[redacted] (b)(3) 10 USC 424

~~Top Secret~~

[redacted]

Space Transportation System (STS) Panoramic Camera System (PCS) Performance Analysis Study Report

ADDSY PROCESSED
Date Initials

~~Top Secret~~

BYE 10686-79
May 1979

Handle via BYEMAN
TALENT-KEYHOLE Control Systems Jointly

Copy No. 10

Approved for Release: 2017/02/08 C05094782

Warning Notice
Sensitive Intelligence Sources and Methods Involved
(WNINTEL)

NATIONAL SECURITY INFORMATION
Unauthorized Disclosure Subject to Criminal Sanctions

DERIVATIVE CL BY	BYE-1
REVW ON	May 1999
DERIVED FROM	BYE-1
	COMIREX-D-2.9/3

SPACE TRANSPORTATION SYSTEM (STS)
PANORAMIC CAMERA SYSTEM (PCS)
PERFORMANCE ANALYSIS STUDY REPORT

BYE-10686-79

May 1979 CY 10

HANDLE VIA BYEMAN TALENT-
KEYHOLE CONTROL SYSTEMS ONLY

TABLE OF CONTENTS

1.0 INTRODUCTION AND SUMMARY 1

2.0 BASIC ASSUMPTIONS 3

2.1 COLLECTION REQUIREMENTS AND PERFORMANCE MEASURES 3

2.2 SENSOR SUBSYSTEM 11

2.3 STS CAPABILITIES 14

3.0 PERFORMANCE ISSUES 15

3.1 STS PCS MISSION SCHEDULING 15

3.2 ORBIT SELECTION 16

3.3 WEATHER ANALYSIS 50

3.4 COLLECTION TARGETING STRATEGY 54

4.0 SELECTED OPERATING CONCEPTS AND PERFORMANCE ANALYSIS RESULTS . . 56

4.1 SELECTED OPERATING CONCEPTS 56

4.2 SIMULATION APPROACH 56

4.2.1 STUDY TOOL DESCRIPTION 56

4.2.2 SIMULATION CASES AND CONDITIONS 58

4.3 SIMULATION RESULTS 60

5.0 CONCLUSIONS 81

6.0 RECOMMENDATIONS FOR FURTHER STUDY 82

APPENDICES

HANDLE VIA BYEMAN TALENT-
KEYHOLE CONTROL SYSTEMS ONLY

1.0 INTRODUCTION AND SUMMARY

In 1978 OD&E [redacted] studied the feasibility of placi (b)(3) 10 USC ⊥ 424 the HEXAGON panoramic camera sensor subsystem on the Space Transportation System orbiter to perform the HEXAGON search and surveillance mission functions. This study concluded that the concept appeared feasible and that there were no substantial technical problems associated with the concept.

Detailed collection performance analyses for the system concept were requested by the NRO staff. The Space Transportation System (STS) Panoramic Camera System (PCS) performance analysis study, documented herein, was performed by OD&E/[redacted] in response to that request. (b)(3) 10 USC ⊥ 424

The study objectives were (1) to identify and analyze performance-related issues, (2) to select, analyze and characterize the performance of promising STS PCS operating concepts, and (3) to identify follow-on studies needed for the further development of the STS PCS concept.

Assumptions relative to collection requirements, the panoramic camera system, and STS capabilities are presented in Section 2.

Performance analyses were conducted relative to mission scheduling, orbit selection, weather, mission duration, and collection targeting strategy. The results of these analyses are presented in Section 3.

Three operating concepts were identified for detailed simulation analysis. A description of these concepts, the simulation approach, and the simulation results are presented in Section 4.

The primary conclusion of the study is that three, 21-day STS PCS missions per year in sun-synchronous or 75-degree inclination orbits can satisfy all current and projected search and MC&G area collection requirements except for the 2-month standing search clusters and special search requirements.

Substantial shortfalls against these requirements result from the limited ability of the sensor to achieve NIIRS 5 quality and from the limited number of accesses available during the year. Further conclusions are presented in Section 5.

A number of issues which should receive detailed analysis but were not addressed in this study are identified in Section 6.

Detailed outputs from selected simulations are presented in the appendices.

~~TOP SECRET~~ HEXAGON [redacted] 20053

(b)(1)
(b)(3) 10 USC ⊥ 424

Approved for Release: 2017/02/08 C05094782

2.0 BASIC ASSUMPTIONS

HEXAGON missions are planned at the rate of one per year through Mission 1220, now scheduled for launch in March, 1984. Mission 1215, currently in orbit, has a planned lifetime of 180 days. Missions 1217 through 1220 have planned lifetimes of 220 days and will fly from March through October with an improved panoramic camera system (PCS) that will provide metric coverage capability.

It is assumed that the STS PCS will be tasked to perform the HEXAGON collection mission following the completion of Mission 1220 in late 1984. Earlier STS PCS missions may be flown during the 145-day winter gap in HEXAGON coverage to test the STS PCS concept in flight and to provide supplementary wide area search photography.

2.1 COLLECTION REQUIREMENTS AND PERFORMANCE MEASURES

The STS PCS mission is to collect imagery to satisfy standing search, special search, metric and non-metric mapping, charting and geodesy (MC&G), and, as a bonus from the search coverage, some NIIRS 4, non-time critical surveillance requirements.

The standing search collection requirements are to photograph large areas without regard to specific targets for the purpose of detecting new targets. Current standing search areas, totaling approximately 14 million square nautical miles (MSNM), are located in the Communist countries and portions of the Middle East. The projected standing search areas for the 1985 to 1990 period are illustrated in Figure 2-1, and encompass an additional 20 MSNM.[1]

---

[1] These data were provided by the Chairman of ICRS for use in this study subject to the following qualifications:

a. The initial data are a general approximation of the anticipated level of effort required to satisfy world-wide standing search requirements in the 1985-1990 time frame. The requirements defined are gross, in a general sense, but should approximate the expected level of collection effort in terms of gross area required, periodicity and geographic distribution of requirements foreseen for this period. It is noted that considerable additional effort to refine the areas and requirements will be required.

b. In the short time available, only minimal Community review and coordination has been possible. Therefore, extreme care should be taken in the use and application of these requirements to insure they are not presented as firm Intelligence Community-approved broad area search requirements for the 1985-90 time period and that no programatic decisions be made on the basis of these very preliminary requirements.

Currently, special coverage requirements consume a large portion of system resources. Based on informal guidance from the Chairman of ICRS for the purposes of this study, 25 percent of the film load is budgeted for special search requirements.

In addition to the search requirements, both metric, i.e. high absolute positional accuracy, and non-metric area MC&G imagery collection requirements are levied to satisfy military and intelligence user's needs. HEXAGON metric MC&G coverage through Mission 1218 is projected to satisfy 60 percent of the world-wide requirements; metric coverage of area not taken during the HEXAGON program is assumed to be a STS PCS task. Non-metric recoverage of all land masses is required at 4- to 12-year intervals to update cultural details on metric MC&G products.

The non-metric MC&G image quality and timeliness requirements are less stringent than those for standing search imagery and are therefore satisfied by coverage against standing search requirements. Although metric MC&G imagery must be taken in stereo, as will be shown in Section 3.2, stereo imagery is also needed to satisfy quality requirements for standing search; thus, MC&G collection requirements are met as a by-product of the standing search mission.

Some of the NIIRS 4 general surveillance requirements with 120-day or longer collection periods can also be satisfied as a bonus from the search coverage. The extent of the surveillance requirement satisfaction is not considered in this study.

STANDING SEARCH REQUIREMENTS

Standing search imagery collection requirements consist of a specific delineation, quantity/timeliness objectives, and image success criteria.

The search area is divided into 12 x 18 NM WAG cells. Each of these cells is placed into one of seven collection period groups (CPG's) based on the likelihood of new activity occurrence per unit area. Table 2-1 summarizes the collection requirements for the different collection period groups. The cells are aggregated into 67 requirement cell groups (RCG's), based on collection period and geography. Tables 2-2 and 2-3 show the gross area coverage requirements in terms of SNM and SNM per year, respectively. Each RCG is considered to be a distinct collection requirement.

