AD-A013 078

DOD SPACE TRANSPORTATION SYSTEM (STS) COMMAND AND CONTROL DATA SYSTEM STUDY. VOLUME V. DOD SHUTTLE MISSION SIMULATOR REQUIREMENTS ANALYSIS RESOURCE ACQUISITION SCHEDULES

D. K. Dorman

Philco-Ford Corporation

Prepared for:

Space and Missile Systems Organization

30 October 1974

SAMSO-TR 75-40

VOL V

PHO-TR591

224111

ADA013078

DOD SPACE TRANSPORTATION SYSTEM COMMAND AND CONTROL DATA SYSTEM STUDY FINAL REPORT

Volume V - DOD Shuttle Mission Simulator Requirements Analysis Resource Acquisition Schedules

Philco-Ford Corporation
Aerospace and Communications Operations
WDL Division, Houston Operation
1002 Gemini Avenue
Houston, Texas 77058

30 October 1974

Final Report for Period 1 February 1974 - 30 October 1974

Contract F04701-74-C-0260

Prepared for

UNITED STATES AIR FORCE SPACE AND MISSILE SYSTEMS ORGANIZATION

El Segundo, California

FOREWORD

This study was performed for the United States Air Force Space and Missile Systems Organization (SAMSO) in accordance with the statement of work for the DOD Space Transportation System CCDS Study. It was performed during the period of 1 February to 30 October 1974 under contract F04701-74-C-0260.

The complete set of volumes comprising this report includes:

- Volume I - Study Summary
- Volume II - System Requirements Analysis Definition
- Volume III - Command and Control Data System Concept Development
- Volume IV - AFSCF/Shuttle Mission Control Center Requirements Analysis
- Volume V - DOD Shuttle Mission Simulator Requirements Analysis and Resource Acquisition Schedules
- Volume VI - Secure Data and Equipment Handling

This study was performed under the direction of DOD/SAMSO. Aerospace Corporation provided assistance to SAMSO. This study was performed by Philco-Ford's Western Development Laboratories Division, Philco Houston Operation with key participation of personnel from Philco-Ford's Satellite Control Facility Operation at Palo Alto.

Donald K Dorman

D. K. Dorman, USAF Study Manager
Philco-Ford Corporation

This final report has been reviewed and is approved. Readers are cautioned that the material presented herein represents the findings and conclusions of the Philco-Ford Study Group and does not necessarily define a DOD/SAMSO position, policy, or decision.

Robert W. Lindemuth

Maj. R. Lindemuth, USAF Study Monitor

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

LIST OF FIGURES

LIST OF TABLES

SECTION 1

INTRODUCTION

1.1 PURPOSE

The purpose of this study task was to 1) analyze the training requirements defined by the National Aeronautics and Space Administration (NASA) for Shuttle flight and ground crews, 2) identify and evaluate those simulation facilities planned by NASA to be used to train these personnel, 3) evaluate the proposed mission frequency and requirements of both the Department of Defense (DOD) and NASA as they affect training, 4) provide cost and schedule estimates for the DOD SMS costs to be based on NASA budgetary figures), and 5) provide reference floor plan layouts for the DOD SMS. This study was in part prompted by the recommendation that both NASA and DOD flight and ground crew personnel be trained using the NASA Lyndon B. Johnson Space Center (JSC) simulation facilities.

Since the joint training philosophy appears qualitatively sound and viable, this study is being used to quantify the requirements of both agencies, and to make system recommendations which will ensure that adequate training of NASA/DOD crews can be obtained. These findings have enabled Philco-Ford to provide preliminary recommendations which will allow the establishment of an adequate and optimized training philosophy to facilitate the common and unique needs of both agencies.

The relationship of this task and this volume to the other study tasks and volumes of the final report is indicated in Figure 1-1.

1.2 SCOPE

The purpose of the SMS study task was accomplished by performing the following:

A. Identify the Shuttle flight crew categories, and evaluate the selection criteria and training requirements for each category based on NASA guidelines.

B. Evaluate the projected usage of the NASA Shuttle Mission Simulator (SMS) for training NASA flight and ground crews.

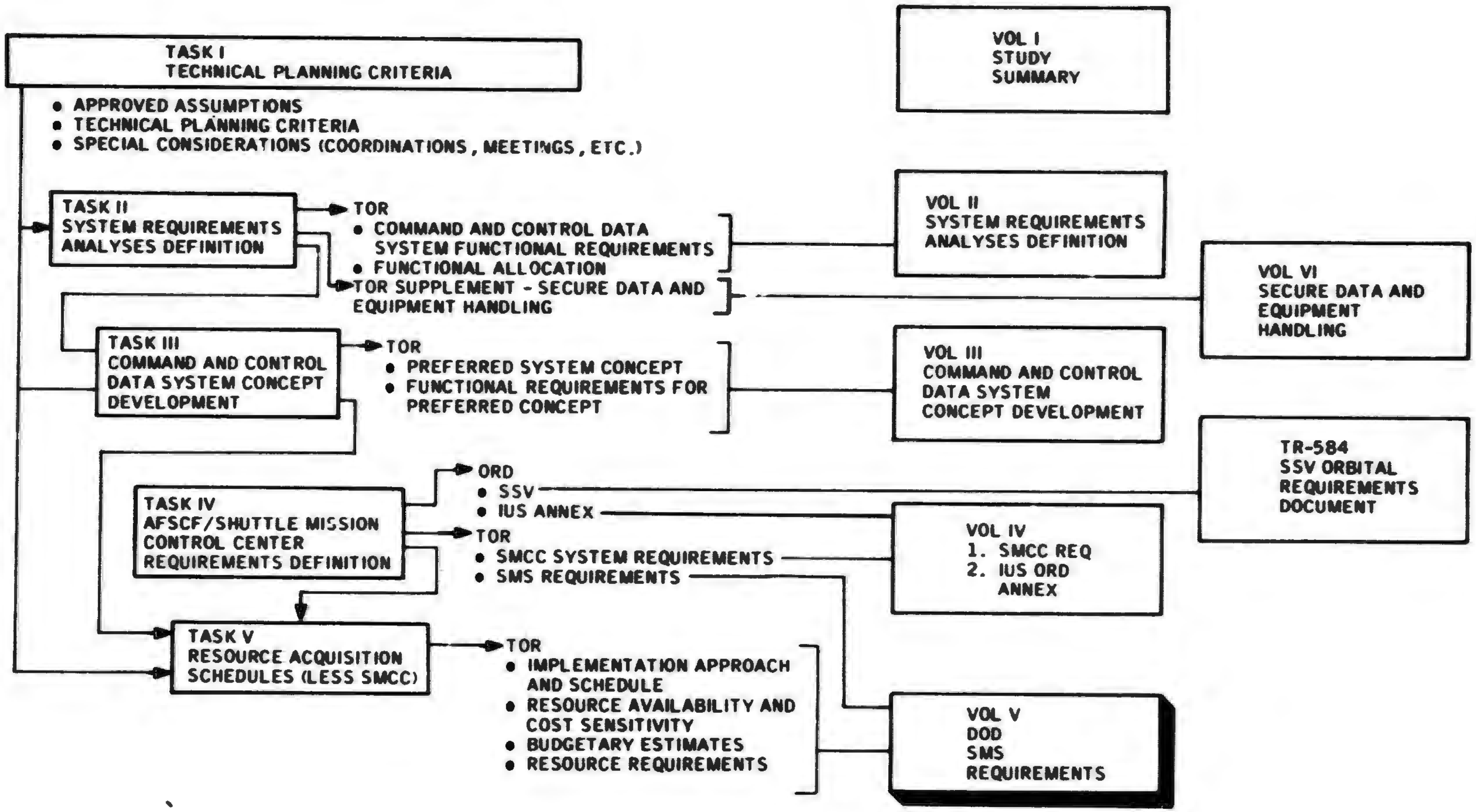


Figure 1-1 Task Interrelationships

C. Determine the impact of a phase-in of DOD flight and ground crews for training on the NASA SMS in order to define simulator saturation timeframes.

D. Define DOD flight controller training requirements, and determine a Mission Control Center Simulation System (MCCSS) concept to be used for training these personnel.

E. Evaluate the following three simulator concepts, and recommend a DOD deployment concept:

- One Fixed and Motion Based Crew Station SMS (2+4) at JSC

- One 2+4 SMS at JSC and Satellite Test Center (STC)

- One 2+4 SMS at JSC and one Fixed Base Crew Station (FBCS) SMS (+4) at STC.

F. Develop cost estimates based on NASA budgetary figures for the simulator deployment concepts above.

G. Provide an implementation approach for phase-in of the DOD simulator based on present NASA simulator procurement plans.

1.3 GROUNDRULES AND ASSUMPTIONS

The following are the groundrules and assumptions used in the SMS analysis:

A. A DOD simulator(s) capability will be required at the STC.

B. Simulator(s) and associated software will be selected from those developed by NASA.

C. The contractor will develop an estimate of the flight control personnel population (including growth and attrition) that would be required for mission support.

D. A flight crew of four each commander/pilot/mission specialist (12 total) is assumed.

E. Costing of various simulator deployment concepts will be based on NASA budgetary figures.

F. The JSC and STC computers will:

- Utilize the same program language
- Accept computer loads, data tapes, etc. generated by the other agency.

G. JSC simulator usage rate will be considered saturated at 2000 machine hours/year for the motion based crew station (MBCS) and 2500 machine hours/year for the FBCS.

H. DOD annual flight rate is 20.

I. Procurement of a NASA-developed simulator(s) will include the associated input/output (I/O) software.

J. SMS configuration control will be the joint responsibility of the Mission Operations Directorate (MOD) Simulation Branch and NASA.

SECTION 2

DOD TRAINING REQUIREMENTS DEFINITION

2.1 TRAINING REQUIREMENTS AND TRAINING SYSTEM RESOURCES PLANNED BY NASA

The bulk of flight crew simulation training will be accomplished on the SMS (known as a full mission simulator), which will be used to train upper deck crews for both NASA and DOD missions. The SMS will simulate the following mission phases: launch, on-orbit operations, deorbit, and entry and landing. The NASA SMS concept consists of one central computer facility driving two crew stations; i.e., one forward crew station comprising commander and pilot stations on a motion base; and an entire upper flight deck comprising commander, pilot, mission specialist, and payload specialist stations with a fixed base. The motion base crew station (MBCS) has 7 degrees of freedom (three translational, three rotational and an extended pitch) for full aerodynamic flight and launch phase simulation fidelity. In addition, the MBCS has a full forward visual simulation. The fixed base crew station (FBCS) is used for full fidelity simulation of payload operations and manipulation. The FBCS will have both a forward and aft visual simulation system.

This configuration for the SMS is referred to as "2+4." It is capable of being interfaced with the SMCC for totally integrated mission simulations involving the flight crew and flight controller personnel.

The integrated mission simulations (viz: SMS/SMCC) are a vital portion of the flight crew and flight controller training. This welds the flight crew into a mission team where each man is able to relate his tasks to each member of the flight crew, and accustoms the individual members to working together as a unit. In addition, during the integrated mission simulations, the flight controllers will be trained through integrated network simulations involving all crew members. This prepares the flight crew and flight controllers to work as a coordinated team in analyzing and correcting malfunctions or anomalies which may occur during the course of the mission.

2.1.1 <u>Mission Training</u>. The pilots will receive extensive training time (less than Apollo, however) using high fidelity ground simulators and a modified aircraft for the approach and landing phase. The mission specialist and payload specialist who will be located in the upper flight deck will receive their most important training through utilization of the SMS.

2.1.1.1 Shuttle Mission Simulator (SMS). The NASA SMS, which comprises MBCS's and FBCS's, is scheduled to be ready for training approximately 1 year before the first vertical flight test (VFT). This allows for some delay in its training readiness date and a lower than predicted simulator training efficiency, a situation that often occurs when initially operating a new sophisticated simulation facility. The first firm training requirements will be four or more flight test pilots and will commence 6 months prior to the VFT mission.

The SMS will accommodate training for all crew members located in the upper deck for NASA and DOD missions. It will simulate the complete mission from launch, on-orbit operations, deorbit, entry and landing. The motion base will provide 6 degrees of freedom for aerodynamic flight phase simulation fidelity plus an extended pitch range for launch phase simulation. Payload operations and manipulation will be simulated as part of the full fidelity FBCS.

The simulation training curriculum is expected to be like Apollo but not as extensive. Initial training will progress from systems to part-task to integrated - perhaps a 40:40:20 ratio. Proficiency training will consist almost exclusively of part-task and integrated simulations. Supplementary training, such as stowage and manipulative body skills, will not generally be incorporated into the simulator; past experience has shown quite clearly this is better accomplished by the use of trainers (mockups). Although not designed primarily as a systems or procedures verification device, the SMS should be an excellent tool for this since malfunction training will be a very important aspect of simulation training. The initial checkout and proficiency training requirements for each crew member are contained in tables 2-1 and 2-2.

2.1.1.2 Shuttle Training Aircraft (STA). The STA role and use during the operational missions will be very similar to that for the Flight Test Program. The same aircraft (modified to simulate the aerodynamics and handling characteristics of the Orbiter) will be utilized to supplement the SMS for the approach and landing phase. The training curriculum will vary from the Flight Test Program in that more emphasis will be put on instruments, night and weather approaches, and more practice at the designated prime and alternate recovery fields. Training will also differ to the extent that flight characteristics are modified due to fuel and payload conditions during the landing phase. Close-in training will be tailored to the type of mission to be flown (payload, landing sites).

TABLE 2-1

SHUTTLE MISSION SIMULATOR TRAINING SUMMARY INITIAL CHECKOUT HOURS

	COMMANDER	PILOT	MISSION SPECIALIST	PAYLOAD SPECIALIST	STATION M OR F
BASIC SYSTEMS	30	30	50		F
LAUNCH AND ABORT	30 10	10 10			M F
RENDEZVOUS AND DOCKING	30 10	10 10			M F
REMOTE MANEUVERING SYSTEM	20	40	10		F
ENTRY	15 5	5 5			M F
APPROACH AND LANDING	40 10	20 10			M F
PAYLOAD - SYSTEMS	10	10	40	20	F
- OPERATIONS		10	50	30	F
FERRY	10	10	—	—	M
TOTALS	220	180	150	50	

NOTES:
1. INTEGRATED SIMS INCORPORATED IN TOTAL HOURS
2. HOURS BASED ON A CREW CAPABILITY FOR ALL MISSIONS EXCEPT EVA
3. M = MOVING BASE; F = FIXED BASE
4. DURING INTEGRATED SIMS IT IS ASSUMED THAT THE COMMANDER AND PILOT WILL PRIMARILY TRAIN IN THE FIXED BASE CREW STATION (THUS THE DOUBLE ENTRIES UNDER CERTAIN MISSION PHASES)

TABLE 2-2

SHUTTLE MISSION SIMULATOR TRAINING SUMMARY RECURRING HOURS PER ANNUM

	COMMANDER	PILOT	MISSION SPECIALIST	PAYLOAD SPECIALIST	STATION M OR F
BASIC SYSTEMS			10		F
LAUNCH AND ABORT	30	10			M
	10	10			F
RENDEZVOUS AND DOCKING	30	10			M
	10	10			F
REMOTE MANEUVERING SYSTEM		40	20		F
ENTRY	15	5			M
	5	5			F
APPROACH AND LANDING	40	20			M
	10	10			F
PAYLOAD - SYSTEMS			20	20	F
- OPERATIONS		10	50	30	F
FERRY					M
TOTALS	150	130	100	50	

NOTES:
1. PAYLOAD SPECIALIST OR EXPERIMENTS ASSUMED DIFFERENT FOR EACH MISSION AND ONE PAYLOAD SPECIALIST ONBOARD FOR EACH TWO MISSIONS
2. DURING INTEGRATED SIMS IT IS ASSUMED THAT THE COMMANDER AND PILOT WILL PRIMARILY TRAIN IN THE FIXED BASED CREW STATION (THUS THE DOUBLE ENTRIES UNDER CERTAIN MISSION PHASES)
3. M = MOTION BASE CREW STATION; F = FIXED BASE CREW STATION

The STA configuration concept is to simulate only the crew commander's position. This is the most feasible concept from both a cost and complexity basis, i.e., modifying the left seat (student position) to include as many of the Shuttle controls and displays as practical and installing a prototype Shuttle avionics package.

Like the ALT program, the majority of STA training flights will take place from the designated "clear air space" training field. Flights to the recovery area will occur for experienced pilots engaged in proficiency flights to allow several approaches and landings at the prime and alternate recovery fields. Present plans are to deploy the STA, as necessary, for initial and proficiency crew training at Ellington and Patrick Air Force Bases, and to the John F. Kennedy Space Center (KSC) and Vandenberg Air Force Base (VAFB) for prime crew premission training.

The importance of regularly flying the STA is directly related to the individual pilot's opportunity to fly the actual flight vehicle. Six Shuttle missions per year are not sufficient to maintain approach and landing proficiency. Therefore, it has been ascertained that the STA proficiency requirements goal will be 4 hours per month. Although this is a minimal amount, it may not be possible to have each pilot of a large pilot cadre routinely receive more than 50 hours per year in the STA if the available fleet is limited to two. The STA will accommodate one student at one time. The aircraft per annum availability is estimated to be approximately 300 to 400 hours initially, and 700 to 800 hours after program maturity.

In order to minimize but achieve the STA flight training requirements and to avoid procurement of a large number of STA's, it is required that judicious planning of simulation training tasks be accomplished on the simulators to proportion as much of the training as possible to the SMS.

Typical STA training missions will consist of the safety pilot (aircraft commander) climbing to approximately 30,000 feet; the student updating the inertial system, using the same technique and equipment used in the spacecraft; and flying a power-off high energy landing approach to the designated airfield, usually followed by a "go around." Emphasis will be put on making approaches to all prime and alternate landing fields in conjunction with various initial mission conditions, such as navigation dispersions and, in a few cases, poor weather conditions. The training curriculum will include a few night approaches. Systems malfunctions will not generally be simulated other than those directly affecting handling qualities or flight control modes.

2.1.2 Part-Task Simulators. The planned training requirements on part-task simulators will be kept to a minimum since they play a primary role in procedures development. Their advantages for training are in early availability, in the specialized and unique simulator experience they provide, and in the comparative economy of "catching up" newly assigned pilots with more experienced crew members.

2.1.2.1 Shuttle Procedures Simulator (SPS). The SPS will initially emphasize displays, controls, and crew procedures for software management during rendezvous and navigation. It is expected that this simulator will progress from a functional to a more flight hardware-oriented simulation as the program matures and avionics hardware becomes available. During the operational phase of the Shuttle Program, the SPS primarily will provide basic procedural training in the more significant flight tasks to new Shuttle pilots before advancing to the more comprehensive full mission training utilizing the SMS. The salient features of the SPS will be early availability for procedures development and a certain amount of training support for the Flight Test Program and the operational missions.

2.1.2.2 Orbiter Aeroflight Simulator (OAS). After completion of the Flight Test Program, the OAS will be updated to provide supplementary training to the SMS, primarily for launch, launch abort, entry and ferry operations. The update will proceed immediately upon completion of the flight testing of vehicle Nos. 1 and 2, unless a significant test program for any of the subsequent Orbiter vehicles is definitely planned. Because it will closely duplicate the commander and pilot stations and include a moving base and visual system, it conceivably could be utilized as the forward crew station for a second SMS.

2.1.2.3 Other Simulation Facilities. It is expected that the Shuttle pilots will utilize the JSC Shuttle Avionics Integration Laboratory (SAIL) facilities and the OAS simulator. The actual use of each will depend upon their training value, need for astronaut involvement in systems and procedures verification, and largely upon the relative readiness of the dedicated training simulators described in the above paragraphs to support the training requirements. Some consideration and study has been directed toward application of the SAIL to a full time flight crew mission simulator if the launch frequency demands a second SMS. Such commitments will obviously require consideration of remaining requirements for systems integration.

2.1.3 Trainers and Special Facilities. High fidelity trainers (mockups) will provide the crew skills in such areas as extra-vehicular activity (EVA) and intravehicular activity (IVA), stowage, housekeeping, i.e., sleeping, eating, entertainment, elimination, ingress-egress, operation of hatches, airlock operations, and scientific equipment operations. The principal use of the trainers will be for mission specialist EVA training, and for the payload specialist operation from the Sortie Laboratory. As a minimum, to provide the most complete possible crewmen training, full scale one-g trainers representing the upper flight deck, lower deck (crew quarters), payload laboratory (Sortie Laboratory) and certain partial mockups for use in a zero-g aircraft and Water Immersion Facility (WIF) will be utilized. The full scale mockups will be tied into the SMS and the Mission Control Center (MCC) much like Skylab.

2.2 NASA'S ASSESSMENT OF FLIGHT CREW TRAINING REQUIREMENTS

Philco-Ford concurs with the requirements criteria established by NASA for the selection and training of their flight crew cadre. The criteria are defined and evaluated in the following paragraphs in order to establish the baseline to be used in estimating the DOD flight crew selection and training criteria, and potential simulator loading during calendar years 1978 through 1991.

2.2.1 Crew Nomenclature and Duties. The Space Shuttle flight crew will consist of four principle categories: 1) commander, 2) pilot, 3) mission specialist, and 4) payload specialist. The following is a brief summary of the responsibilities for each crew category:

A. Commander. In command of the mission and responsible for the overall space vehicle, personnel, payload flight operations, and vehicle safety. Proficient in all phases of vehicle flight; manipulator; docking; and subsystem command, control, and monitor operations. Knowledgable of payload and payload systems as they relate to flight operations, communication requirements, data handling, and vehicle safety.

B. Pilot. Duties essentially equivalent to those of the commander. Second in command, operates the manipulator, backup EVA crewman.

C. Mission Specialist. Responsible for interfacing of payload and Orbiter operations. Proficient in vehicle and payload subsystems, flight operation, and payload communications data management. Performs EVA. *NOTE: Certain missions may require more than one mission specialist.*

D. Payload Specialist. Responsible for the applications, technology, and science payload/instrument operations. Detailed knowledge of payload instruments, operations, requirements, objectives, and support equipment. *NOTE: Certain missions may require more than one payload specialist.*

Table 2-3 shows a more detailed breakdown of crew duties and training areas. The commander and pilot will not be greatly involved in payload operations other than vehicle control and possible payload manipulation. The areas of crew category responsibility are separated into two main areas: 1) vehicle operations, and 2) mission operations.

TABLE 2-3

SHUTTLE CREW DUTIES AND TRAINING MATRIX

DUTIES AND TRAINING \ NOMENCLATURE	COMMANDER	PILOT	MISSION SPECIALIST	PAYLOAD SPECIALIST (FLIGHT DECK)	PAYLAOD SPECIALIST (LABORATORY)	PASSENGER
<u>VEHICLE OPERATIONS</u>						
FLIGHT DYNAMICS - AERO	1	2	-	-	-	-
FLIGHT DYNAMICS - SPACE	1	2	4	-	-	-
RENDEZVOUS, DOCKING, UN-DOCKING	1	2	4	-	-	-
VEHICLE AND FLIGHT PRO-CEDURES	1	1	1	2	4	4
EMERGENCIES	1	1	1	2	2	2
VEHICLE SYSTEMS	1	1	1	3	4	-
BOOSTER SYSTEMS	1	1	4	-	-	-
<u>MISSION OPERATIONS</u>						
MISSION SAFETY	1	2	2	2	2	2
COMMUNICATIONS A/G	2	1	1	4	4	-
CONSUMABLES CONTROL	1	2	1	3	3	-
FLIGHT PLANNING	1	2	1	3	3	-
EVA	3	2	1	4	-	-
MAINTENANCE AND REPAIR	3	2	1	2	2	-
PMS	3	1	2	-	-	-
PAYLOAD SYSTEMS	3	2	1	1	1	-
PAYLOAD OPERATIONS	3	3	1	1	1	-
SCIENTIFIC INVESTIGATION	4	4	2	1	1	-
HOUSEKEEPING	2	2	2	2	2	2
RESCUE AND ALERT	1	1	2	-	-	-
FERRY	1	1	-	-	-	-

RESPONSIBILITY:
1. PRIME
2. PRIME SUPPORT
3. SECONDARY SUPPORT, WORKING KNOWLEDGE
4. FAMILIARIZATION

2.2.2 Flight Assignment. Each operational mission will require as a minimum, a crew consisting of a commander, pilot, and mission specialist. Generally the commanders, pilots, and mission specialists will have a sufficiently broad capability and training background to warrant assignment to any type of Shuttle mission. The more experienced pilots will be assigned as commanders. Pilots and mission specialists, if pilot rated, will upgrade as a result of flight and training experience.

Each crewman will specialize to the maximum extent to reduce training time and cost. This will require each commander and pilot to have concentrated training in the *vehicle* operations areas, with the mission specialist and payload specialist training concentrated in the *mission* operations area.

2.2.3 Crew Selection. Pilots assigned to perform the orbital test flights and subsequently man the early operational missions should have test pilot experience. The present astronaut cadre is expected to provide the majority of the necessary pilots for these flights. The selection criteria for the additional pilots required should be similar, but less stringent, to those established for prior manned spaceflight programs. The recommended selection criteria are contained in table 2-4.

Although the training costs per pilot and mission specialists will be less than previous programs, training costs coupled with mission cost and criticality warrant the continued selection of pilots and mission specialists who possess more than the necessary basic skill requirements. Criteria such as age, number of and type of aircraft flying hours, physical size, advanced degrees, and language capability are minor in comparison to the basic skills.

New pilots and mission specialists should be brought onboard at least 1 year prior to their participation in Shuttle flights. This is predicated on the accomplishment beforehand of a 3-month academic

TABLE 2-4

NASA SHUTTLE CREWMEN SELECTION REQUIREMENTS

CRITERIA	PILOTS	MISSION SPECIALISTS	PAYLOAD SPECIALISTS
BACHELOR OF SCIENCE	MANDATORY	HIGHLY DESIRABLE	EXPERIMENT DEPENDENT - DESIRABLE TO MANDATORY
ADVANCED DEGREE	DESIRABLE	DESIRABLE	EXPERIMENT DEPENDENT - DESIRABLE TO MANDATORY
CLASS II PHYSICAL	MANDATORY	MANDATORY	CLASS III MANDATORY
1000 HOURS FIRST PILOT HIGH PERFORMANCE AIRCRAFT	MANDATORY	NEED NOT BE RATED PILOT	NOT APPLICABLE
QUALIFIED MENTAL AND EMOTIONAL	MANDATORY	MANDATORY	MANDATORY
AGE 35 OR LESS	HIGHLY DESIRABLE	HIGHLY DESIRABLE	LESS RESTRICTIVE
SIZE AND WEIGHT >5, <95 PERCENTILE	HIGHLY DESIRABLE	HIGHLY DESIRABLE	LESS RESTRICTIVE
OUTSTANDING AIRCPAFT EXPERIENCE/ PERFORMANCE RECORD	HIGHLY DESIRABLE	NOT APPLICABLE	NOT APPLICABLE
CURRENT AIRCRAFT FLIGHT STATUS	MANDATORY	NOT APPLICABLE	NOT APPLICABLE
BILINGUAL	NOT REQUIRED	DESIRABLE	NOT REQUIRED

training program followed by an operational training program of approximately 8 months. A small group of new astronauts may be selected annually.

