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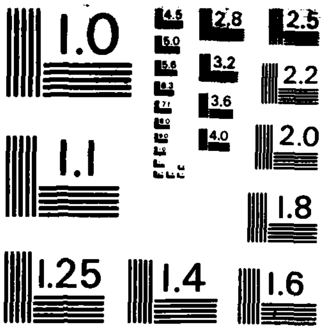

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# ANALYSIS OF THE ACQUISITION COSTS OF UNIQUELY-BUILT SPACECRAFT VERSUS MULTI-MISSION MODULAR SPACECRAFT SURROGATES FOR THE MILITARY SPACE PROGRAM OF THE 1970'S

THESIS

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AFIT/GSO/OS/83D-2

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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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# 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 Handling |
| CER | Cost Estimating Relationship |
| 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 Attitude Control 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 <u>civilian</u> 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 <u>MMS Description</u>

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 <u>Multimissions Modular Spacecraft (MMS) External Interface Specification and User's Guide</u> (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

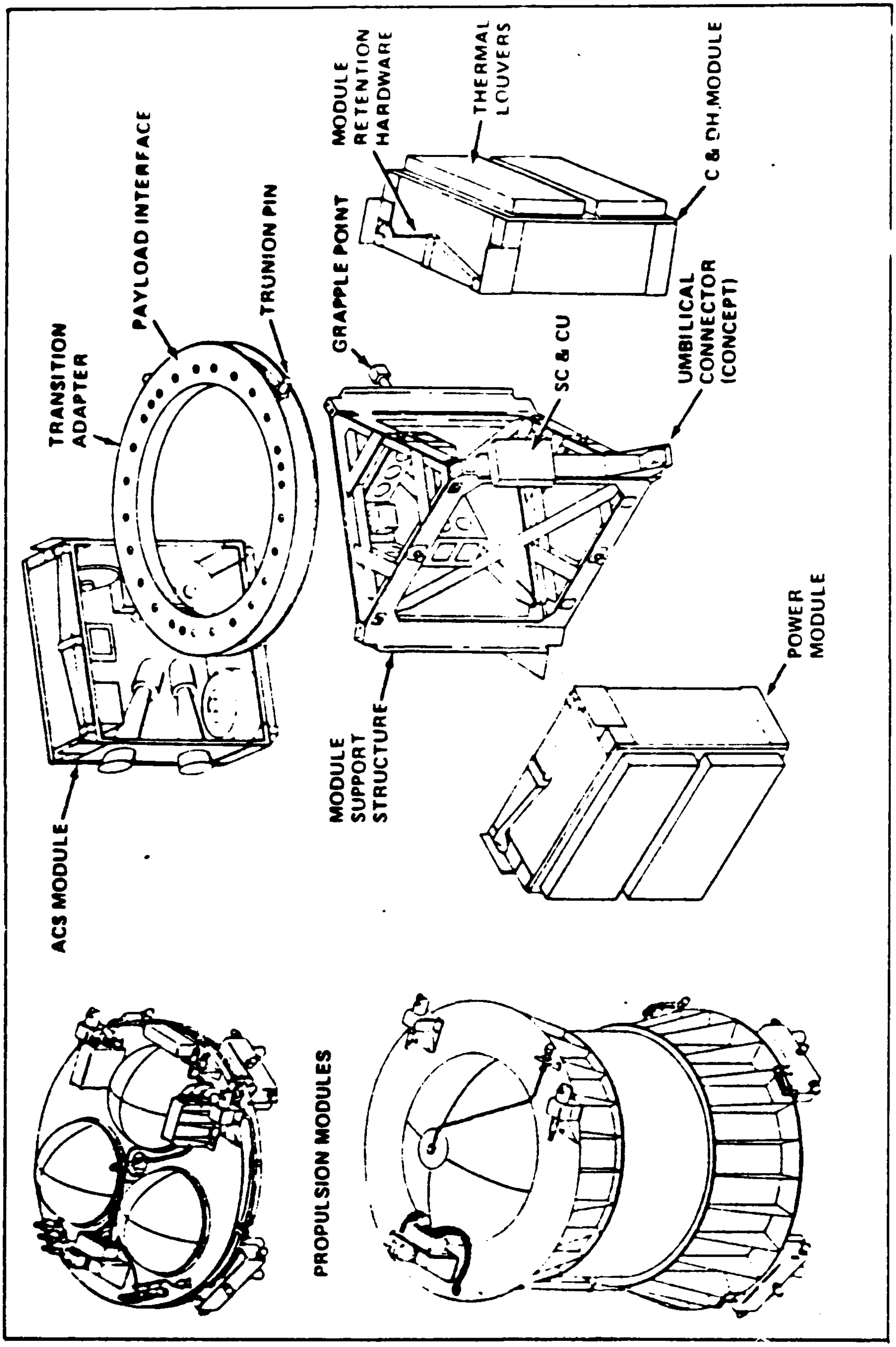


Fig. 1 Multimission Modular Spacecraft

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 <u>Low Cost Modular Spacecraft Description</u> (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 $4.5 \times 10^8$ 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

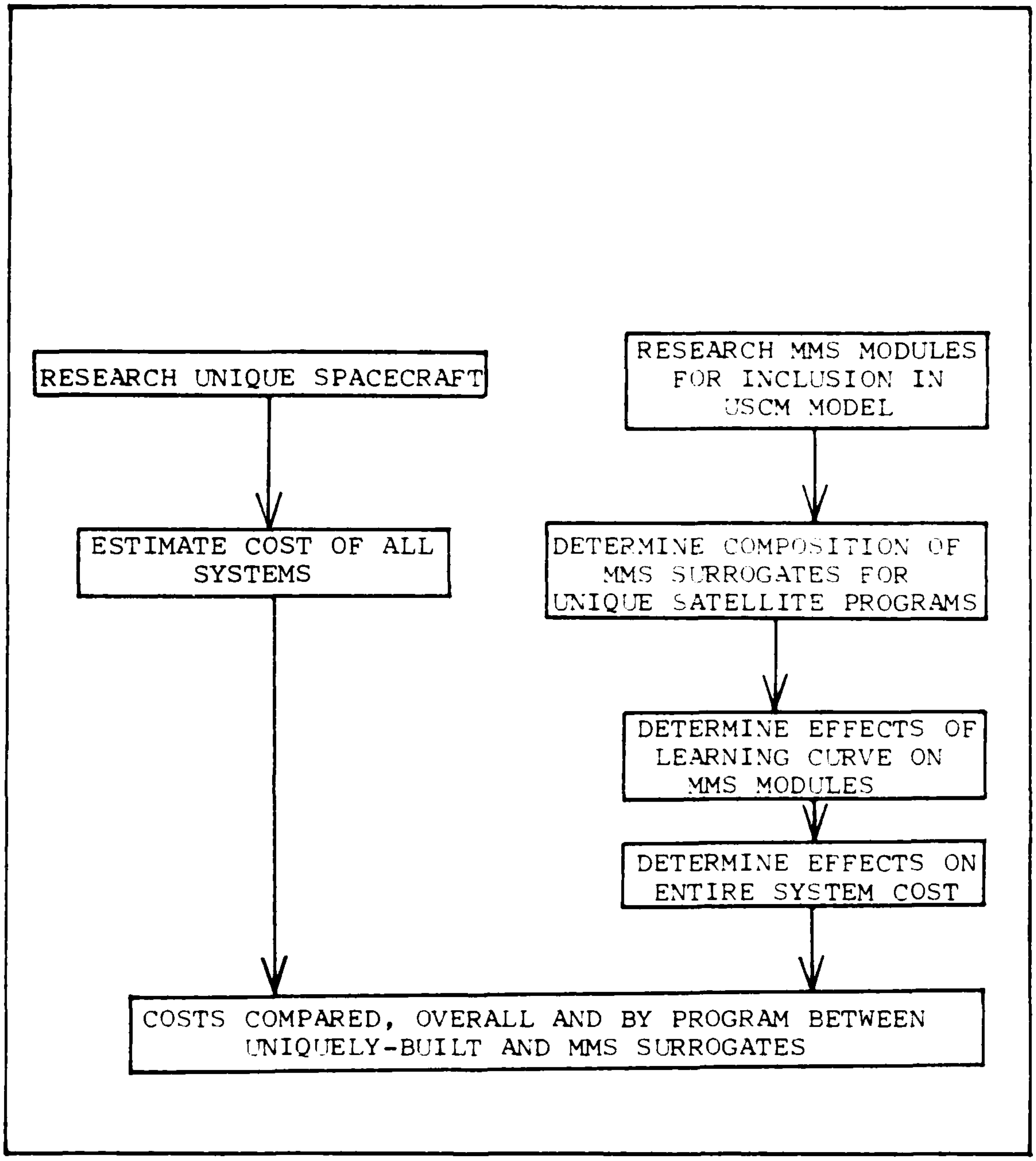


Fig. 2. Methodology Flow Chart

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 carryover 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 nonrecurring 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

| | STRUCTURE, THERMAL & INTERSTAGE | | TELEMETRY, TRACKING & CONTROL | |
|---|---|---|---|---|
| PROGRAM | R & D | FU PROD. | R & D | 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 |

| | ATTITUDE CONTROL SYSTEM | | ELECTRICAL POWER SYSTEM | |
|---|---|---|---|---|
| PROGRAM | R & D | FU PROD. | R & D | 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 |

| | COMMUNICATIONS | |
|---|---|---|
| PROGRAM | R & D | 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 nonrecurring 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

<u>FLTSAT 1979 Thousands of Dollars</u>

| (1)<br>MODULE | (2)<br>WEIGHT | (3)<br>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)<br>R & D NORM. FACTOR | (5)<br>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

<u>Quoted Versus Estimated Price Comparison (in 1979 K $)</u>

| 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 <u>Unmanned Spacecraft Cost Model</u> 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

<u>Solar Array Price Estimate</u>

| | BOL POWER | ESTIMATED | X (BOL X WT) | R&D COST | FU COST |
|---|---|---|---|---|---|
| PROGRAM | (WATTS) | WEIGHT (LBS) | (WATTS-LBS) | (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 <u>cumulative</u> <u>average</u> 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:

$$Y = AN^{B} \tag{III.1}$$

TOTAL COST (T) OF QUANTITY N UNITS:

$$T = AN^{B+1} \tag{III.2}$$

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.