~~TOP SECRET~~ HEXAGON [redacted] 20053 (b)(1)
(b)(3) 10 USC ⊥ 424

TABLE 2-1 PROJECTED STANDING AREA SEARCH COLLECTION REQUIREMENTS FOR 1985-90

@ 100%

COLLECTION PERIOD	COLLECTION PERCENT*	MODE	AREA (MSNM)	MIN. REQD COVERAGE MSNM/YR	REQ'D NIIRS	DES'D NIIRS	DES'D NIIRS PERCENT
CURRENT							
2 MO	80	STEREO	.18	1.06	4	5	50
4 MO	80	STEREO	1.07	3.20	3	4	80
6 MO	80	STEREO	.75	1.51	3	4	80
9 MO	80	STEREO	1.69	2.25	3	4	80
12 MO	80	MONO	3.62	3.62	3	4	80
18 MO	80	MONO	3.41	2.27	3	4	80
24 MO	80	MONO	.44	.23	3	4	80
			11.16	14.14			
NEW							
9 MO	80	MONO	8.71	11.61	3	4	80
18 MO	80	MONO	9.73	6.49	3	4	80
24 MO	80	MONO	4.53	2.27	3	4	80
			22.97	20.38			
			34.13	34.52			

*ONCE DUE POINT ON REQUIRED AGE DISTRIBUTION

(b)(1)
(b)(3) 10 USC ⊥ 424

TABLE 2-2 Preliminary 1985 - 1990 Standing Search Areas in Required MSNM by Country and Period

	Region	Collection Period							
		2 Mo	4 Mo	6 Mo	9 Mo	12 Mo	18 Mo	24 Mo	Total
Current									
1	USSR (UR)	.13	.46	.34	.96	2.25	2.41	.31	6.86
2	PRC (CH)	.03	.32	.24	.48	.96	.66	.13	2.82
3	Mongolia (MG)	0	.004	.005	.02	.20	.23	0	.46
4	East Europe (EE)	0	.18	.10	.09	.04	0	0	.41
5	North Korea (KN)	.01	.03	.01	.01	.004	0	0	.06
6	S. East Asia (SE)	0	.02	.02	.06	.08	.06	0	.24
7	Cuba (CU)	0	.01	.01	.01	.01	.02	0	.06
8	Middle East (ME)	.01	.05	.02	.06	.08	.03	0	.25
New (Preliminary Version)									
9	West Europe (WE)	0	0	0	0	0	.65	.51	1.16
10	North Africa (NA)	0	0	0	1.56	0	0	0	1.56
11	East Africa (EA)	0	0	0	1.47	0	0	0	1.47
12	West Africa (WA)	0	0	0	0	0	3.81	0	3.81
13	South Africa (SA)	0	0	0	1.64	0	.18	0	1.82
14	Near East (NE)	0	0	0	.89	0	.72	0	1.61
15	Far East (FE)	0	0	0	1.03	0	.75	.14	1.92
16	[redacted]	0	0	0	.21	0	0	0	.21
17	South Pacific (SP)	0	0	0	0	0	0	1.05	1.05
18	[redacted]	0	0	0	0	0	0	2.30	2.30
19		0	0	0	.51	0	.26	.02	.79
20	N. South America (NS)	0	0	0	.48	0	3.19	.51	4.18
21	S. South America (SS)	0	0	0	.92	0	.17	0	1.09
Total Current	(b)(1) (b)(3)	.18	1.07	.75	1.69	3.62	3.41	.44	11.16
Total New	10 USC ⊥ 424	0	0	0	8.71	0	9.73	4.53	22.97
Grand Total		.18	1.07	.75	10.40	3.62	13.14	4.97	34.13

HANDLE VIA BYEMAN TALENT-
KEYHOLE CONTROL SYSTEMS ONLY

TABLE 2-3 Preliminary 1985 - 1990 Standing Search Areas in Required MSNM per Year by Country and Period

	Region	2 Mo	4 Mo	6 Mo	9 Mo	12 Mo	18 Mo	24 Mo	Total
		Collection Period							
Current									
1	USSR (UR)	.78	1.37	.69	1.28	2.25	1.61	.16	8.14
2	PRC (CH)	.19	.97	.48	.64	.96	.44	.07	3.75
3	Mongolia (MG)	0	.01	.01	.03	.20	.15	0	.40
4	East Europe (EE)	0	.54	.20	.11	.04	0	0	.89
5	North Korea (KN)	.04	.08	.01	.01	.004	0	0	.14
6	S. East Asia (SE)	0	.05	.05	.08	.08	.04	0	.30
7	Cuba (CU)	0	.03	.02	.02	.01	.01	0	.09
8	Middle East (ME)	.05	.15	.05	.08	.08	.02	0	.43
New (Preliminary Version)									
9	West Europe (WE)	0	0	0	0	0	.43	.26	.69
10	North Africa (NA)	0	0	0	2.08	0	0	0	2.08
11	East Africa (EA)	0	0	0	1.96	0	0	0	1.96
12	West Africa (WA)	0	0	0	0	0	2.54	0	2.54
13	South Africa (SA)	0	0	0	2.19	0	.12	0	2.31
14	Near East (NE)	0	0	0	1.19	0	.48	0	1.67
15	Far East (FE)	0	0	0	1.37	0	.50	.07	1.94
16	[redacted]	0	0	0	.28	0	0	0	.28
17	South Pacific (SP)	0	0	0	0	0	0	.53	.53
18	[redacted]	0	0	0	0	0	0	1.15	1.15
19		0	0	0	.68	0	.17	.01	.86
20	N. South America (NS)	0	0	0	.64	0	2.13	.26	3.03
21	S. South America (SS)	0	0	0	1.23	0	.11	0	1.34
Total Current		1.06	3.20	1.51	2.25	3.62	2.27	.23	14.14
Total New		0	0	0	11.61	0	6.48	2.28	20.38
Grand Total		1.06	3.20	1.51	13.86	3.62	8.75	2.51	34.52

(b)(1)
(b)(3)
10 USC 424

BYE-10686-79
Page 8

HANDLE VIA BYEMAN TALENT-KEYHOLE CONTROL SYSTEMS ONLY

~~TOP SECRET~~ HEXAGON [redacted] 20053

The desired quantity/timeliness of standing search coverage, or age distribution, is defined by a curve showing the minimum levels of unique coverage versus coverage age to be maintained at all times. Figure 2-2 shows the standing area search quantity/timeliness age distribution requirement. Fifty percent of the area must be uniquely photographed within the most recent half coverage period, 80 percent within the most recent whole coverage period, and 96 percent within the most recent two coverage periods.

Image quality requirements are specified by COMIREX in terms of a required and desired NIIRS and a desired NIIRS percentage. Useful photography must be cloud-free at the required NIIRS value or better. In addition, a specified percentage of the coverage, the desired NIIRS percentage (DNP), must be rated at the desired NIIRS value or better. A mode, mono or stereo, is specified for each collection requirement. The 9-month and more frequent collection period groups require stereo coverage.

PERFORMANCE MEASURES

System performance is measured by comparing the coverage, age, mode and quality distribution of photography with the COMIREX requirements. Performance relative to photographic quality, quantity, and timeliness is measured in terms of status. Status is the percentage of cells, in a given requirement, uniquely photographed cloud-free within the past collection period. The measure "XN status" is the percentage of cells, in a given category, uniquely photographed cloud-free at any NIIRS value. Similarly, the percentage of cells uniquely photographed cloud-free at the required or desired NIIRS value or better is denoted "RN status" or "DN status", respectively. Once-due status is the percentage of area uniquely photographed within the collection period, and the twice-due status is the area uniquely photographed within the past two collection periods. Another measure, COMIREX status, reflects the judgement that a certain fraction of the imagery is acceptable at a quality less than the desired NIIRS. COMIREX status, or "CX status" combines the RN and DN statuses into a single measure as follows: CX status is the lesser of: RN status or DN status x 100/DNP, where DNP is the percentage of the acceptable coverage which is required to be rated at the desired NIIRS value or higher. The ratio of accomplished CX status to required status, CX A/R, is a single system performance measure which considers most aspects of performance relative to the stated requirements.

