.046	
WITH PM-1			19249.785	
WITH PM-1A			19730.177	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.950

b= -0.074 b + 1 = 0.926

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	20723.354	22115.775	10102.486
P72-2	1	1.00	1	7060.589	20852.797	9525.558
S-3	1	3.00	3	15308.610	20219.628	9236.326
P78-1	1	1.00	1	7179.401	21118.254	9646.819
P78-2	1	1.00	1	7142.995	20993.089	9589.643
DSP-II	1	8.00	8	38326.366	22260.541	10168.615
DMSP	1	12.00	12	55328.682	20436.659	9335.466
CLASSIF	1	0.00	0	0.000		
TOTALS		30.00	30	151069.997		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	32218.261	128873.043	149596.398
P72-2	1736.50	30378.355	30378.355	37438.944
S-3	1714.10	29455.954	88367.862	103676.471
P78-1	1799.30	30765.073	30765.073	37944.474
P78-2	1743.50	30582.733	30582.733	37725.728
DSP-II	2009.20	32429.156	259433.249	297759.615
DMSP	1779.10	29772.125	357265.502	412594.184
CLASSIF	6 to 8 K			
TOTALS			925665.816	1076735.813

PROGRAM	ACQUISITION COST / SAT
DSP-I	37399.099
P72-2	37438.944
S-3	34558.824
P78-1	37944.474
P78-2	37725.728
DSP-II	37219.952
DMSP	34382.849
CLASSIF	

AVERAGE COST PER SAT 35891.194

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.900

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COSTS
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	30	9449.775	1605.756	957.530
COMMUNICATIONS & DATA HANDLING (C & DH)	30	12988.919	5851.470	3489.297
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	30	37789.088	10399.483	6201.329
MODULAR POWER SYSTEM(MPS)	30	6235.393	3200.118	1908.266
PROPULSION SYSTEM-1(PM-1)	6	5331.565	1511.424	1151.078
PROPULSION SYSTEM-1A(PM-1A)	12		2168.344	1486.241
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	30	3899.624	1999.617	1192.394
SUBTOTAL		75694.364	26736.212	16386.136
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			13748.817	
WITH PM-1			14899.895	
WITH PM-1A			15235.058	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.900

b= -0.152 b + 1 = 0.848

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	20723.354	17620.656	8049.116
P72-2	1	1.00	1	7060.589	16502.907	7538.528
S-3	1	3.00	3	15308.610	15869.738	7249.296
P78-1	1	1.00	1	7179.401	16768.364	7659.789
P78-2	1	1.00	1	7142.995	16643.199	7602.613
DSP-II	1	8.00	8	38326.366	17765.422	8115.245
DMSP	1	12.00	12	55328.682	16259.431	7427.308
CLASSIF	1	0.00	0	0.000		
TOTALS		30.00	30	151069.997		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	25669.772	102679.087	123402.441
P72-2	1736.50	24041.435	24041.435	31102.024
S-3	1714.10	23119.034	69357.102	84665.711
P78-1	1799.30	24428.153	24428.153	31607.554
P78-2	1743.50	24245.813	24245.813	31388.808
DSP-II	2009.20	25880.667	207045.336	245371.702
DMSP	1779.10	23686.738	284240.861	339569.543
CLASSIF	6 to 8 K			
TOTALS			736037.787	887107.784

	ACQUISITION COST / SAT
DSP-I	30850.610
P72-2	31102.024
S-3	28221.904
P78-1	31607.554
P78-2	31388.808
DSP-II	30671.463
DMSP	28297.462
CLASSIF	

AVERAGE COST PER SAT 29570.259

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.850

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COSTS
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	30	9449.775	1605.756	723.346
COMMUNICATIONS & DATA HANDLING (C & DH)	30	12988.919	5851.470	2635.915
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	30	37789.088	10399.483	4684.661
MODULAR POWER SYSTEM(MPS)	30	6235.393	3200.118	1441.559
PROPULSION SYSTEM-1(PM-1)	6	5331.565	1511.424	992.972
PROPULSION SYSTEM-1A(PM-1A)	12		2168.344	1210.870
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	30	3899.624	1999.617	900.769
SUBTOTAL		75694.364	26736.212	12590.091
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			10386.249	
WITH PM-1			11379.220	
WITH PM-1A			11597.119	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.850

b= -0.234 b + 1 = 0.766

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	20723.354	13982.717	6387.305
P72-2	1	1.00	1	7060.589	12982.232	5930.284
S-3	1	3.00	3	15308.610	12349.063	5641.052
P78-1	1	1.00	1	7179.401	13247.689	6051.545
P78-2	1	1.00	1	7142.995	13122.524	5994.369
DSP-II	1	8.00	8	38326.366	14127.483	6453.434
DMSP	1	12.00	12	55328.682	12896.862	5891.287
CLASSIF	1	0.00	0	0.000		
TOTALS		30.00	30	151069.997		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	20370.022	81480.089	102203.444
P72-2	1736.50	18912.516	18912.516	25973.105
S-3	1714.10	17990.115	53970.344	69278.954
P78-1	1799.30	19299.234	19299.234	26478.635
P78-2	1743.50	19116.894	19116.894	26259.888
DSP-II	2009.20	20580.918	164647.341	202973.707
DMSP	1779.10	18788.149	225457.789	280786.472
CLASSIF	6 to 8 K			
TOTALS			582884.207	733954.205

	ACQUISITION COST / SAT
DSP-I	25550.861
P72-2	25973.105
S-3	23092.985
P78-1	26478.635
P78-2	26259.888
DSP-II	25371.713
DMSP	23398.873
CLASSIF	