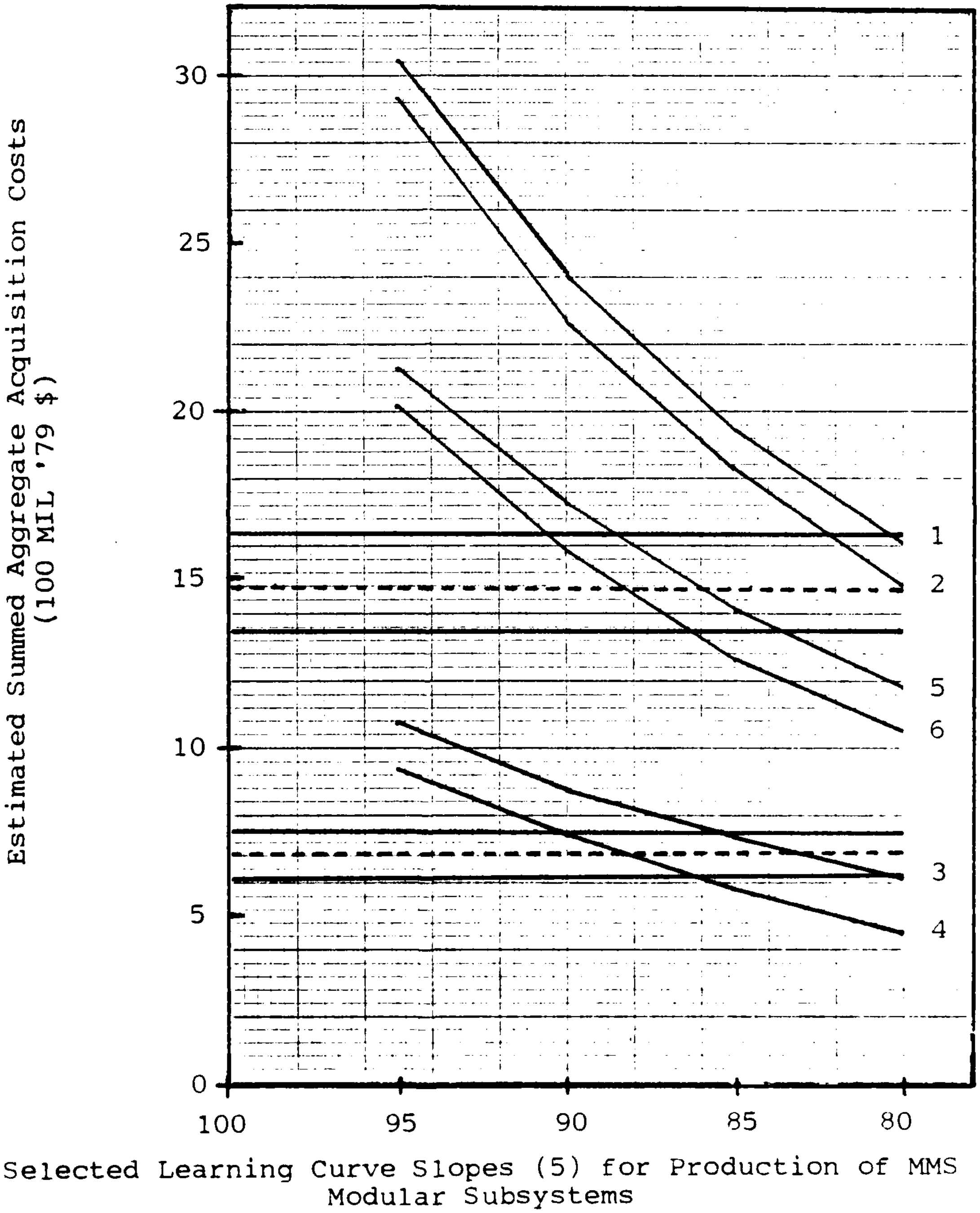


Fig. 3 The Effect of Increased Learning on Summed Aggregate Acquisition Costs for MMS Surrogate Satellite Programs

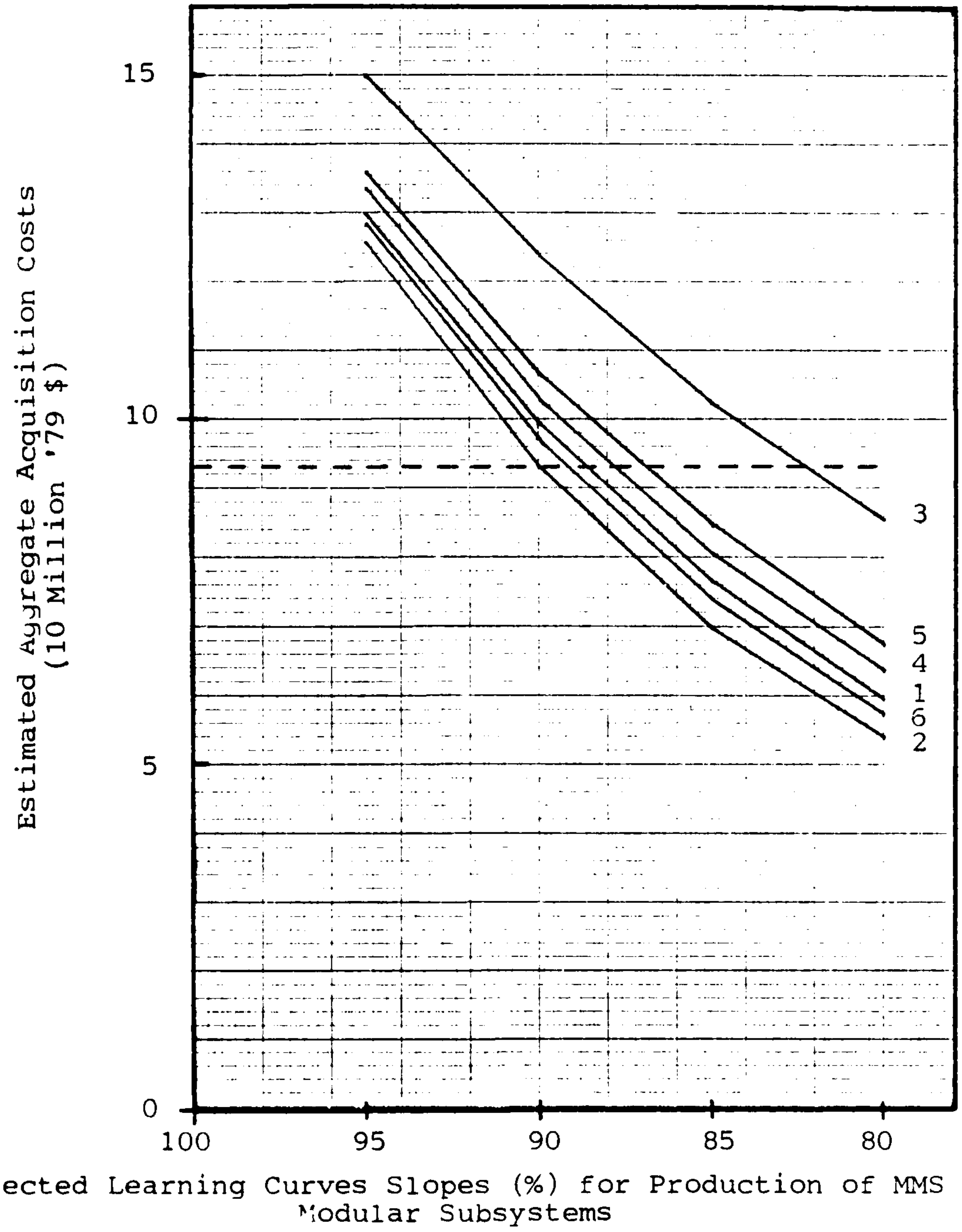


Fig. 4 The Effect of Increased Learning on Aggregate Acquisition Costs for MMS Surrogate DPS-1 Program