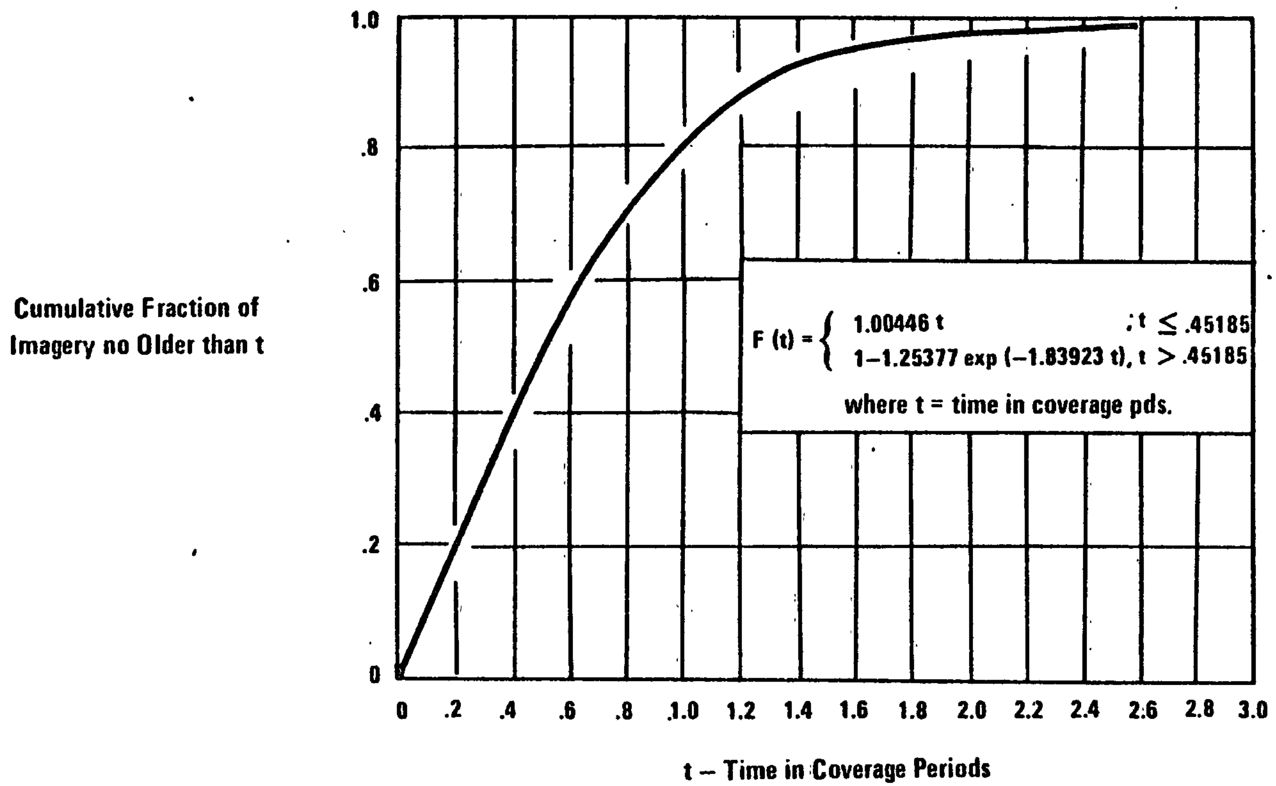


FIGURE 2-2 -- REQUIRED AGE DISTRIBUTION

For example, for the 2-month search areas the required once-due CX status and desired NIIRS percentage are both 80 percent. If the accomplished RN and DN once-due statuses are 85 and 60 percent, respectively, then CX status is the lesser of 85 or (60 x 100/80) percent which is 75 percent. CX A/R is then 75/80 or .94.

To satisfy the requirements CX A/R should be 1.0 at all times for each requirement. It is clear, however, that the required age distribution cannot be maintained for the 2-month requirements during large gaps between missions.

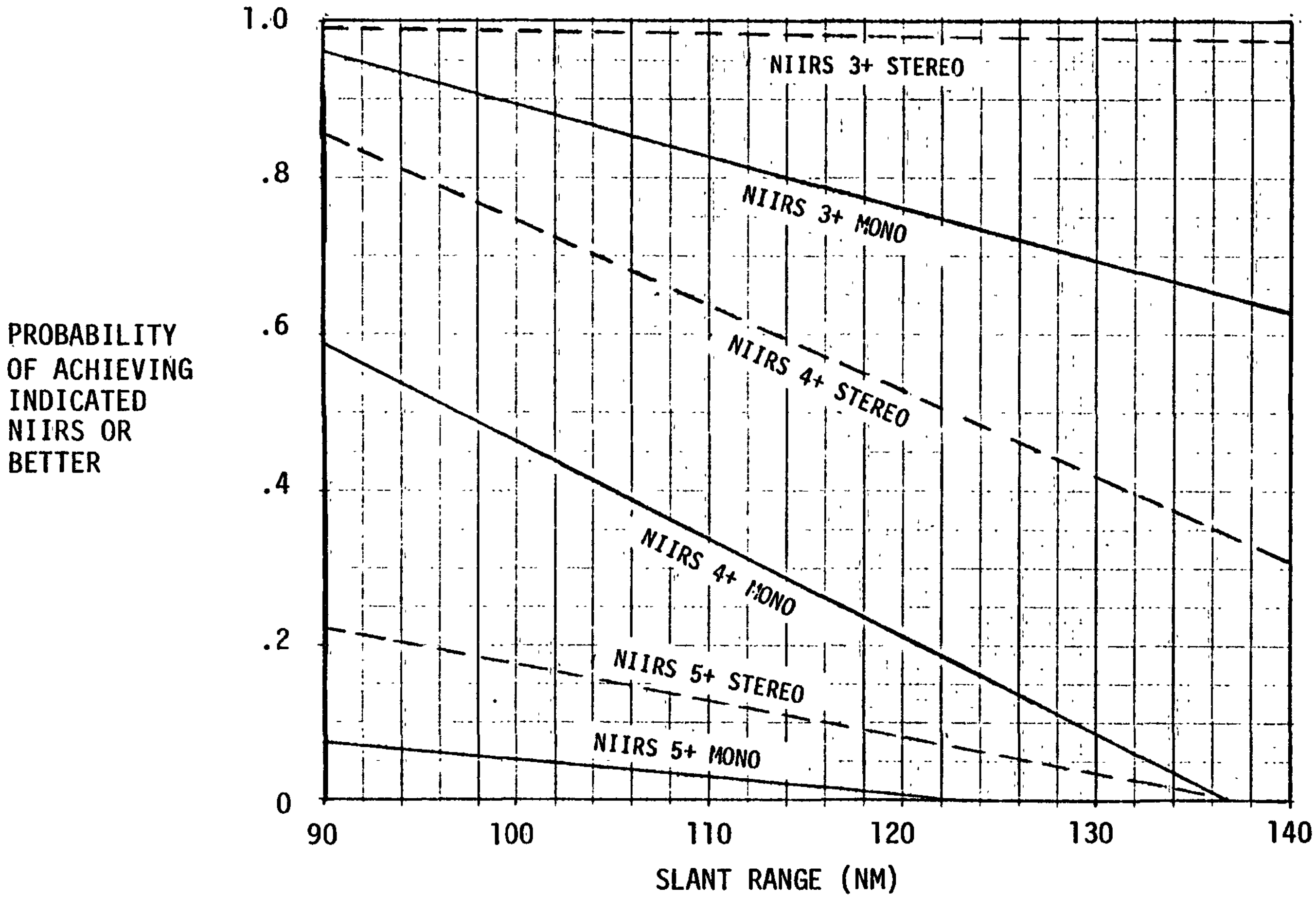
The performance in aggregate area groupings is defined as the weighted sum of the performance in the component requirements. Component weights are based on the required area per year.

2.2 SENSOR SUBSYSTEM

The baseline STS pallet-mounted panoramic camera system (PCS) is assumed to be similar to that planned for HEXAGON Mission 1217. The 1217 sensor subsystem will have 142K feet of stereo film, two optical bars, four film takeups, and a solid-state stellar (S3) sensor. Interoperation film waste is assumed to be a constant 38 inches, which is considerably less than that of the HEXAGON Mission 1215 camera system. The panoramic camera and S3 sensor provide, in combination, a metric accuracy that is capable of meeting MC&G requirements.

The PCS is 17 feet in length, weights 11,000 pounds, and requires 2 kw of power for operation. PCS operation is assumed to be independent of orbiter operation. Command and telemetry support are provided through the Satellite Control Facility (SCF).