The selection criteria for the payload specialists (the principle scientists who may fly only one mission) vary from the more operationally selective criteria established for the career pilot and mission specialist (reference table 2-4). The technical capability of the payload specialist will be a prime selection criterion, coupled with a general good health condition and no known predisposition to motion sickness. Age should not be a significant consideration and physical requirements should be similar to the Class III military physical.

2.2.4 Rescue and Alert. "Dedicated rescue crews" are not assumed to be a requirement. The training to prepare crews to perform a rescue operation for the more routine earth orbit missions will be included in regular training.

A 48-hour rescue capability has been assumed which allows the selected rescue crew to train for their assigned normal mission and acquire the proficiency required to perform a rescue mission without serious interference. A crew or crews should be put on "alert," assuring rapid availability to fly a rescue mission. Prime alert crews can engage in all training activities or may be off-duty; in either case, they should be able to arrive at the launch site within 2 to 4 hours. Rescue crew preparations within the 48-hour period will be kept to a minimum, consisting of briefings on the emergency conditions and status, review of particular procedures or systems if mission conditions warrant, and perhaps a simulator or trainer exercise to cover the more critical or off-nominal events (docking, EVA, transfer operations, etc.), and final countdown preparations.

Generally, one rescue crew should be on alert any time a mission is in progress, and should suffice unless the 48-hour rescue requirement is significantly reduced. A very quick response rescue capability (e.g., an 8-hour requirement) would necessitate a prime rescue team be located at the launch site, and perhaps a designated backup rescue crew either at the launch site or at JSC. The alert schedule should alternate crews to ensure that each pilot receives a proportionate amount of this experience. The prime or backup crews in training for upcoming missions will perform alert duty. The rescue crew would normally consist of the commander and pilot. The mission specialist would be required only if EVA was involved or the payload was an integral aspect to the rescue operation.

2.2.5 Background Training - New NASA Crew Members. New crew members selected to fly Shuttle operational missions will complete a prerequisite background training program to familiarize them with spaceflight environmental aspects and to attain a level of competency in a variety of operational and technical spaceflight subjects. Background training for payload specialists will require approximately 2 weeks and can be accomplished any time prior to their participation in integrated operational training at JSC. The payload specialist may accomplish this training at the nearest location having the necessary facilities or capability. JSC will have the necessary facilities to accomplish all of the background training. The specific training subjects are contained in table 2-5. The program for astronauts is quite similar to past background training requirements; therefore, except for the specific training subjects below, elaboration is not considered necessary.

Survival training will be patterned after previous programs, i.e., field exercises in appropriate locations representing true environmental conditions or procedurally correct exercises and demonstrations performed onsite or at the local area. Past survival training has been primarily accomplished by the military services at Fairchild AFB, Spokane (arctic and desert), Albrook AFB, Panama (tropical), and the Naval Air Station, Pensacola (water), at a fairly low cost with travel being the biggest cost item.

It is possible to conduct a reasonable facsimile of all the above survival training onsite or locally (except the area environment). This would require procurement of a certain amount of equipment not otherwise required and a few cognizant survival instructors.

It is most appropriate to accomplish this training at a military survival school because of its relative capability and the minor cost differential involved. Whether all or a specific part of the survival training is required will depend upon the missions; however, the descending order of importance appears to be water, desert, tropical, arctic. The astronauts will receive the full survival training program; whereas, an onsite briefing and demonstration of survival techniques and procedures for the specific mission assignment should be sufficient for the payload specialist.

Preparatory to participating in STA training flights, the Shuttle pilot students should undergo a transition training program either at a military or commercial airline training center (preferably the former) to give them the basic familiarization in piloting heavy multiengine aircraft. Although the present STA configuration concept is to have a safety pilot command the aircraft, the student

TABLE 2-5

BACKGROUND TRAINING FOR NEW NASA CREW MEMBERS

ACTIVITY	HOURS PILOTS AND MISSION SPECIALISTS	HOURS PAYLOAD SPECIALISTS
ACADEMICS		
ASTRONOMY (INCL. PLANETARIUM, OBSERVATORY)	12	
METEOROLOGY	8	
PHYSIOLOGY AND BIOSCIENCE	8	
EARTH RESOURCES	8	
SPACE FLIGHT DYNAMICS	16	
COMPUTERS	8	
COMM AND ROCKET PROPULSION	8	
AERODYNAMICS	16	
STABILITY CONTROL	16	
SPACE FLIGHT EXPERIENCE		
MERCURY AND GEMINI	4	
APOLLO	8	
SKYLAB	4	
FUTURE MANNED/UNMANNED	4	
TOURS - GOVERNMENT AND CONTRACTOR FACILITIES	40	
SHUTTLE PROGRAM		
MISSION DESCRIPTION - OBJECTIVES, PROFILES, SCHEDULE	4	
VEHICLE DESCRIPTION - PERFORMANCE, GENERAL SYSTEMS	8	4
MISSION OPERATIONS - LAUNCH, RENDEZVOUS, PAYLOADS, SCIENTIFIC, TRANSFER, ENTRY, RECOVERY	8	4
ENVIRONMENTAL FAMILIARIZATION		
CENTRIFUGE	4	4
ZERO "G" AIRCRAFT	8	4
SCUBA C/O	16	16
WIF	8	4
PHYSIOLOGICAL (ALTITUDE CHAMBER)	4	4
SURVIVAL - DESERT, TROPICAL, WATER, ARCTIC	50	8
TRANSITION FLYING (HEAVY A/C - PILOTS ONLY)	30	—
TOTAL	300	48

should be sufficiently skilled to also land the aircraft from either seat position in case of an emergency. In addition, some knowledge of how the "like STA" handles should enhance student training during later STA training flights.

Transition training is applicable only to astronauts and pilots who do not have recent heavy aircraft experience. The program as presently envisioned would consist of a balance of ground school devoted to general systems and operations and several instructional flights in the aircraft selected. Program duration would probably be 1 to 2 weeks, depending upon aircraft flying availability.

2.2.6 Mission Training. Training for a specific mission will consist of briefings and reviews on a variety of subjects ranging from basic systems to detailed procedures, operational training exercises utilizing simulators and trainers, and use of special facilities for certain unique tasks. The training will, like past programs, progress from individual crew member part-task exercises to fully integrated mission phases encompassing all crewmen, simulators, trainers, and the MCC. A much more "production training" approach is visualized as compared to previous space programs which were tailored very much to the specific mission and individual crew member needs.

Preliminary analysis indicates that the commander and pilot initial checkout training will require approximately 800 hours of formal instruction, 700 hours or slightly less for the mission specialist, and 150 hours or slightly less for the payload specialist which includes the prerequisite environmental background training. This can be equated to a training program duration of 7 to 9 months for the pilots and mission specialists and 2 months or less for the payload specialist. A summary of the training activities and associated hours for each crew member category is contained in table 2-6.

2.2.7 Emergency Egress. All crewmen will receive the necessary training to assure rapid and efficient egress from the Orbiter during various situations, i.e., emergency landing conditions on runways and nonprepared surfaces (including water ditching), ejection seat if utilized, escape routes while on the pad (high speed elevator, slide tube, etc.), and training in conjunction with any spacecraft tests accomplished in an altitude chamber or under certain closed hatch conditions. Included as part of this program will be familiarization with smoke and fire detection and suppression, as well as rapid decompression contingencies. Training, using the one-g trainers, will comprise briefings, demonstrations, procedural practice, and emergency alert drills.

TABLE 2-6

INITIAL TRAINING REQUIREMENTS (HOURS)
FOR SHUTTLE OPERATIONAL MISSIONS

(A) ACTIVITY	COMMANDER AND PILOT	MISSION SPECIALIST	PAYLOAD SPECIALIST
REVIEWS			
FLIGHT PLAN, CHECKLISTS, PROCEDURES, MISSION RULES, RESCUE	100	130	10
LAUNCH, ENTRY, AND RECOVERY OPERATIONS	25	10	
EVA, EGRESS, FIRE	15	30	5
RENDEZVOUS, ORBITAL NAVIGATION	20		
TRANSFER, PAYLOADS, MANIPULATOR OPERATIONS	20	30	5
SYSTEMS BRIEFINGS			
ORBITER, PAYLOAD, BOOSTER	125	150	10
SOFTWARE	40	30	
SHUTTLE TRAINING AIRCRAFT	20		
SPACECRAFT TESTS			
FLIGHT READINESS REVIEW COUNTDOWN	20	20	
VEHICLE ANOMALIES BRIEFING			
SIMULATORS			
SHUTTLE MISSION SIMULATOR	200	150	(B) 50
SHUTTLE TRAINING AIRCRAFT	75		
PART-TASK (SPS, HFS)	50		
SPECIAL FACILITIES/MOCKUPS			
EMERGENCY EGRESS - PAD, LAND, WATER, EJECTION	20	20	5
FIRE/SMOKE/DECOMPRESSION	10	10	5
STOWAGE, HOUSEKEEPING	30	40	10
ZERO G AIRCRAFT AND WIF	10	10	5
ONE-G WALKTHRUS	30	70	(B) 50
TOTAL	810	700	105

NOTES: (A) COVERS NOMINAL, CONTINGENCY AND EMERGENCY TRAINING
(B) PERFORMED IN EITHER THE SMS OR ONE-G TRAINERS -- NOT BOTH

2.2.8 Housekeeping and Stowage. Housekeeping and stowage responsibilities are commonly shared by each crewman and training will be required by all crew members. The crew quarters lower deck will be commonly shared by as many as eight crewmen working from both the upper flight deck and the payload laboratory. The mission timeline must be well established and familiar to each crew member to minimize interference between vehicle and payload operations and off-duty activities such as sleeping and eating. Training exercises will be accomplished to cover the spectrum of specific housekeeping duties, including food preparation, use and cleanup of each facility, and ultimate full-scale training exercises utilizing the one-g trainers and simulators involving all crewmen rehearsing the actual flight plan timeline.

2.2.9 EVA and IVA. The mission specialist will require the full EVA training curriculum which will provide, in addition to the one-g trainers, partial trainers suitable for training exercises in the WIF and zero-g aircraft. It is also expected that verification tests of the EVA equipment will be performed in the Space Environment Simulation Laboratory (SESL). The Shuttle pilot will receive some EVA training (the actual amount and kind dependent upon the support role to be performed); no EVA training is planned for the commander and payload specialist. All crewmen will receive IVA training which will largely involve proper operation of hatches and transfer operations between the various Shuttle vehicle stations. In addition, they will all receive as a minimum, a briefing and demonstration on suit operations, particularly quick suit donning.

2.2.10 Scientific Training. A high fidelity full-scale Payload Laboratory Trainer will be required at JSC to conduct the necessary operational training for the payload specialists located in the Sortie Laboratory. It will be configured to the mission to be flown and include high fidelity training hardware for all scheduled experiments. It is assumed that the engineering development of the scientific equipment will have been previously accomplished and that the payload specialist prior to his arrival at JSC is familiar with his equipment and the scientific principals involved for his experiment(s). The intent of the training at JSC will be to expose the payload specialist more directly to spaceflight operational situations including the procedures, flight plan, mission timeline, inflight emergencies and contingencies on an interactive basis with the other crewmen and mission support organizations. The key interaction will occur between the payload specialist(s) and the mission specialist. Training exercises will vary from part-task exercises, including only the payload specialist and Sortie

Laboratory Trainer, to major exercises encompassing the other one-g trainers, SMS, full crew complement and MCC.

2.2.11 Special Facilities and Training. These facilities include the centrifuge, T-38's, zero-g aircraft, WIF, SESL and man-rated altitude chambers. They all serve to provide a nearly total background and mission training capability at JSC.

Other than for the initial familiarization for new crew members, neither the centrifuge or planetarium appear to be required for training for operational missions. Certain missions, such as the Sortie mission, may warrant some payload specialist refamiliarization with star field navigation, depending upon the scientific tasks. Likewise, it may be advantageous to give Shuttle Orbiter pilots an exposure to reentry-go profiles utilizing a centrifuge, if mission duration indicates this desirability.

Pressure suit training will depend upon the ultimate suit configuration and use. The mission specialist responsible for EVA will require considerable suit training; whereas, a single briefing and demonstration for the payload specialist might suffice.

2.2.12 Proficiency Training. Proficiency training relates to several factors, such as mission complexity and variability, but primarily to past flight experience. Proficiency or recurring training for the pilots and mission specialists who may fly as many as six missions per year are reduced from their initial training for their first mission. Crew specialization allows for a small amount of recurring training, particularly for the commander and pilot who are scheduled to fly subsequent missions very similar to those flown in the past.

To the extent each crew member's inflight tasks can be confined to his skilled areas (either by training or flight experience), required training, training resources, crew preparation time, crew complement and even such factors as the need for backup crews and dedicated rescue crews may be reduced significantly. The recurring training for the mission specialist will be more variable due to the different payloads involved. The greatest amount of recurring training is expected to involve the payload specialist since he may only fly one mission or the particular experiment may only be flown once.

For the more routine missions, 3 to 4 weeks of preflight proficiency training for all crew members is considered minimal. The more operationally complex missions and the Sortie mission will require a greater preflight training period for the mission specialist. The above generality should not be utilized for determining pilot and mission specialist maximum flight frequency per year. Several other considerations, i.e., other crew duties, rest, off duty and vacation, space or flight exposure, motivation, personal and family considerations, are applied to arrive at the respective pilot and mission specialist flight frequencies and the minimum preflight training periods.

Preliminary proficiency training hour estimates are contained in table 2-7 and the figures are based on these applied assumptions. The requirements become an increasingly greater percentage of the total load on the training resources as the program matures and the necessary crew complement becomes quite large and constant. The impact of proficiency training probably will be the most critical relative to the STA and to the payload specialist utilizing the SMS for the reasons previously discussed.

TABLE 2-7

RECURRING TRAINING REQUIREMENTS (HOURS) FOR SHUTTLE OPERATIONAL MISSIONS

ACTIVITY	COMMANDER AND PILOT		MISSION SPECIALIST	
	MISSION	ANNUAL	MISSION	ANNUAL
<u>REVIEWS</u>				
FLIGHT PLAN, CHECKLISTS PROCEDURE, MISSION RULES, RESCUE LAUNCH, ENTRY AND RECOVERY OPS	25		25 - 35	
EVA, EGRESS, FIRE RENDEZVOUS, ORBITAL NAVIGATION			0 - 20	
TRANSFER, PAYLOAD, MANIPULATOR OPS	5		10 - 20	
<u>SYSTEM BRIEFINGS</u>				
VEHICLE, PAYLOAD, BOOSTER SOFTWARE SHUTTLE TRAINING AIRCRAFT	15			
<u>SPACECRAFT TESTS</u>				
FRR, COUNTDOWN VEHICLE ANOMALIES BRIEFING	5		5	
<u>SIMULATORS</u>				
SHUTTLE MISSION SIMULATOR	25	150	17	100
SHUTTLE TRAINING AIRCRAFT	8	50		
PART-TASK (SPS, HFS)	8	50		
<u>AIRCRAFT FLYING (T-38)</u>				
60-1 (100 HOURS YEAR/MINIMUM)		250		
<u>SPECIAL FACILITIES/MOCKUPS</u>				
EMERGENCY EGRESS - PAD, LAND WATER, EJECTION FIRE/SMOKE/DECOMPRESSION				
STOWAGE, HOUSEKEEPING	5		10	
ZERO G - A/C/WIF	0 - 10		0 - 10	
ONE - G WALKTHRUS	5		15 - 30	
APPROXIMATE TOTAL (EXCLUDES AIRCRAFT FLYING)	105 - 115		80 - 150	

NOTES: REQUIREMENTS BASED UPON SIX MISSIONS PER YEAR FOR COMMANDERS, PILOTS, AND MISSION SPECIALISTS. TRAINING COVERS NOMINAL, CONTINGENCY, AND EMERGENCIES. ASTERISK PERFORMED IN EITHER THE SMS OR ONE-G TRAINER - NOT BOTH. VARIABLE HOURS FOR MISSION SPECIALIST IS PRIMARILY DUE TO MISSIONS WITH AND WITHOUT EVA.

2.3 DOD FLIGHT CREW TRAINING REQUIREMENTS DEFINITION

By using the criteria established for the selection and training of flight crews defined by NASA and evaluated in paragraph 2.2 as a baseline, the selection and functional training requirements are defined for the DOD. In addition, a definition of the simulator usage requirements (to evaluate possible saturation) is evaluated and defined for both NASA and DOD as a function of Shuttle mission frequency and the training requirements established for each crew member.

2.3.1 Flight Crew Cadre. The number of pilots, mission specialists, and the required training to man the Orbiter for operational missions are dependent upon several factors such as, launch frequency, mission complexity, variability and duration, crew turnover, crew reserve requirements, rotation, and related requirements. For the purpose of this analysis, several assumptions are required to derive a cadre for each of the three career crew men categories.

The same basic assumptions are used in arriving at the number of crewmen for the categories of commander, pilot and mission specialist. The basic assumption is that the mission specialist will be a rated pilot and the progression will be from mission specialist to pilot to commander.

The annual manning required for career astronauts is determined by the following: 1) six flights per year per crew, 2) an attrition rate of approximately 20 percent per year (assumed to be commanders),* 3) one reserve crew and mission specialist, and 4) an assumption of 17 launches per year for DOD Shuttles. This indicates a requirement for four commanders, four pilots, and five mission specialists.

2.3.2 Functional Training. Table 2-8 shows the number of commanders, pilots, and mission specialists required as a function of launch frequency. It assumes that a mission specialist, in addition to the pilots, will fly on all missions. Table 2-9 illustrates the annual simulator training requirements for the flight crew based upon the assumption that each DOD upgrading requires the full training identified by NASA for the corresponding position (i.e., a pilot upgrading to a commander requires an additional 220 hours of SMS training and the mission specialist upgrading to a pilot requires an additional 180 hours of SMS training). See tables 2-1 and 2-2.

New DOD pilots and mission specialists will require approximately 1 year of SMS training, similar to that recommended for new NASA

---

*Section 5 of this report depicts training requirements and SMS loading analysis results using a 10 percent attrition rate.

TABLE 2-8

DOD SHUTTLE FLIGHT CREW MEMBERS

	CALENDAR YEAR													
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
NUMBER OF MISSIONS	-	-	3	5	5	13	16	17	16	16	15	16	17	17
<u>CREW CATEGORY REQUIRED</u>														
COMMANDERS	-	3	4	4	4	4	4	4	4	4	4	4	4	4
PILOTS	-	3	3	3	3	3	4	4	4	4	4	4	4	4
MISSION SPECIALIST	-	3	3	3	4	5	5	5	5	5	5	5	5	5
<u>CREW MEMBERS IN TRAINING</u> (A)														
COMMANDERS (B)	3	3	2	2	2	2	2	2	2	2	2	2	2	2
PILOTS (C)	3	3	2	2	2	3	2	2	2	2	2	2	2	2
MISSION SPECIALISTS (D)	3	3	2	3	3	3	2	2	2	2	2	2	2	2

ASSUMPTIONS:
(A) ATTRITION OF 2 COMMANDERS PER YEAR (~20% ATTRITION)
(B) PILOTS UPRATING TO COMMANDER - 220 HOURS IN SMS
(C) MISSION SPECIALIST UPRATING TO PILOT - 180 HOURS IN SMS
(D) NEW MISSION SPECIALIST TRAINING - 150 HOURS IN SMS

TABLE 2-9

DOD ANNUAL SIMULATOR REQUIREMENTS INITIAL CHECKOUT, OPERATIONAL AND CREW UPRATING

	CALENDAR YEAR													
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
INITIAL CHECKOUT AND CREW UPRATING (SIMULATOR HOURS)														
COMMANDERS	660	660	440	440	440	440	440	440	440	440	440	440	440	440
PILOTS	540	540	360	360	360	540	360	360	360	360	360	360	360	360
MISSION SPECIALISTS	450	450	300	450	450	450	300	300	300	300	300	300	300	300
SUBTOTAL (HOURS)	1650	1650	1100	1250	1250	1430	1100	1100	1100	1100	1100	1100	1100	1100
OPERATIONAL (PROFICIENCY TRAINING)														
COMMANDERS	-	450	600	600	600	600	600	600	600	600	600	600	600	600
PILOTS	-	390	390	390	390	390	520	520	520	520	520	520	520	520
MISSION SPECIALISTS	-	300	300	300	400	500	500	500	500	500	500	500	500	500
SUBTOTAL (HOURS)	-	1140	1290	1290	1390	1490	1620	1620	1620	1620	1620	1620	1620	1620
TOTAL ANNUAL SMS HOURS	1650	2790	2390	2540	2640	2920	2720	2720	2720	2720	2720	2720	2720	2720

astronauts, prior to participation in Shuttle flights. This assumes an academic and experience level similar to the NASA astronaut selection criteria as illustrated in table 2-10.

Table 2-11 identifies the background training subjects and hours of study for each applicable subject recommended in this study for DOD flight crews.

Initial mission training consists of briefings, reviews of basic systems and detailed procedures, and operational training exercises. These operational training exercises include the use of simulators, trainers (mockups) and special facilities (for unique tasks). Preliminary analysis indicates that the initial training requirements for Shuttle operational missions are as follows: commander and pilot - 800 hours (each), mission specialist - 700 hours, and payload specialist - 150 hours. The training period for the commander, pilot, and mission specialist is for 7 to 9 months, while that of the payload specialist is approximately 2 months. A complete breakdown of initial training activities is given in table 2-6.

2.3.3 Proficiency Training. The proficiency training relates to several factors such as mission complexity and variability, but relates primarily to past flight experience. Proficiency (or recurring) training for pilots and mission specialists who fly as many as six missions per year may be reduced from that required for their first mission. Because of crew specialization, this is especially true for crews who train and fly together. The missions will be similar to those flown in the past, and the crews will be accustomed to performing together as a team.

The greatest amount of recurring training will involve integrating the payload specialist into a team because he may fly only one mission. Additional recurring training will be initiated by changes in experiments or payloads for each mission. NASA estimates that proficiency training will consist primarily of part-task training and integrated mission simulations. Preliminary estimates are 3 to 4 weeks of preflight proficiency training will be required for routine missions. As the program matures there will be a requirement to increase proficiency training, and reduce training of new crews. Figure 2-1 illustrates this based upon the number of DOD crews and an assumed attrition of approximately 20 percent. Section 5 contains a similar analysis based on an assumed attrition rate of approximately 10 percent.

TABLE 2-10

DOD SHUTTLE CREWMEN SELECTION REQUIREMENTS

CRITERIA	PILOTS	MISSION SPECIALISTS	PAYLOAD SPECIALISTS
BACHELOR OF SCIENCE	MANDATORY	HIGHLY DESIRABLE	EXPERIMENT DEPENDENT - DESIRABLE TO MANDATORY
ADVANCED DEGREE	DESIRABLE	DESIRABLE	EXPERIMENT DEPENDENT - DESIRABLE TO MANDATORY
CLASS II PHYSICAL	MANDATORY	MANDATORY	CLASS III MANDATORY
1000 HOURS FIRST PILOT HIGH PERFORMANCE AIRCRAFT	MANDATORY	SHOULD BE RATED PILOT	NOT APPLICABLE
QUALIFIED MENTAL AND EMOTIONAL	MANDATORY	MANDATORY	MANDATORY
AGE 35 OR LESS	HIGHLY DESIRABLE	HIGHLY DESIRABLE	LESS RESTRICTIVE
SIZE AND WEIGHT >5, <95 PERCENTILE	HIGHLY DESIRABLE	HIGHLY DESIRABLE	LESS RESTRICTIVE
OUTSTANDING AIRCRAFT EXPERIENCE/ PERFORMANCE RECORD	HIGHLY DESIRABLE	DESIRABLE	NOT APPLICABLE
CURRENT AIRCRAFT FLIGHT STATUS	MANDATORY	DESIRABLE	NOT APPLICABLE
BILINGUAL	NOT REQUIRED	DESIRABLE	NOT REQUIRED

TABLE 2-11

BACKGROUND TRAINING FOR NEW DOD CREW MEMBERS

ACTIVITY	HOURS PILOTS AND MISSION SPECIALISTS	HOURS PAYLOAD SPECIALISTS
ACADEMICS		
ASTRONOMY (INCL. PLANETARIUM, OBSERVATORY)	12	
METEOROLOGY	8	
PHYSIOLOGY AND BIOSCIENCE	8	
EARTH RESOURCES	8	
SPACE FLIGHT DYNAMICS	16	
COMPUTERS	8	
COMM AND ROCKET PROPULSION	8	
AERODYNAMICS	16	
STABILITY CONTROL	16	
SHUTTLE PROGRAM		
MISSION DESCRIPTION - OBJECTIVES, PROFILES, SCHEDULE	4	
VEHICLE DESCRIPTION - PERFORMANCE, GENERAL SYSTEMS	8	4
MISSION OPERATIONS - LAUNCH, RENDEZVOUS, PAYLOADS, SCIENTIFIC, TRANSFER, ENTRY, RECOVERY	8	4
ENVIRONMENTAL FAMILIARIZATION		
CENTRIFUGE	4	4
ZERO "G" AIRCRAFT	8	4
SCUBA C/O	16	16
WIF	8	4
PHYSIOLOGICAL (ALTITUDE CHAMBER	4	4
*SURVIVAL - DESERT, TROPICAL, WATER, ARCTIC	50	8
TRANSITION FLYING (HEAVY A/C - PILOTS ONLY)	30	—
TOTAL	240	48

*BASED UPON CONDUCTING AT JSC

NOTE: Transition flying training is begun prior to the pilot's participation in the STA flights, and is only applicable to those pilots who have not had recent heavy aircraft flying experience. Its purpose will be pilot familiarization with the flying of heavy, multiengined aircraft. This training can be held at either a military or commercial aircraft training center (preferably the former location).