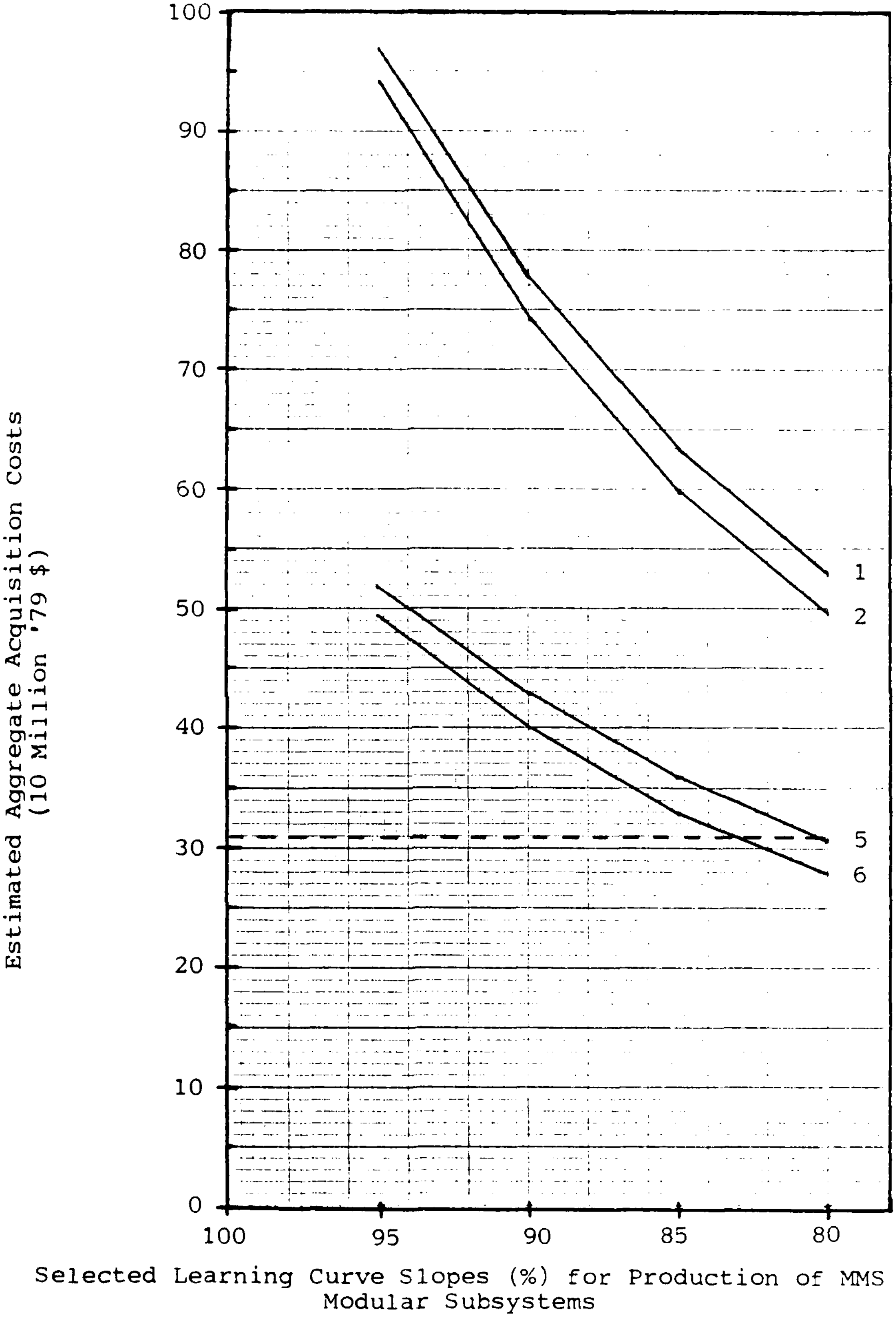


Fig. 5 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate DSCS-II Program

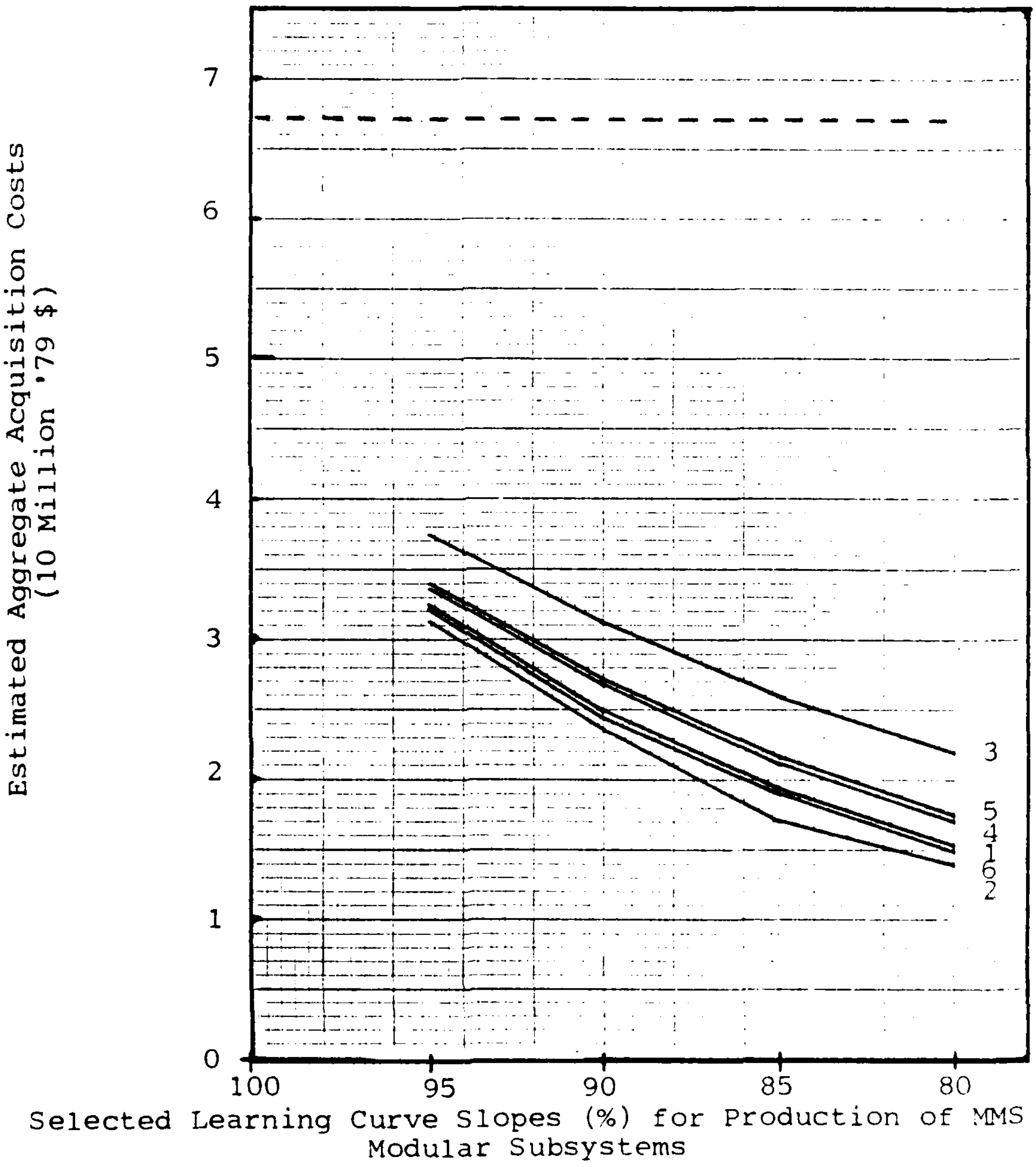


Fig. 6 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate P72-2 Program

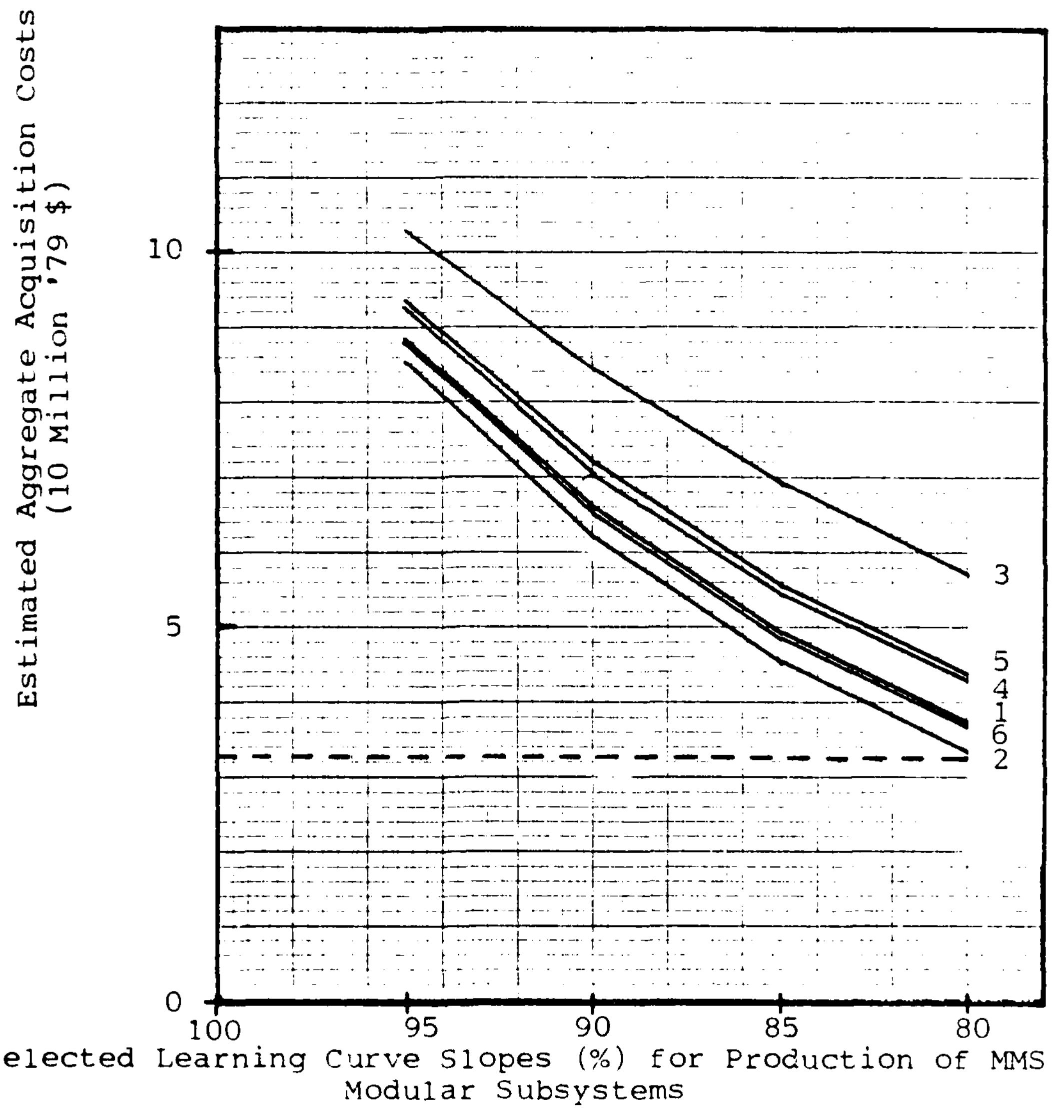