The NRO Program A study slant range NIIRS model is assumed to predict PCS image quality for sun elevation angles greater than 3 degrees. Target illumination is assumed to be inadequate for photography at lower sun angles. Although the model has known deficiencies in that it does not include geographical, seasonal, and illumination dependencies, it is the best HEXAGON search NIIRS prediction model currently available. Figure 2-3 illustrates the assumed dependence of quality, expressed as the probability of achieving NIIRS 3, 4 or 5 in mono or stereo, on slant range, i.e. the distance from the orbiter to the search area. Slant range is a function of imaging altitude and obliquity. The probability of achieving NIIRS 4 or better is shown as a function of altitude and obliquity in Figure 2-4. The data in the figure suggest that to have a reasonable probability of NIIRS 4 or



SLANT RANGE				
ALT NM	OBLIQUITY 15°	30°	45°	60°
85	88	98	120	170
95	98	110	134	190
105	109	121	148	210
115	119	133	163	230
125	129	144	177	250
135	140	156	191	270
145	150	167	205	290

FIGURE 2-3 NRO PROGRAM A HEXAGON SLANT RANGE NIIRS MODEL

HANDLE VIA BYEMAN TALENT-KEYHOLE CONTROL SYSTEMS ONLY

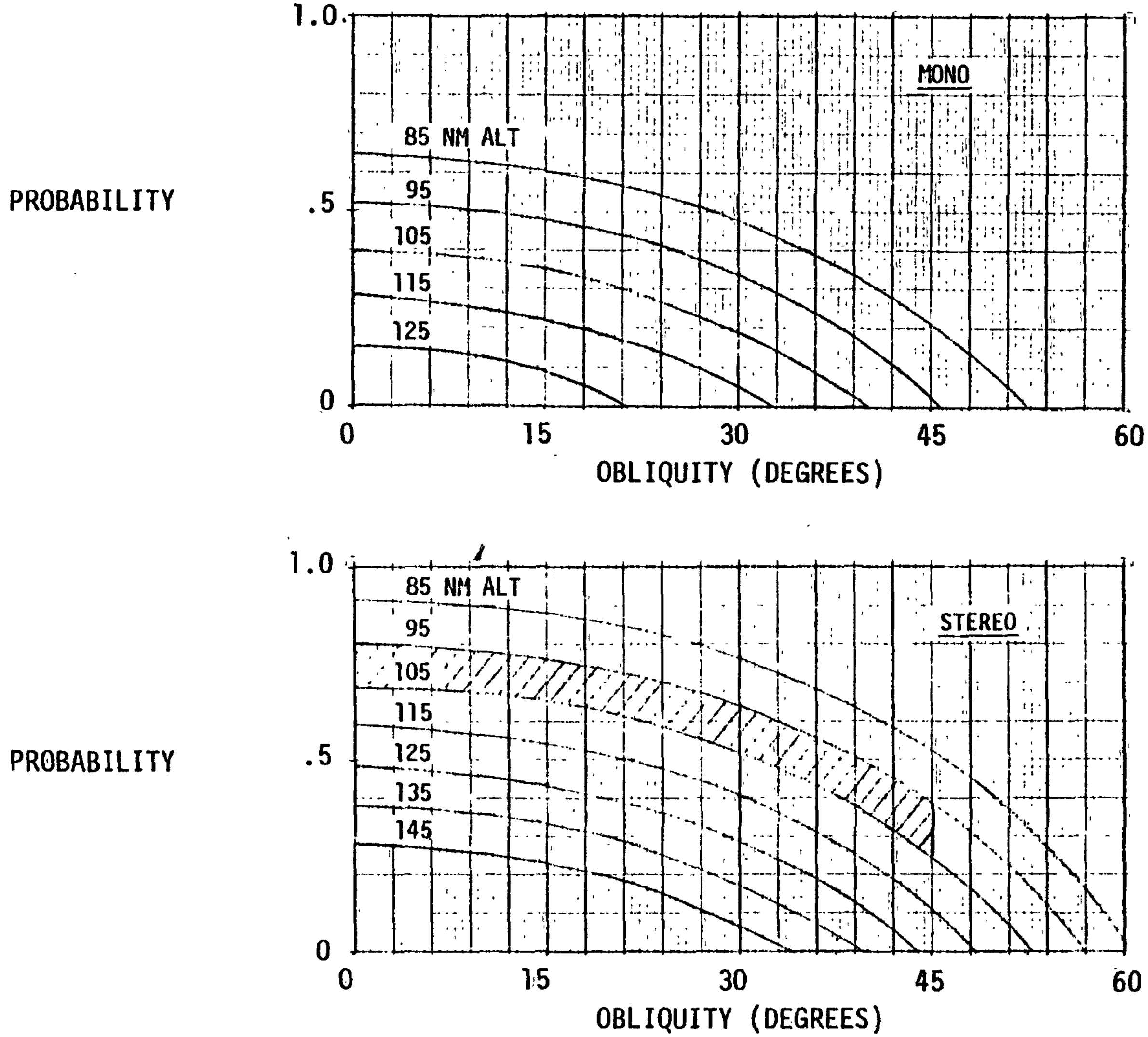


FIGURE 2-4 NRO PROGRAM A HEXAGON SLANT RANGE NIIRS MODEL PROBABILITY OF NIIRS 4 OR BETTER FOR DIFFERENT ALTITUDES AND OBLIQUITIES. THE STS PCS OPERATING RANGE IS SHOWN AS THE SHADED PORTION OF THE LOWER FIGURE.

better coverage, all photography should be taken in stereo, at altitudes below 105 NM, and with obliguity angles less than 45 degrees.

It is noted that the above NIIRS model is based on the analysis of data from missions flying type SO208 film. Improved film, e.g., SO315, may provide improved image quality.

2.3 STS CAPABILITIES

Shuttle launches from the Eastern Test Range (ETR) at Cape Canaveral, Fla., are planned beginning in late 1979. ETR launches are limited to inclinations below 57 degrees for reasons of range safety. Higher inclination orbits require Western Test Range (WTR) launches. The WTR STS facility at Vandenburg Air Force Base, CA, is planned for mid-1983 availability.

A preliminary analysis of STS payload capacity indicated that 21-day missions would require perigee altitudes above 95 NM and thrust augmentation might be needed at sun-synchronous inclinations. The preliminary analysis also indicated that a 21-day mission with a 95 NM perigee could be achieved with a non-thrust augmented STS at inclinations below approximately 75 degrees. Further analyses are needed to establish the precise STS capabilities for the STS PCS.

3.0 PERFORMANCE ISSUES

This section presents the results of analyses of mission scheduling, orbital parameter selection, weather, and targeting strategy. Understanding the issues in each of these areas is the key to the selection of good STS PCS operational concepts.

3.1 STS PCS MISSION SCHEDULING

The factors that determine the mission schedule are the required age distribution, the geographical distribution of illumination, the seasonal dependence of activities of intelligence interest, and STS costs.

Maintenance of the required age distribution at all times requires a near-continuous search system capability. Consideration of the required collection periods suggests uniform mission spacings at 2-, 3- or 4-month intervals. Successful photography requires a sun elevation angle greater than about 3-degrees which severely limits the search area in the Northern Hemisphere near winter solstice. Also, most construction and other activities of interest in the Northern Hemisphere, particularly at higher latitudes, occur during spring through fall. Thus, a search mission during the spring through fall period is preferred for intelligence utility. Finally, the number of missions should be minimized to reduce costs.

These considerations imply that a reasonable mission schedule is one with a fixed interval between missions and with one such interval centered at winter solstice. Table 3-1 gives a launch schedule designed in this manner for three missions per year.

TABLE 3-1 -- LAUNCH DATES FOR THREE 21-DAY MISSIONS PER YEAR

MISSION	LAUNCH DATE
1	Feb 13
2	June 15
3	Oct 15

Initial performance simulations showed that all requirements except specials and 2-month collection period requirements could be satisfied with three missions per year. More frequent missions would have resulted in substantial over satisfaction of all requirements except the 2-month and special requirements. Therefore, only three mission per year STS PCS operational concepts were considered in this study.

3.2 ORBIT SELECTION

The mission orbit strongly affects system performance. Trade-off considerations, however, are complex because the parameters that define the orbit have highly correlated and non-linear influences on performance measures. The key orbit parameters studied are inclination, perigee, apogee, argument of perigee, and time of launch. Key considerations for selecting specific values for these parameters are as follows:

Orbit Parameters	Key Considerations
Inclination	STS Capability SCF Contact Schedule Geographic distribution of the Collection Requirements
Perigee	STS Capability Image Quality
Apogee	STS Capability Image Quality Access Closure Time
Argument of Perigee	Geographic Distribution of the Collection Requirements
Launch Time	Illumination Over the Mission

INCLINATION

A preliminary analysis of STS payload capabilities concluded that 21-day missions with the NRO Program A baseline sun-synchronous inclination orbit (between 96 and 97 degrees for altitudes of interest) might not be achievable without thrust augmentation. Lower STS PCS orbital inclinations in which 21-day missions could be achieved without thrust augmentation were consequently considered.