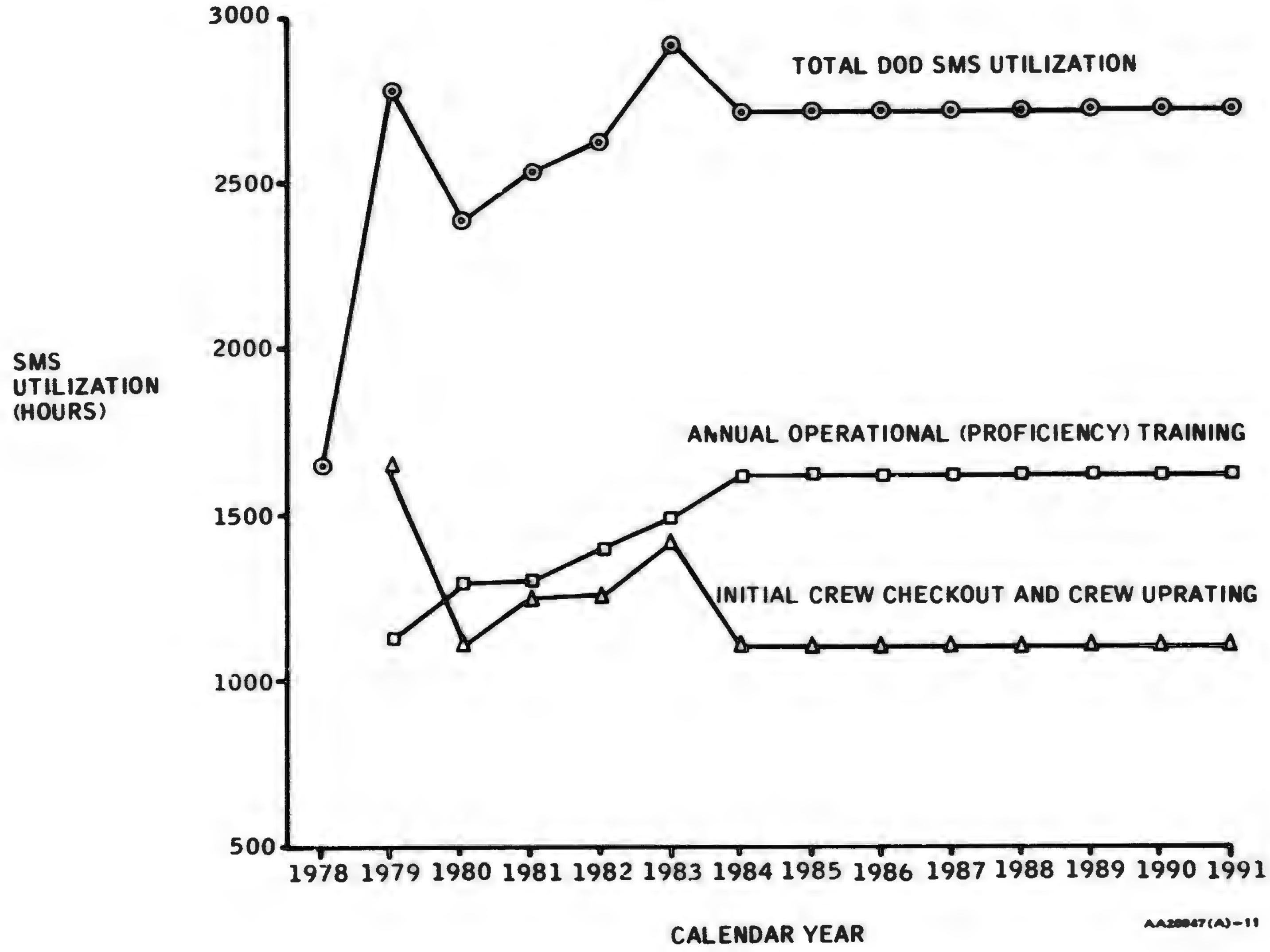


Figure 2-1 DOD Simulator Utilization (Hours)

2.4 SMS LOADING ANALYSIS

The NASA and DOD joint flight crews training is currently planned to take place initially at JSC utilizing the NASA training facilities. Table 2-12 illustrates the NASA flight crew buildup and estimated annual initial crew training requirements to provide necessary growth and overcome an anticipated attrition of two crew members (approximately 20 percent attrition) in each career category each year.

Table 2-13 lists the training hours required on the SMS MBCS and FBCS for both NASA and DOD. This table is based upon the following assumptions:

- New commanders receive 125 hours training in MBCS and 95 hours in FBCS
- New pilots receive 55 hours training in MBCS and 125 hours in FBCS
- New mission specialists receive 150 hours training in FBCS
- Commanders receive 115 hours in MBCS and 35 hours in FBCS annually
- Pilots receive 45 hours in MBCS and 85 hours in FBCS annually
- Mission Specialists receive 100 hours in FBCS annually
- Upgrading of crew requires the same simulator hours as for a new crew member
- DOD upgrades crew members as a result of commander attrition (in NASA documents referenced in paragraph 1.5, NASA's SMS hours are based on replacement of crew members as opposed to upgrading)
- Probable loading is most representative of simulator utilization by flight crews.

Figures 2-2, 2-3, 2-4, and 2-5 show the individual and combined DOD/NASA estimate of simulator loading for the SMS. As shown in figure 2-3, the "probable" loading on the MBCS exceeds the NASA estimated saturation level of 2000 hours in the timeframe between 1978 and 1979, with the "minimum" loading approaching this saturation level in 1982. Figure 2-5 shows that the probable BFCS loading can exceed the NASA estimated saturation level of 2500 hours as early as 1978, with positive saturation occurring in the 1978-1979 timeframe.

TABLE 2-12

NASA SHUTTLE FLIGHT CREWS

	CALENDAR YEAR													
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
PROJECTED MISSIONS	-	11	14	32	28	41	45	51	52	45	48	44	53	48
CREW MEMBERS REQUIRED														
COMMANDERS	3	4	7	7	9	9	11	11	11	11	11	11	11	11
PILOTS	2	3	6	6	8	9	10	11	11	11	11	11	11	11
MISSION SPECIALISTS	3	5	7	7	9	10	11	11	11	11	11	11	11	11
CREW MEMBERS IN TRAINING														
COMMANDERS	4	4	2	3	2	4	2	2	2	2	2	2	2	2
PILOTS	3	4	1	3	3	3	3	2	2	2	2	2	2	2
MISSION SPECIALISTS	5	3	2	3	3	3	2	2	2	2	2	2	2	2

ASSUMPTION: 20 PERCENT ATTRITION OF CREW MEMBERS ANNUALLY

TABLE 2-13
SMS UTILIZATION (HOURS)

MOTION BASE TRAINING HOURS

CALENDAR YEAR	DOD			NASA			TOTAL		
	MIN (A)	PROB (B)	MAX (C)	MIN (A)	PROB (B)	MAX (C)	MIN (A)	PROB (B)	MAX (C)
1978	375	457.5	540	500	582.5	665	875	1040.0	1205
1979	720	870.0	1020	960	1137.5	1315	1680	2007.5	2335
1980	710	832.5	955	1055	1217.5	1380	1765	2050.0	2335
1981	710	832.5	955	1180	1397.5	1615	1890	2230.0	2570
1982	710	832.5	955	1285	1547.5	1810	1995	2380.0	2765
1983	710	860.0	1010	1535	1870.0	2205	2245	2730.0	3215
1984	710	855.0	1000	1515	1822.5	2130	2225	2677.5	3130
1985	710	855.0	1000	1515	1817.5	2120	2225	2672.5	3120
1986	710	855.0	1000	1515	1817.5	2120	2225	2672.5	3120
1987	710	855.0	1000	1515	1817.5	2120	2225	2672.5	3120
1988	710	855.0	1000	1515	1817.5	2120	2225	2672.5	3120
1989	710	855.0	1000	1515	1817.5	2120	2225	2672.5	3120
1990	710	855.0	1000	1515	1817.5	2120	2225	2672.5	3120
1991	710	855.0	1000	1515	1817.5	2120	2225	2672.5	3120

FIXED BASE TRAINING HOURS

CALENDAR YEAR	DOD MIN (A)	DOD PROB (B)	DOD MAX (C)	NASA MIN (A)	NASA PROB (B)	NASA MAX (C)	TOTAL MIN (A)	TOTAL PROB (B)	TOTAL MAX (C)
1978	450	825.0	1110	750	1125.0	1505	1200	1950.0	2615
1979	750	1380.0	1770	950	1705.0	2225	1700	3085.0	3995
1980	600	1105.0	1435	1000	1635.0	2070	1600	2740.0	3505
1981	750	1255.0	1585	1150	2035.0	2565	1900	3290.0	4150
1982	850	1355.0	1685	1350	2405.0	2910	2200	3760.0	4595
1983	950	1580.0	1910	1450	2590.0	3285	2400	4170.0	5195
1984	800	1390.0	1720	1400	2625.0	3200	2200	4015.0	4920
1985	800	1390.0	1720	1400	2585.0	3160	2200	3975.0	4880
1986	800	1390.0	1720	1400	2585.0	3160	2200	3975.0	4880
1987	800	1390.0	1720	1400	2585.0	3160	2200	3975.0	4880
1988	800	1390.0	1720	1400	2585.0	3160	2200	3975.0	4880
1989	800	1390.0	1720	1400	2585.0	3160	2200	3975.0	4880
1990	800	1390.0	1720	1400	2585.0	3160	2200	3975.0	4880
1991	800	1390.0	1720	1400	2585.0	3160	2200	3975.0	4880

ASSUMPTIONS:
A) ALL CREW MEMBERS TRAINING PERFORMED WITHIN TIMEFRAME OF CREW MEMBER REQUIRING MAXIMUM SIMULATOR TIME (I.E., MBCS - 125 HRS COMMANDER, FBCS - 150 HRS MISSION SPECIALIST)

B) MBCS = COMMANDER PLUS 1/2 PILOT REQUIREMENT, FBCS = MISSION SPECIALIST PLUS PILOT REQUIREMENTS

C) ALL CREW MEMBERS TRAINED INDEPENDENTLY

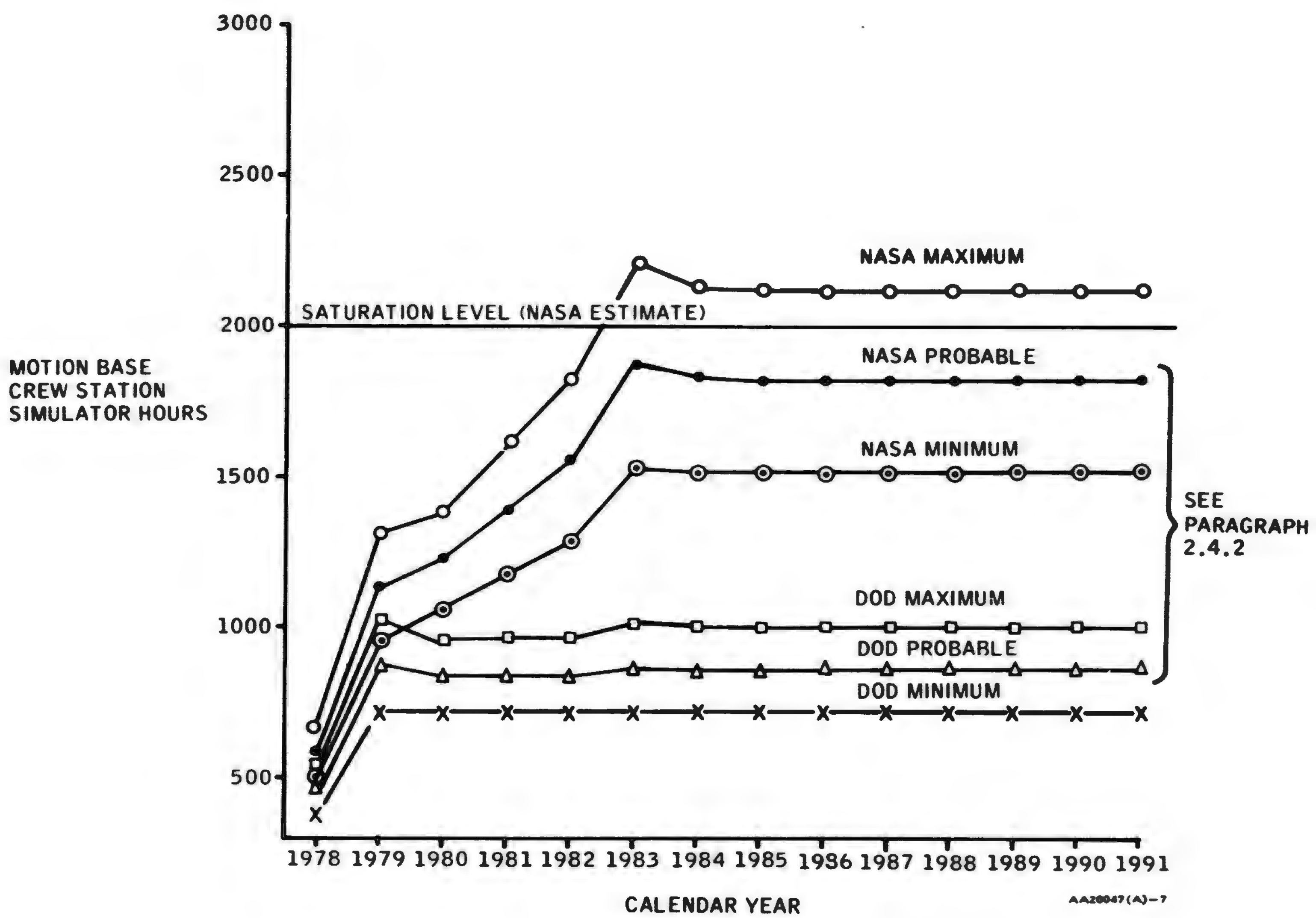


Figure 2-2 DOD/NASA MBCS Simulator Hours vs Calendar Year

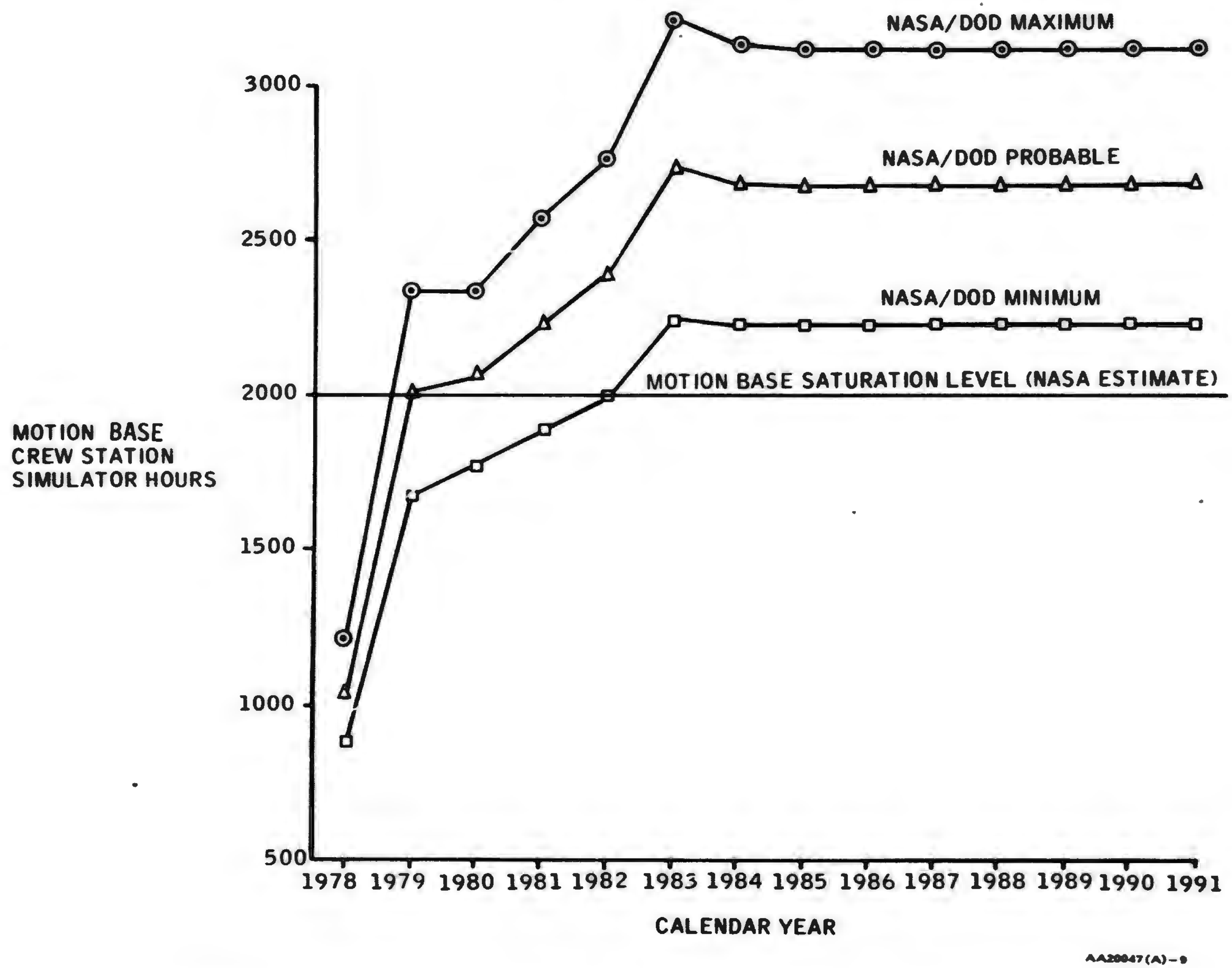


Figure 2-3 Total MBCS Simulator Hours vs Calendar Year

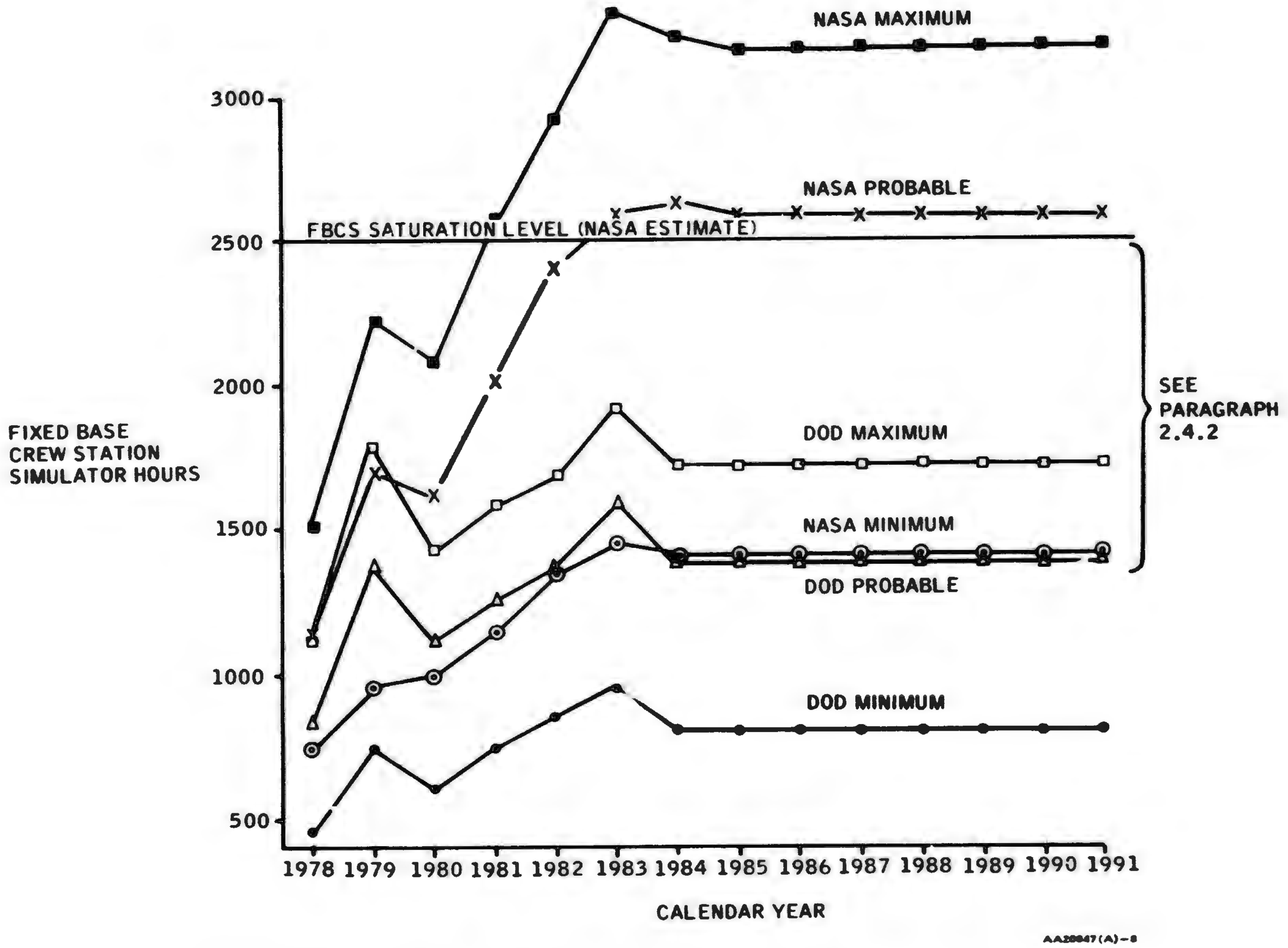


Figure 2-4 DOD/NASA FBCS Simulator Hours vs Calendar Year

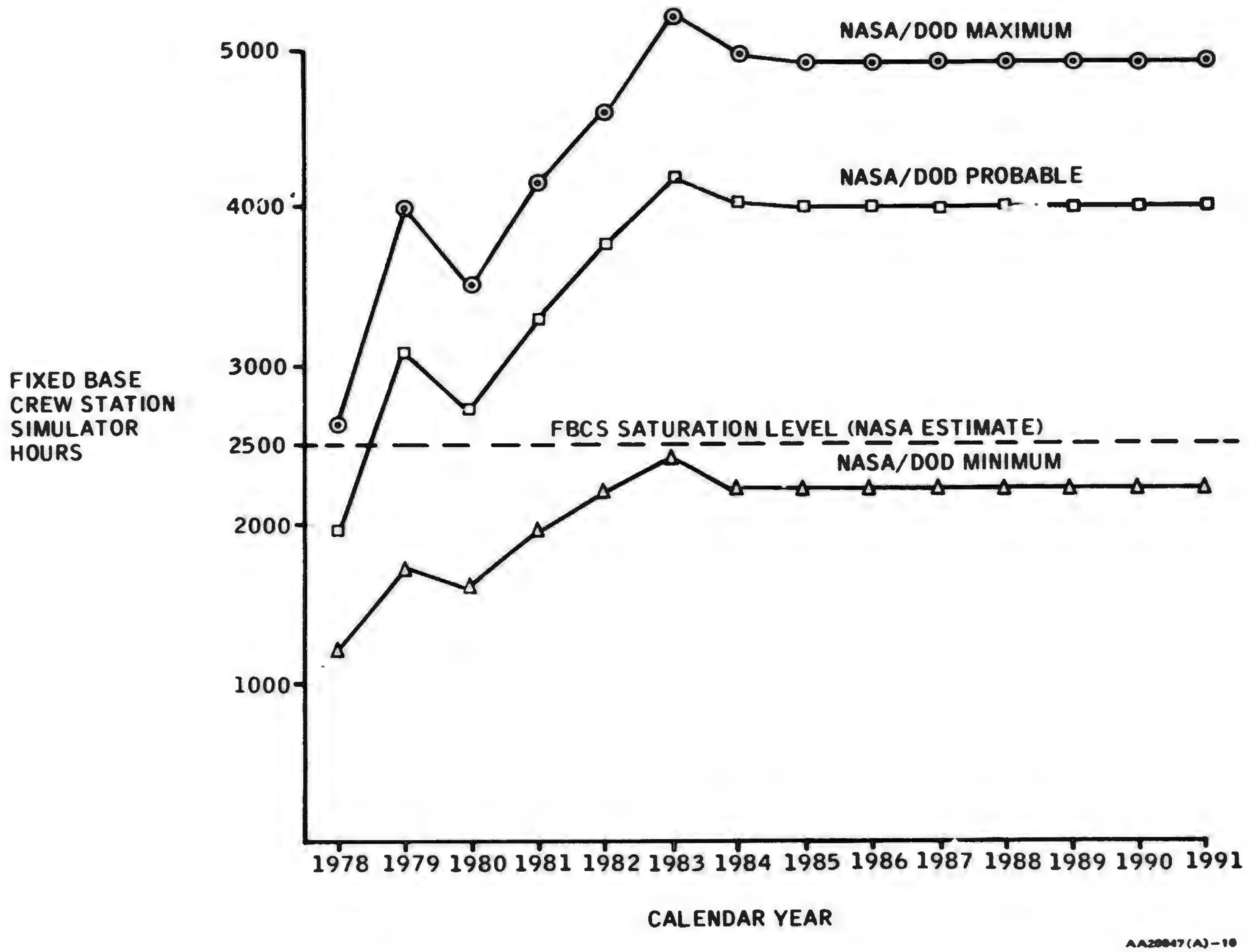


Figure 2-5 Total FBCS Simulator Hours vs Calendar Year

2.4.1 Additional Loading Factors. The preceding analysis, which indicates almost instantaneous saturation of the JSC SMS (refer to figures 2-3 and 2-5), is based upon those training and mission-related tasks that were quantified in paragraphs 2.2 and 2.3. There are additional tasks which have traditionally been performed by flight crew members in support of manned space flight which were not included in the analysis, such as:

A. Backup. Mission Operations Directorate (MOD) provides two or three backups for its three crew members on each mission. This may necessitate additional mission unique training, thus increasing simulator loading.

B. CAPCOM. Although there will be no spacecraft communicator (CAPCOM) required during the Shuttle operational era, backup crew members must be on telephone alert and be able to report to the Shuttle MCC within an hour.

C. Flight Procedures Development. Crew members will have major responsibilities in this area. The flight crew for the next mission will be involved in, and expected to participate in, the procedures development. They will validate all end items.

D. Flight Planning. The prime crew for each mission will have significant responsibilities in this area during the flight planning process.

E. Aircraft Operations. Shuttle crew may be needed for aircraft scheduling, functional check flights, instructor pilots, and flight examiners.

2.4.2 Resultant High Fidelity Simulator Requirements. Additional training will be required, and simulator loading will increase proportionately. The following activities are areas in which significant and high fidelity simulator training will be required and will impact simulator usage:

A. Procedures Development. Mission flexibility may require developing new flight crew and flight controller procedures which will, in turn, require additional simulator time to develop and train personnel to proficiency.

B. Full Crew Integration. Based upon the annual proficiency guidelines contained in table 2-7, the commander, pilot, and mission specialist are allotted approximately 6 hours of integrated training prior to each mission. DOD may require considerably more simulator time to integrate the payload specialist and flight controllers into a proficient mission team to ensure accomplishment of the assigned mission.