AVERAGE COST PER SAT 24465.140

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.800

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COSTS
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	30	9449.775	1605.756	537.221
COMMUNICATIONS & DATA HANDLING (C & DH)	30	12988.919	5851.470	1957.664
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	30	37789.088	10399.483	3479.244
MODULAR POWER SYSTEM(MPS)	30	6235.393	3200.118	1070.629
PROPULSION SYSTEM-1(PM-1)	6	5331.565	1511.424	848.941
PROPULSION SYSTEM-1A(PM-1A)	12		2168.344	974.338
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	30	3899.624	1999.617	668.991
SUBTOTAL		75694.364	26736.212	9537.027
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			7713.749	
WITH PM-1			8562.690	
WITH PM-1A			8688.086	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.800

b= -0.322 b + 1 = 0.678

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	20723.354	11073.684	5058.459
P72-2	1	1.00	1	7060.589	10165.702	4643.693
S-3	1	3.00	3	15308.610	9532.532	4354.461
P78-1	1	1.00	1	7179.401	10431.159	4764.953
P78-2	1	1.00	1	7142.995	10305.994	4707.778
DSP-II	1	8.00	8	38326.366	11218.450	5124.588
DMSP	1	12.00	12	55328.682	10224.363	4670.489
CLASSIF	1	0.00	0	0.000		
TOTALS		30.00	30	151069.997		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	16132.143	64528.573	85251.928
P72-2	1736.50	14809.395	14809.395	21869.984
S-3	1714.10	13886.993	41660.980	56969.589
P78-1	1799.30	15196.112	15196.112	22375.513
P78-2	1743.50	15013.772	15013.772	22156.767
DSP-II	2009.20	16343.039	130744.309	169070.675
DMSP	1779.10	14894.851	178738.216	234066.899
CLASSIF	6 to 8 K			
TOTALS			460691.358	611761.355

	ACQUISITION COST / SAT
DSP-I	21312.982
P72-2	21869.984
S-3	18989.863
P78-1	22375.513
P78-2	22156.767
DSP-II	21133.834
DMSP	19505.575
CLASSIF	

AVERAGE COST PER SAT 20392.045

PROGRAM	RATIO MMS/ UNIQUE	# OF UNIQUE	# OF MMS(MPS/ SC&CU/C&DH/MACS S,TC&I	WT (LBS)	# OF PM-1	WT (LBS)	# OF PM-1A	WT (LBS)	PRORATED RATIO MMS/TOTAL
DSP-I	1	4	4	1429.100		165	4	235	0.0597
P72-2	1	1	1		1				0.0149
S-3	1	3	3		3				0.0448
P78-1	1	1	1		1				0.0149
P78-2	1	1	1		1				0.0149
DSP-II	1	8	8				8		0.1194
DMSP	1	12	12		0		0		0.1791
CLASSIF	1	37	37				37		0.5522
		67	67		6		49		1.0000

LEARNING CURVE FACTORS:

FORMULAS: CUMULATIVE AVG COST AT QUATITY n Y = a n where

TOTAL COST OF n UNITS

T = a n

Y = cumulative avg. cost for n items

a = cost of 1st item

n = quantity produced

T = total cost of n item

b = log(learning curve) /log(2)

UNIQUE & MMS MSN SPECIFIC LEARNING CURVE SLOPE	0.950	b =	-0.0740
		b+1=	0.9260
check DSCS-II			
MMS MODULES LEARNING CURVE SLOPE	0.950	b =	-0.0740
		b+1=	0.9260
check PM-1	0.876		
	5.255		

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.950

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COSTS
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	67	9449.775	1605.756	1176.384
COMMUNICATIONS & DATA HANDLING (C & DH)	67	12988.919	5851.470	4286.811
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	67	37789.088	10399.483	7618.705
MODULAR POWER SYSTEM(MPS)	67	6235.393	3200.118	2344.420
PROPULSION SYSTEM-1(PM-1)	6	5331.565	1511.424	1323.740
PROPULSION SYSTEM-1A(PM-1A)	49		2168.344	1625.746
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	67	3899.624	1999.617	1464.928
SUBTOTAL		75694.364	26736.212	19840.734
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			16891.248	
WITH PM-1			18214.988	
WITH PM-1A			18516.994	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.950

b= -0.074 b + 1 = 0.926

PROGRAM	RATIO OF MMS/UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	11418.221	20902.592	9548.304
P72-2	1	1.00	1	4734.306	19818.000	9052.862
S-3	1	3.00	3	8329.760	19184.830	8763.630
P78-1	1	1.00	1	4853.118	20083.457	9174.123
P78-2	1	1.00	1	4816.712	19958.292	9116.948
DSP-II	1	8.00	8	19716.100	21047.358	9614.433
DMSP	1	12.00	12	27413.283	19401.861	8862.770
CLASSIF	1	37.00	37	69788.498		
TOTALS		67.00	67	151069.997		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	30450.895	121803.582	133221.803
P72-2	1736.50	28870.862	28870.862	33605.167
S-3	1714.10	27948.460	83845.381	92175.141
P78-1	1799.30	29257.580	29257.580	34110.697
P78-2	1743.50	29075.239	29075.239	33891.951
DSP-II	2009.20	30661.791	245294.326	265010.426
DMSP	1779.10	28264.632	339175.579	366588.863
CLASSIF	6 to 8 K			
TOTALS			877322.550	958604.049

	ACQUISITION COST / SAT
DSP-I	33305.451
P72-2	33605.167
S-3	30725.047
P78-1	34110.697
P78-2	33891.951
DSP-II	33126.303
DMSP	30549.072
CLASSIF	