Inclination affects the ability of the system to access geographic search area. Figure 3-1 shows the density, in terms of required SNM per year, of the search requirements as a function of latitude. Less than 0.1 percent of the requirements (34,500 SNM per year) are within 10 degrees of the poles.

HANDLE VIA BYEMAN TALENT-
KEYHOLE CONTROL SYSTEMS ONLY

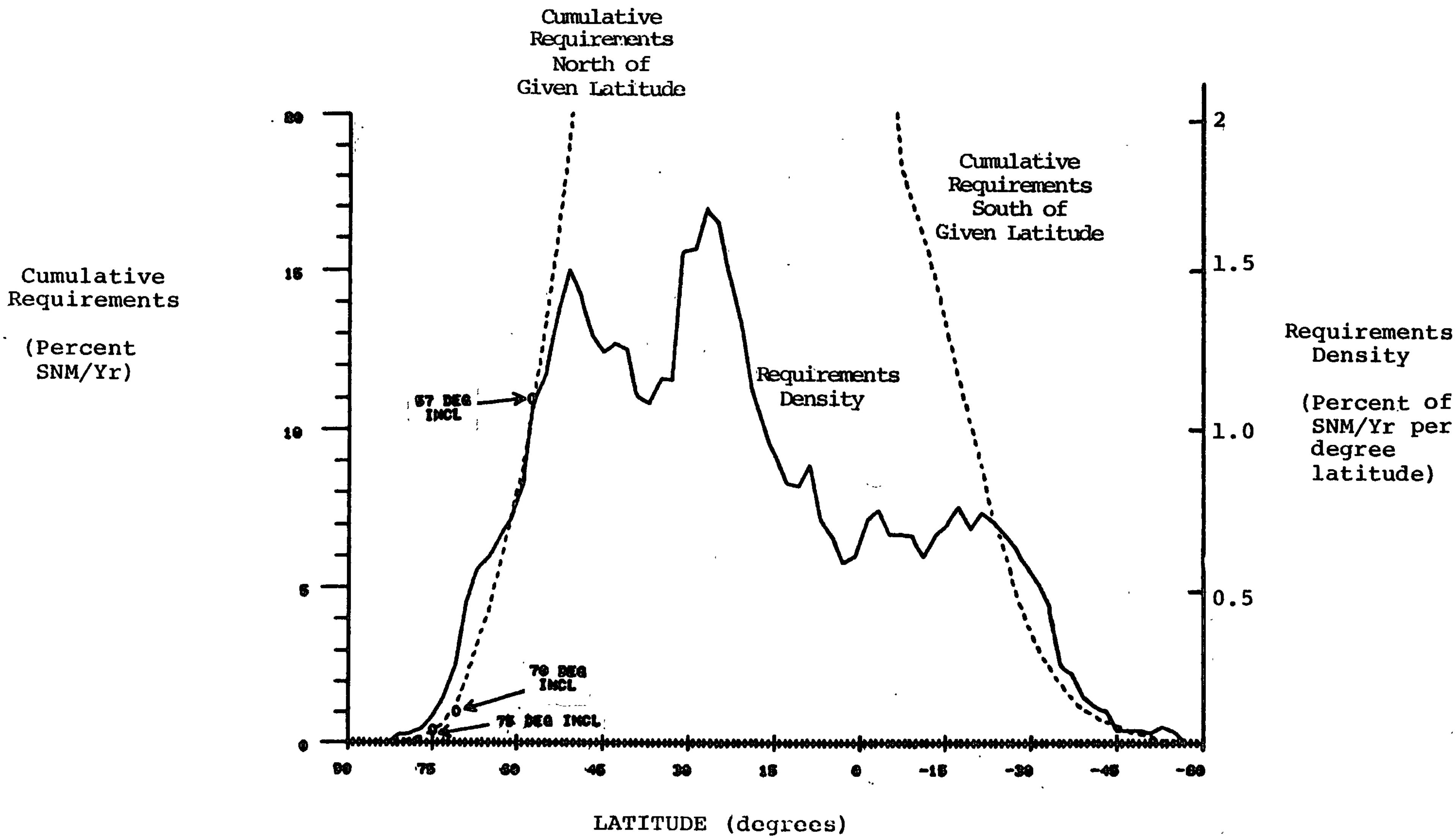


FIGURE 3-1 -- PROPOSED REQUIREMENTS DENSITY VERSUS LATITUDE

Sun-synchronous orbits provide complete access whereas lower inclination orbits at 75, 57 and 28.5 degrees provide access to 99.6 percent, 89.2 percent and 50 percent of the required coverage per year, respectively. The 28.5-degree inclination orbit, which is the maximum payload launch inclination from the ETR, provides essentially no coverage of the USSR, North Korea, or Eastern Europe. This orbit was not considered.

Figure 3-2 illustrates the accessible latitudes for orbital inclinations of 57, 75 and 97 degrees. As shown in the figure, lower inclination orbits concentrate a higher percentage of their coverage over high-density search latitudes. For example, a vehicle in a 75-degree inclination orbit spends 6 percent of its time between 50 and 60 degrees north latitude - 10 percent more time than a vehicle in a sun-synchronous orbit. At higher latitudes, the difference is more dramatic. The 75 degree inclination orbit provides more than twice as many accesses per unit time to regions between 70 and 75 degrees latitude than do sun-synchronous orbits.

The availability of SCF contacts was studied and found to be adequate for STS PCS operation at orbital inclinations between 57 and 97 degrees.

The effect of orbital inclination on the rate of orbital precession (and thus the temporal and geographical distribution of illumination) and the mission lifetime will be discussed in the following sections.

PERIGEE, ARGUMENT OF PERIGEE AND APOGEE

Choice of the orbit size and shape is essentially a trade-off between STS capabilities and image quality. In general, the specification of orbits is done most conveniently in terms of apogee, perigee, and the geodetic latitude of perigee. For orbits with a difference between the apogee and perigee altitudes much greater than the 11.5 NM difference between the polar and equatorial radii of the earth, it is possible to specify those three parameters independently and thus uniquely derive the associated Keplerian elements, semi-major axis, eccentricity, and argument of perigee. For most orbits of interest, however, this condition is not satisfied and the earth's equatorial bulge limits the range of latitudes