Fig. 7 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate S-3 Program

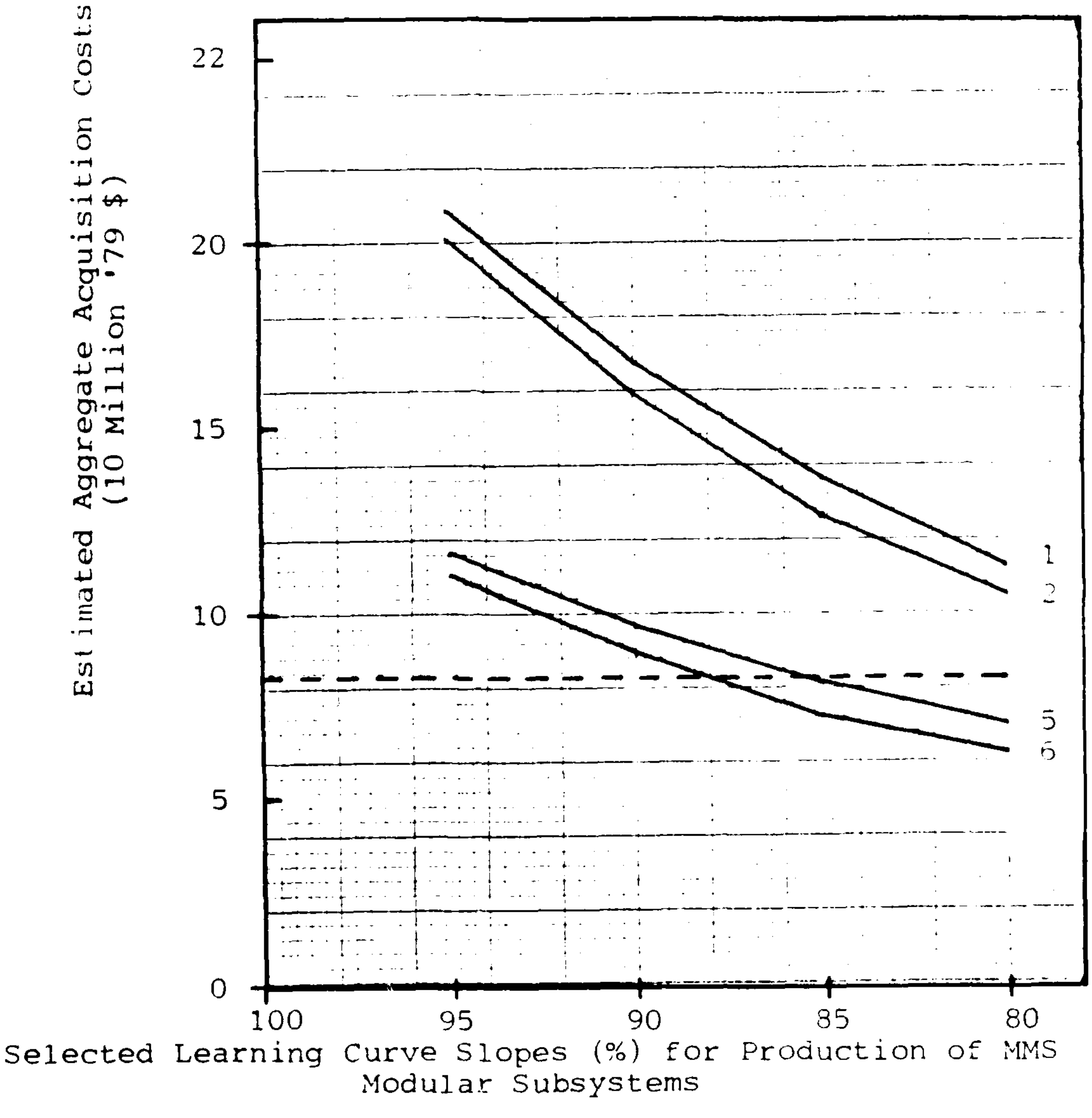


Fig. 8 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate NATO 3 Program

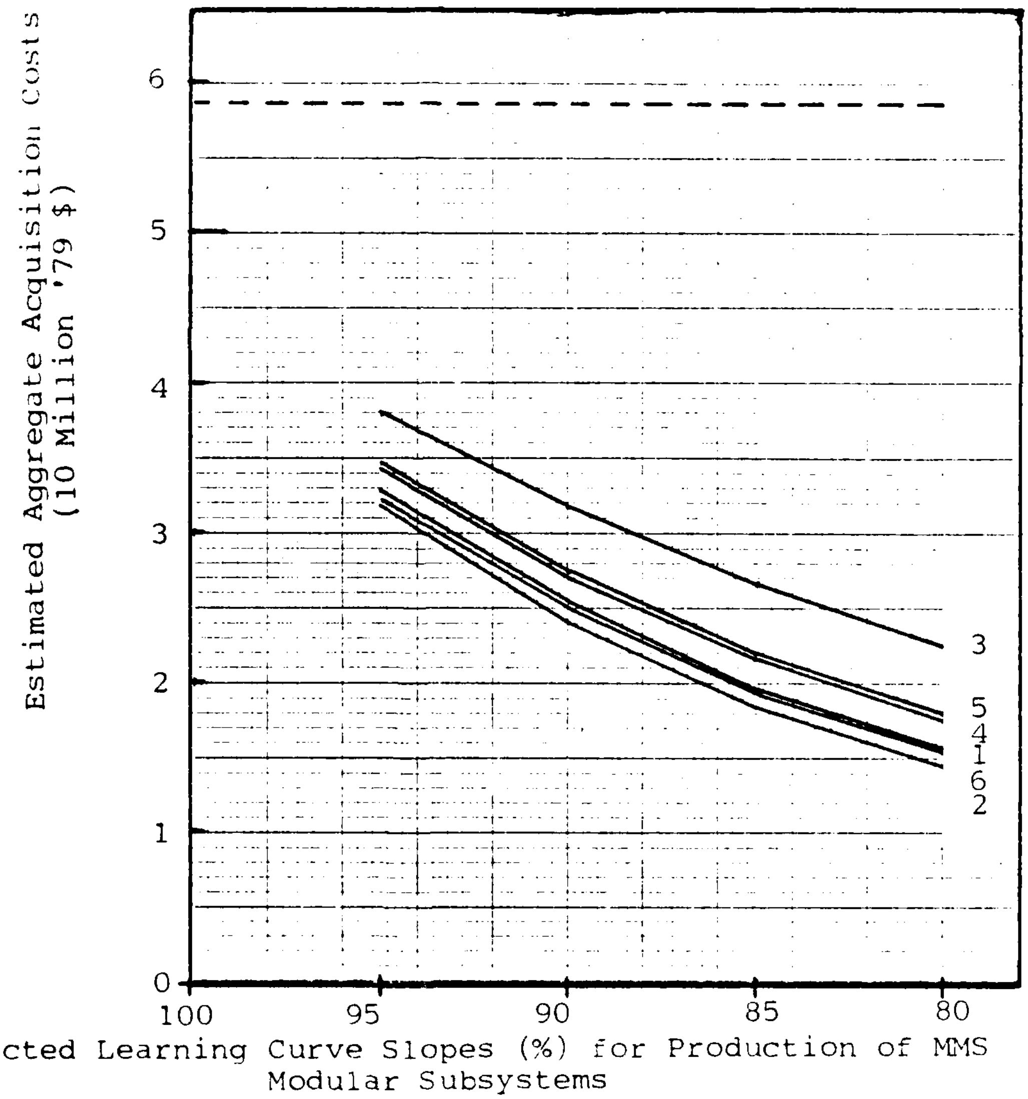


Fig. 9 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate P78-1 Program