AVERAGE COST PER SAT 14307.523

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.900

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COSTS
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	67	9449.775	1605.756	847.443
COMMUNICATIONS & DATA HANDLING (C & DH)	67	12988.919	5851.470	3088.133
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	67	37789.088	10399.483	5488.362
MODULAR POWER SYSTEM(MPS)	67	6235.393	3200.118	1688.873
PROPULSION SYSTEM-1(PM-1)	6	5331.565	1511.424	1151.078
PROPULSION SYSTEM-1A(PM-1A)	49		2168.344	1200.088
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	67	3899.624	1999.617	1055.305
SUBTOTAL		75694.364	26736.212	14519.282
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			12168.115	
WITH PM-1			13319.193	
WITH PM-1A			13368.203	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.900

b= -0.152 b + 1 = 0.848

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	11418.221	15753.801	7196.336
P72-2	1	1.00	1	4734.306	14922.205	6816.463
S-3	1	3.00	3	8329.760	14289.036	6527.232
P78-1	1	1.00	1	4853.118	15187.662	6937.724
P78-2	1	1.00	1	4816.712	15062.497	6880.549
DSP-II	1	8.00	8	19716.100	15898.567	7262.466
DMSP	1	12.00	12	27413.283	14678.729	6705.243
CLASSIF	1	37.00	37	69788.498		
TOTALS		67.00	67	151069.997		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	22950.138	91800.550	103218.772
P72-2	1736.50	21738.669	21738.669	26472.975
S-3	1714.10	20816.268	62448.803	70778.563
P78-1	1799.30	22125.387	22125.387	26978.504
P78-2	1743.50	21943.046	21943.046	26759.758
DSP-II	2009.20	23161.033	185288.263	205004.363
DMSP	1779.10	21383.972	256607.665	284020.948
CLASSIF	6 to 8 K			
TOTALS			661952.383	743233.883

	ACQUISITION COST / SAT
DSP-I	25804.693
P72-2	26472.975
S-3	23592.854
P78-1	26978.504
P78-2	26759.758
DSP-II	25625.545
DMSP	23668.412
CLASSIF	

AVERAGE COST PER SAT 11093.043

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.850

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COSTS
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	67	9449.775	1605.756	599.140
COMMUNICATIONS & DATA HANDLING (C & DH)	67	12988.919	5851.470	2183.302
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	67	37789.088	10399.483	3880.258
MODULAR POWER SYSTEM(MPS)	67	6235.393	3200.118	1194.029
PROPULSION SYSTEM-1(PM-1)	6	5331.565	1511.424	992.972
PROPULSION SYSTEM-1A(PM-1A)	49		2168.344	870.635
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	67	3899.624	1999.617	746.098
SUBTOTAL		75694.364	26736.212	10466.434
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			8602.828	
WITH PM-1			9595.800	
WITH PM-1A			9473.463	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.850

b= -0.234 b + 1 = 0.766

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	11418.221	11859.061	5417.219
P72-2	1	1.00	1	4734.306	11198.812	5115.617
S-3	1	3.00	3	8329.760	10565.642	4826.385
P78-1	1	1.00	1	4853.118	11464.269	5236.878
P78-2	1	1.00	1	4816.712	11339.104	5179.703
DSP-II	1	8.00	8	19716.100	12003.827	5483.348
DMSP	1	12.00	12	27413.283	11113.442	5076.620
CLASSIF	1	37.00	37	69788.498		
TOTALS		67.00	67	151069.997		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	17276.279	69105.117	80523.339
P72-2	1736.50	16314.429	16314.429	21048.734
S-3	1714.10	15392.027	46176.082	54505.842
P78-1	1799.30	16701.147	16701.147	21554.264
P78-2	1743.50	16518.806	16518.806	21335.518
DSP-II	2009.20	17487.175	139897.397	159613.497
DMSP	1779.10	16190.062	194280.740	221694.024
CLASSIF	6 to 8 K			
TOTALS			498993.719	580275.218

PROGRAM	ACQUISITION COST / SAT
DSP-I	20130.835
P72-2	21048.734
S-3	18168.614
P78-1	21554.264
P78-2	21335.518
DSP-II	19951.687
DMSP	18474.502
CLASSIF	

AVERAGE COST PER SAT 8660.824

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.800

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COSTS
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	67	9449.775	1605.756	414.777
COMMUNICATIONS & DATA HANDLING (C & DH)	67	12988.919	5851.470	1511.472
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	67	37789.088	10399.483	2686.253
MODULAR POWER SYSTEM(MPS)	67	6235.393	3200.118	826.611
PROPULSION SYSTEM-1(PM-1)	6	5331.565	1511.424	848.941
PROPULSION SYSTEM-1A(PM-1A.	49		2168.344	619.450
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	67	3899.624	1999.617	516.514
SUBTOTAL		75694.364	26736.212	7424.019
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			5955.628	
WITH PM-1			6804.569	
WITH PM-1A			6575.078	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.800

b= -0.322 b + 1 = 0.678

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	11418.221	8960.676	4093.237
P72-2	1	1.00	1	4734.306	8407.581	3840.583
S-3	1	3.00	3	8329.760	7774.411	3551.351
P78-1	1	1.00	1	4853.118	8673.038	3961.844
P78-2	1	1.00	1	4816.712	8547.873	3904.668
DSP-II	1	8.00	8	19716.100	9105.442	4159.366
DMSP	1	12.00	12	27413.283	8466.241	3867.379
CLASSIF	1	37.00	37	69788.498		
TOTALS		67.00	67	151069.997		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	13053.913	52215.652	63633.874
P72-2	1736.50	12248.164	12248.164	16982.469
S-3	1714.10	11325.762	33977.287	42307.047
P78-1	1799.30	12634.882	12634.882	17487.999
P78-2	1743.50	12452.541	12452.541	17269.253
DSP-II	2009.20	13264.808	106118.467	125834.567
DMSP	1779.10	12333.621	148003.446	175416.730
CLASSIF	6 to 8 K			
TOTALS			377650.439	458931.939

	ACQUISITION COST / SAT
DSP-I	15908.468
P72-2	16982.469
S-3	14102.349
P78-1	17487.999
P78-2	17269.253
DSP-II	15729.321
DMSP	14618.061
CLASSIF	