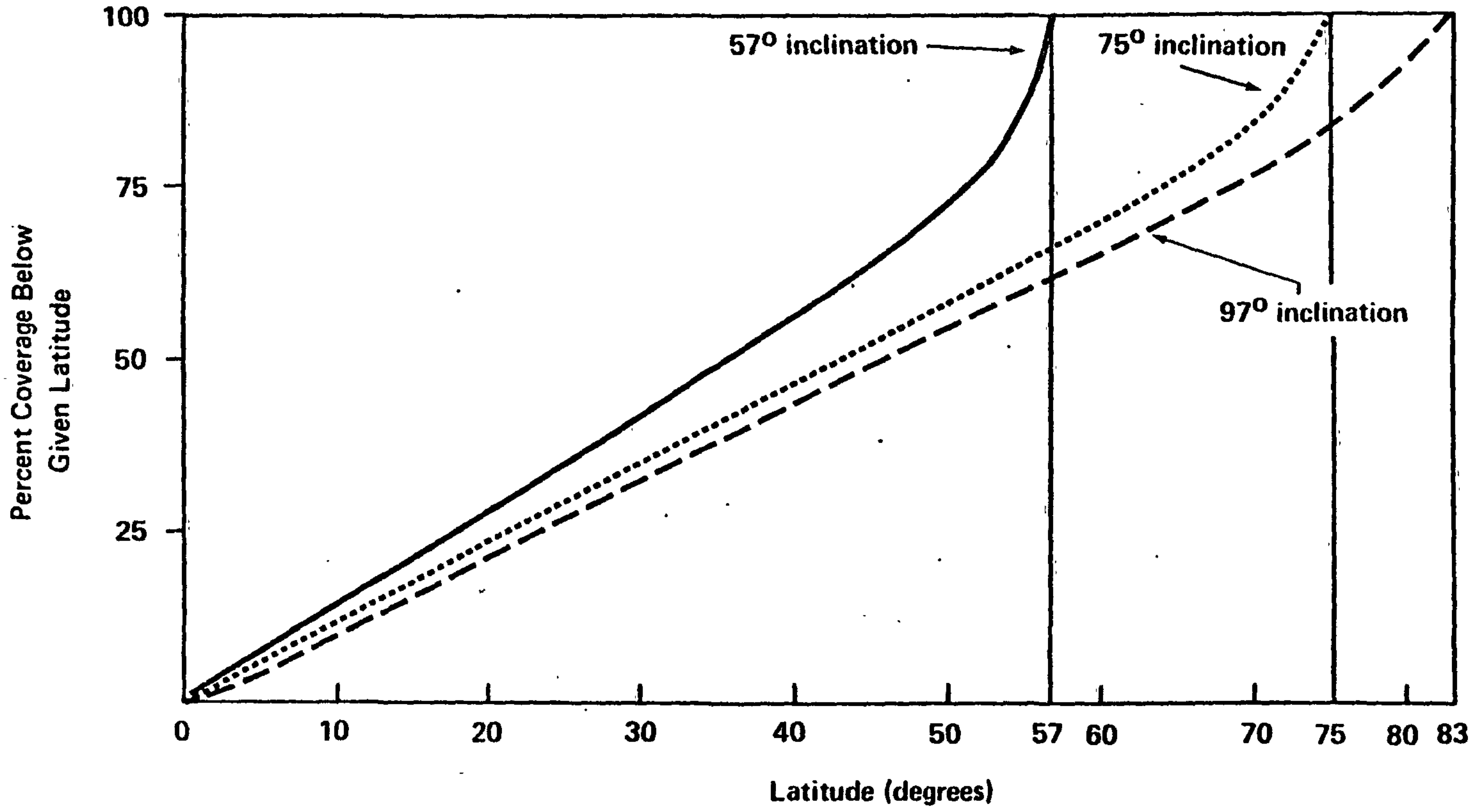


FIGURE 3-2 -- RELATIVE GEOGRAPHICAL COVERAGE FOR VEHICLES IN VARIOUS ORBITS over which geodetic perigee (the point of closest approach to the earth's surface) can occur. For near circular orbits, geodetic perigee occurs closer to the equator than geocentric perigee (the point of closest approach to the earth's center).

In this report, perigee denotes the altitude over a specified latitude, generally between 40 and 60 degrees north latitude. Apogee denotes the altitude one half period following perigee. From Figure 3-1 it can be seen that perigee should be maintained between 20 and 50 degrees north latitude, near the centroid of the imaging requirements. Although the line of apsides rotates at a rate dependent primarily on the inclination, the fuel required to maintain perigee over a specific latitude is less than that needed to compensate for drag and rotation of the line of apsides is neglected.

Perigee is fixed at 95 NM, the lowest obtainable based on a preliminary analysis of STS capabilities, and the argument of perigee and apogee are chosen so that most search areas accessible below 105 NM as described in Section 2.2. Figures 3-3 to 3-5 illustrate the imaging altitude above the oblate earth for the HEXAGON orbit and two lower inclination orbits. For the HEXAGON orbit, placement of the argument of perigee at 60 degrees north latitude where the altitude is 95 NM, puts geodetic perigee at 92.5 NM over 37 degrees north latitude. This orbit also places the spacecraft below 105 NM for all targets north of 12 degrees south latitude (only 15 percent of the standing search requirements are south of this latitude). The lower inclination orbits place geodetic perigee at between 92 and 94 NM over about 10 degrees north latitude and permit access to at least 97 percent of the required area below 105 NM.

LAUNCH TIME SELECTION

The time and direction of launch determine the angle between the orbit plane and the earth to sun line and therefor the time of day at a given latitude. Figures 3-6 to 3-8 illustrate the effect of launch time on sun angle for a 57-degree inclination orbit at winter solstice and 75- and 96.4-degree inclination orbits at summer solstice. Also shown is the curve denoting the maximum obtainable sun angle at each latitude. A maximum sun angle of 90 degrees occurs at $\pm$ 23.44 degrees latitude during summer and winter solstice. A 90-degree inclination orbit with a 12 PM descending node provides the maximum sun angle at all latitudes; however, the 96.4-degree inclination launch at 1300 local time provides sun angles close to the highest obtainable.

~~TOP SECRET H~~EXAGON [redacted] 20053 (b)(1)
(b)(3) 10 USC ⊥ 424

(b)(1)
(b)(3) 10 USC ⊥ 424

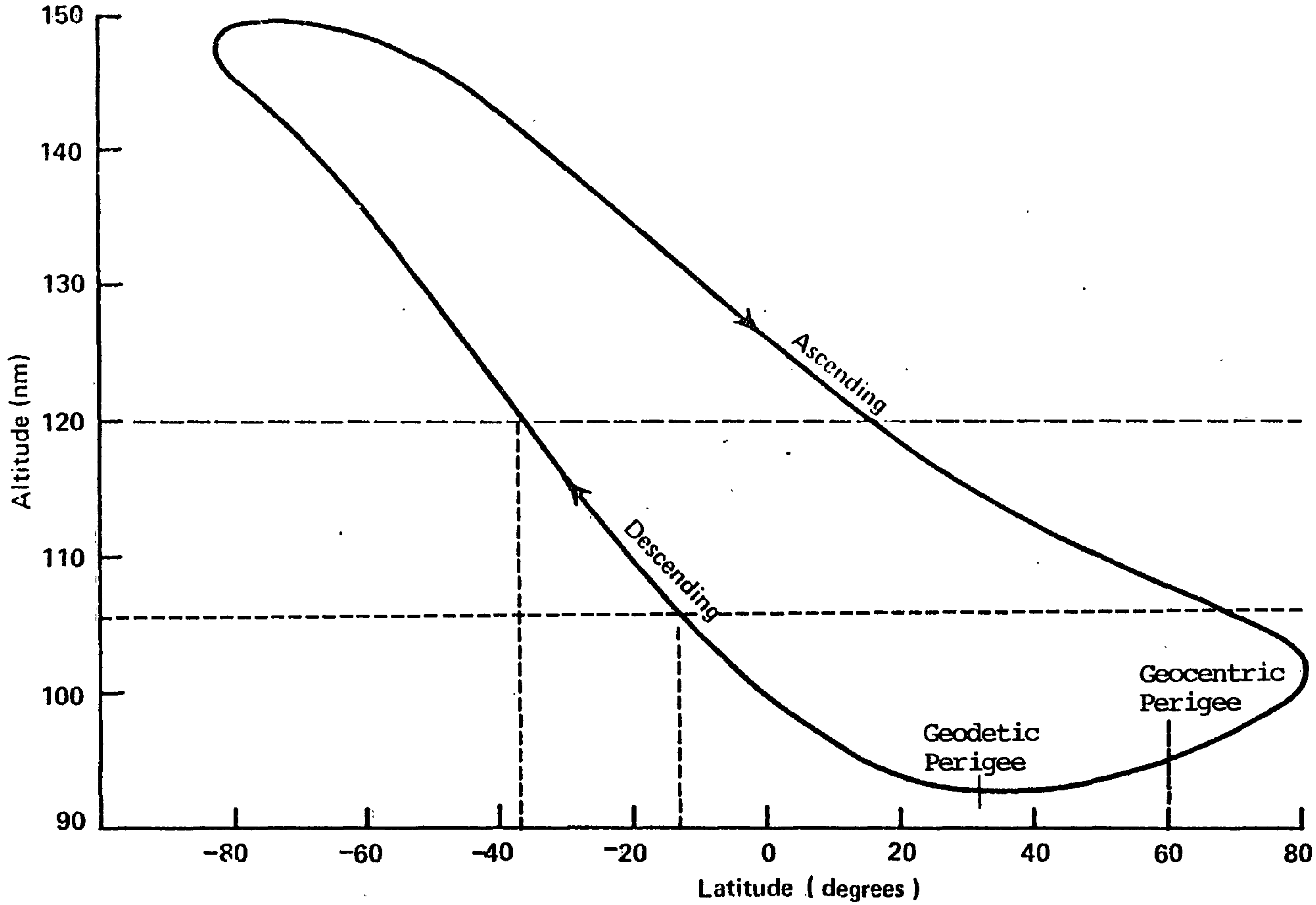


FIGURE 3-3 -- ALTITUDE ABOVE OBLATE SPHEROID
(i = 96.4°, 95 x 150 NM, PERIGEE AT 60° N)