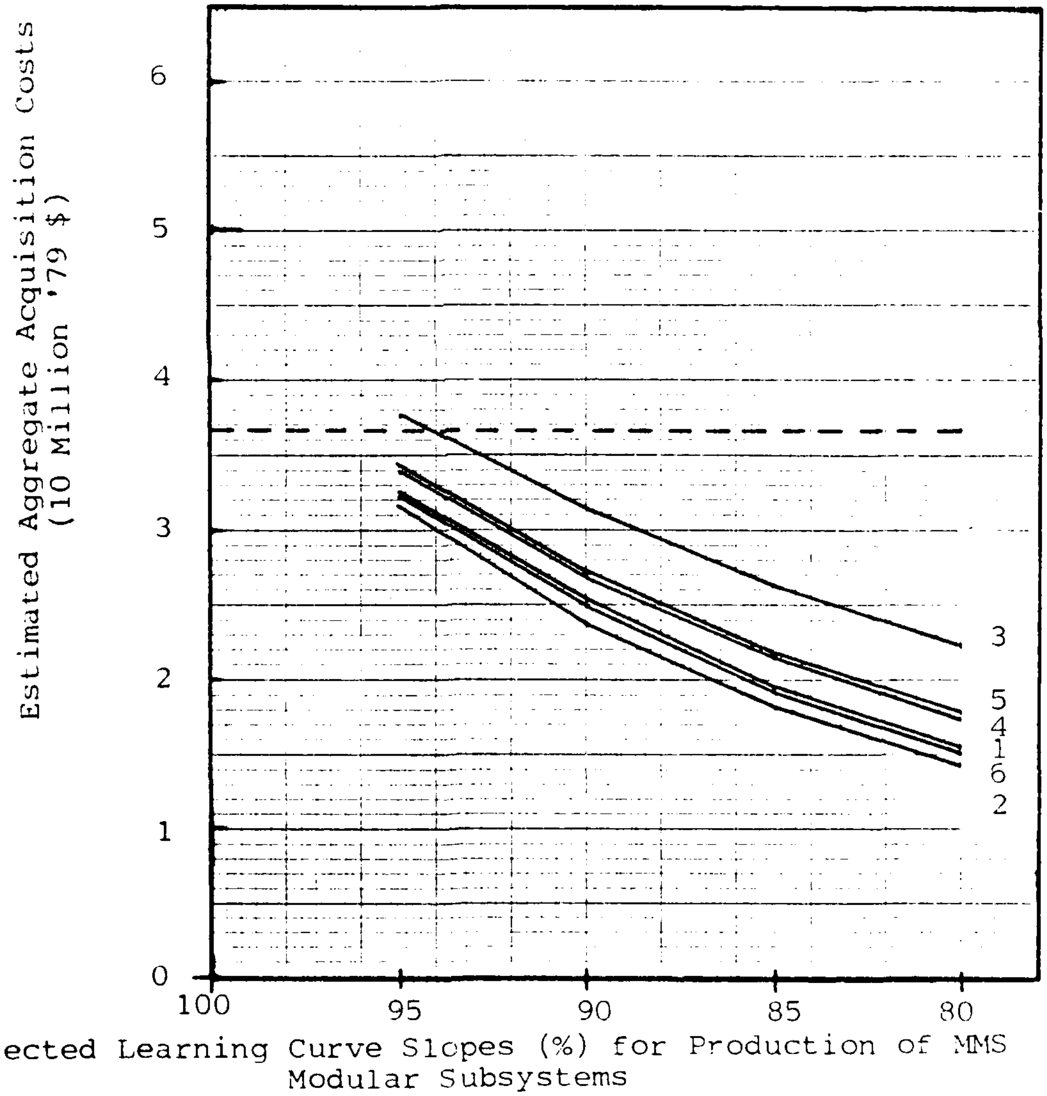


Fig. 10 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate P78-2 Program

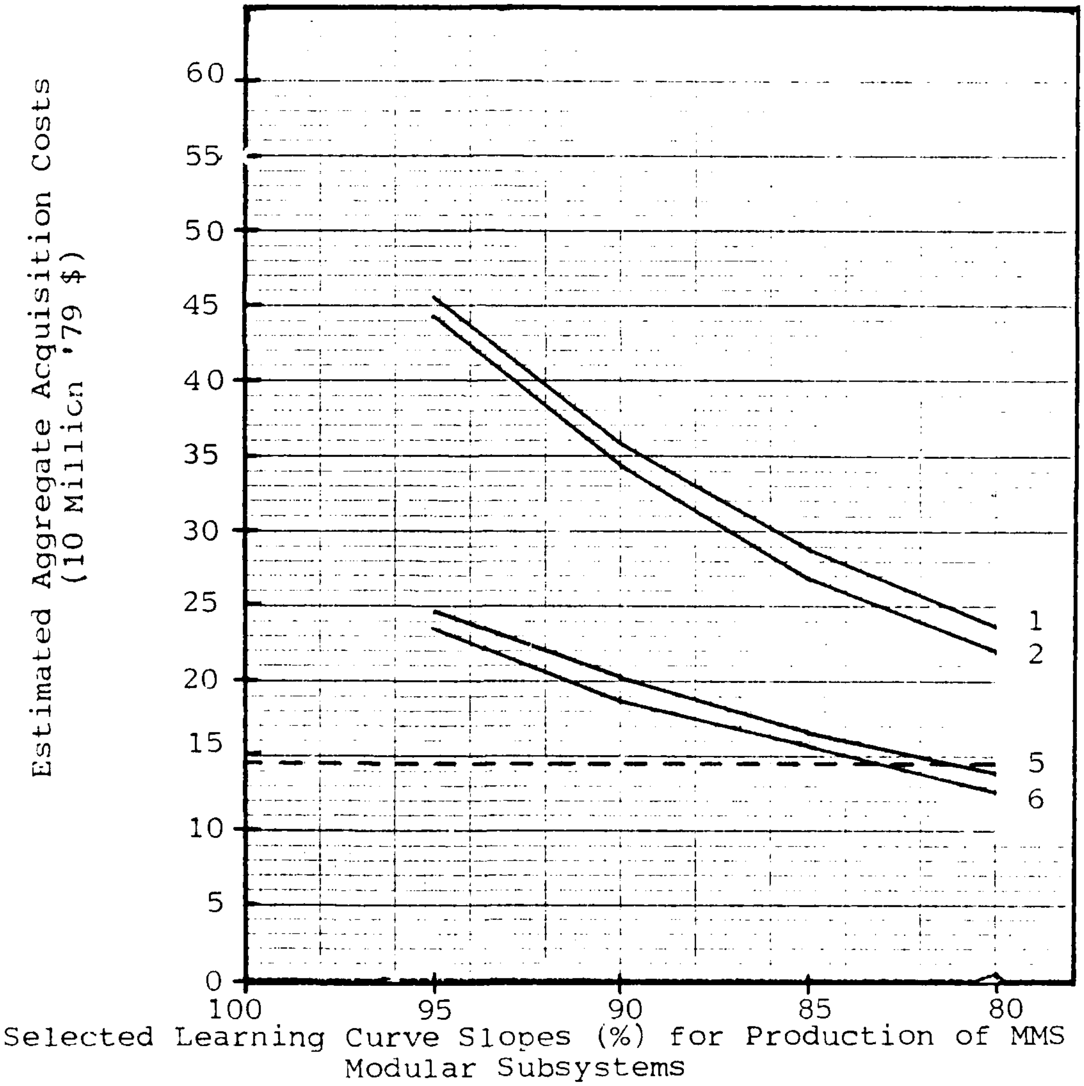


Fig. 11 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate GPS-1 Program

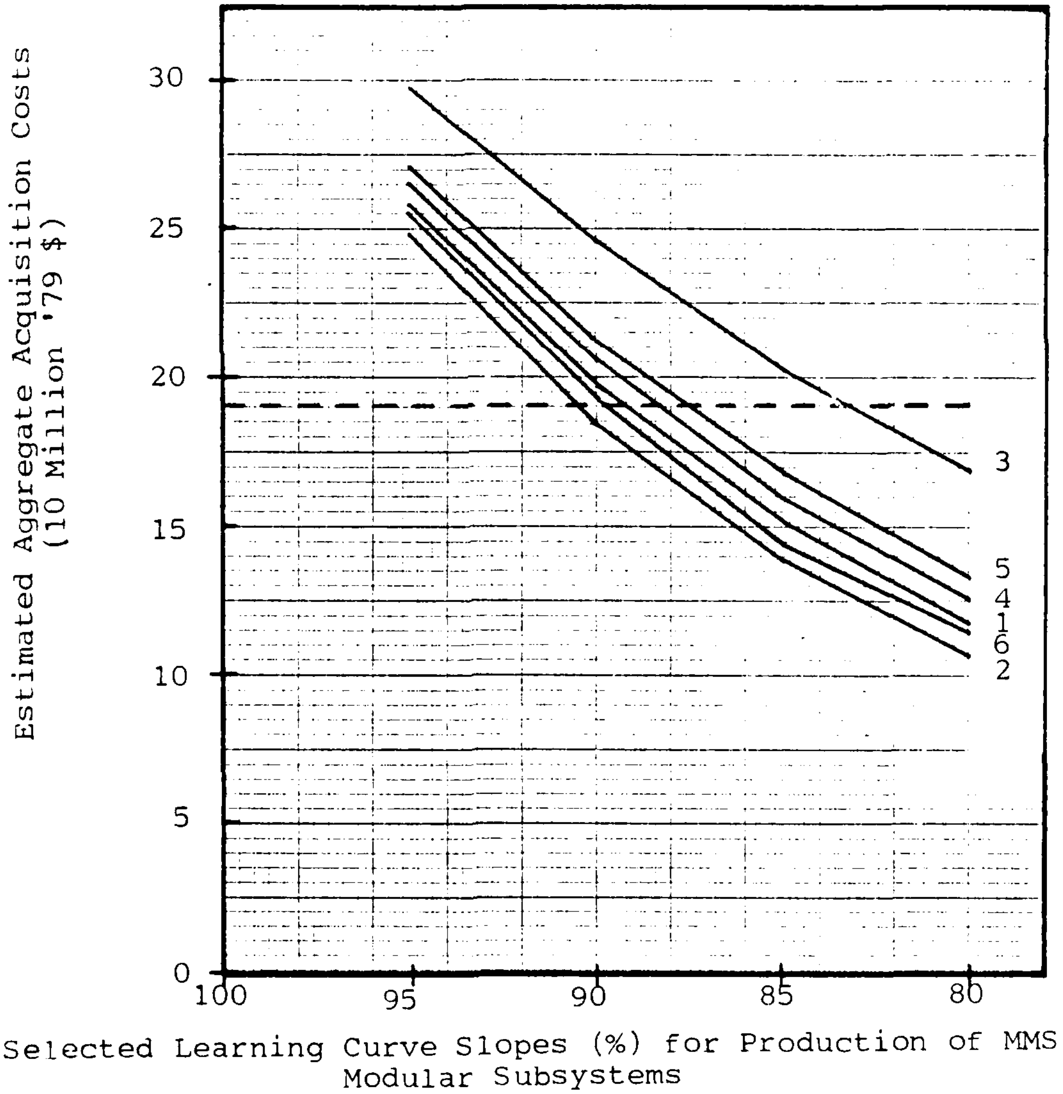