C. Proficiency Training. The assumption that annual proficiency requirements would be accomplished satisfactorily within the guidelines in table 2-7 may have to be revised due to the mission preparation requirements in addition to an annual proficiency requirement in abort, systems malfunction, and mission anomaly procedures for individuals as well as mission team members.

D. Standardization and Check Flights. DOD crew members may be required to pass an initial or annual standardization simulator flight conducted by check pilots/mission specialists to retain individual or crew operational status. The standardization and check flight time will add an additional load to the simulator, as well as the time required to maintain check pilot/mission specialist proficiency.

E. Security. During joint NASA/DOD training, DOD mission security requirements (i.e., payloads, trajectory, encryption/decryption of data, etc.) may impose an additional load on simulator utilization which has not been considered in the preceding paragraphs.

F. Flight Controllers. All flight controller training has been assumed to be performed in parallel with flight crew training. This assumption may not be feasible, and if not the overall simulator loading would be increased.

G. Additional Crew Members. No consideration for special-function crew members (over and above the normal four crew members) has been included in the simulator loadings discussed in the preceding paragraphs. The Shuttle may carry more than eight personnel, which may entail additional simulator training to integrate all personnel into an efficient mission team.

H. Rescue. No provision for real-time simulator emergency analysis or rescue training has been included. Many anomalies were solved and work-around procedures developed in real-time (through effective use of the available simulators) for emergencies that occurred in previous manned spaceflights.

I. Modifications. As the Shuttle Program matures, many changes may be expected in the flight hardware/software and missions which must be included in the simulator. These will impose two types of loading on the simulator 1) hardware/software development and implementation, and 2) flight crew training with the modified hardware/software.

As indicated on figures 2-2 and 2-4, an additional 2+4 SMS at the DOD STC will allow for the accommodation of the additional training requirements defined above.

2.4.3 Analysis Summary. The data used in performing the SMS utilization analysis was restricted to initial and proficiency training parameters quantified by NASA estimates. The values estimated are viewed as the *minimal* simulator training hours required during the operational Shuttle phase (1980-1991 timeframe). Therefore, the estimate of motion and fixed based crew station simulation saturation, for a single JSC 2+4 SMS, is considered to be valid in the 1979 timeframe. Use of part-task simulators (OAS, SPS) may relieve full mission simulator loading; however, the activities and tasks discussed above will be most prevalent in the 1978-1981 timeframe.

These activities and tasks could not be quantified. However, based upon past experience, these activities and tasks have caused a greater load on simulator utilization than initial and proficiency training. Therefore, the saturation estimated for the 1979 timeframe is considered to be the best case condition.

2.5 DOD FLIGHT CONTROLLER TRAINING AND MISSION CONTROL CENTER SIMULATION (MCCSS) REQUIREMENTS

2.5.1 DOD Flight Controller Background. In an effort to fully define the present and near future Space Shuttle simulation capability at JSC, a study of all available and related NASA documentation was conducted. This information was then viewed in light of the joint *NASA/DOD Space Transportation System (STS) Program Plan*, the *DOD STS Operations Concept*, and *FOD Shuttle Academic Training Analysis Study* (PHO-TR577) in order to determine the impact of DOD personnel training at JSC facilities and the capability of these facilities to adequately support their training.

Figure 2-6 is a timeline of NASA's proposed simulator procurement schedules, including the schedules for training on the individual facilities (SPS, OAS, SMS MBCS, SMS FBCS) at JSC, and the STA. The initial involvement of DOD flight controllers will be in ALT and Orbital Flight Test (OFT) academic training at JSC. In conjunction with this, OFT procedures will be developed on the SPS concurrent with NASA flight crews.

Figure 2-7 is a schedule of the projected timeline for flight controller and crew training during the flight test phase of the Shuttle Program. Based on preliminary figures from the Shuttle Mission Control Center (SMCC) portion of this study, the DOD will use 15 flight controllers to cover the 3-shift Space Shuttle Vehicle (SSV) support in the SMCC, with an additional 21 for contingency support. The Interim Upper Stage (IUS) support will include six for 3-shift coverage and six more for contingency coverage. All of the contingency support personnel will have dual responsibilities and will be drawn from branches of the MOD.

For purposes of this study, however, the numbers given above will be considered as separate individuals. In addition, it is assumed (and recommended) that the DOD flight controllers will begin their JSC Shuttle academic training no later than the start of NASA academic and practical exercise training for the bulk of their flight controllers. This has tentatively been scheduled for July 1976. Table 2-14 is a projection of DOD flight controller hours required to complete the NASA curriculum as presently envisioned for VFT academic training. The student hours were based on the

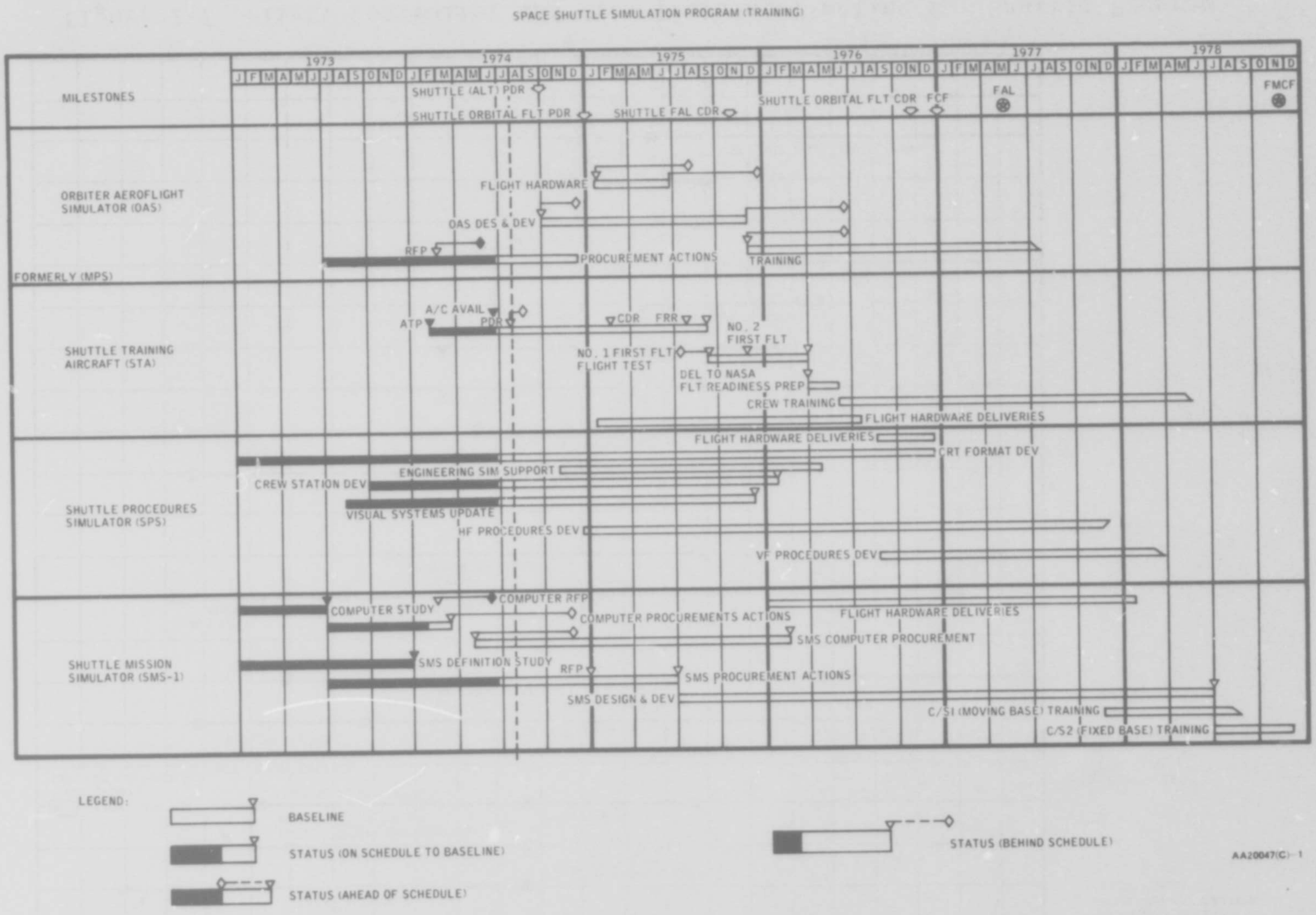


Figure 2-6 NASA Simulator Procurement Schedule

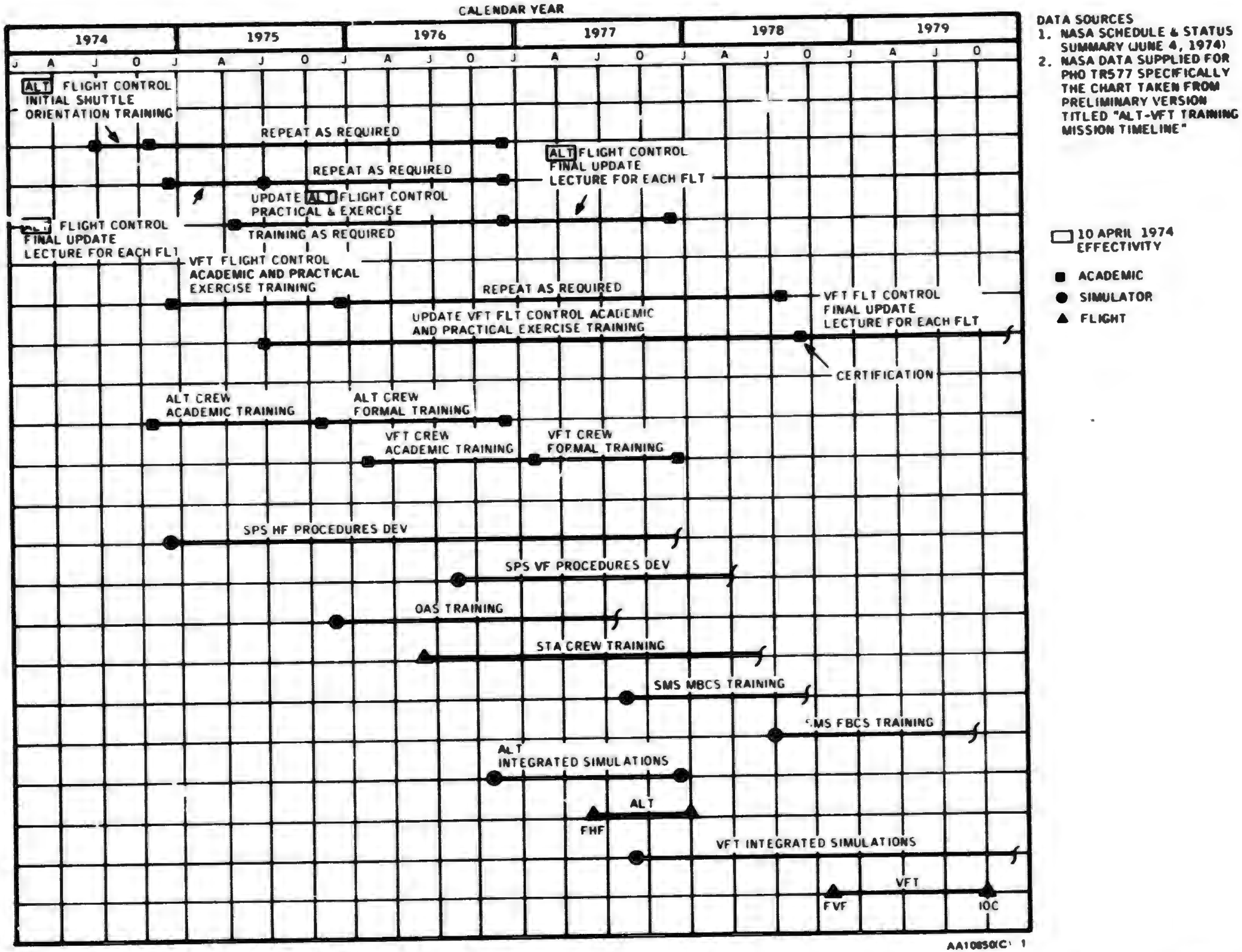


Figure 2-7 Flight Controller and Crew Training Timeline for Shuttle Program

breakdown of the individual courses into subsections and assigning specific flight controllers to the classes required for their particular functional area.

In addition to the NASA JSC curriculum, it will be necessary for those students attending the course (including NASA personnel) to attend a DOD-sponsored course covering the Air Force Satellite Control Facility (AFSCF), including the STC, and the NASA Tracking and Data Relay satellite (TDRS) in order to fully understand the joint command and control capabilities of NASA/DOD. It is recommended that this course be taught at JSC immediately after the STDN course.

2.5.2 DOD Flight Controller Mission Simulation Requirements. Flight controller simulation training consists of vehicle system familiarization (cockpit interior, controller/control switch locations, display locations, and checklist activities) and mission simulation exercises [SMS/SMCC integrated mode and SMCC standalone (MCCSS) without an SMS input]. Vehicle system familiarization could be obtained by flight controllers in the JSC and/or DOD simulators (SMS and SPS) on a non-interference basis with flight crew training. Also, DOD flight controllers could participate with the SMS crew instructors during flight crew training for further vehicle system familiarization.

Integrated mission simulation exercises help develop the interrelationships between flight controller personnel and the flight crew, thus enabling the two groups to function as a team. These exercises require the SMCC and a simulated network between the flight crew simulator and the MCC and provide the procedural flight environment for both the crew and the flight controller teams. In general terms, this capability provides the means to test and verify the accuracy and feasibility of procedures in the actual operational situations for which they are written. These include procedures which are used to monitor and conduct the mission and identify problem areas, and procedures to implement recovery or contingency actions when called for. The average number of integrated mission simulation exercises will vary with mission frequency, mission complexity (common and DOD-unique missions). and on-orbit mission contingencies. It has been projected by NASA that 20 percent of the flight crew simulation training hours will involve integrated mission simulation exercises with the flight

TABLE 2-14

REPRESENTATIVE OFT ACADEMIC TRAINING REQUIREMENTS FOR FLIGHT CONTROLLERS (NASA ESTIMATED)

COURSE	LENGTH (HOURS)
• BASICS (28 HOURS)	
INTRODUCTION TO SHUTTLE	8
AERODYNAMIC CONCEPTS	4
S AND C CONCEPTS	8
PRINCIPLES OF FLIGHT	4
PRINCIPLES OF FLIGHT TEST	4
• FC QUALIFICATIONS (291 HOURS)	
SHUTTLE SYSTEMS (130 HOURS)	
ORIENTATION	8
ME OVERVIEW	4
ME (DETAIL)	12
OAMS/RCS OVERVIEW	3
OAMS/RCS (DETAIL)	9
EPS OVERVIEW	3
EPS (DETAIL)	9
CREW STA/EQU OVERVIEW	2
CREW STA/EQU (DETAIL)	6
STRUCTURES OVERVIEW	1
STRUCTURES (DETAIL)	5
AVIONICS HW AND CONT OVERVIEW	5
AVIONICS HW AND CONT (DETAIL)	15
ECS AND LSS OVERVIEW	5
ECS AND LSS (DETAIL)	15
HYD/APU OVERVIEW	2
HYD/APU (DETAIL)	6
PYRO	4
SRB OVERVIEW	3
SRB (DETAIL)	9
ET	4
AVIONICS SOFTWARE (65 HOURS)	
AVIONICS SW OVERVIEW	8
G AND N OVERVIEW	6
G AND N (DETAIL)	24
PMF(S) OVERVIEW	5
PMF(S) (DETAIL)	15
FLIGHT PLAN OVERVIEW	5
FLIGHT PLAN (DETAIL)	0
PAYLOAD INTERFACE OVERVIEW	2
PAYLOAD INTERFACE (DETAIL)	0
MCC (8 HOURS)	
MCC OVERVIEW	2
MCC (DETAIL)	6

TABLE 2-14 .(CONT'D)

COURSE	LENGTH (HOURS)
STDN (12 HOURS)	
STDN OVERVIEW	3
STDN (DETAIL)	9
SUPER-MOPS (VMMPS) (48 HOURS)	
SMOPS OVERVIEW	6
SASP OVERVIEW	2
SASP (DETAIL)	8
SMDRS OVERVIEW	4
SMDRS (DETAIL)	16
SPEARL OVERVIEW	2
SPEARL (DETAIL)	8
S OTHER OVERVIEW	2
S OTHER (DETAIL)	0
AVIATION WEATHER (8 HOURS)	
LECTURE	6
WEATHER STATION VISIT	2
AERODYNAMICS (20 HOURS)	
AERODYNAMICS OVERVIEW	4
ORBITER AERO PERFORMANCE	3
HYPERSONIC TRANSITION	3
SUBSONIC STAB AND CONTROL	4
TERMINAL AERA ENERGY MANAGE	3
LANDING	3

controllers. DOD should consider the fact that when integrated simulations are spaced too far apart, deterioration of the interrelationship developed between the flight crew and flight controllers occurs, resulting in lost training time. Therefore, DOD should plan on adequately spacing their integrated mission exercises to accommodate their launch frequency profile.

2.5.3 MCCSS Requirement. Limited flight controller training in a simulated SMCC environment can be accomplished without the use of an MCCSS by generating STC format-compatible data tapes for the trajectory, telemetry (onboard systems data words and bilevels and flight computer data words), communication, timing, and faulting information (in an encrypted format); and processing these data tapes through the SMCC Front End Processor (FEP) computers to the display, monitor, and control consoles of the SMCC. These data tapes can be generated (as previously done at JSC) by proper programming and configuring the SMCC computers for generation of the above-mentioned network data. Insertion of header words, sync patterns, error codes and site-vehicle-source ID codes into an STC-compatible, serially-formatted data stream would be done while generating the data tapes.

However, a DOD MCCSS for standalone flight controller (FC) training at the SMCC would also provide extremely flexible verification and checkout capabilities while providing the following highly desirable features of FC training:

- Development, verification, and exercising of alternate mission plans, procedures, etc.
- Standalone FC training capability which can be easily modified to test DOD unique mission design
- Malfunction analysis using simulated faults without use of the JSC or STC SMS
- On-orbit contingency support training
- Trajectory analysis and modification exercises

- Capability of handling secure payloads and trajectory information by DOD

- DOD flight controllers' ability to obtain their training in their own MCC environment.

These FC training capabilities provided by an MCCSS are not available with the use of canned data tapes (except during integrated simulation). Very limited FC training capabilities are obtained using the canned data tape concept. When the SMS reaches near saturation with flight crew training, limitations are imposed on the availability of dynamic simulations for FC training. It is therefore recommended, based on preliminary analysis, that the DOD SMCC implement a capability for standalone mission simulations for use in both FC training and in the checkout and operational verification of the SMCC.

SECTION 3

DOD SIMULATOR(S) REQUIREMENT DEFINITION

3.1 SHUTTLE MISSION SIMULATOR

The projected saturation date for the JSC SMS indicates a requirement for an additional full capability SMS to meet the DOD and NASA crew and FC training requirements. Location of this added SMS is suggested to be at the STC. Resource acquisition costs and schedules for this capability will be documented in Task V, TOR V.

3.2 STC MCCSS

3.2.1 Development Guidelines and Functions. The suggested STC MCCSS should have the total capability of training mission operations personnel, developing and validating operational concepts and procedures, and validating ground systems processing/display and control capabilities. Mission management (statusing, flight planning, network control, mission control and abort decisions), systems support (management and verification of vehicle systems) and payload data support should be the operations functions to be exercised by DOD flight controllers using the STC MCCSS.

3.2.2 Functional Description. A generalized description of the MCCSS elements as shown in figure 3-1 is as follows.

A. Math Models. Vehicle and groundtrack math models for the Shuttle systems, upper stage (when required), booster, external tanks, and experiments/payloads are contained in the math model computer. These models would have display and control capabilities remoted to the simulation control consoles, and have a capability of both time-tagged and real-time fault insertion from these consoles. An interface would be provided to the trajectory simulation element for ephemeris computations and to the simulated network computer for telemetry commands and air/ground voice radio frequency (RF) links.

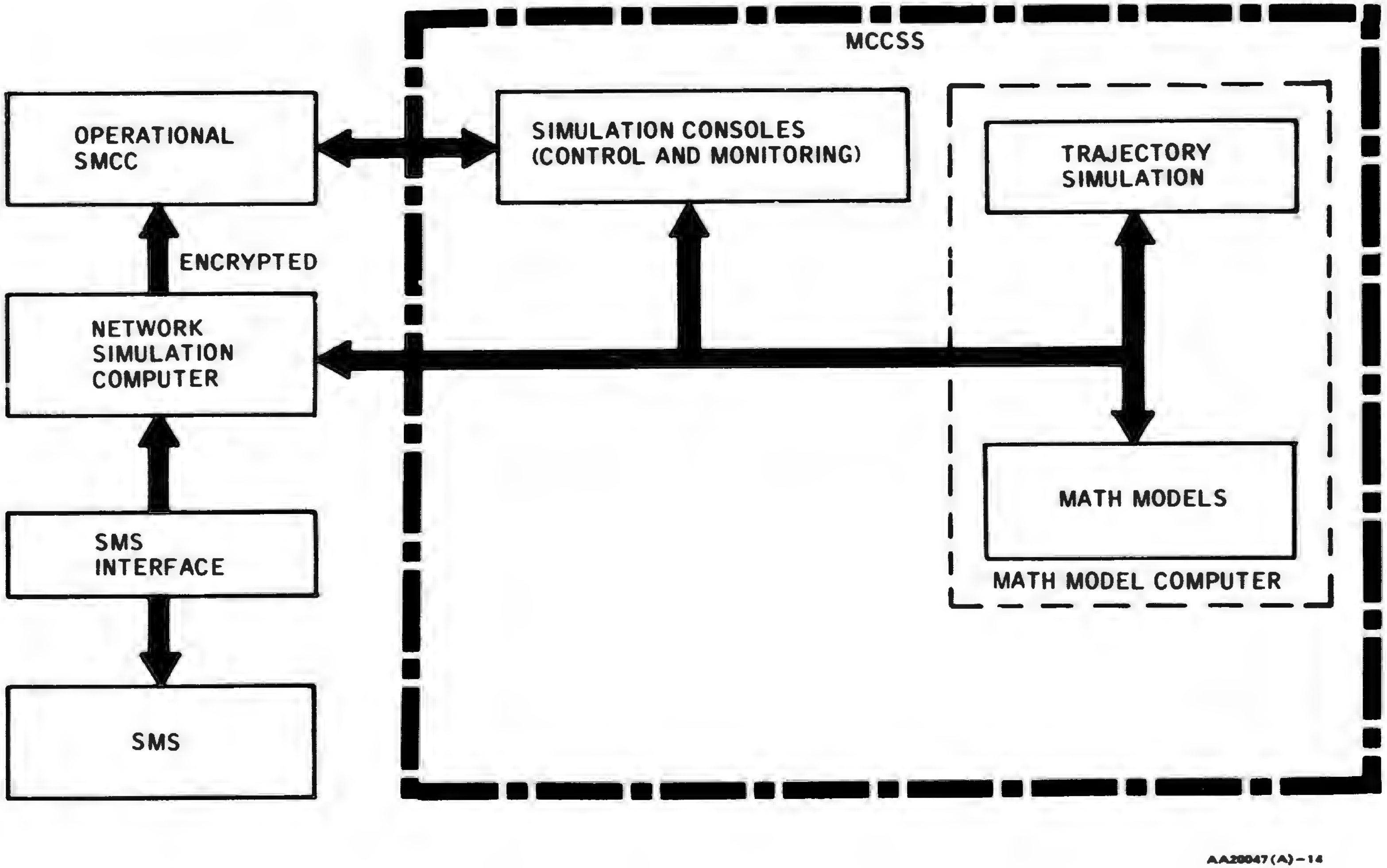


Figure 3-1 STC Mission Control Center Simulation System

B. Trajectory Simulation Element. This element is located in math model computer and provides ephemeris and trajectory information as a function of the vehicle math model computer's guidance, navigation, and propulsion systems, or as a function of the velocity data from the SMS for orbital maneuvers during integrated simulation. Trajectory data processing, signal acquisition, and site location data would be computed based on RF systems status from the math model computer and displayed on the simulation control consoles.

C. Simulation Consoles. These consoles provide the display and control interfaces with the MCCSS functional elements. The capability to monitor the progress of the simulation is also provided by paralleling the displays and voice loops from the operational SMCC elements. Those displays and controls (located on the simulation control consoles for SMCC standalone simulations) which the flight crew uses in configuring and monitoring the vehicle systems would also be monitored via the simulation consoles.

D. Simulated Network Computer. This computer is primarily responsible for the simulation of the SMCC operational interfaces, i.e., SCF sites, STDN/TDRS/JSC-SMCC via the Goddard Space Flight Center (GSFC). The transmission and reception of all air/ground links with the math model computer software would be enabled by this computer based on the acquisition of signal/loss of signal and signal strength computation from the trajectory simulation element. Continuous monitoring and control of the math model computer software is provided via the simulation control consoles by displaying the data prior to its processing by the SMCC operational interfaces. The simulated network computer would also convert the telemetry data [math model computer-generated, experimental data-generated, or JSC SMS (non-encrypted) or SMS (encrypted) data generated during integrated simulation] into the STC ground data flow format to provide compatible formats with the SMCC, in addition to exercising the data management and control functions. Malfunctions may be inserted via the simulation control consoles to the simulation network computer systems for real-time contingency analysis.

As shown in figure 3-1, the network simulation computer is required for interfacing the SMS to the SMCC; therefore, it is not an integral part of the MCCSS. The SMS interface device and the network simulation computer would have to provide essentially the same functions provided by the STC simulation interface processor as defined in paragraph 3.2.2. Encryption/decryption of the data which interfaces with the SMCC FEP would be performed in these devices. The requirements imposed on the network simulation computer while interfaced with the MCCSS (stand-alone) configuration would be more extensive; therefore, a reduced capability would be required of it when it is used for interfacing the SMS to the SMCC.

E. SMS Interface. This interface, in conjunction with the network simulation computer, would provide the encrypted/decrypted air/ground link, simulation-peculiar data interchange, and voice coordination to the SMS in order to integrate the required MCCSS elements during SMS-SMCC integrated simulations.

3.3 DOD SIMULATOR(S) INTERFACE REQUIREMENTS

3.3.1 Simulator Interface Modes. Due to the training requirements for DOD flight crew and flight controller personnel, the SMS should simulate earth-orbital missions in two modes, i.e., SMS independent (non-integrated) and SMS-SMCC (integrated).