(b)(1)
(b)(3) 10 USC ⊥ 424

HANDLE VIA BYEMA
KEYHOLE CONTROL ONLY

(b)(1)
(b)(3) 10 USC ⊥ 424

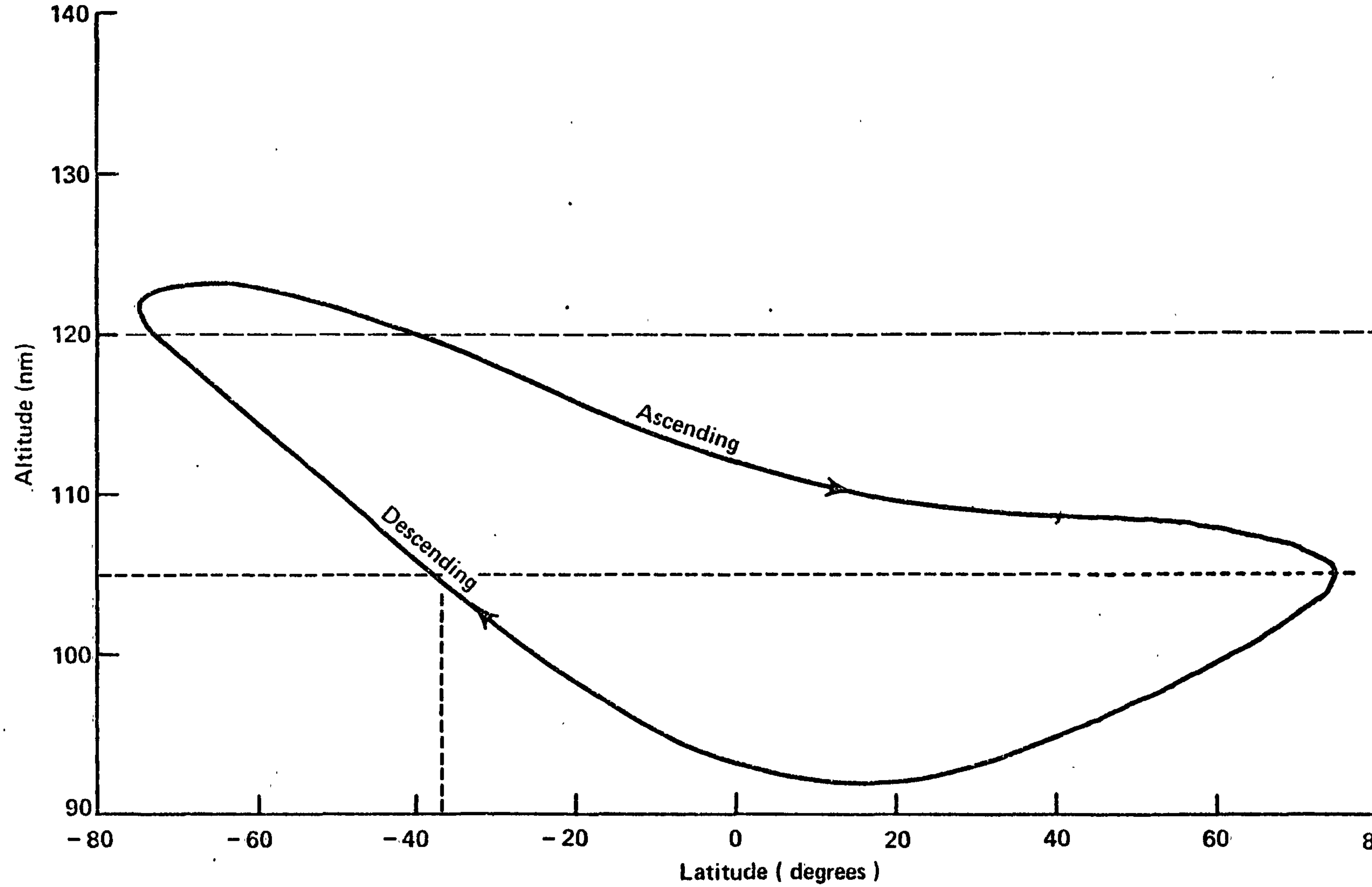


FIGURE 3-4 -- ALTITUDE ABOVE OBLATE SPHEROID (i = 75°, 95 x 122 NM. PERIGEE AT 40° N)

(b)(1)
(b)(3) 10 USC ⊥ 424
Approved for Release: 2017/02/08 C05094782

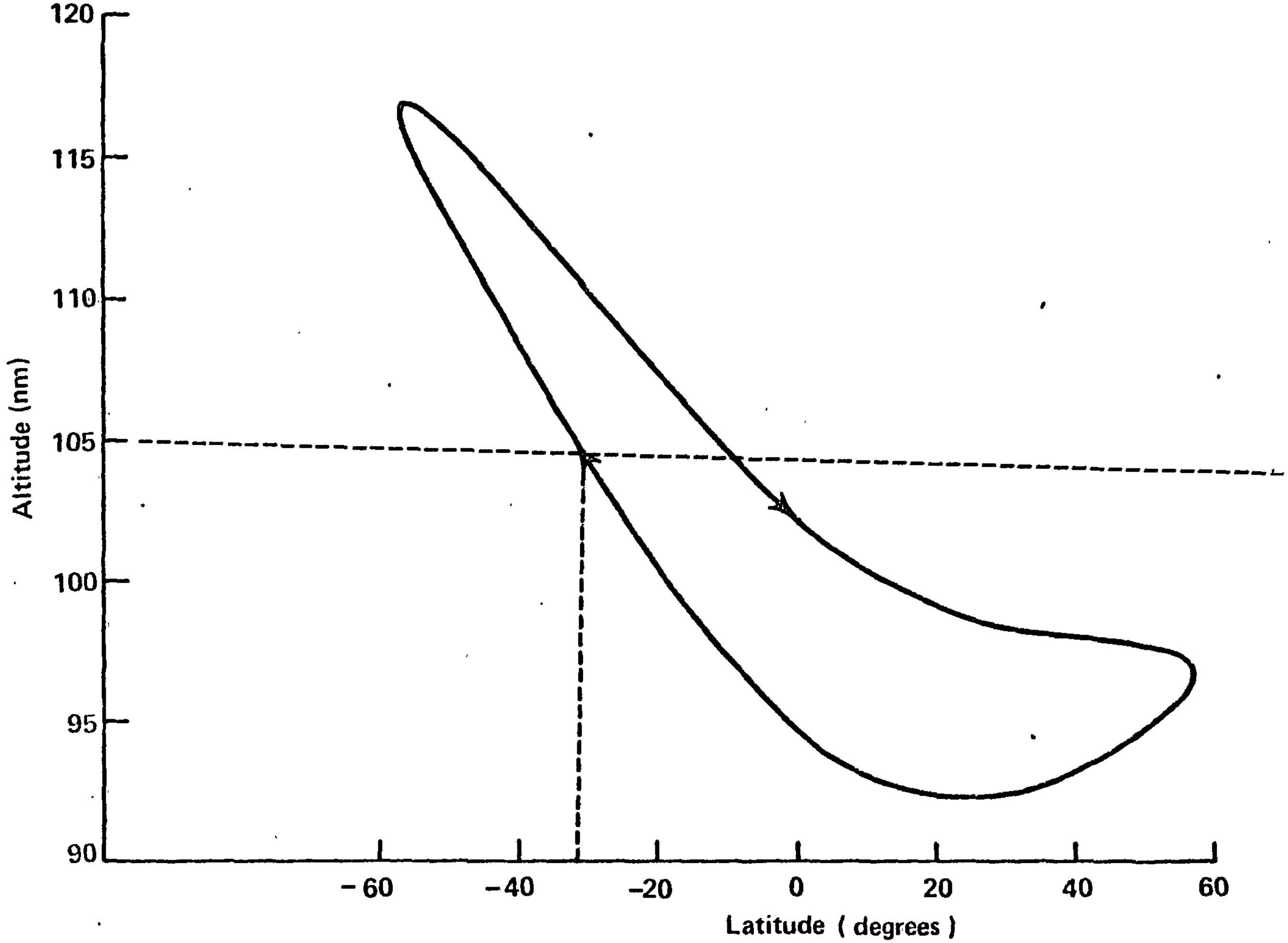


FIGURE 3-5 -- ALTITUDE ABOVE OBLATE SPHEROID (i = 57°, 95 x 117 NM, PERIGEE AT 52° N)