AVERAGE COST PER SAT 6849.730

PROGRAM	RATIO MMS/ UNIQUE	# OF UNIQUE	# OF MMS(MPS/ SC&CU/C&DH/MACS S,TC&I	WT (LBS)	# OF PM-1	WT (LBS)	# OF PM-1A	WT (LBS)	PRORATED RATIO MMS/TOTAL
DSP-I	1	4	4	1429.100		165	4	235	0.0678
DSCS-II	1	14	14		14				0.2373
P72-2	1	1	1		1				0.0169
S-3	1	3	3		3				0.0508
NATO 3	1	3	3				3		0.0508
P78-1	1	1	1		1				0.0169
P78-2	1	1	1		1				0.0169
GPS-1	1	7	7		7				0.1186
DSP-II	1	8	8				8		0.1356
DMSP	1	12	12		0		0		0.2034
FLTSAT	1	5	5				5		0.0847
CLASSIF	1	0	0				0		0.0000
		59	59		27		20		1.0000

LEARNING CURVE FACTORS:

FORMULAS: CUMULATIVE AVG COST AT QUATITY n Y = a n where

TOTAL COST OF n UNITS
T = a n

Y = cumulative avg. cost for n items
a = cost of 1st item
n = quantity produced
T = total cost of n item
b = log(learning curve) /log(2)

UNIQUE & MMS MSN SPECIFIC LEARNING CURVE SLOPE	0.950	b =	-0.0740
		b+1=	0.9260
check DSCS-II	0.823 11.516		
MMS MODULES LEARNING CURVE SLOPE	0.950	b =	-0.0740
		b+1=	0.9260
check PM-1	0.784 21.156		

MMS MISSION SPECIFIC ITEMS('79 K $)

PROGRAM	# OF ITEM	NR $	FU $	WEIGHT	AVERAGE COST
SOLAR ARRAYS					
DSP-I	4	3873.519	2347.477	93.80	2118.598
DSCS-II	14	3450.049	2078.892	74.90	1710.085
P72-2	1	2848.130	1408.012	36.40	1408.012
S-3	3	2671.233	840.467	14.00	774.842
NATO 3	3	3444.191	2074.540	74.60	1912.558
P78-1	1	2966.942	1601.469	46.20	1601.469
P78-2	1	2930.536	1548.304	43.40	1548.304
GPS-1	7	3394.305	2036.558	72.10	1763.433
DSP-II	8	4626.695	2694.695	121.10	2310.364
DMSP	12	4779.176	2753.036	126.00	2290.614
FLTSAT	5	9180.568	3806.594	229.60	3379.188
CLASSIF	37	0.000	0.000	0.00	
COMMUNICATION PACKAGES					
DSP-I					
DSCS-II	14	13636.609	6288.929	236.90	5173.239
P72-2					
S-3					
NATO 3	3	9452.505	3652.650	132.98	3367.447
P78-1					
P78-2					
GPS-1	7	9721.880	3695.604	124.30	3199.983
DSP-II					
DMSP					
FLTSAT	5	21581.989	11843.421	443.90	10513.637
CLASSIF					

contractor fee of 12.5% added to comm packages

BATTERIES		WEIGHT	AVERAGE COST
DSP-I		159.00	267.000
DSCS-II	2 - 20 Ampere-Hour - 106 lbs.	159.00	267.000
P72-2		106.00	195.000
S-3	3 - 20 Ampere-Hour - 159 lbs.	106.00	195.000
NATO 3		159.00	267.000
P78-1	2 - 50 Ampere-Hour - 224 lbs.	159.00	267.000
P78-2		106.00	195.000
GPS-1	3 - 50 Ampere-Hour - 336 lbs.	159.00	267.000
DSP-II		224.00	220.000
DMSP		224.00	220.000
FLTSAT		224.00	220.000
CLASSIF			

BATTERIES HAVE A FIXED COST FOR A SPECIFIC CONFIGURATION.

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.950

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	59	9449.775	1605.756	1187.505
COMMUNICATIONS & DATA HANDLING (C & DH)	59	12988.919	5851.470	4327.339
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	59	37789.088	10399.483	7690.732
MODULAR POWER SYSTEM(MPS)	59	6235.393	3200.118	2366.584
PROPULSION SYSTEM-1(PM-1)	27	5331.565	1511.424	1184.308
PROPULSION SYSTEM-1A(PM-1A)	20		2168.344	1737.206
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	59	3899.624	1999.617	1478.777
SUBTOTAL		75694.364	26736.212	19972.450
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			17050.937	
WITH PM-1			18235.245	
WITH PM-1A			18788.142	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.950

b= -0.074 b + 1 = 0.926

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	12441.232	21173.740	9672.165
DSCS-II	1	14.00	14	47073.653	25385.569	8354.391
P72-2	1	1.00	1	4990.058	19838.257	9062.116
S-3	1	3.00	3	9097.018	19205.087	8772.884
NATO 3	1	3.00	3	19322.481	24335.148	8008.697
P78-1	1	1.00	1	5108.870	20103.714	9183.376
P78-2	1	1.00	1	5072.464	19978.549	9126.201
GPS-1	1	7.00	7	28109.683	23465.661	7722.549
DSP-II	1	8.00	8	21762.121	21318.507	9738.294
DMSP	1	12.00	12	30482.315	19561.551	8935.716
FLTSAT	1	5.00	5	41472.198	32900.968	10827.708
CLASSIF	1	0.00	0	0.000		
TOTALS		59.00	59	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	30845.905	123383.621	135824.852
DSCS-II	2064.90	33739.960	472359.439	519433.092
P72-2	1736.50	28900.372	28900.372	33890.431
S-3	1714.10	27977.971	83933.913	93030.931
NATO 3	2030.68	32343.845	97031.534	116354.015
P78-1	1799.30	29287.090	29287.090	34395.960
P78-2	1743.50	29104.750	29104.750	34177.214
GPS-1	1949.50	31188.210	218317.471	246427.153
DSP-II	2009.20	31056.800	248454.403	270216.524
DMSP	1779.10	28497.267	341967.203	372449.518
FLTSAT	2561.60	43728.676	218643.381	260115.579
CLASSIF	6 to 8 K			
TOTALS			1891383.176	2116315.270