Fig. 12 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate DPS-II Program

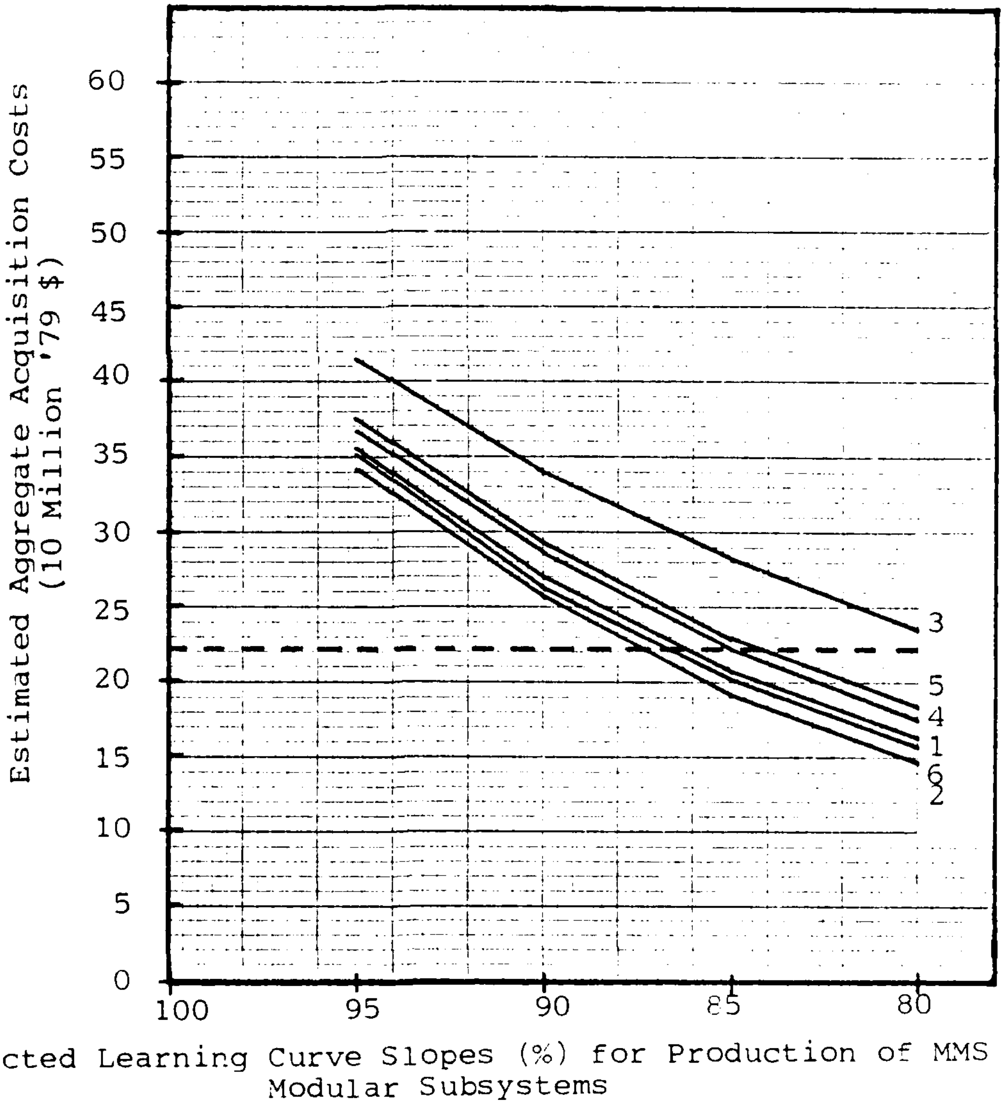
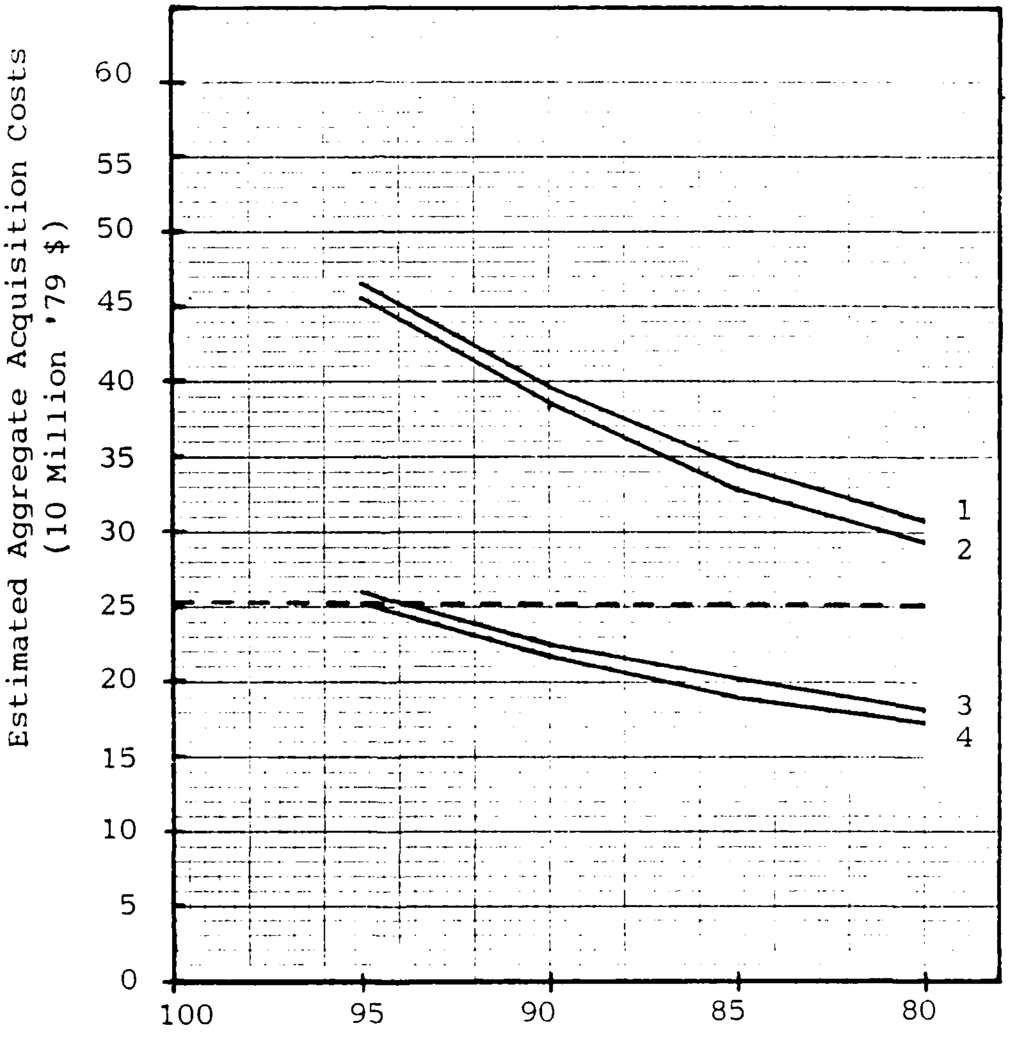


Fig. 13 The Effect of Increased Learning on Aggregate Acquisition Costs for a MMS Surrogate DMSP Program



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).