This simulation training, as required for DOD, should provide for the following mission phases for both integrated and non-integrated modes:

- Prelaunch
- Liftoff
- Orbiter/external tank (ET)/solid rocket booster (SRB)-mated ascent
- SRR jettison
- Orbiter/ET ascent
- ET separation
- On-orbit operations (payload delivery and retrieval)
- Upper stage orbit transfer
- Rendezvous
- Docking
- Circular and elliptical earth orbits
- Synchronous orbits (IUS)
- Parking orbits
- Deorbit maneuvers
- Entry
- Terminal Area Energy Management (TAEM)

- Approach and landing
- Rollout
- Mission aborts.

The primary purpose of the JSC or STC SMS independent mode (non-integrated) is to provide crew training in on-orbit activities; it allows the SMS instructors to have complete control of the SMS operation. Trajectory data for the Orbiter is computed within the SMS complex, transmission of telemetry data between the SMS and SMCC is halted, and simulated network communication between SMS and SMCC is terminated.

In the SMS-SMCC (integrated) mode, the procedure for establishing Orbiter-to-ground network communication status consists of sending data from the SMS to the SMCC, and having SMCC perform all subsequent calculations. This task falls logically to the SMCC because it controls sequencing of remote network facilities, and the SMS has no knowledge of which remote network facilities are operating. Orbiter network communication status is normally computed by the SMCC and sent to the SMS instructor console.

SMS computer status and time reference are transmitted together with trajectory data to permit the SMCC to evaluate and use the received trajectory data in real-time. The SMS and SMCC would compute Orbiter trajectory information in parallel; computations in the SMS would be used to determine the trajectory during Orbiter-initiated maneuvers; and computations at the SMCC would be used to determine the trajectory during ballistic flight. The SMS/SMCC simulation network interface consists of the following data links:

- Trajectory
- Telemetry (onboard systems and flight computer data)
- Communication
- Timing
- Biomedical (if desired by DOD).

Because of DOD's encryption/decryption of downlinked data ("bent-pipe" technique) there would be differences in DOD versus NASA SMS/SMCC interface hardware and software.

3.3.2 Interface Development Concept. An interface development concept for the DOD SMCC is illustrated in figure 3-2. As shown in figure 3-2a, the SMCC would consist of an MCCSS stand-alone capability for DOD flight controller training and the JSC SMS to SMCC interfaces for NASA/DOD joint flight crew training. This configuration should be adequate for DOD training during the early Shuttle development phases (prior to DOD integrated training requirements at STC). During this time (ALT phase) the SMCC will be developed, verified, and checked out. It should be noted that initial DOD flight controller training would start at the JSC facilities.

Prior to VFT-integrated training, DOD would provide a wideband data simulation network as shown in figure 3-2b. This would provide DOD with an integrated mission training capability via an STC simulation interface processor. This processor would be located at JSC to provide serially assembled transfer data for the simulation network interface that is STC-compatible. Part of the processor's functions would be to receive JSC SMS state vector information, convert it to tracking data, and extract site location information to send back to the JSC SMS. Other functions of the processor would be any unique DOD requirement, such as format assembly of tracking (trajectory), telemetry, communications, biomedical, and timing data; inserting sync patterns, error codes, site-vehicle-source ID codes; and serially outputting the data to the simulation network JSC modem for transmission to the STC SMCC.

It is assumed that only unclassified mission data would be transmitted during integrated mission simulations, thus eliminating the requirement for encoded interfaces.

Prior to JSC SMS FBCS projected usage saturation, the DOD would procure an SMS FBCS and its associated computer complex. The DOD would also provide for interfacing it with SMCC by modifying the STC SMS interface software and hardware for encryption/decryption technqiues. The JSC SMS/STC SMCC interface should remain intact for DOD mission on-orbit contingency support from NASA. This configuration is shown in figure 3-2c.

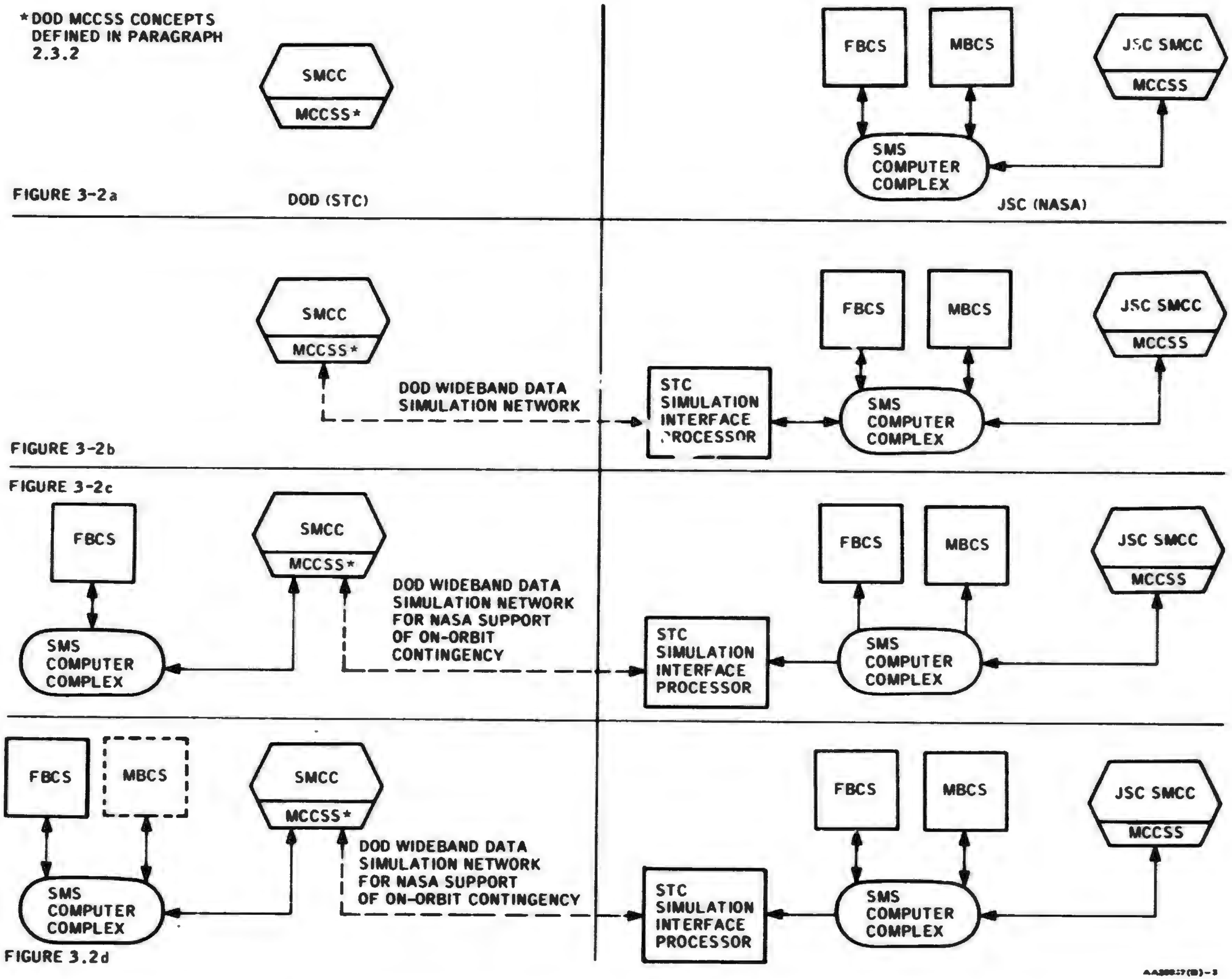


Figure 3-2 Functional DOD SMCC Interface Development

Figure 3-2d shows addition of the SMS MBCS capability, when required (JSC MBCS saturates) during the Shuttle operation phase which would then require upgrading of the STC SMS computer complex to accommodate the MBCS.

3.3.3 Command and Control Data System (CCDS) Functional Element Interface Concept. No requirements were identified for interfacing the SMS with other CCDS elements (Launch Control, Range, etc.). Interfaces with user satellite MCC's is assummed to be via the SMCC.

SECTION 4

STC SIMULATOR DEPLOYMENT CONCEPTS

4.1 GENERAL

A large number of possible combinations of hardware and personnel exist which would satisfy the DOD requirements for a "simulation and training capability." In light of the groundrules agreed upon by the USAF and Philco-Ford for the simulation subtask, three basic concepts emerge. Concept 1 is the minimal cost configuration which would eliminate any simulators at STC but would provide the DOD with a limited MCCSS. Concept 2 places a 2+4 SMS at both JSC and STC including a DOD unique MCCSS. Concept 3 places a 2+4 SMS at JSC and a +4 SMS (FBCS) at STC. Table 4-1 is a summary of the simulator deployment concepts considered.

4.2 CONCEPT 1 - ONE 2+4 SMS AT JSC

The first concept is less costly than the others but was found to be unsatisfactory in almost all other respects. Simulation-unique hardware at the STC would consist of interface data conversion equipment to enable DOD mission controllers to receive and monitor JSC data during integrated simulations or math model only simulations. This is considered unsatisfactory because it does not offer the effectiveness or the operational realism considered necessary for adequate training. It would create all of the attendant problems related to crew training at a site remote from the mission management. Problems in this area include:

- Reduced DOD STS program management visibility into pilot proficiency required for crew selection and intracrew matching
- Extensive remote site travel
- Coordination and separation of preflight and real-time mission activities.

TABLE 4-1

SIMULATOR DEPLOYMENT CONCEPT SUMMARY

CONCEPT NO. 1	ONE 2+4 SMS AT JSC; MCCSS CAPABILITY AT STC
PHILOSOPHY	LOWEST COST (FACILITIES) METHOD OF GIVING STC A TRAINING CAPABILITY
TWO OPTIONS	1) MINIMUM MCCSS HARDWARE. JSC SMS DATA (MBCS AND FBCS) RELAYED TO JSC SMCC THEN TO STC SMCC THRU APPROPRIATE DATA CONTROL UNITS. STC SMCC TO HAVE ONLY A MONITOR CAPABILITY (I.E., NO STC INPUT CAPABILITY). WOULD ALSO ALLOW STC TO MONITOR JSC SMCC ONLY SIM'S (SMCC MATH MODEL ASTRONAUT CONTROL PANELS (ACP) INTERACTION WITH NO CREW FOR FLIGHT CONTROLLER TRAINING ONLY) 2) IMPROVED - ACP'S AT STC SMCC. SAME AS (1) WITH THE ADDED BENEFITS OF STC BEING ABLE TO RUN A STANDALONE SIMULATION FOR IN-HOUSE DOD FLIGHT CONTROL PERSONNEL USING JSC MATH MODELS, ETC.
ADVANTAGES	• MINIMAL COST TRAINING CAPABILITY
DISADVANTAGES	• COMPLETE DEPENDENCY ON NASA FACILITIES AND PERSONNEL FOR TRAINING OF CREW AND CONTROLLERS • OVERLOAD SMS IN 1979 TIMEFRAME • TRAVEL, HOUSING SCHEDULING ETC. COSTS FOR DOD PERSONNEL TDY AT JSC • NO ONSITE SIMULATOR FOR USE BY CONTROL ELEMENTS FOR CONTINGENCY SUPPORT, REAL-TIME TRAJECTORY CHANGE ANALYSIS, FAMILIARIZATION, ETC. • SECURITY PROBLEMS CREATED BY LACK OF ONSITE FACILITIES FOR CHECKOUT OF DOD CLASSIFIED AND DOD UNIQUE TRAJECTORIES, ETC. • SEPARATES PREFLIGHT AND REAL-TIME ACTIVITIES CONTRARY TO OPS CONCEPT FOR THE MISSION OPERATION DIRECTORATE (MOD) • REQUIRES ADDITIONAL DOD STAFFING AT JSC (FLIGHT READINESS DIVISION) CONTRARY TO OPS CONCEPT • DOD SPECIAL (LAUNCH ON FAILURE, ETC.) OR NASA RESCUE MISSIONS COULD IMPACT SMS TRAINING SUFFICIENTLY TO PERTURB FLIGHT SEQUENCE, ETC. REQUIRING PERSONNEL CHANGES, SCHEDULE REVISIONS, TRAJECTORY CHANGES FOR SLIPPED LAUNCH DATES - ALL OF WHICH ARE COSTLY

TABLE 4-1 (CONT'D)

CONCEPT NO. 2	FULL CAPABILITY SMS 2+4 AT BOTH JSC AND STC
PHILOSOPHY	PROVIDES DOD WITH COMPLETE SIMULATION AND TRAINING CAPABILITY, ELIMINATING SCHEDULE CONSTRAINTS, ETC. OF JSC SMS, BUT AT HIGH COST (PERSONNEL AND FACILITIES)
DOD FACILITIES AT STC	• 2+4 SMS WITH ASSOCIATED INSTRUCTOR OPERATOR STATION (IOS) AND COMPUTER(S) • FULL MCCSS EQUIPMENT (ACP'S MATH MODELS, STC SMCC/SMS DCU'S, STC SMCC/JSC SMCC DCU's)
DISADVANTAGES	• HIGH INITIAL AND OPERATING COST • ADDITIONAL PERSONNEL (DOD) • ADDITIONAL CONTRACTOR PERSONNEL
ADVANTAGES	• REDUCED DEPENDING ON NASA FACILITIES • ELIMINATES OVER SATURATION OF NASA SMS • INCREASED CONTINGENCY SUPPORT CAPABILITY • PROVIDES BACKUP SIMULATION FACILITY IN CASE OF JSC SMS PROBLEMS • ELIMINATES SOME COSTS ASSOCIATED WITH STC EXPANSION FROM +4 TO 2+4 • ELIMINATES JSC SIMULATOR SUPPORT DELAYS • SIMULATION SUPPORT (CONTRACTORS, FLIGHT INSTRUCTORS, ETC.); FORM A NUCLEUS OF A KNOWLEDGEABLE TEAM FOR MALFUNCTION ANALYSIS AND CONTINGENCY SUPPORT. STS PROGRAM MANAGEMENT • IMPROVES DOD VISIBILITY INTO PILOT PROFICIENCY AND ENABLES CMDR/PILOT SELECTION BASED ON DOD PERSONNEL REPORTING AND FIRST-HAND OBSERVATION

TABLE 4-1 (CONT'D)

CONCEPT NO. 3	2+4 SMS AT JSC, +4 SMS AT STC
PHILOSOPHY	PROVIDES DOD WITH ONSITE SIMULATION AND TRAINING FACILITY, ELIMINATING THE NEED TO USE JSC SMS FOR ALL RECURRING TRAINING EXCEPT FOR AEROFLIGHT PHASE OF MISSION. SMS MBCS OR OAS AT JSC OR SHUTTLE TRAINING AIRCRAFTS (STA'S) TO BE USED FOR INITIAL OR RECURRING AEROFLIGHT TRAINING NEEDS.
DOD FACILITIES AT STC	• SMS FBCS AND ASSOCIATED IOS AND COMPUTER (COMPATIBLE BUT POSSIBLY REDUCED IN SIZE TO JSC COMP.) • FULL MCCSS CAPABILITY AND ALL ASSOCIATED EQUIPMENT (ACP'S, MATH MODELS DCU'S, ETC.)
DISADVANTAGES	• ADDITIONAL PERSONNEL (DOD) • ADDITIONAL CONTRACTOR PERSONNEL • ADDITIONAL COST IF EXPANSION TO 2+4 SMS REQUIRED AT A LATER DATE • SATURATION OF NASA MBCS
ADVANTAGES	• REDUCED DEPENDENCY ON NASA FACILITIES • INCREASED CONTINGENCY SUPPORT CAPABILITY • PREVENTS OVER SATURATION OF NASA FBCS • PROVIDES BACKUP FBCS SIMULATION SUPPORT IN CASE OF JSC FBCS FAILURE • ELIMINATES JSC SIMULATOR SUPPORT DELAYS INVOLVING FBCS • SIMULATION SUPPORT PERSONNEL FORM A NUCLEUS OF A KNOWLEDGEABLE TEAM FOR MALFUNCTION ANALYSIS AND CONTINGENCY SUPPORT • IMPROVES DOD VISIBILITY INTO PILOT PROFICIENCY AND ENABLES CMDR/PILOT SELECTION TO BE BASED ON DOD PERSONNEL REPORTING AND FIRST-HAND OBSERVATION

The absence of a simulator would also reduce the effectiveness of several of the mission support and planning groups. Those areas include malfunction trend analysis, real-time trajectory changes, security relative to DOD classified payloads and trajectories, and flight controller familiarity with onboard procedures which would limit their ability to make real-time changes when required.

This concept is considered to have minimum flexibility and reduced training time for several reasons; the overriding reason is the projected saturation of the JSC SMS (see figures 2-3 and 2-5). The FBCS would be the primary facility for training all NASA and DOD user payload specialists. The number of these individuals that will require training, the diversity of their jobs/tasks, and the probability of extensive crew station modifications for each mission indicate that an estimated SMS saturation will occur in the CY 1979 timeframe. The workload on the JSC SMS MBCS could be off-loaded to the OAS and/or the STA; no facilities are planned for the relief of the FBCS workload.

Although this concept is the least costly of the three considered, it is not without considerable expenditures. Travel to and from JSC for recurring training for the flight crew, flight controllers and support personnel, their housing while at JSC, and the additional staff required to support this effort are significant.

4.3 CONCEPT 2 - ONE 2+4 SMS EACH AT JSC AND STC

Except for the high initial and operating costs, concept 2 is the ideal case. It would eliminate the need for DOD personnel to acquire their recurring training at JSC, thereby alleviating the workload on the JSC SMS. It would provide an easily modified test bed for mission design, malfunction analysis and contingency support, trajectory analysis/modifications, etc. The capability would also exist for the DOD and NASA to conduct dual mission-integrated simulations for contingency and nominal cases, thus improving the ability of the two agencies to support each other.

Present data indicate an annual flight rate of 60, whereas the latest combined launch traffic figures indicate as many as 70. NASA has indicated that it will be difficult to achieve 2000 (MBCS) and 2500 (FBCS) training hours on the JSC SMS. The JSC SMS is scheduled to be operational approximately 1 year prior to the first vertical flight. This is to allow for any delays in installation and for lower than predicted simulator training efficiency which can occur and often does when initially operating a sophisticated simulation facility. This, plus the higher launch traffic rate, has led NASA to speculate on the need for a second 2+4 SMS. The decision on whether a second SMS is required at JSC will be based on empirical data that is obtained during the operational phase of the program. The installation of an SMS at STC would eliminate the very real possibility of a launch rate limitation due to training delays caused by overloading the JSC SMS.

Some of the additional benefits which could be derived from this deployment concept are:

A. Simulation support personnel (contractors, flight instructors, etc.) form the nucleus of a knowledgeable team for malfunction analysis and contingency support.

B. Simulator support personnel (MOD Rehearsal Branch) of the Flight Readiness Division, in conjunction with the Mission Planning Branch and Flight Procedures Branch (Mission Development Division), provide personnel for dual mission second SMCC operation.

C. The problem of NASA 8-hour response time for contingency support is reduced by providing DOD a tool for increased malfunction analysis and workaround procedure development.

D. The ability of program management to make commander/pilot selections and aid intracrew matching is improved.

E. The SMS communications system at STC would be allowed to use encryption/decryption flight hardware with minimal security problems.

F. The necessary travel of a large number of experts from various areas who are required for training support in their specialty areas (including top management, continuous team support and those individuals who brief the crew on a single subject requiring only a few minutes) is precluded.

G. The nature of DOD payloads indicates the desirability of DOD payload specialists receiving their initial training at STC to improve coordination with their SMCC personnel and personnel of the various DOD flight control elements with whom they must interface (e.g., Mission Design Section, Orbiter Manager, etc.).

H. Flight crew training time with STA being deployed at or near STC, part-task trainers for DOD unique training at STC, and an SMS at STC for premission integrated simulations may be used efficiently.

4.4 CONCEPT 3 - ONE 2+4 SMS AT JSC AND ONE +4 AT STS

Concept 3 is a compromise of the first two concepts, but is affected by the saturation dates indicated in paragraph 2.2. This concept has lower costs than concept 2 while offering virtually the same effectiveness. The usage of an FBCS only at STC, coupled with a DOD unique MCCSS, results in considerable savings, if it could be assumed feasible for adequate training. Initial and continuous operating costs of the MBCS are much greater than the FBCS. The existence of two moving base simulators (OAS, SMS MBCS) at JSC, supplemented by the STA, indicates the possible capability to support NASA and DOD initial and recurring aerodynamic flight training in the early phases of the operational part of the STC program. Subject to STC SMS computer sizing and selection, this concept is very flexible and the expansion from a +4 to a 2+4 configuration could be completed with little difficulty if an MBCS at STC is required. By deploying an FBCS at STC initially, all of the benefits derived from an STC 2+4 SMS (as defined in concept 2), including the ability to run JSC/STC integrated simulations for dual or rescue missions are assured. NASA had been assigned the task of performing rescue missions and valuable training in this area could be realized by this form of training.

As the launch rate increases, the possibility of one agency having two Orbiters in operation simultaneously is increased. During single DOD flights, the STC FBCS could be used to run a dual mission integrated simulation, using the SSV in orbit as the second "simulated" Orbiter. This capability must exist for dual missions if simultaneous data handling is to be performed. All inputs to the data system must be identifiable as to source, i.e., SSV ID and/or remote tracking station (RTS), and to which SMCC it should be routed. Outputs (communications, uplink, etc.) must be managed in a similar manner to ensure they are routed to the proper output element (RTS or SMCC/MCC display). An FBCS would be ideally suited to perform this task during single SSV flight support periods. This would also be an added training capability for the simulation support (and other MOD) personnel in preparation for manning the second SMCC during dual missions.

SECTION 5

PROBABLE SATURATION DATES (10 PERCENT ATTRITION)

Saturation for the SMS determined in previous sections assumed a 20 percent attrition rate. This section consists of tables and graphs which indicate probable saturation dates for the NASA JSC SMS fixed and motion base crew stations based on an approximate 10 percent crew attrition rate.

TABLE 5-1

DOD SHUTTLE FLIGHT CREW MEMBERS

	CALENDAR YEAR													
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
NUMBER OF MISSIONS	-	-	3	5	5	13	16	17	16	16	15	16	17	17
<u>CREW CATEGORY REQUIREMENTS</u>														
COMMANDERS (A)	-	3	4	4	4	4	4	4	4	4	4	4	4	4
PILOTS	-	3	3	3	3	3	4	4	4	4	4	4	4	4
MISSION SPECIALISTS	-	3	3	3	4	5	5	5	5	5	5	5	5	5
<u>CREW IN-TRAINING REQUIREMENTS</u>														
COMMANDERS (B)	3	2	1	1	1	1	1	1	1	1	1	1	1	1
PILOTS (C)	3	1	1	1	1	2	1	1	1	1	1	1	1	1
MISSION SPECIALISTS (D)	3	1	1	2	2	3	1	1	1	1	1	1	1	1

ASSUMPTIONS:
(A) ATTRITION OF 1 COMMANDER PER YEAR
(B) PILOTS UPRATING TO COMMANDER - 220 HOURS IN SMS
(C) MISSION SPECIALIST UPRATING TO PILOT - 180 HOURS IN SMS
(D) NEW MISSION SPECIALIST TRAINING - 150 HOURS IN SMS

TABLE 5-2

DOD ANNUAL SIMULATOR REQUIREMENTS INITIAL CHECKOUT, OPERATIONAL AND CREW UPRATING

	CALENDAR YEAR													
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
INITIAL CHECKOUT (HOURS)														
COMMANDERS	660	440	220	220	220	220	220	220	220	220	220	220	220	220
PILOTS	540	180	180	180	180	360	180	180	180	180	180	180	180	180
MISSION SPECIALISTS	450	150	150	300	300	450	150	150	150	150	150	150	150	150
SUBTOTAL (HOURS)	1650	770	550	700	700	1030	550	550	550	550	550	550	550	550
OPERATIONAL AND CREW UPRATING (HOURS)														
COMMANDERS	-	450	600	600	600	600	600	600	600	600	600	600	600	600
PILOTS	-	390	390	390	390	390	520	520	520	520	520	520	520	520
MISSION SPECIALISTS	-	300	300	300	400	500	500	500	500	500	500	500	500	500
SUBTOTAL (HOURS)	-	1140	1290	1290	1390	1490	1620	1620	1620	1620	1620	1620	1620	1620
TOTAL DOD SMS (HOURS)	1650	1910	1840	1990	2090	2520	2170	2170	2170	2170	2170	2170	2170	2170

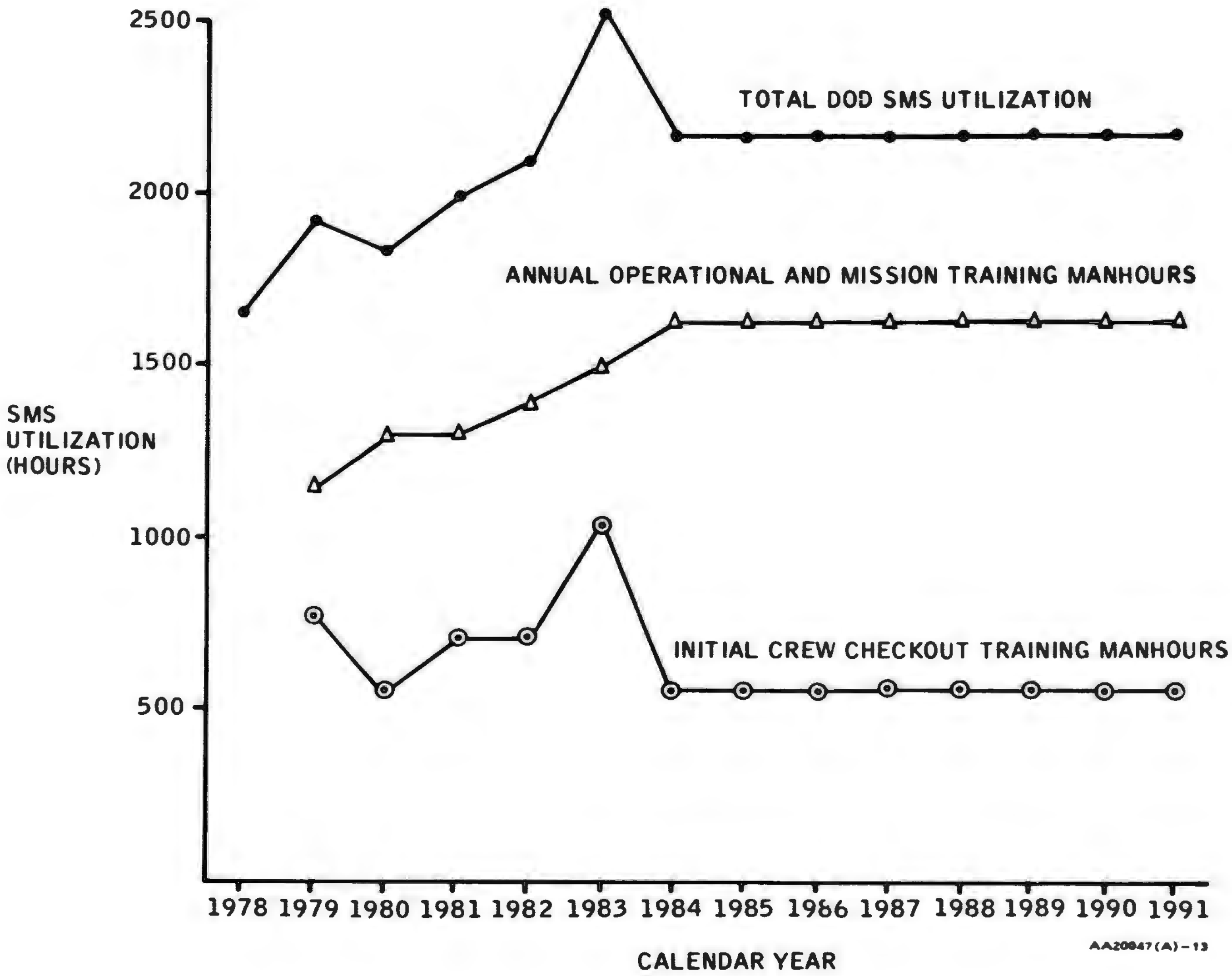


Figure 5-1 DOD Simulator Manhour Utilization

TABLE 5-3

NASA SHUTTLE FLIGHT CREWS

	CALENDAR YEAR													
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
NUMBER OF MISSIONS	-	11	14	32	28	41	45	51	52	45	48	44	53	48
<u>CREW MEMBERS REQUIRED</u>														
COMMANDERS	3	4	7	7	9	9	11	11	11	11	11	11	11	11
PILOTS	2	3	6	6	8	9	10	11	11	11	11	11	11	11
MISSION SPECIALISTS	3	5	7	7	9	10	11	11	11	11	11	11	11	11
<u>PERSONNEL IN TRAINING</u>														
COMMANDERS	4	4	1	3	1	3	1	1	1	1	1	1	1	1
PILOTS	3	4	1	3	2	2	2	1	1	1	1	1	1	1
MISSION SPECIALISTS	5	3	1	3	2	2	1	1	1	1	1	1	1	1