PROGRAM	ACQUISITION COST / SAT
DSP-I	33956.213
DSCS-II	37102.364
P72-2	33890.431
S-3	31010.310
NATO 3	38784.672
P78-1	34395.960
P78-2	34177.214
GPS-1	35203.879
DSP-II	33777.066
DMSP	31037.460
FLTSAT	52023.116
CLASSIF	

AVERAGE COST PER SAT 35869.750

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.900

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	59	9449.775	1605.756	863.982
COMMUNICATIONS & DATA HANDLING (C & DH)	59	12988.919	5851.470	3148.401
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	59	37789.088	10399.483	5595.472
MODULAR POWER SYSTEM(MPS)	59	6235.393	3200.118	1721.833
PROPULSION SYSTEM-1(PM-1)	27	5331.565	1511.424	915.829
PROPULSION SYSTEM-1A(PM-1A)	20		2168.344	1375.205
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	59	3899.624	1999.617	1075.900
SUBTOTAL		75694.364	26736.212	14696.623
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			12405.588	
WITH PM-1			13321.417	
WITH PM-1A			13780.793	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.900

b= -0.152 b + 1 = 0.848

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	12441.232	16166.391	7384.807
DSCS-II	1	14.00	14	47073.653	20471.742	6737.250
P72-2	1	1.00	1	4990.058	14924.429	6817.479
S-3	1	3.00	3	9097.018	14291.260	6528.247
NATO 3	1	3.00	3	19322.481	19327.798	6360.778
P78-1	1	1.00	1	5108.870	15189.886	6938.740
P78-2	1	1.00	1	5072.464	15064.721	6881.565
GPS-1	1	7.00	7	28109.683	18551.833	6105.408
DSP-II	1	8.00	8	21762.121	16311.157	7450.937
DMSP	1	12.00	12	30482.315	14916.201	6813.721
FLTSAT	1	5.00	5	41472.198	27893.618	9179.790
CLASSIF	1	0.00	0	0.000		
TOTALS		59.00	59	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	23551.199	94204.795	106646.027
DSCS-II	2064.90	27208.992	380925.884	427999.537
P72-2	1736.50	21741.908	21741.908	26731.967
S-3	1714.10	20819.507	62458.521	71555.539
NATO 3	2030.68	25688.577	77065.730	96388.211
P78-1	1799.30	22128.626	22128.626	27237.496
P78-2	1743.50	21946.286	21946.286	27018.750
GPS-1	1949.50	24657.242	172600.693	200710.376
DSP-II	2009.20	23762.094	190096.752	211858.873
DMSP	1779.10	21729.922	260759.066	291241.381
FLTSAT	2561.60	37073.408	185367.041	226839.239
CLASSIF	6 to 8 K			
TOTALS			1489295.302	1714227.395

PROGRAM	ACQUISITION COST / SAT
DSP-I	26661.507
DSCS-II	30571.396
P72-2	26731.967
S-3	23851.846
NATO 3	32129.404
P78-1	27237.496
P78-2	27018.750
GPS-1	28672.911
DSP-II	26482.359
DMSP	24270.115
FLTSAT	45367.848
CLASSIF	

AVERAGE COST PER SAT 29054.702

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.850

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	59	9449.775	1605.756	617.272
COMMUNICATIONS & DATA HANDLING (C & DH)	59	12988.919	5851.470	2249.374
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	59	37789.088	10399.483	3997.684
MODULAR POWER SYSTEM(MPS)	59	6235.393	3200.118	1230.163
PROPULSION SYSTEM-1(PM-1)	27	5331.565	1511.424	697.881
PROPULSION SYSTEM-1A(PM-1A)	20		2168.344	1074.192
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	59	3899.624	1999.617	768.676
SUBTOTAL		75694.364	26736.212	10635.242
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			8863.170	
WITH PM-1			9561.050	
WITH PM-1A			9937.361	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.850

b= -0.234 b + 1 = 0.766

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	12441.232	12322.959	5629.128
DSCS-II	1	14.00	14	47073.653	16711.375	5499.713
P72-2	1	1.00	1	4990.058	11164.062	5099.744
S-3	1	3.00	3	9097.018	10530.893	4810.512
NATO 3	1	3.00	3	19322.481	15484.367	5095.905
P78-1	1	1.00	1	5108.870	11429.519	5221.004
P78-2	1	1.00	1	5072.464	11304.354	5163.829
GPS-1	1	7.00	7	28109.683	14791.467	4867.872
DSP-II	1	8.00	8	21762.121	12467.726	5695.257
DMSP	1	12.00	12	30482.315	11373.783	5195.544
FLTSAT	1	5.00	5	41472.198	24050.187	7914.916
CLASSIF	1	0.00	0	0.000		
TOTALS		59.00	59	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	17952.087	71808.349	84249.581
DSCS-II	2064.90	22211.088	310955.237	358028.890
P72-2	1736.50	16263.806	16263.806	21253.864
S-3	1714.10	15341.405	46024.214	55121.232
NATO 3	2030.68	20580.272	61740.815	81063.296
P78-1	1799.30	16650.524	16650.524	21759.394
P78-2	1743.50	16468.184	16468.184	21540.648
GPS-1	1949.50	19659.339	137615.370	165725.052
DSP-II	2009.20	18162.983	145303.861	167065.982
DMSP	1779.10	16569.328	198831.930	229314.245
FLTSAT	2561.60	31965.103	159825.516	201297.714
CLASSIF	6 to 8 K			
TOTALS			1181487.805	1406419.898

PROGRAM	ACQUISITION COST / SAT
DSP-I	21062.395
DSCS-II	25573.492
P72-2	21253.864
S-3	18373.744
NATO 3	27021.099
P78-1	21759.394
P78-2	21540.648
GPS-1	23675.007
DSP-II	20883.248
DMSP	19109.520
FLTSAT	40259.543
CLASSIF	