## Quantity Considerations as a Cost Driver

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.

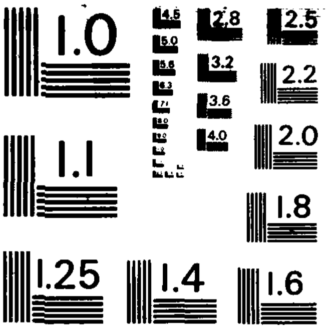
Short-lived (less than four years) satellites, especially the programs with only a few spacecraft, should be considered potential candidates for using the MMS. This fact may be even more attractive for the Air Force since the R & D costs are already sunk and are not being amortized over each program 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 2/2
SPACECRAFT VERSUS MUL..(U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. L M COLE
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: Parametric Cost Estimating Relationships

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

## Normalized Structure, Thermal Control and Interstage

### 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:

   $6820.00 <= X <= 362500.00$

   $68.20 <= \text{weight} <= 725.00$

   $100.00 <= \text{power} <= 900.00$

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:

   $6820.00 <= X <= 362500.00$

   $68.20 <= \text{weight} <= 725.00$

   $100.00 <= \text{power} <= 900.00$

## 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)
   $9.10 <= \text{weight} <= 619.60$
   $25.10 <= \text{power} <= 1640.00$

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)

   $9.10 <= \text{weight} <= 619.60$

   $25.10 <= \text{power} <= 1640.00$

## 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:

$6820.00 <= X <= 362500.00$
$68.20 <= \text{weight} <= 725.00$
$100.00 <= \text{power} <= 900.00$

## 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)
$9.10 <= \text{weight} <= 619.60$
$25.10 <= \text{power} <= 1640.00$

# 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 | | | |
| 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 |

| | 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 |

| | 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 |

| | 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 |
| P78-1 | 31850.695 |
| P78-2 | 31631.948 |
| GPS-1 | 31515.876 |
| DSP-II | 31092.333 |
| DMSP | 28564.111 |
| FLTSAT | 45475.082 |
| CLASSIF | |

AVERAGE COST PER SAT 23491.041

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 |

| | ACQUISITION COST / SAT |
|---|---|
| DSP-I | 23252.853 |
| DSCS-II | 26492.606 |
| 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

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              MMS MODULE COSTS ( '79 K $ )
     LEARNING CURVE SLOPE              0.850
                                # OF                              AVERAGE
          SUBSYSTEM             MODS     NR $           FU $        COST


 STRUCTURE, THERMAL CONTROL &  125    9449.775     1605.756     517.639
     INTERSTAGE(S,TC & I)
    COMMUNICATIONS & DATA      125   12988.919     5851.470    1886.307
      HANDLING (C & DH )
   MODULAR ATTITUDE CONTROL    125   37789.088    10399.483    3352.426
       SYSTEM ( MACS )
  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 125    3899.624     1999.617     644.606
       UNIT ( SC & CU )

          SUBTOTAL                  75694.364    26736.212    8857.215

        PROGRAM LEVEL               35122.185

      AEROSPACE GROUND
      EQUIPMENT ( AGE )             15557.217

     ESTIMATED COMPOSITE            126373.766
      NONRECURRING COST

 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 |

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

AVERAGE COST PER SAT 11933.010

| 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

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

## 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 |

| | 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 | AVERAGE COST PER SAT | 29570.259 |
| P78-2 | 31388.808 | | |
| DSP-II | 30671.463 | | |
| DMSP | 28297.462 | | |
| CLASSIF | | | |

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<br>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 |  |

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                        MMS SUBSTITUTION COMPARISON ( '79 K $ )
LEARNING CURVE                    0.900
                        b=       -0.152             b + 1 =         0.848
                             NONRECURRING
       RATIO                   COMPOSITE        ESTIMATED         ESTIMATED
        OF      # OF         PRORATED COST      COMPOSITE          PROGRAM
       MMS/   UNIQUE  # OF  (PRORATED NR$+      HARDWARE            LEVEL
PROGRAMUNIQS    SATS   MMS   NR$ MSN SPEC)        COST               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

                            COMPOSITE COST                        AGGREGATE
                             PER SURROGATE       COMPOSITE       ACQUISITION
                              (HARDWARE +        PRODUCTION         COSTS
PROGRAM          WEIGHT        PROGRAM)            COST          (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
                                              AVERAGE COST
 P78-1                          26978.504       PER SAT           11093.043
 P78-2                          26759.758