ASSUMPTION: ONE CREW MEMBER IN EACH CATEGORY ATTRITION PER YEAR (~10% ATTRITION)

TABLE 5-4
SMS UTILIZATION (HOURS)

DOD

CALENDAR YEAR	MOTION BASE MIN (A)	MOTION BASE PROB (B)	MOTION BASE MAX (C)	FIXED BASE MIN (D)	FIXED BASE PROB (E)	FIXED BASE MAX (F)
1978	375	457.5	540	450	825	1110
1979	595	690.0	785	450	830	1125
1980	585	680.0	775	450	830	1065
1981	585	680.0	775	600	980	1215
1982	585	680.0	775	700	1080	1315
1983	585	707.5	830	950	1455	1690
1984	585	702.5	820	650	1115	1350
1985	585	702.5	820	650	1115	1350
1986	585	702.5	820	650	1115	1350
1987	585	702.5	820	650	1115	1350
1988	585	702.5	820	650	1115	1350
1989	585	702.5	820	650	1115	1350
1990	585	702.5	820	650	1115	1350
1991	585	702.5	820	650	1115	1350
NASA						
1978	500	582.5	665	750	1125	1505
1979	960	1137.5	1315	950	1705	2225
1980	930	1092.5	1255	850	1485	1825
1981	1180	1397.5	1615	1150	2035	2565
1982	1160	1395.0	1630	1200	2130	2540
1983	1410	1667.5	1925	1300	2315	2915
1984	1390	1670.0	1950	1250	2350	2830
1985	1390	1665.0	1940	1250	2310	2790
1986	1390	1665.0	1940	1250	2310	2790
1987	1390	1665.0	1940	1250	2310	2790
1988	1390	1665.0	1940	1250	2310	2790
1989	1390	1665.0	1940	1250	2310	2790
1990	1390	1665.0	1940	1250	2310	2790
1991	1390	1665.0	1940	1250	2310	2790

ASSUMPTIONS:
A) COMMANDER TRAINING WILL INCLUDE ALL PILOTS REQUIREMENTS
B) COMMANDER TRAINING WILL INCLUDE ONE HALF PILOTS REQUIREMENTS
C) COMMANDERS AND PILOTS TRAINED SEPARATELY
D) COMMANDER AND PILOT WILL ACCOMPLISH THEIR TRAINING DURING MISSION SPECIALISTS SIMULATOR TRAINING
E) MISSION SPECIALIST AND PILOT TRAIN SEPARATELY - COMMANDER TRAINING CONCURRENT
F) EACH CREW MEMBER TRAINED SEPARATELY

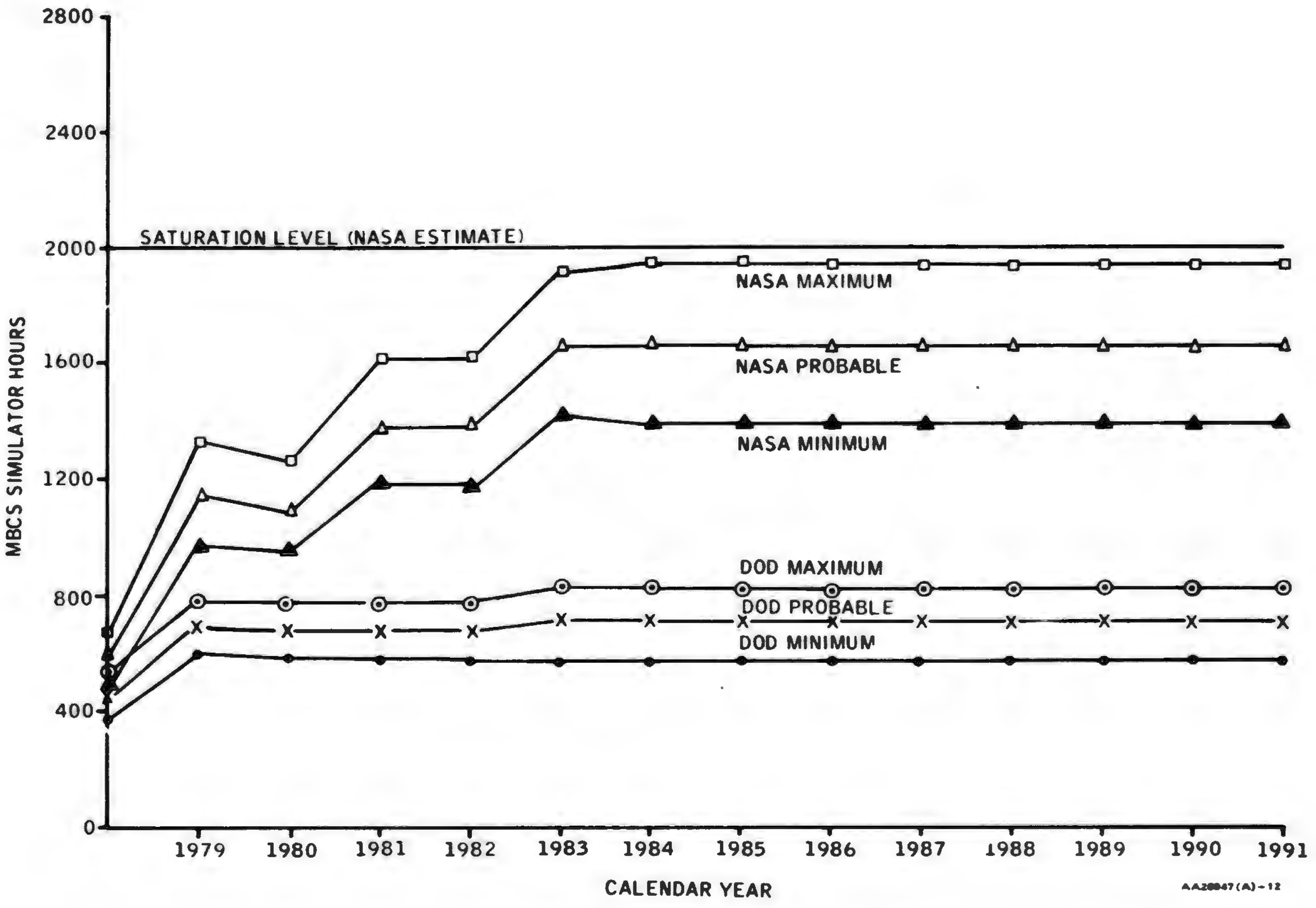


Figure 5-2 DOD/NASA MBCS Simulator Hours vs Calendar Year

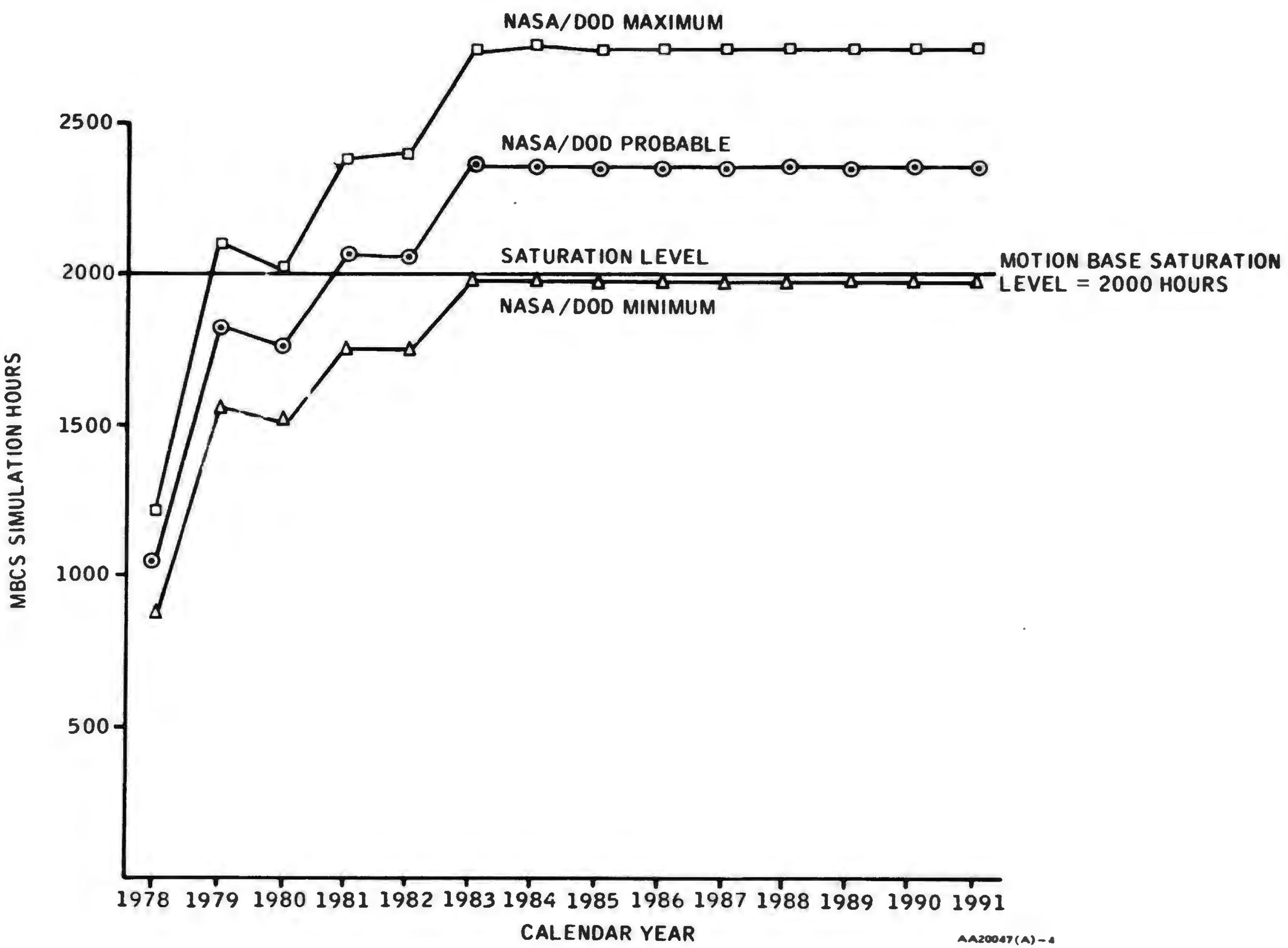


Figure 5-3 Total MBCS Simulator Hours vs Calendar Year

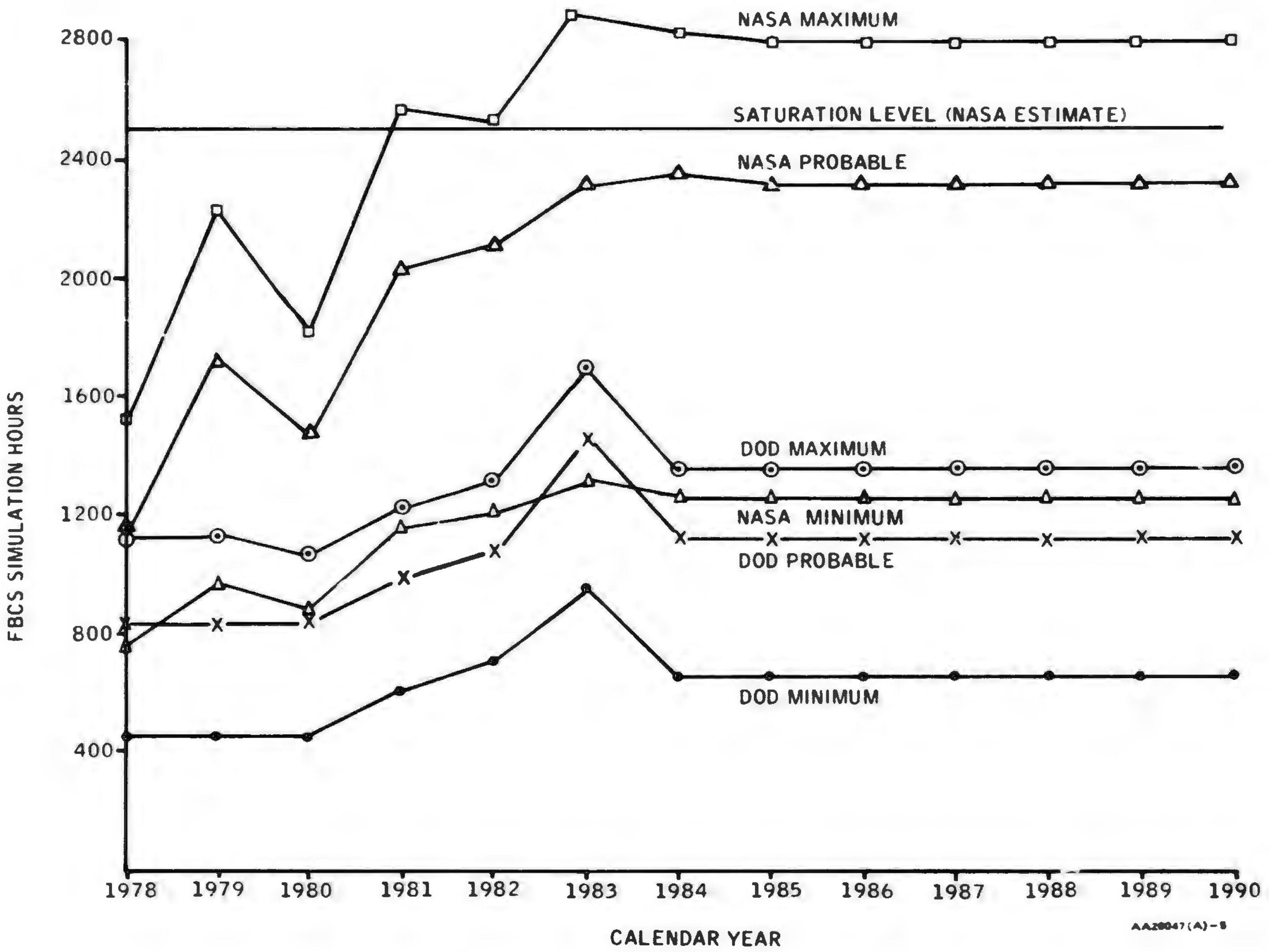


Figure 5-4 DOD/NASA FBCS Simulator Hours vs Calendar Year

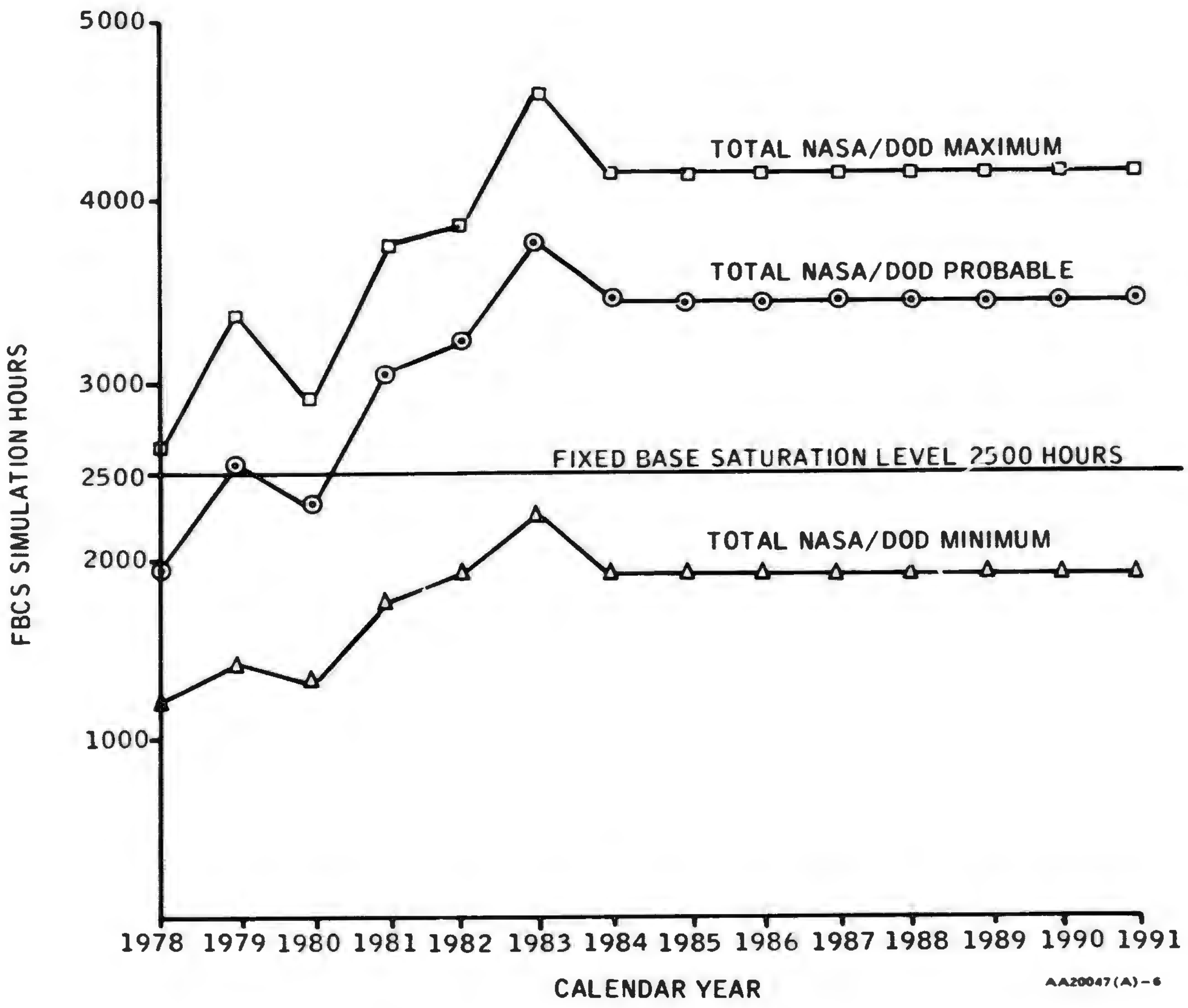


Figure 5-5 Total FBCS Simulator Hours vs Calendar Year

SECTION 6

SMS RESOURCE ANALYSIS

6.1 GENERAL

Optimization of the schedules and costs presented in this section were governed primarily by the assumption that maximum use would be made of the software/hardware systems development and acquisition tasks performed by NASA in their procurement of a 2+4 SMS at JSC. From a cost standpoint, as evidenced in paragraph 6.2 and tables 6-1 through 6-3, indications are that concepts 1 and 3 would prove less expensive than the recommended concept 2. Scheduling considerations indicated similar results from a delivery/availability standpoint, in that concept 1 is already in the procurement stage, and concept 3 would result in reduced implementation time due to implementation of only a fixed base crew station (FBCS) at the Satellite Test Center (STC). These indications, however, were judged insufficient in merit to override the conclusion that only concept 2 alleviates the joint use (NASA/DOD) saturation constraints imposed by concepts 1 and 3. As such, the resource acquisition schedule reflects concept 2.

As indicated in the resource acquisition network, figure 6-4, the approximate period for completion of requirements studies and initiation of procurement actions should be the fourth quarter of calendar year 1975. Subsequent release of requests for proposals (RFP's) in 1976 would ensure contract award, development integration and delivery of an operational 2+4 DOD SMS at the STC on or before the second quarter of calendar year 1979. Delivery would be prior to the estimated saturation of the JSC SMS and would afford maximum benefit from NASA SMS design and procurement activities.

6.2 COST SENSITIVITY ANALYSIS

The ROM cost estimates presented in this report (tables 6-1 through 6-3) are based upon cost estimates defined in reference documents 10 and 12, and Philco-Ford studies. NASA studies -- *Simulation Techniques Study*, 17 November 1972, and *Shuttle Mission Simulator Baseline Definition Report*, 22 June 1973 -- provided a baseline cost for the SMS Motion and Fixed Base Crew Stations and the host computer. Philco-Ford studies provided cost estimates for the SMS motion base and visual hardware/software. The cost estimates presented for the DOD SMS deployment concepts were defined anticipating maximum use of the engineering design concepts developed for

TABLE 6-1
COST BASELINE-CONCEPT 1
2+4 SMS AT JSC
MOTION BASE CREW STATION

COMPONENT	NASA COST
CREW STATION	$ 1,452,000
INSTRUCTOR STATION	421,000
ANCILLARY EQUIPMENT	327,000
ONBOARD COMPUTERS (OBC/HOST COM I/F HW/SW)	966,000**
COMPUTER COMPLEX AUGMENTATION	367,000
DIGITAL CONVERSION EQUIPMENT	1,125,000
SOFTWARE	3,097,000
SYSTEM INTEGRATION	829,000
INSTALLATION, TEST AND C/O	1,587,000
DOCUMENTATION	664,000
PROGRAM MANAGEMENT/ENGINEERING	1,749,000
MISCELLANEOUS HW/SW	1,312,000
SPARES PROVISIONING	282,000
SUPPORT	221,000
MOTION	851,700*
VISUAL	3,000,000*
TOTAL	$18,250,700

NOTE: The above items do not include the costs of facilities and government furnished parts.

*These prices are based on internal PHO studies and are 1974 dollars.

**Does not include cost of five GFE onboard computers.

TABLE 6-1 (CONT'D)

FIXED BASE CREW STATION

COMPONENT	NASA COST
CREW STATION	$ 1,214,000
INSTRUCTOR STATION	528,000
ANCILLARY EQUIPMENT	157,000
ONBOARD COMPUTERS (OBC/HOST COMP I/F HW/SW)	567,000**
COMPUTER COMPLEX AUGMENTATION	250,000
DIGITAL CONVERSION EQUIPMENT	834,000
SOFTWARE	480,000
SYSTEM INTEGRATION	148,000
INSTALLATION, TEST AND C/O	1,207,000
DOCUMENTATION	397,000
PROGRAM MANAGEMENT/ENGINEERING	2,002,000
MISCELLANEOUS HW/SW	1,019,000
SPARES PROVISIONING	262,000
SUPPORT	189,000
VISUAL	2,600,000*
TOTAL	$11,854,000

NOTE: The above items do not include the costs of facilities and government furnished parts.

*These prices are based on internal PHO studies and are FY 1974 dollars.

**Does not include cost of five GFE onboard computers.

TABLE 6-1 (CONT'D)

COMPUTER COMPLEX

COMPONENT		NASA COST
4 MEGABYTE CPU		$ 3,311,100
TWO BLOCK MPX CHANNELS AND		218,080
CHANNEL INDIRECT DATA ADDRESSING		14,100
MULTIPLEXER CHANNELS AND		103,500
CHANNEL INDIRECT DATA ADDRESSING		9,430
SYSTEM CONSOLE		160,560
POWER AND COOLANT DISTRIBUTION UNIT		119,040
	TOTAL	$ 3,935,810

TOTAL SMS COST

COMPONENT		NASA COST
MOTION BASE CREW STATION		$18,250,700
FIXED BASE CREW STATION		11,854,000
COMPUTER COMPLEX		3,935,810
	TOTAL	$34,040,510

TABLE 6-2

COST BASELINE-CONCEPT 2

2+4 SMS AT JSC AND STC

MOTION BASE CREW STATION

COMPONENT	NASA COST	DOD COST
CREW STATION	$ 1,452,000	$ 1,016,400
INSTRUCTOR STATION	421,000	294,700
ANCILLARY EQUIPMENT	327,000	228,900
ONBOARD COMPUTERS (OBC/HOST COMP I/F HW/SW)	966,000**	676,200**
COMPUTER COMPLEX AUGMENTATION	367,000	256,900
DIGITAL CONVERSION EQUIPMENT	1,125,000	787,500
SOFTWARE	3,097,000	2,167,900
SYSTEM INTEGRATION	829,000	580,300
INSTALLATION, TEST AND C/O	1,587,000	1,110,900
DOCUMENTATION	664,000	464,800
PROGRAM MANAGEMENT/ENGINEERING	1,749,000	1,224,300
MISCELLANEOUS HW/SW	1,312,000	918,400
SPARES PROVISIONING	282,000	197,400
SUPPORT	221,000	154,700
MOTION	851,700*	596,190*
VISUAL	3,000,000*	2,100,000*
TOTAL	$18,250,700	$12,775,490

NOTE: The above items do not include the costs of facilities and government furnished parts.

*These prices are based on PHO internal studies and are FY 1974 dollars.