AVERAGE COST PER SAT 23837.625

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.800

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	59	9449.775	1605.756	432.108
COMMUNICATIONS & DATA HANDLING (C & DH)	59	12988.919	5851.470	1574.628
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	59	37789.088	10399.483	2798.496
MODULAR POWER SYSTEM(MPS)	59	6235.393	3200.118	861.150
PROPULSION SYSTEM-1(PM-1)	27	5331.565	1511.424	523.106
PROPULSION SYSTEM-1A(PM-1A)	20		2168.344	826.590
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	59	3899.624	1999.617	538.096
SUBTOTAL		75694.364	26736.212	7554.175
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			6204.479	
WITH PM-1			6727.585	
WITH PM-1A			7031.069	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.800

b= -0.322 b + 1 = 0.678

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	12441.232	9416.667	4301.533
DSCS-II	1	14.00	14	47073.653	13877.910	4567.220
P72-2	1	1.00	1	4990.058	8330.597	3805.417
S-3	1	3.00	3	9097.018	7697.428	3516.185
NATO 3	1	3.00	3	19322.481	12578.074	4139.444
P78-1	1	1.00	1	5108.870	8596.054	3926.678
P78-2	1	1.00	1	5072.464	8470.889	3869.502
GPS-1	1	7.00	7	28109.683	11958.002	3935.378
DSP-II	1	8.00	8	21762.121	9561.433	4367.663
DMSP	1	12.00	12	30482.315	8715.093	3981.054
FLTSAT	1	5.00	5	41472.198	21143.894	6958.456
CLASSIF	1	0.00	0	0.000		
TOTALS		59.00	59	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	13718.200	54872.801	67314.033
DSCS-II	2064.90	18445.130	258231.819	305305.473
P72-2	1736.50	12136.014	12136.014	17126.073
S-3	1714.10	11213.613	33640.839	42737.856
NATO 3	2030.68	16717.518	50152.554	69475.035
P78-1	1799.30	12522.732	12522.732	17631.602
P78-2	1743.50	12340.392	12340.392	17412.856
GPS-1	1949.50	15893.380	111253.661	139363.344
DSP-II	2009.20	13929.095	111432.764	133194.884
DMSP	1779.10	12696.147	152353.763	182836.077
FLTSAT	2561.60	28102.349	140511.747	181983.946
CLASSIF	6 to 8 K			
TOTALS			949449.085	1174381.178

PROGRAM	ACQUISITION COST / SAT
DSP-I	16828.508
DSCS-II	21807.534
P72-2	17126.073
S-3	14245.952
NATO 3	23158.345
P78-1	17631.602
P78-2	17412.856
GPS-1	19909.049
DSP-II	16649.361
DMSP	15236.340
FLTSAT	36396.789
CLASSIF	

AVERAGE COST PER SAT 19904.766

PROGRAM	RATIO MMS/ UNIQUE	# OF UNIQUE	# OF MMS(MPS/ SC&CU/C&DH/MACS, TC&I	WT (LBS)	# OF PM-1	WT (LBS)	# OF PM-1A	WT (LBS)	PRORATED RATIO MMS/TOTAL
DSP-I	1	4	4	1429.100		165	4	235	0.0417
DSCS-II	1	14	14		14				0.1458
P72-2	1	1	1		1				0.0104
S-3	1	3	3		3				0.0313
NATO 3	1	3	3				3		0.0313
P78-1	1	1	1		1				0.0104
P78-2	1	1	1		1				0.0104
GPS-1	1	7	7		7				0.0729
DSP-II	1	8	8				8		0.0833
DMSP	1	12	12		0		0		0.1250
FLTSAT	1	5	5				5		0.0521
CLASSIF	1	37	37				37		0.3854
		96	96		27		57		1.0000

LEARNING CURVE FACTORS:

FORMULAS: CUMULATIVE AVG COST AT QUATITY n   Y = a n where

TOTAL COST OF n UNITS
T = a n

Y = cumulative avg. cost for n items
a = cost of 1st item
n = quantity produced
T = total cost of n item
b = log(learning curve) /log(2)

UNIQUE & MMS MSN SPECIFIC LEARNING CURVE SLOPE	0.950	b =	-0.0740
		b+1=	0.9260
check DSCS-II	0.823 11.516		
MMS MODULES LEARNING CURVE SLOPE	0.950	b =	-0.0740
		b+1=	0.9260
check PM-1	0.784 21.156		

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.950

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	96	9449.775	1605.756	1145.487
COMMUNICATIONS & DATA HANDLING (C & DH)	96	12988.919	5851.470	4174.224
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	96	37789.088	10399.483	7418.610
MODULAR POWER SYSTEM(MPS)	96	6235.393	3200.118	2282.847
PROPULSION SYSTEM-1(PM-1)	27	5331.565	1511.424	1184.308
PROPULSION SYSTEM-1A(PM-1A)	57		2168.344	1607.653
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	96	3899.624	1999.617	1426.453
SUBTOTAL		75694.364	26736.212	19239.583
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			16447.621	
WITH PM-1			17631.929	
WITH PM-1A			18055.275	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.950

b= -0.074 b + 1 = 0.926

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	9139.093	20440.873	9337.391
DSCS-II	1	14.00	14	35516.166	24782.254	8155.840
P72-2	1	1.00	1	4164.523	19234.941	8786.521
S-3	1	3.00	3	6620.413	18601.772	8497.289
NATO 3	1	3.00	3	16845.876	23602.280	7767.510
P78-1	1	1.00	1	4283.335	19500.398	8907.782
P78-2	1	1.00	1	4246.929	19375.233	8850.607
GPS-1	1	7.00	7	22330.939	22862.346	7523.998
DSP-II	1	8.00	8	15157.842	20585.639	9403.520
DMSP	1	12.00	12	20575.897	18958.235	8660.122
FLTSAT	1	5.00	5	37344.524	32168.100	10586.522
CLASSIF	1	37.00	37	48706.556		
TOTALS		96.00	96	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	29778.264	119113.054	128252.147
DSCS-II	2064.90	32938.093	461133.307	496649.472
P72-2	1736.50	28021.462	28021.462	32185.986
S-3	1714.10	27099.061	81297.183	87917.596
NATO 3	2030.68	31369.790	94109.371	110955.247
P78-1	1799.30	28408.180	28408.180	32691.516
P78-2	1743.50	28225.840	28225.840	32472.769
GPS-1	1949.50	30386.344	212704.405	235035.344
DSP-II	2009.20	29989.159	239913.271	255071.113
DMSP	1779.10	27618.357	331420.284	351996.181
FLTSAT	2561.60	42754.622	213773.109	251117.633
CLASSIF	6 to 8 K			
TOTALS			1838119.466	2014345.004