DSP-II                          25625.545
 DMSP                           23668.412

CLASSIF
```

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<br>11.516 | | |
| MMS MODULES LEARNING CURVE SLOPE | 0.950 | b = | -0.0740 |
| | | b+1= | 0.9260 |
| check PM-1 | 0.784<br>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

| PROGRAM | | WEIGHT | AVERAGE COST |
|---|---|---|---|
| BATTERIES | | | |
| 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 |

| | 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 |

| | 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 |

| | 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 |

| | 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 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 | 0.0417 |
| 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<br>11.516 | | |
| MMS MODULES LEARNING CURVE SLOPE | 0.950 | b = | -0.0740 |
| | | b+1= | 0.9260 |
| check PM-1 | 0.784<br>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 |

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

AVERAGE COST PER SAT 20982.760

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 |
| P78-1 | 25122.938 |
| P78-2 | 24904.192 |
| GPS-1 | 26671.346 |
| DSP-II | 24072.960 |
| DMSP | 22155.557 |
| FLTSAT | 43097.287 |
| CLASSIF | |

AVERAGE COST PER SAT 16531.825

## 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 |

| | 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

# Bibliography

1. Baker, John C., M. Wechslter, P.S. Szymanski, Cost Implementations of Methods of Satellite Procurement of the Air Force, Analytic Services, Inc., Sept 1977.

2. Barthelemy, Robert R. and others. "Aerospace Power Systems - A Building Surge," Astronautics and Aeronautics, 17:64-72 (February 1979).

3. Boren, H. E. Jr. and H.G. Campbell, Learning-Curve Tables: Vol I, 55-69 Percent Slopes. Santa Monica: The Rand Corporation, 1970.

4. Cepollina, Frank J. and E.I. Pritchard, Cost Benefits of Multimission Spacecraft (MMS) an On-orbit Shuttle Serviceability, a briefing to John Yardley, The Aerospace Corporation, 9 May 1977.

5. Culp, Robert D. "The NASA Multimission Spacecraft Modular Attitude Control System," Proceedings of the Annual Rocky Mountain Guidance and Control Conference. 313-354. American Astronautical Society, Keystone, CO, February 1979.

6. Ellion, M, Edmund, Assistant Division Manager/Technology Division. Personal Correspondence. Hughes Aircraft Company, El Segundo, CA, 8 August 1983.

7. Final Report, Military Operational Standard Spacecraft Study, Vol. 2, Contract F04701-76-C-0204. TRW Defense and Space Systems Group, Redondo Beach CA, Feb 1977.

8. Finston, R. and L. M. Spicer. "Propulsion Subsystem for the Multi-Mission Modular Spacecraft (MMS)," Proceedings of the Sixteenth Joint Propulsion Conference. AIAA Paper 80-1291. AIAA, New York, 1980.

9. Fiul, Abraham, "Final Report - Servicing the DSCS II with the STS, Vol. II." Report to TRW Systems Group, Contract F04701-74-C-0330. Redondo Beach, CA, September 1975

10. Gilbert, Christi, Business Manager/C & DH Module. Personal Correspondence. Fairchild Space Company, Germantown, MD, 15 August 1983.

11. Haley Jr., J.F. "The Mark II Propulsion Module," Proceedings of the Seventeenth Joint Propulsion Conference. AIAA Paper 81-1411. AIAA, New Yor, 1981.

12. Harris, Elwyn D., Standard Spacecraft Procurement Analysis: A Case Study in NASA-DOD Coordination in Space Programs, PhD Dissertation. Rand Graduate Institute, Santa Monica, CA, May 1980.

13. Knox, Earl, Modular Attitude Control System Program Manager. Telephone Interview. General Electric Space Division, Valley Forge, PA, 3 October 1983.

14. Koscielski, Michael, Resource Analyst/Directorate of Cost Analysis. Telephone Conversations. Space Division, Los Angeles, CA, Jan-Dec 1983.

15. MMS Mission List. Unpublished Chart. NASA, Goddard Space Flight Center, Greenbelt, MD. Undated.

16. Mosher, Larry and Rolland Schreib. "Options for Enhanced Multi-Mission Modular Spacecraft (MMS) Maneuver Capability," Proceedings of the Sixteenth Joint Propulsion Conference. AIAA Paper 80-1292. AIAA, New York, 1980.

17. Mueller, V. C. and D. A. Webb. "Nickel-Cadmium Batteries For The Modular Power Subsystem," Proceedings of the Fifteenth Intersociety Energy Conversion Engineering Conference. 1638-1642. AIAA, New York, 1980.

18. Navy Space Systems Activity, U.S. Space Launch Systems, 2nd Rev. Report No. NSSA-R-20-72-2. Los Angeles: Navy Space Systems Activity, 1 July 1977.

19. 1978 Price Table For Subsystems. Memorandum for Record. NASA/Goddard Resource Analysis Office. Greenbelt, MD. 1978.

20. Purdy, W. Dean, MPS Program Manager. Telephone Interview. McDonnell Douglas Astronautics Company-East, St. Louis, MO, 26 August 1983.

21. P80-3/MMS Compatability Study, Final Report. Saint Louis, MO: McDonnell Souglas Astronautics Company-East, 1976.

22. Report on Active and Planned Spacecraft and Experiments. National Space Science Data Center/World Data Center A For Rockets and Satellites. NSSDC/WDC-A-R&S 79-03. Greenbelt, MD: NASA, 1979.

23. Report on Active and Planned Spacecraft and Experiments. National Space Science Data Center/World Data Center A For Rockets and Satellites. NSSDC/WDC-A-R&S 81-10. Greenbelt, MD: NASA, 1981.

24. S-700-11. Multimission Modular Spacecraft (MMS) External Interface Specification and User's Guide, c.3.(1981) MMS Project Office. Goddard Space Flight Center, Greenbelt, MD, February 1978.

25. Spacecraft Subsystem Normalization Criteria. Unpublished file. Directorate of Cost Analysis, Space Division, Los Angeles, CA, undated.

26. Spacecraft Subsystem Numerical Normalization Factors. Unpublished file. Directorate of Cost Analysis, Space Division, Los Angeles, CA, undated.

27. Standardized Spacecraft Study, Battelle Columbus Laboratories, 6 November 1978.

28. Stevens, John R. and Alfred L. Vampola. "Description of Space Test Program P78-2 Spacecraft and Payloads." Report to Space and Missile Systems Organization. AFSC, Los Angeles, CA, 31 October 1978.

29. "The Multimission Modular Spacecraft (MMS) and the SMM Repair Mission," A briefing presented to the AXAF/STS Utilization Conference, April 21, 1982. NASA, April 1982.

30. The Standard for Performance and Economy, Multimission Modular Spacecraft. Product Brochure. Greenbelt, MD, 1977.

31. Titman, Martin. Standard Communications and Data Handling Subsystem. Product Brochure. Fairchild Space and Electronics Company, Germantown, MD, no date.

32. TRW Space Log 1978/79. TRW Defense and Space Systems Group. Redondo Beach, CA: 1979.

33. TRW Space Log 1980. TRW Defense and Space Systems Group. Redondo Beach, CA: 1981.

34. Unmanned Spacecraft Cost Model, Fifth Edition, Directorate of Cost Analysis/Space Division (AFSC), Los Angeles, CA, June 1981.

35. USCM Historical Subsystem Weight Composition. Unpublished file. Directorate of Cost Analysis, Space Division, Los Angeles, CA, undated.

36. Weinrab, Marius. "Study of the Astrophysics Explorer Missions - A Briefing," 29 December 1978.

37. X-700-75-140, Low Cost Modular Spacecraft Description. Technical Information Division/Goddard Space Flight Center, Greenbelt, MD, May 1975.

## Related Sources

Accounting Records, MMS Project/NASA Goddard Space Flight Center, Greenbelt, MD. 13 January 1983.

*Analysis of Utilization of Space Shuttle*, ECO Systems International, Inc., June, 1978.

Augenstein, B.W., D. Dreyfuss, A.G. Parish, Bunch Launch, Bunched Acquisition, and Workgrounds - Elements of Alternative Spacecraft Policies, Contract F49620-77-C-0023, Rand Corporation, Santa Monica, CA, October 1979.

Pritchard, Ernest I., BRAVO (Business Risk and Value of Operations in Space) Economic Study of Landsat Follow-on - Final Report, Contract NAS5-23592, The Aerospace Corporation, El Segundo, CA, January 1977.

Coleman, J.E. *Multimission Modular Spacecraft*. Product Brochure. St. Louis, MO, McDonnell Doublas Astronautics Company-East, no date.

Cost Savings Assessment For The Block Purchase of MMS Hardware. Briefing by the Resource Analysis Office NASA/Goddard Space Flight Center, Greenbelt, MD, May 6, 1981.

Davis, Robert E. and Ernest I. Pritchard, "BRAVO Economic Study of Landsat Follow-on - Final Briefing," The Aerospace Corporation, El Segundo, CA, January 1977.

de Leon, Peter. *The Evaluation of Technology R & D: A Continuing Dilemma*, Rand Corporation, Santa Monica, CA, August 1981.

Dryden, J. A. and J. P. Large. *A Critique of Spacecraft Cost Models*, Contract F49620-77-C-0023, Rand Corporation, Santa Monica, CA, September 1977.

Elson, Benjamin M. "Solar Array Capabilities Increase," *Aviation Week and Space Technology*, 95:50-55 (September 13, 1971).

Final Report, Military Operational Standard Spacecraft Study, Vol. 1, Contract F04701-76-C-0204. TRW Defense and Space Systems Group, Redondo Beach, CA, February 1977.

Greenwell, T. J. "Testing Programs For The Multimission Modular Spacecraft," *Proceedings of the Fourth Aerospace Testing Seminar*. 69-74. Prospect, IL: Institute of Environmental Sciences, 1978.

Harris, Dale W. "The Modular Power Subsystem for the Multimission Modular Spacecraft," *Proceedings of the 13th Intersociety Energy Conversion Engineering Conference*. 9-19. San Diego, CA: August 1978.

Kichak, Robert A. "Standard Power Regulator for the Multi-Mission Modular Spacecraft." *Proceedings of the Fourteenth Intersociety Energy Conversion Engineering Conference*. 1350-1355. Washington, D.C.: American Chemical Society, 1979.

LF-0 - An Economic Study of Landsat Follow-on, A Repairable Satellite. NASA Publication. Goddard Space Flight Center. Greenbelt, MD, April 1978.

Logan, F. Michael, NASA/Assistant MMS Project Manager. Telephone Conversations. Goddard Space Flight Center, Greenbelt, MD, January-December 1983.

MACS Modular Attitude Control System - For the Multimission Modular Spacecraft and Other Applications. Product Brochure. General Electric Corporation, Valley Forge Space Center, PA: no date.

Menton, Martin, NASA/Deputy for Resources MMS Project. Telephone Conversations. Goddard Space Flight Center, Greenbelt, MD. April-May 1983.

Multimission Modular Spacecraft (MMS) Block Buy Cost and Potential Savings. Memorandum for Record. Resource Analysis Office/Goddard Space Flight Center, Greenbelt, MD, 16 January 1981.

*Multimission Modular Spacecraft Subsystem Modules Cost Comparison*. Resource Analysis Office/Goddard Space Flight Center, Greenbelt, MD, April 29, 1983.

Parish, G. and W. Sollfry, A Preliminary Analysis of the Effects of Workarounds on Space Systems Performance and Procurement Requirements - A Proposal, Contract F49620-77-C-0023, Rand Corporation, Santa Monica, CA, March 1980.

Pritchard, Ernest I., BRAVO (Business Risk and Value of Operations in Space) Economic Study of Landsat Follow-on - Final Report, Contract NAS5-23592, The Aerospace Corporation, El Segundo, CA, January 1977.

Pritchard, Ernest I. Final Report Standard Mission Destination for Sun Synchronous Satellites Study, Aerospace Report No. ATR-79(7668-01)-1, The Aerospace Corporation, El Segundo, CA, no date.

Rogers, R. Timothy. "Digital Multiplexed Spacecraft Communications and Data Handling Subsystem," _Proceedings of the Third Digital Avionics Systems Conference_. 96-99. New York, NY: IEEE, November 1979.

Stope, Don, NASA Resource Analyst/Department of Cost Analysis. Telephone Conversations. Goddard Space Flight Center, Greenbelt, MD, 19 May 1983.

# VITA

Major Lawrence M. Cole was born to an Air Force family on 5 April 1958 in Rio de Janeiro, Brazil. He graduated from Burges High School in El Paso, Texas in 1966 and attended the New Mexico Military Institute for one year. He received his Bachelor of Science degree from the U.S. Air Force Academy in June 1971. He completed pilot training and received his wings in June 1972. He then served as a line C-130 pilot at Langley AFB, Virginia, flying in both the South East Asian and European theaters. His next assignment was to Hq. 21st A.F. where he served as an Airlift Director for C-130 operations. During this tour, he earned the Master of Business Administration degree from Southern Illinois University. This assignment was followed by a tour with the 28th Bombardment Wing (H). Major Cole served as a B-52H aircraft commander, flight instructor, and evaluation pilot with the 28th WB(H) until entering the School of Engineering, Air Force Institute of Technology, in May 1982.

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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.