**Does not include cost of four GFE onboard computers.

TABLE 6-2 (CONT'D)

FIXED BASE CREW STATION

COMPONENT	NASA COST	DOD COST
CREW STATION	$ 1,214,000	$ 849,800
INSTRUCTOR STATION	528,000	369,600
ANCILLARY EQUIPMENT	157,000	109,900
ONBOARD COMPUTERS (OBC/HOST COMP I/F HW/SW)	567,000**	396,900**
COMPUTER COMPLEX AUGMENTATION	250,000	175,000
DIGITAL CONVERSION EQUIPMENT	834,000	583,000
SOFTWARE	480,000	336,000
SYSTEM INTEGRATION	148,000	103,600
INSTALLATION, TEST AND C/O	1,207,000	844,900
DOCUMENTATION	397,000	277,900
PROGRAM MANAGEMENT/ENGINEERING	2,002,000	1,401,400
MISCELLANEOUS HW/SW	1,019,000	713,300
SPARES PROVISIONING	262,000	183,400
SUPPORT	189,000	132,300
VISUAL	2,600,000*	1,820,000
TOTAL	$11,854,000	$ 8,297,000

NOTE: The above items do not include the costs of facilities and government furnished parts.

*These prices are based on PHO internal studies and are FY 1974 dollars.

**Does not include cost of five GFE onboard computers.

TABLE 6-2 (CONT'D)

COMPUTER COMPLEX

COMPONENT	NASA COST	DOD COST
4 MEGABYTE CPU	$ 3,311,100	$ 2,317,770
TWO BLOCK MPX CHANNELS AND	218,080	152,656
CHANNEL INDIRECT DATA ADDRESSING	14,100	9,870
MULTIPLEXER CHANNELS AND	103,500	72,450
CHANNEL INDIRECT DATA ADDRESSING	9,430	6,601
SYSTEM CONSOLE	160,560	112,392
POWER AND COOLANT DISTRIBUTION UNIT	119,040	83,328
TOTAL	$ 3,935,810	$ 2,755,067

TOTAL SMS COST

COMPONENT	NASA COST	DOD COST
MOTION BASE CREW STATION	$18,250,700	$12,775,490
FIXED BASE CREW STATION	11,854,000	8,297,000
COMPUTER COMPLEX	3,935,810	2,755,067
TOTAL	$34,040,510	$23,827,557

TABLE 6-3
COST BASELINE-CONCEPT 3
2+4 SMS AT JSC AND +4 SMS AT STC
MOTION BASE CREW STATION

COMPONENT	NASA COST
CREW STATION	$ 1,452,000
INSTRUCTOR STATION	421,000
ANCILLARY EQUIPMENT	327,000
ONBOARD COMPUTERS (OBC/HOST COMP I/F HW/SW)	966,000**
COMPUTER COMPLEX AUGMENTATION	367,000
DIGITAL CONVERSION EQUIPMENT	1,125,000
SOFTWARE	3,097,000
SYSTEM INTEGRATION	829,000
INSTALLATION, TEST AND C/O	1,587,000
DOCUMENTATION	664,000
PROGRAM MANAGEMENT/ENGINEERING	1,749,000
MISCELLANEOUS HW/SW	1,312,000
SPARES PROVISIONING	282,000
SUPPORT	221,000
MOTION	851,700*
VISUAL	3,000,000*
TOTAL	$18,250,700

NOTE: The above items do not include the costs of facilities and government furnished parts.

*These prices are based on PHO internal studies and are FY 1974 dollars.

***Does not include cost of four GFE onboard computers.

TABLE 6-3 (CONT'D)

FIXED BASE CREW STATION

COMPONENT	NASA COST	DOD COST
CREW STATION	$ 1,214,000	$ 1,092,600
INSTRUCTOR STATION	528,000	475,200
ANCILLARY EQUIPMENT	157,000	141,300
ONBOARD COMPUTERS (OBC/HOST COMP I/F HW/SW)	567,000**	510,300**
COMPUTER COMPLEX AUGMENTATION	250,000	225,000
DIGITAL CONVERSION EQUIPMENT	834,000	750,600
SOFTWARE	480,000	1,500,000*
SYSTEM INTEGRATION	148,000	133,200
INSTALLATION, TEST AND C/O	1,207,000	1,086,300
DOCUMENTATION	397,000	357,300
PROGRAM MANAGEMENT/ENGINEERING	2,002,000	1,801,800
MISCELLANEOUS HW/SW	1,019,000	917,100
SPARES PROVISIONING	262,000	235,800
SUPPORT	189,000	170,100
VISUAL	2,600,000*	3,500,000*
TOTAL	$11,854,000	$12,896,000

NOTE: The above items do not include the costs of facilities and government furnished parts.

*These prices are based on PHO internal studies and are FY 1974 dollars.

**Does not include cost of five GFE onboard computers.

TABLE 6-3 (CONT'D)

COMPUTER COMPLEX

COMPONENT		NASA COST	DOD COST
COMPUTER COMPLEX †		$ 3,311,100	$ 2,841,700
TWO BLOCK MPX CHANNELS AND		218,080	218,080
CHANNEL INDIRECT DATA ADDRESSING		14,100	14,100
MULTIPLEXER CHANNELS AND		103,500	103,500
CHANNEL INDIRECT DATA ADDRESSING		9,430	9,430
SYSTEM CONSOLE		160,560	160,560
POWER AND COOLANT DISTRIBUTION UNIT		119,040	119,040
	TOTAL	$ 3,935,810	$ 3,466,410

TOTAL SMS COST

COMPONENT		NASA COST	DOD COST
MOTION BASE CREW STATION		$18,250,700	$ --
FIXED BASE CREW STATION		11,854,000	12,896,600
COMPUTER COMPLEX		3,935,810	3,466,410
	TOTAL	$34,040,510	$16,363,010

† NASA - 4 MEGABYTE CPU
DOD - 2 MEGABYTE CPU

the NASA SMS. It should be noted that no costs were escalated to the proposed DOD procurement timeframes. Those costs resulting from the Philco-Ford studies are for 1974; those from other sources are FY73. The software costs were based on the experience of the Skylab and Orbiter aeroflight simulator programs, which had documentation, program control and programming language distribution requirements similar to those specified and envisioned for the SMS. Hardware costs were based on complexity comparisons to similar components and systems.

The ROM cost estimate for concept 1 (one 2+4 SMS at JSC) is shown in table 6-1, including Philco-Ford cost study results for the visual and motion base systems. The visual system estimate assumes a range of $2.5 to $3.5 million for the OAS motion base visual system with the average value of $3 million selected as representative of cost for an SMS MBCS visual system. Since the MBCS contains only the forward visual system, an additional $2 million has been estimated for the aft visual system required in the FBCS for the payload manipulator plus an additional $600,000 for the six window displays which would share the MBCS image generation system.

The ROM cost estimate for concept 2 (2+4 SMS at both JSC and STC) was based upon the following assumptions: 1) initial developmental and engineering costs will be included in the initial procurement (NASA); 2) an average cost savings of 30 percent can be realized due to reduced development and engineering cost. Table 6-2 summarizes the cost estimates for concept 2.

ROM cost estimate for concept 3 (2+4 SMS at JSC +4 SMS at STC) assumes that the single FBCS at STC will not realize full development and engineering reductions shown for the DOD FBCS configuration in table 6-2 because of differences in the simulator configuration which represent different prototype designs and requirements. In addition, a different computer complex would be required for the concept 3 (FBCS only) SMS configuration. A combined fore and aft visual system will be required for the FBCS and costs cannot be shared as in the 2+4 configuration; however, an approximate 30 percent reduction may be possible due to lower design and development costs if the JSC visual system design (i.e., MBCS plus FBCS visual design, $3,500,000 total) were utilized.

6.3 FACILITY CONSIDERATIONS

The facility layouts presented in figures 6-1 and 6-2 represent a combination of several floor plan concepts defined for NASA in reference documents 11, 20, and 21, in addition to Philco-Ford studies and evaluations of the DOD SMS requirements. The layouts represent what are considered to be optimum arrangements and define preferred area sizes and dimensions which could be rearranged to adapt to existing or planned DOD facilities at the STC.

The constraints to rearrangement of the layouts are: 1) the high bay area size and basic dimensions should not be changed appreciably; 2) the computer complex and Orbit and Payload Image Generation System basic dimensions should be maintained; 3) all other areas should be sized relative to those unique requirements established [i.e., maintenance and operations, tool and spares crib(s), and hydraulic and electrical power facilities].

The arrangement illustrated in figure 6-1 is for the 2+4 SMS defined by concept 2 and include the motion and fixed based crew station simulators, both located in a high bay area with a 31-foot-high clear-ceiling and a concrete floor adequately reinforced to accommodate the relatively high static and dynamic loading imposed by the motion base system. Local cable-trough filling and leveling beneath the motion base plates will be required. The 28-foot width next to the motion base crew station is devoted to the raised fixed base crew station and platform.

The computer complex area should have a ceiling height of at least 120 inches, with an under floor depth of 16 inches for cables and cooling. The Approach and Landing Image Generation System (ALIGS) is located in the high bay area to accommodate the terrain model, cloud cover and other special effects image generation equipment for approach and landing simulation. A high bay area does not appear to be necessary for the Orbit and Payload Image Generation System (OPIGS) which includes starfield, payload and manipulator, target vehicle and high altitude earth and horizon image generation equipment. It should be noted that the OPIGS and ALIGS are used by both the fixed and motion based simulators.

The arrangement illustrated in figure 6-2 is for a +4 SMS defined by concept 3 and includes only a fixed based crew station simulator with identical image generation systems and computer complex areas. The image generation systems are identical for the concept 2 and 3 SMS configurations because the elimination of the motion base crew station simulator only deletes the capability for motion cue simulation and the requirements for reinforced floors and a hydraulic facility.

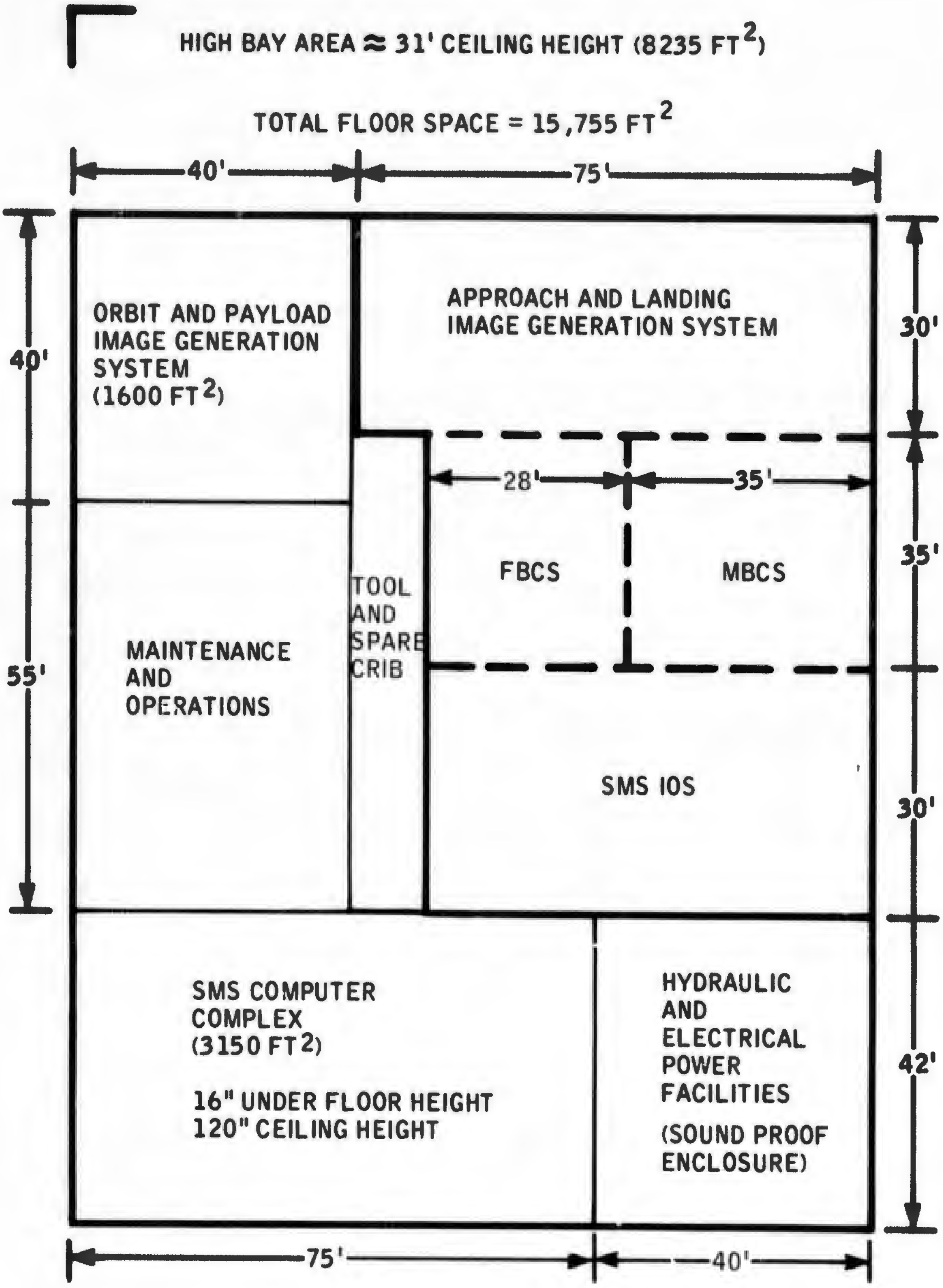


Figure 6-1 Facility Layout for (2+4) SMS at DOD STC (Concept 2)

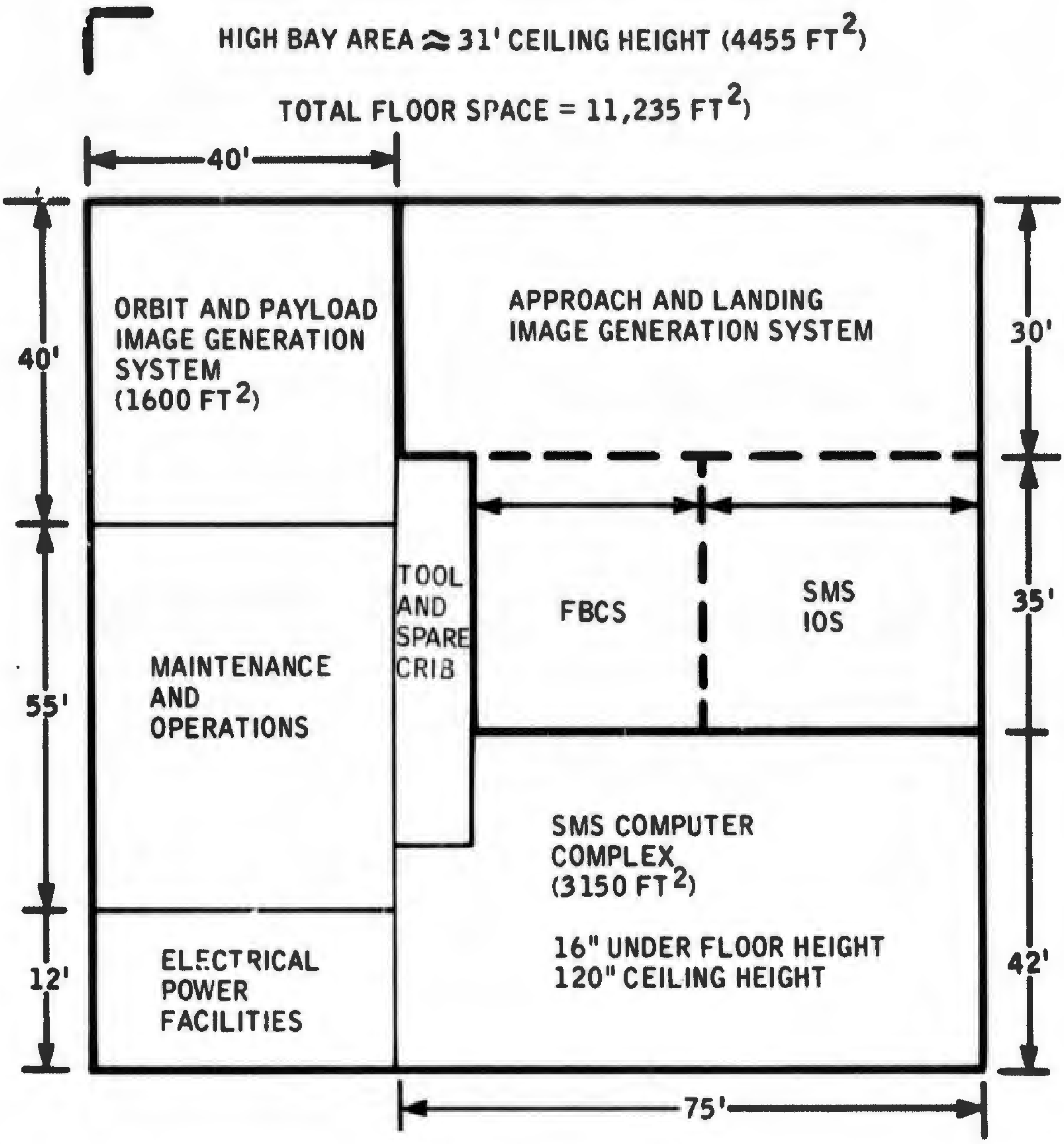


Figure 6-2 Facility Layout for (+4) SMS at DOD STC (Concept 3)

6.4 SMS RESOURCE ACQUISITION SCHEDULES

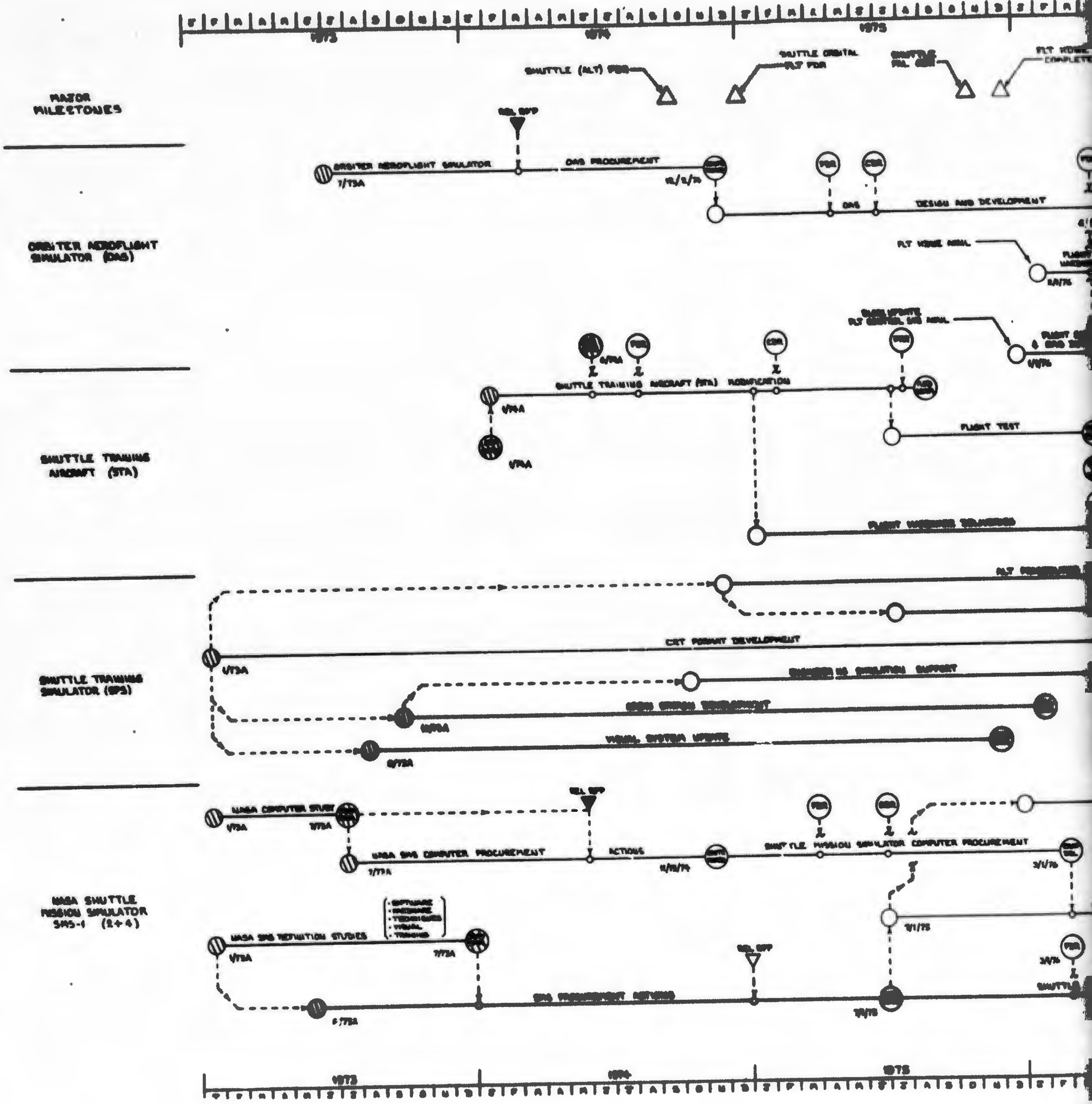
In order to define and propose a schedule for the definition and procurement of a DOD SMS, an evaluation was made of NASA's proposed plans for the development of its simulation facilities. The four primary simulation elements evaluated in this study and scheduled for implementation and/or use at the Lyndon B. Johnson Space Center are the Orbiter Aeroflight Simulator (OAS), the Shuttle Training Aircraft (STA), the Shuttle Procedures Simulator (SPS) and the 2+4 Shuttle Mission Simulator (SMS). Figure 6-3 illustrates the definition, procurement and implementation schedules presently planned for deployment of these simulation facilities and forms the baseline for the acquisition of the DOD SMS. Figure 6-4 illustrates the proposed schedule for implementation of the DOD SMS using the development of the NASA SMS as the pacing item.

The initial DOD activities indicated are studies intended to reassess and further analyse the DOD SMS utility requirements, assess NASA's SMS definitions for DOD applicability, and to fully define the DOD simulation systems required for STS operations. These systems would include the simulation capabilities required for training both crew and ground controllers. Outputs from these studies should provide the information for major DOD procurement decisions during the last quarter of CY75 (computer complex acquisition) and the first quarter of CY76 (other SMS equipment).

The design activities indicated are expected to consist primarily of adapting NASA's SMS design for DOD applications, and the installation and interface design for integration of the capability into the DOD CCDS.

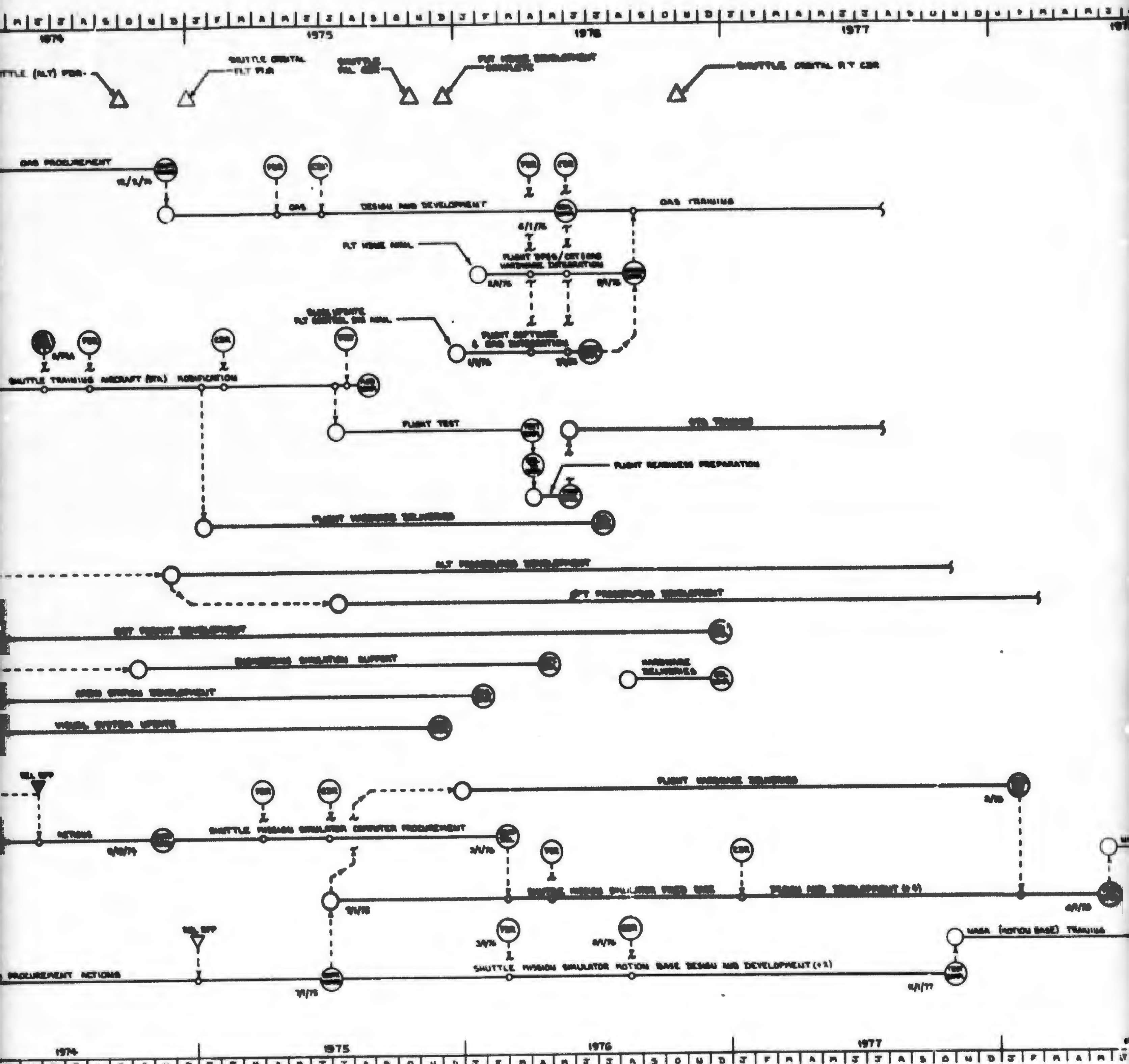
6.5 SCHEDULE RISK FACTORS

Table 6-4 lists SMS schedule risk factors by functional SMS grouping. Historically, the visual system is generally the pacing item in the implementation of a simulator, if this item is not an off-the-shelf procurement, due to the complexity and scope of the design efforts. The SMS visual system does not fall into the category of off-the-shelf equipment; however, maximum utilization will be made of NASA SMS visual design efforts which will reduce the schedule risk factor.