PROGRAM	ACQUISITION COST / SAT		
DSP-I	32063.037		
DSCS-II	35474.962		
P72-2	32185.986		
S-3	29305.865		
NATO 3	36985.082	AVERAGE COST	
P78-1	32691.516	PER SAT	20982.760
P78-2	32472.769		
GPS-1	33576.478		
DSP-II	31883.889		
DMSP	29333.015		
FLTSAT	50223.527		
CLASSIF			

MMS MODULE COSTS ('79 K $)
LEARNING CURVE SLOPE 0.900

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	96	9449.775	1605.756	802.358
COMMUNICATIONS & DATA HANDLING (C & DH)	96	12988.919	5851.470	2923.840
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	96	37789.088	10399.483	5196.374
MODULAR POWER SYSTEM(MPS)	96	6235.393	3200.118	1599.023
PROPULSION SYSTEM-1(PM-1)	27	5331.565	1511.424	915.829
PROPULSION SYSTEM-1A(PM-1A)	57		2168.344	1172.816
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	96	3899.624	1999.617	999.161
SUBTOTAL		75694.364	26736.212	13609.401
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			11520.756	
WITH PM-1			12436.585	
WITH PM-1A			12693.571	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.900

b= -0.152   b + 1 = 0.848

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	9139.093	15079.169	6888.165
DSCS-II	1	14.00	14	35516.166	19586.910	6446.052
P72-2	1	1.00	1	4164.523	14039.597	6413.288
S-3	1	3.00	3	6620.413	13406.428	6124.056
NATO 3	1	3.00	3	16845.876	18240.576	6002.974
P78-1	1	1.00	1	4283.335	14305.054	6534.549
P78-2	1	1.00	1	4246.929	14179.889	6477.373
GPS-1	1	7.00	7	22330.939	17667.002	5814.210
DSP-II	1	8.00	8	15157.842	15223.936	6954.294
DMSP	1	12.00	12	20575.897	14031.369	6409.530
FLTSAT	1	5.00	5	37344.524	26806.397	8821.985
CLASSIF	1	37.00	37	48706.556		
TOTALS		96.00	96	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	21967.334	87869.336	97008.428
DSCS-II	2064.90	26032.962	364461.461	399977.627
P72-2	1736.50	20452.885	20452.885	24617.408
S-3	1714.10	19530.484	58591.451	65211.864
NATO 3	2030.68	24243.550	72730.651	89576.527
P78-1	1799.30	20839.603	20839.603	25122.938
P78-2	1743.50	20657.262	20657.262	24904.192
GPS-1	1949.50	23481.212	164368.482	186699.421
DSP-II	2009.20	22178.229	177425.834	192583.676
DMSP	1779.10	20440.899	245290.787	265866.684
FLTSAT	2561.60	35628.382	178141.909	215486.433
CLASSIF	6 to 8 K			
TOTALS			1410829.661	1587055.198

	ACQUISITION COST / SAT		
DSP-I	24252.107		
DSCS-II	28569.830		
P72-2	24617.408		
S-3	21737.288		
NATO 3	29858.842	AVERAGE COST PER SAT	16531.825
P78-1	25122.938		
P78-2	24904.192		
GPS-1	26671.346		
DSP-II	24072.960		
DMSP	22155.557		
FLTSAT	43097.287		
CLASSIF			

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.850

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	96	9449.775	1605.756	550.688
COMMUNICATIONS & DATA HANDLING (C & DH)	96	12988.919	5851.470	2006.741
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	96	37789.088	10399.483	3566.465
MODULAR POWER SYSTEM(MPS)	96	6235.393	3200.118	1097.469
PROPULSION SYSTEM-1(PM-1)	27	5331.565	1511.424	697.881
PROPULSION SYSTEM-1A(PM-1A)	57		2168.344	840.304
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	96	3899.624	1999.617	685.761
SUBTOTAL		75694.364	26736.212	9445.310
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			7907.125	
WITH PM-1			8605.006	
WITH PM-1A			8747.429	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.850

b= -0.234 b + 1 = 0.766

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	9139.093	11133.027	5085.567
DSCS-II	1	14.00	14	35516.166	15755.330	5185.079
P72-2	1	1.00	1	4164.523	10208.018	4663.022
S-3	1	3.00	3	6620.413	9574.848	4373.791
NATO 3	1	3.00	3	16845.876	14294.434	4704.298
P78-1	1	1.00	1	4283.335	10473.475	4784.283
P78-2	1	1.00	1	4246.929	10348.310	4727.108
GPS-1	1	7.00	7	22330.939	13835.422	4553.237
DSP-II	1	8.00	8	15157.842	11277.793	5151.696
DMSP	1	12.00	12	20575.897	10417.739	4758.823
FLTSAT	1	5.00	5	37344.524	22860.254	7523.310
CLASSIF	1	37.00	37	48706.556		
TOTALS		96.00	96	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	16218.594	64874.376	74013.468
DSCS-II	2064.90	20940.409	293165.730	328681.896
P72-2	1736.50	14871.040	14871.040	19035.564
S-3	1714.10	13948.639	41845.916	48466.330
NATO 3	2030.68	18998.732	56996.197	73842.074
P78-1	1799.30	15257.758	15257.758	19541.093
P78-2	1743.50	15075.418	15075.418	19322.347
GPS-1	1949.50	18388.659	128720.616	151051.555
DSP-II	2009.20	16429.489	131435.914	146593.756
DMSP	1779.10	15176.562	182118.739	202694.636
FLTSAT	2561.60	30383.564	151917.820	189262.344
CLASSIF	6 to 8 K			
TOTALS			1096279.524	1272505.062

PROGRAM	ACQUISITION COST / SAT
DSP-I	18503.367
DSCS-II	23477.278
P72-2	19035.564
S-3	16155.443
NATO 3	24614.025
P78-1	19541.093
P78-2	19322.347
GPS-1	21578.794
DSP-II	18324.219
DMSP	16891.220
FLTSAT	37852.469
CLASSIF	

AVERAGE COST PER SAT 13255.261

MMS MODULE COSTS ('79 K $)

LEARNING CURVE SLOPE 0.800

SUBSYSTEM	# OF MODS	NR $	FU $	AVERAGE COST
STRUCTURE, THERMAL CONTROL & INTERSTAGE(S,TC & I)	96	9449.775	1605.756	369.429
COMMUNICATIONS & DATA HANDLING (C & DH)	96	12988.919	5851.470	1346.220
MODULAR ATTITUDE CONTROL SYSTEM (MACS)	96	37789.088	10399.483	2392.561
MODULAR POWER SYSTEM(MPS)	96	6235.393	3200.118	736.236
PROPULSION SYSTEM-1(PM-1)	27	5331.565	1511.424	523.106
PROPULSION SYSTEM-1A(PM-1A)	57		2168.344	590.015
SIGNAL CONDITIONING & CONTROL UNIT (SC & CU)	96	3899.624	1999.617	460.043
SUBTOTAL		75694.364	26736.212	6417.610
PROGRAM LEVEL		35122.185		
AEROSPACE GROUND EQUIPMENT (AGE)		15557.217		
ESTIMATED COMPOSITE NONRECURRING COST		126373.766		
AVERAGE MMS HARDWARE COST: WITHOUT PROPULSION MODULES			5304.489	
WITH PM-1			5827.595	
WITH PM-1A			5894.503	

MMS SUBSTITUTION COMPARISON ('79 K $)

LEARNING CURVE 0.800

b= -0.322 b + 1 = 0.678

PROGRAM	RATIO OF MMS/ UNIQS	# OF UNIQUE SATS	# OF MMS	NONRECURRING COMPOSITE PRORATED COST (PRORATED NR$+ NR$ MSN SPEC)	ESTIMATED COMPOSITE HARDWARE COST	ESTIMATED PROGRAM LEVEL COST
DSP-I	1	4.00	4	9139.093	8280.101	3782.350
DSCS-II	1	14.00	14	35516.166	12977.920	4271.033
P72-2	1	1.00	1	4164.523	7430.607	3394.301
S-3	1	3.00	3	6620.413	6797.438	3105.070
NATO 3	1	3.00	3	16845.876	11441.508	3765.400
P78-1	1	1.00	1	4283.335	7696.064	3515.562
P78-2	1	1.00	1	4246.929	7570.899	3458.387
GPS-1	1	7.00	7	22330.939	11058.012	3639.192
DSP-II	1	8.00	6	15157.842	8424.867	3848.479
DMSP	1	12.00	12	20575.897	7815.102	3569.939
FLTSAT	1	5.00	5	37344.524	20007.328	6584.412
CLASSIF	1	37.00	37	48706.556		
TOTALS		96.00	96	224932.093		

PROGRAM	WEIGHT	COMPOSITE COST PER SURROGATE (HARDWARE + PROGRAM)	COMPOSITE PRODUCTION COST	AGGREGATE ACQUISITION COSTS (NR$ + RC$)
DSP-I	1916.90	12062.451	48249.806	57388.898
DSCS-II	2064.90	17248.953	241485.341	277001.506
P72-2	1736.50	10824.908	10824.908	14989.432
S-3	1714.10	9902.507	29707.521	36327.935
NATO 3	2030.68	15206.909	45620.726	62466.602
P78-1	1799.30	11211.626	11211.626	15494.962
P78-2	1743.50	11029.286	11029.286	15276.215
GPS-1	1949.50	14697.203	102880.422	125211.361
DSP-II	2009.20	12273.347	98186.774	113344.616
DMSP	1779.10	11385.041	136620.493	157196.390
FLTSAT	2561.60	26591.740	132958.701	170303.225
CLASSIF	6 to 8 K			
TOTALS			868775.605	1045001.142

PROGRAM	ACQUISITION COST / SAT
DSP-I	14347.225
DSCS-II	19785.822
P72-2	14989.432
S-3	12109.312
NATO 3	20822.201
P78-1	15494.962
P78-2	15276.215
GPS-1	17887.337
DSP-II	14168.077
DMSP	13099.699
FLTSAT	34060.645
CLASSIF	

AVERAGE COST PER SAT 10885.429

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The purpose of the analysis was to determine and compare the costs of certain uniquely-built spacecraft of the 1970's with surrogate programs using the Multimission Modular Spacecraft. Using the Unmanned Spacecraft Cost Model, costs were developed for the unique satellites. After the feasibility of using the cost model was determined, the costs of the MMS were estimated from the cost model. Mission unique item costs such as, solar arrays, batteries, and communications equipment were also determined.

The surrogate MMS program costs were simulated varying the quantity of modules built and the slope of the learning curve in building the modules. These costs compared with the estimated costs of the uniquely-built satellites, both aggregate and program, enabled a cost comparison of the 1970's military space program had the U.S. used the MMS exclusively. The analysis concludes with the determination that the MMS is a highly cost effective method of decreasing the cost of utilizing space when it is employed within its design criteria.

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