1973
1974
1975
SHUTTLE (ALT) PDR
SHUTTLE ORBITAL FLT PDR
MAJOR MILESTONES
ORBITER AEROFLIGHT SIMULATOR
OAS PROCUREMENT
7/73A
DESIGN AND DEVELOPMENT
ORBITER AEROFLIGHT SIMULATOR (OAS)
SHUTTLE TRAINING AIRCRAFT (STA) MODIFICATION
FLIGHT TEST
SHUTTLE TRAINING AIRCRAFT (STA)
CRT FORMAT DEVELOPMENT
1/73A
SHUTTLE TRAINING SIMULATOR (SPS)
VISUAL SYSTEM UPDATE
NASA COMPUTER STUDY
NASA SMS COMPUTER PROCUREMENT
ACTIONS
SHUTTLE MISSION SIMULATOR COMPUTER PROCUREMENT
NASA SHUTTLE MISSION SIMULATOR SMS-1 (2+4)
NASA SMS DEFINITION STUDIES
1973
1974
1975

a



1974
1975
1976
1977
DESIGN AND DEVELOPMENT
SHUTTLE TRAINING AIRCRAFT (STA) MODIFICATION
FLIGHT TEST
FLIGHT READINESS PREPARATION
HARDWARE DELIVERIES
SHUTTLE MISSION SIMULATOR COMPUTER PROCUREMENT
SHUTTLE MISSION SIMULATOR MOTION BASE DESIGN AND DEVELOPMENT (+2)
PROCUREMENT ACTIONS

Figure 6-

b

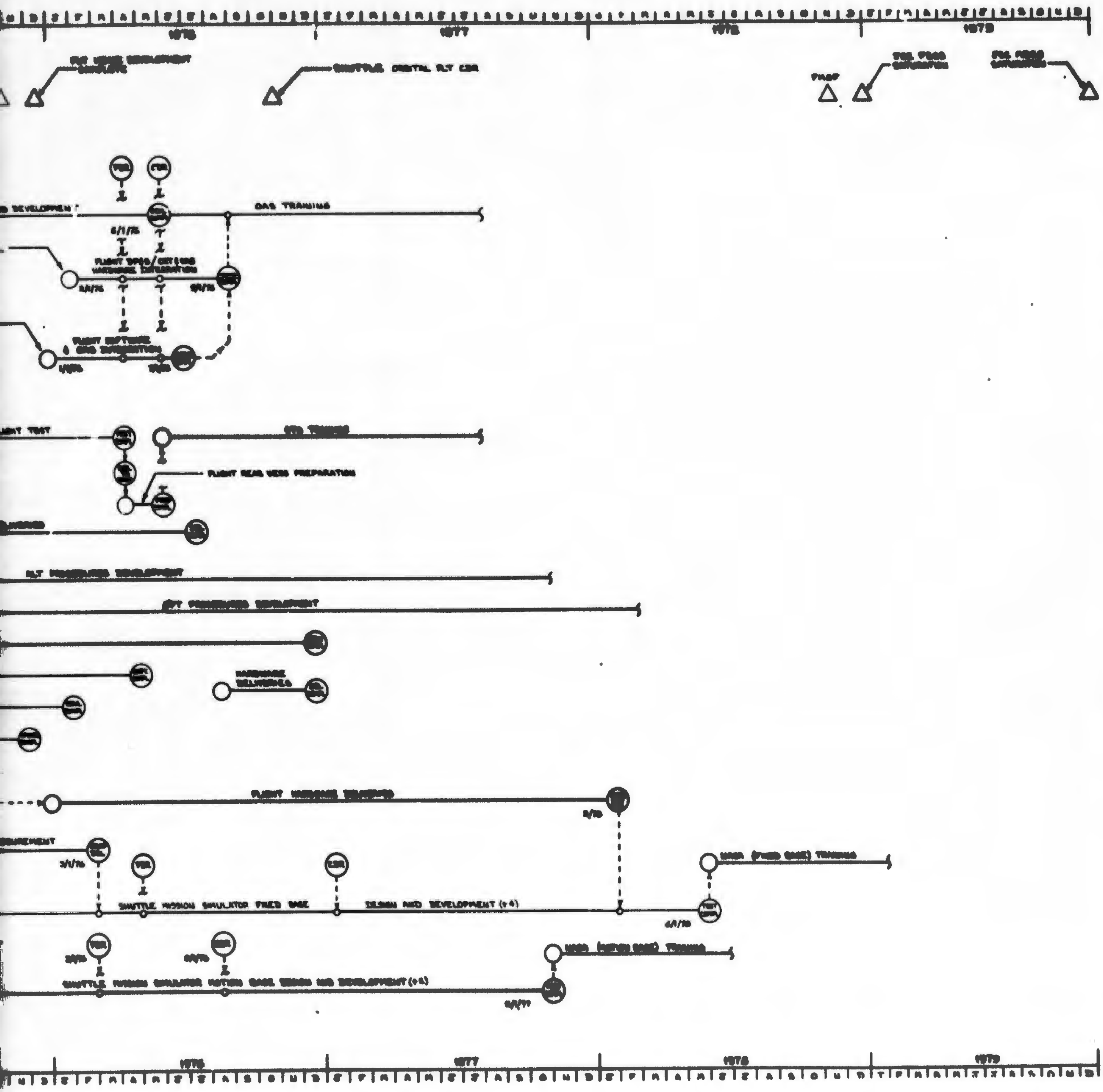
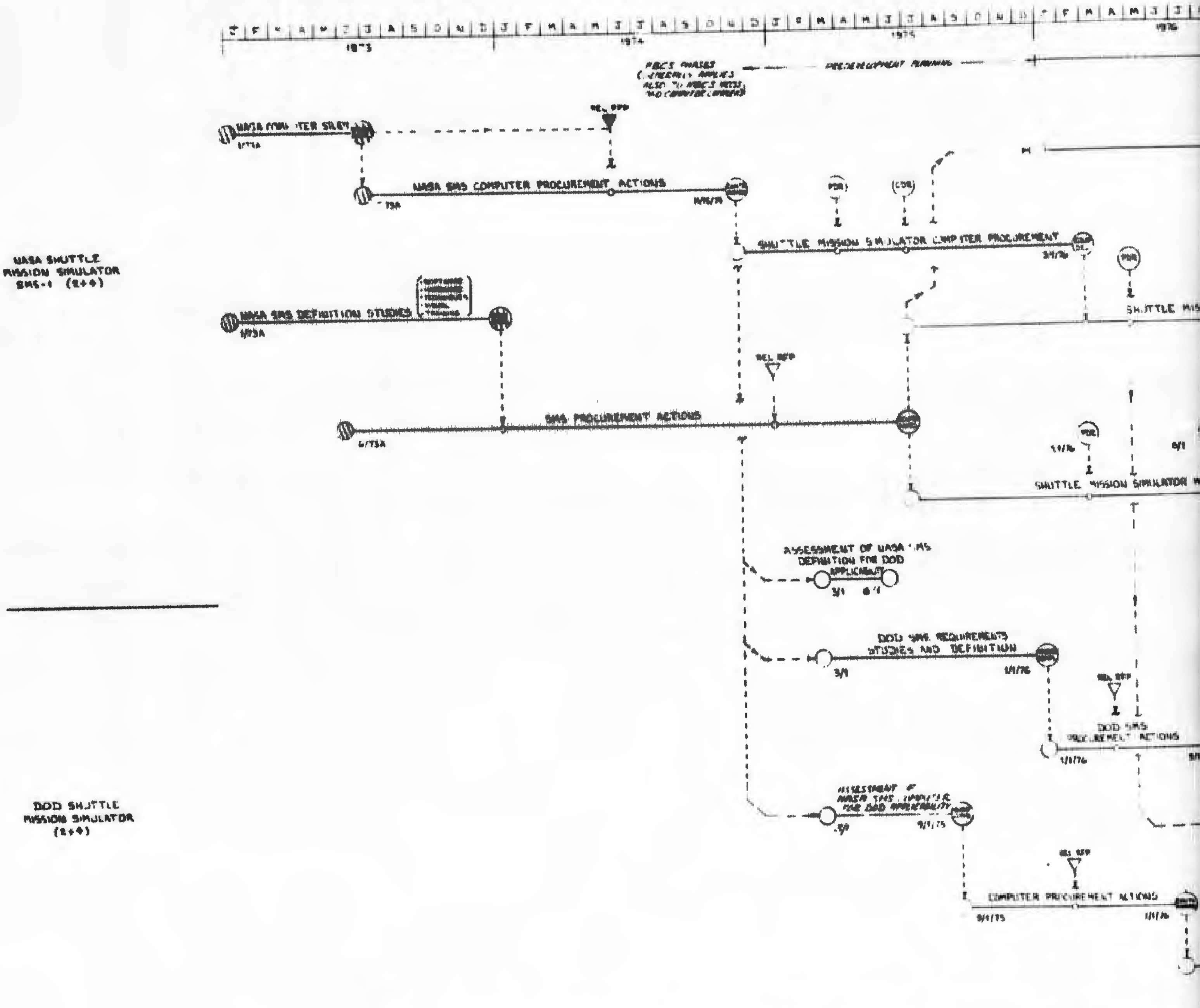


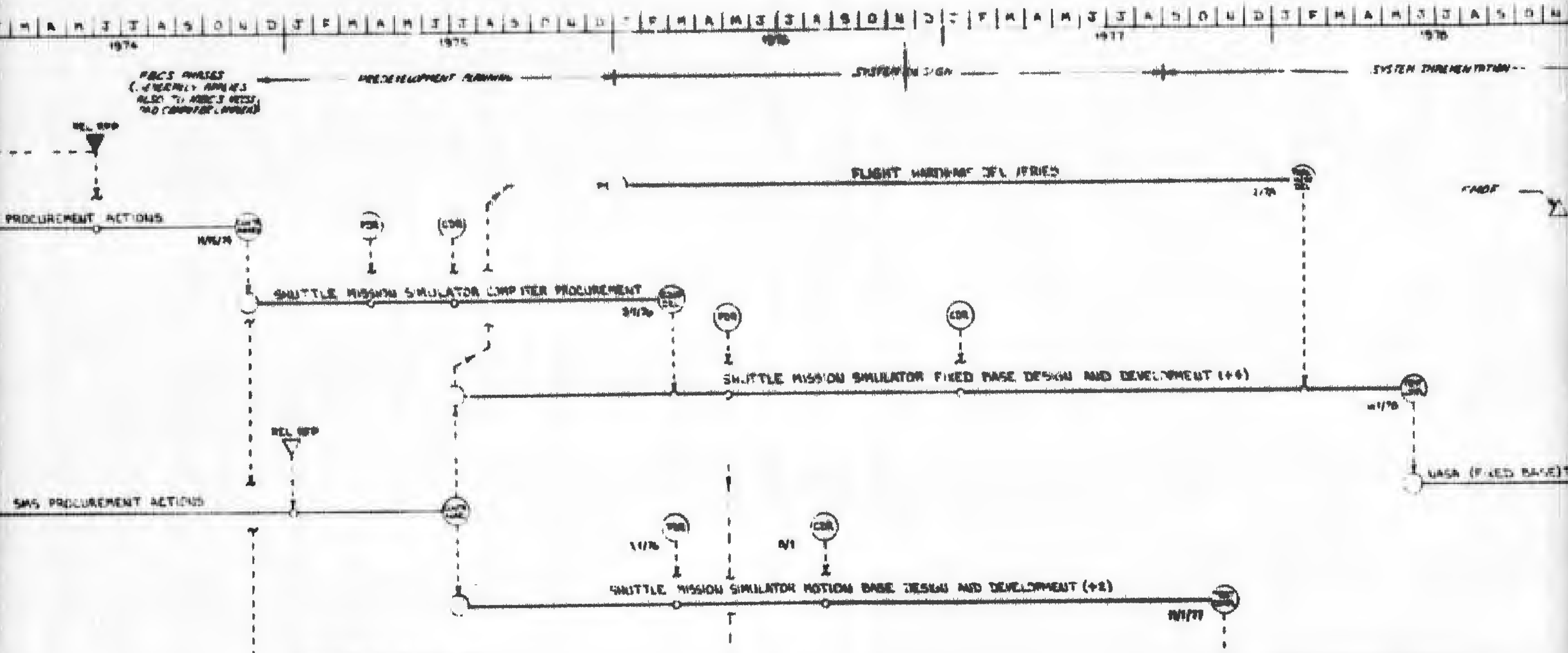
Figure 6-3 NASA Space Shuttle Simulato and Training Aircraft Development and Procurement Schedules

b

c


1973
1974
1975
1976
NASA SHUTTLE MISSION SIMULATOR SMS-1 (2+4)
DOD SHUTTLE MISSION SIMULATOR (2+4)
PREDEVELOPMENT PLANNING
REL RFP
NASA SMS COMPUTER PROCUREMENT ACTIONS
SHUTTLE MISSION SIMULATOR COMPUTER PROCUREMENT
NASA SMS DEFINITION STUDIES
SMS PROCUREMENT ACTIONS
SHUTTLE MISSION SIMULATOR
ASSESSMENT OF NASA SMS DEFINITION FOR DOD APPLICABILITY
DOD SMS REQUIREMENTS STUDIES AND DEFINITION
DOD SMS PROCUREMENT ACTIONS
COMPUTER PROCUREMENT ACTIONS
PDR
CDR

a


1974
1975
1976
1977
1978
PROCUREMENT ACTIONS
FLIGHT HARDWARE DELIVERIES
SHUTTLE MISSION SIMULATOR COMPUTER PROCUREMENT
SHUTTLE MISSION SIMULATOR FIXED BASE DESIGN AND DEVELOPMENT
NASA (FIXED BASE)
SMS PROCUREMENT ACTIONS
SHUTTLE MISSION SIMULATOR MOTION BASE DESIGN AND DEVELOPMENT
NASA (MOTION BASE) TRAINING
ASSESSMENT OF NASA SMS DEFINITION FOR DOD APPLICABILITY
DOD SMS REQUIREMENTS STUDIES AND DEFINITION
DOD SMS PROCUREMENT ACTIONS
FLIGHT HARDWARE DELIVERIES
COMPUTER PROCUREMENT ACTIONS
DOD MISSION SIMULATOR COMPUTER PROCUREMENT
MODIFICATIONS/ AUGMENTATION OF NASA DESIGN

Figure

b

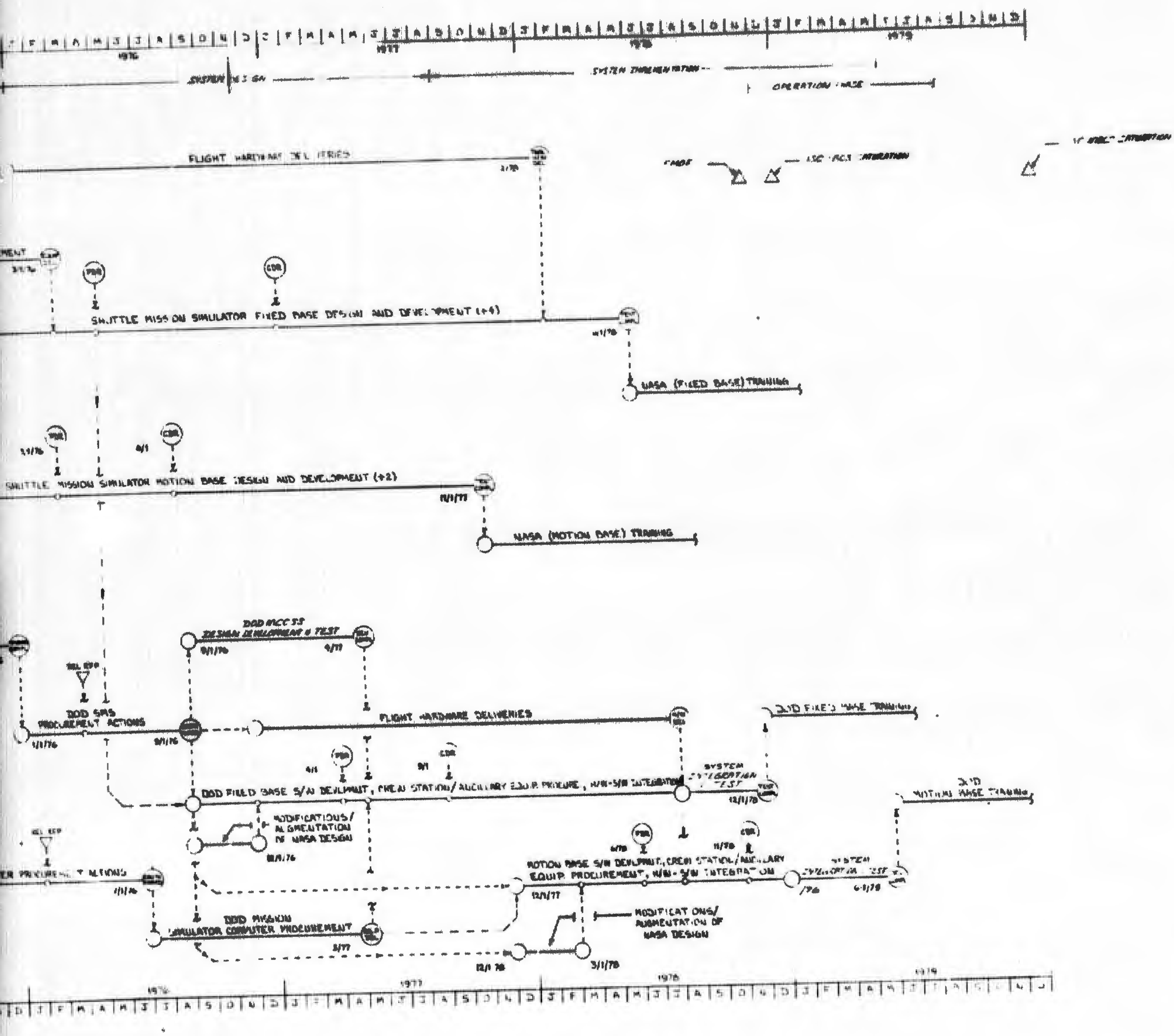


Figure 6-4 Proposed DOD Space Shuttle Simulation Elements Development and Procurement Schedules

TABLE 6-4

SCHEDULE RISK FACTORS BY FUNCTIONAL SMS GROUPING

FUNCTIONAL GROUP	SCHEDULE RISK FACTORS
CREW STATION	• LEAD TIME ASSOCIATED WITH PROCUREMENT OF SPACECRAFT PANEL COMPONENTS
MOTION SYSTEM	• VISUAL SYSTEM FORWARD DISPLAY SYSTEM CONSTRAINS DESIGN OF MOTION PLATFORM AND TILT MECHANISM • TIMELY TESTING OF TOTAL MOTION SYSTEM TO VERIFY PERFORMANCE AND SAFETY
INSTRUCTOR OPERATOR STATION	• AVAILABILITY OF SPACECRAFT COMPONENTS • CRT LEAD TIME • CRT CONSTRAINS SIMULATOR CONTROL SOFTWARE; IT MUST BE OPERATING PRIOR TO START OF HARDWARE/SOFTWARE INTEGRATION AND PRIOR TO SYSTEM INTEGRATION
ANCILLARY EQUIPMENT	• SIMULATOR POWER SYSTEM INSTALLATION • CENTRAL TIMING EQUIPMENT
DATA PROCESSING AND SOFTWARE	• AVAILABILITY OF INTERFACE MINICOMPUTERS, FLIGHT COMPUTERS AND CRT'S, AND FLIGHT SOFTWARE
DIGITAL CONVERSION EQUIPMENT	• MINICOMPUTER AVAILABILITY • INCORPORATION OF OFF-THE-SHELF DCE AS MUCH AS POSSIBLE • EARLY RELEASE OF STANDARD DESIGN ITEMS • DCE MUST BE AVAILABLE PRIOR TO START OF TESTING AND HARDWARE/SOFTWARE INTEGRATION

TABLE 6-4 (CONT'D)

FUNCTIONAL GROUP	SCHEDULE RISK FACTORS
MINICOMPUTER COMPLEX	• EARLY AVAILABILITY OF MINICOMPUTER FOR CHECKOUT OF THE HOST COMPUTER (HC)/MINICOMPUTER INTERFACE AND TO CHECK OUT THE CRT/MINI/HC HARDWARE/SOFTWARE COMPATIBILITY AT START OF SYSTEMS INTEGRATION • REMAINING COMPUTERS FOR CHECKOUT OF DCE AND DPS HARDWARE
SHUTTLE SYSTEMS SOFTWARE	• SPACECRAFT DATA AVAILABILITY
SIMULATOR APPLICATIONS SOFTWARE	• SPACECRAFT DATA AVAILABILITY
SIMULATOR CONTROL SOFTWARE	• WORK CONTROL PROGRAMS FOR START OF SYSTEMS INTEGRATION
SUPPORT SOFTWARE	• EARLY ESTABLISHMENT OF PROCEDURES AND SOFTWARE FOR DESIGN, CODE, AND CHECKOUT OF OTHER SOFTWARE
SYSTEMS INTEGRATION	• AVAILABILITY OF SIMULATOR SOFTWARE PROGRAMS • CRT SYSTEM HARDWARE AND SOFTWARE IN PROPER SEQUENCE FOR INTEGRATION
INSTALLATION, TEST AND DEMONSTRATION	• AVAILABILITY OF SIMULATOR HARDWARE AND SOFTWARE • INSTITUTION OF WORK-AROUND PLANS TO ENABLE SYSTEM TESTING ON INDIVIDUAL SIMULATOR GROUPS
VISUAL SYSTEM	• AVAILABILITY OF VISUAL SYSTEM FOR SYSTEM TESTS AND INTEGRATION

Other schedule risk factors arise from availability of minicomputers, spacecraft components, onboard CRT's, spacecraft data availability, software and hardware test procedures, and off-the-shelf digital conversion equipment.

SECTION 7

CONCLUSIONS AND RECOMMENDATIONS

Philco-Ford concurs with the basic philosophy (established by NASA) which defines the criteria for selection and training of its flight and ground crews for shuttle. We recommend that the DOD adapt these basic philosophies, with some minor modifications, to effect a definition of similar criteria for their Shuttle flight and ground crew cadre.

The planned frequency of NASA and DOD Shuttle missions and the anticipated flight crew and controller population preclude the joint use of a single fixed and motion base (2+4) simulator for adequate training of both agencies' flight crews and controllers. Similarly, the joint use of the JSC MBCS and of a DOD FBCS at the STC is also inadequate. It is therefore Philco-Ford's recommendation that the DOD deploy (at their STC) a Shuttle mission simulator with both a fixed and motion base crew station (2+4) and an MCCSS prior to the end of calendar year 1979. Deployment of the 2+4 SMS by DOD in 1979 will prevent saturation of the JSC 2+4 SMS and will ensure adequate and timely training of DOD flight and ground crews.

Acquisition analyses included consideration of dual procurement activities by NASA (i.e., concurrent dual procurement of both NASA and DOD systems). In the case of computer procurement, it was determined that the necessary assessment of NASA's computer specifications for DOD applicability (refer to figure 6-4) could not be completed before 1 September 1975, which is beyond the critical design review (CDR) in NASA's procurement cycle. Philco-Ford's initial assessment indicated that dual procurement savings would be insignificant if the DOD computer were added to NASA's procurement at this point, since the major savings in such dual arrangements occur in the vendor's initial parts ordering, component subcontracting and scheduling activities -- the majority of which nominally occur long before CDR.

Similar indications were noted for the flight hardware and crew station/ancillary equipment procurements for DOD; i.e., the necessary assessment of each for DOD applicability precludes concurrent dual procurement and related cost benefits. Note, however, that these conclusions apply primarily to actual hardware and product-line software outlay; they do not preclude DOD benefitting from the extensive NASA/NASA-vendor design activities leading to preparation of RFP's and definition of applications-unique software. This latter benefit is reflected both in cost tables in section 6 and in the schedule shown in figure 6-40.

Estimated cost of the requirements definition studies (preceding RFP release) is approximately $200,000. Procurement of the SMS and host computer is estimated at $24 million, excluding recurring maintenance and configuration update costs which may occur after delivery.

REFERENCES

1. JSC-NASA. JSCA 74-8-28, *Realignment of JSC Operational Functions and Responsibilities*, January 1974.

2. *Specification for Shuttle Mission Simulator Computer Complex* Preliminary, 29 April 1974.

3. SAMSO (AFSC), Deputy for Launch Vehicles, Reusable Launch Vehicle SPO, Operations and Evaluation Division (LVRO). *DOD Space Transportation System Operations Concept*, 10 May 1974, and subsequent drafts.

4. Report to the Congress. B-157905, *Greater Use of Flight Simulators in Military Pilot Training Can Lower Costs and Increase Pilot Proficiency*, 9 August 1973.

5. MSC-NASA. MSC-05285, *Space Shuttle Simulation Program*, 1 December 1971.

6. JSC-NASA. JSC-08077, *Shuttle Operations Crew Training Plan* Preliminary, August 1973.

7. MSC-NASA. MSC-06900, *Space Shuttle Baseline Accommodations for Payloads*, 27 June 1972.

8. PHO. PHO-TR577, *FOD Shuttle Academic Training Analysis Study*, 28 June 1974.

9. *Space Shuttle Program Shuttle Simulation Program Plan*, Vol. I, 22 June 1973.

10. Singer, *Shuttle Mission Simulator baseline Definition Report*, Contract NAS 9-12836, 22 June 1973.

11. NASA. RFP No. 9-BC271-A12-4-50P, *Request for Proposal for the Orbiter Aeroflight Simulator (OAS) Program*, 21 May 1974.

12. Singer. *Simulation Techniques Study, Final Report*, Contract NAS 9-12836, 17 November 1972.

13. NASA/USAF. *Joint NASA/DOD Space Transportation System Program Plan*, Preliminary, November 1973.

14. NASA/DOD. *NASA/DOD Memorandum of Understanding on Management and Operation of the Space Transportation System.*

15. DOD. *DOD STS Command and Control Data Systems Study,* SOW Revision, 18 April 1974.

16. Rockwell International. SD72-SH-0071B, *Orbiter Definition Handbook,* 4 February 1974.

17. JSC-NASA. JSC Internal Note No. 73-FM-47-JSC-07896, *Space Shuttle System Baseline Reference Missions,* Vol. I, Mission 1, Rev. 1, 8 May 1974.

18. JSC-NASA. JSC Internal Note No. 73-FM-47-JSC-07896, *Space Shuttle System Baseline Reference Missions,* Vol. II, Mission 2, Rev. 1, 29 May 1974.

19. JSC-NASA. JSC Internal Note No. 73-FM-47-JSC-07896, *Space Shuttle System Baseline Reference Missions,* Vol. III, Missions 3A and 3B, Rev. 1, 7 May 1974.

20. Singer. *Shuttle Mission Simulator Hardware Conceptual Design Report,* Contract NAS 9-12836, 23 March 1973.

21. NASA. *Request for Proposal No. 9-BB22-33-4-37P for a Shuttle Mission Simulation Complex,* June 1974.