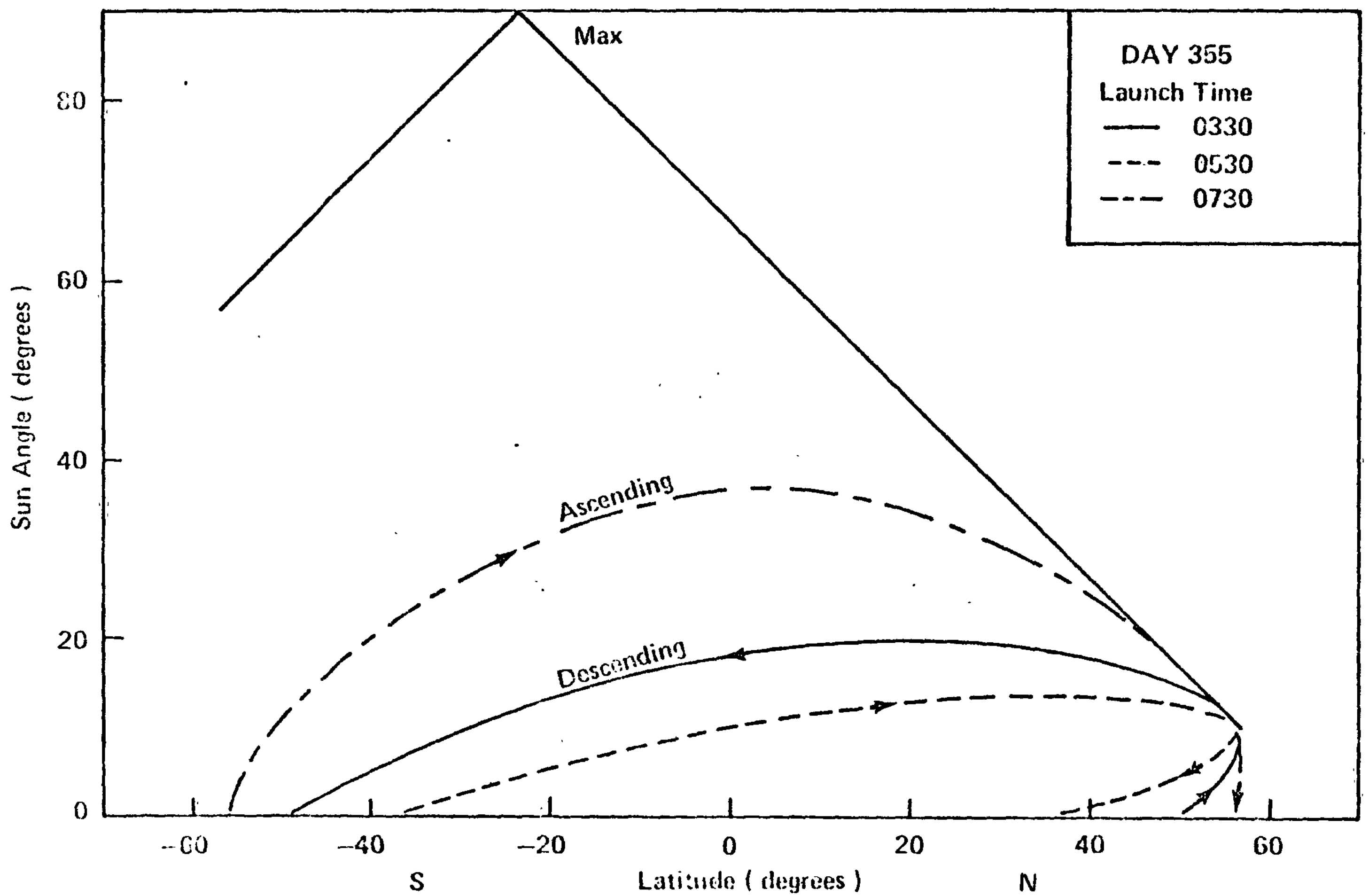


FIGURE 3-6 -- SUN ELEVATION ANGLE PROFILE FOR VARIOUS LAUNCH TIMES (i = 57°, WINTER SOLSTICE)

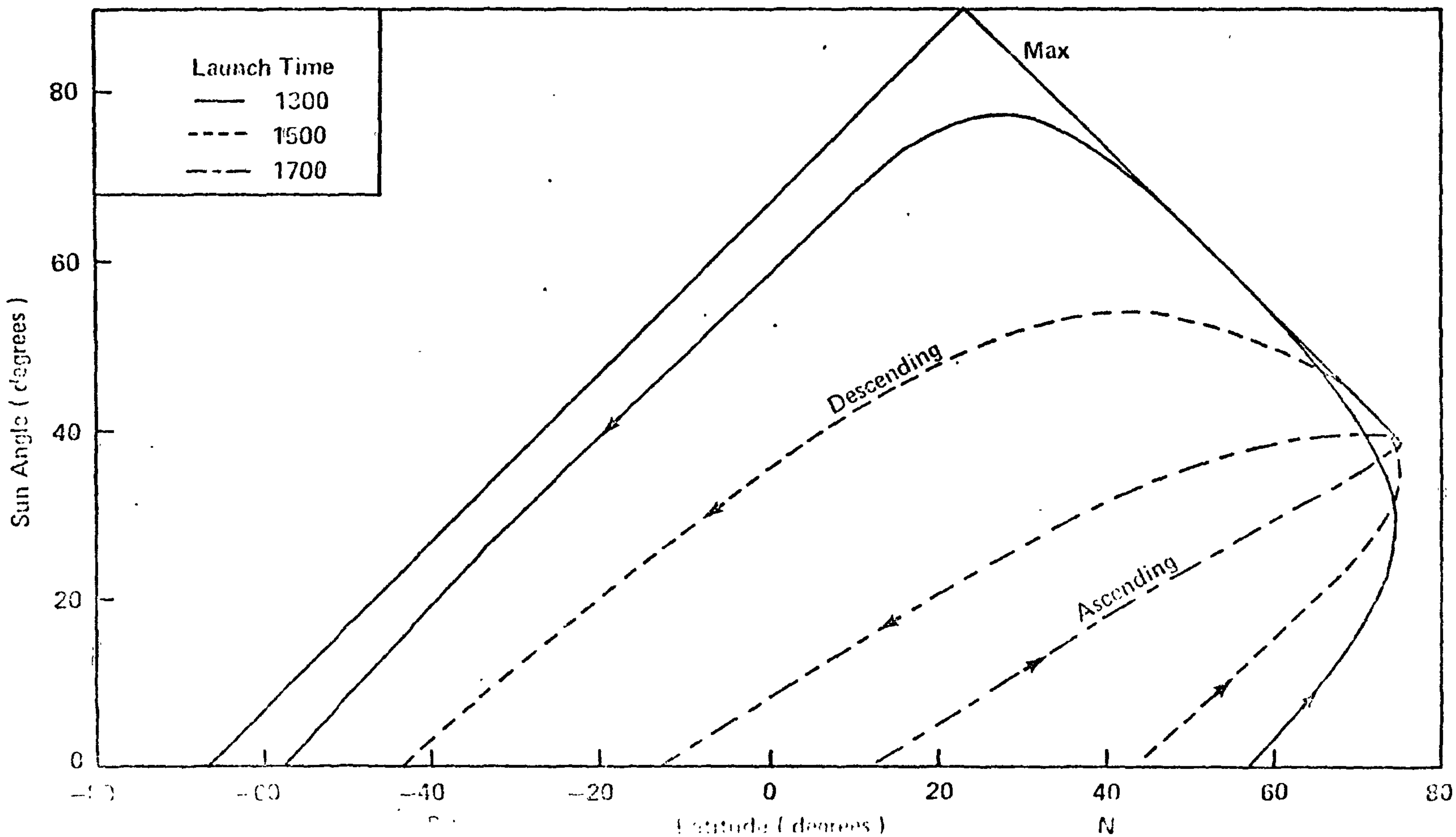


FIGURE 3-7 -- SUN ELEVATION ANGLE PROFILE FOR VARIOUS LAUNCH TIMES (i = 75°, SUMMER SOLSTICE)

(b)(1)
(b)(3) 10 USC ⊥ 424

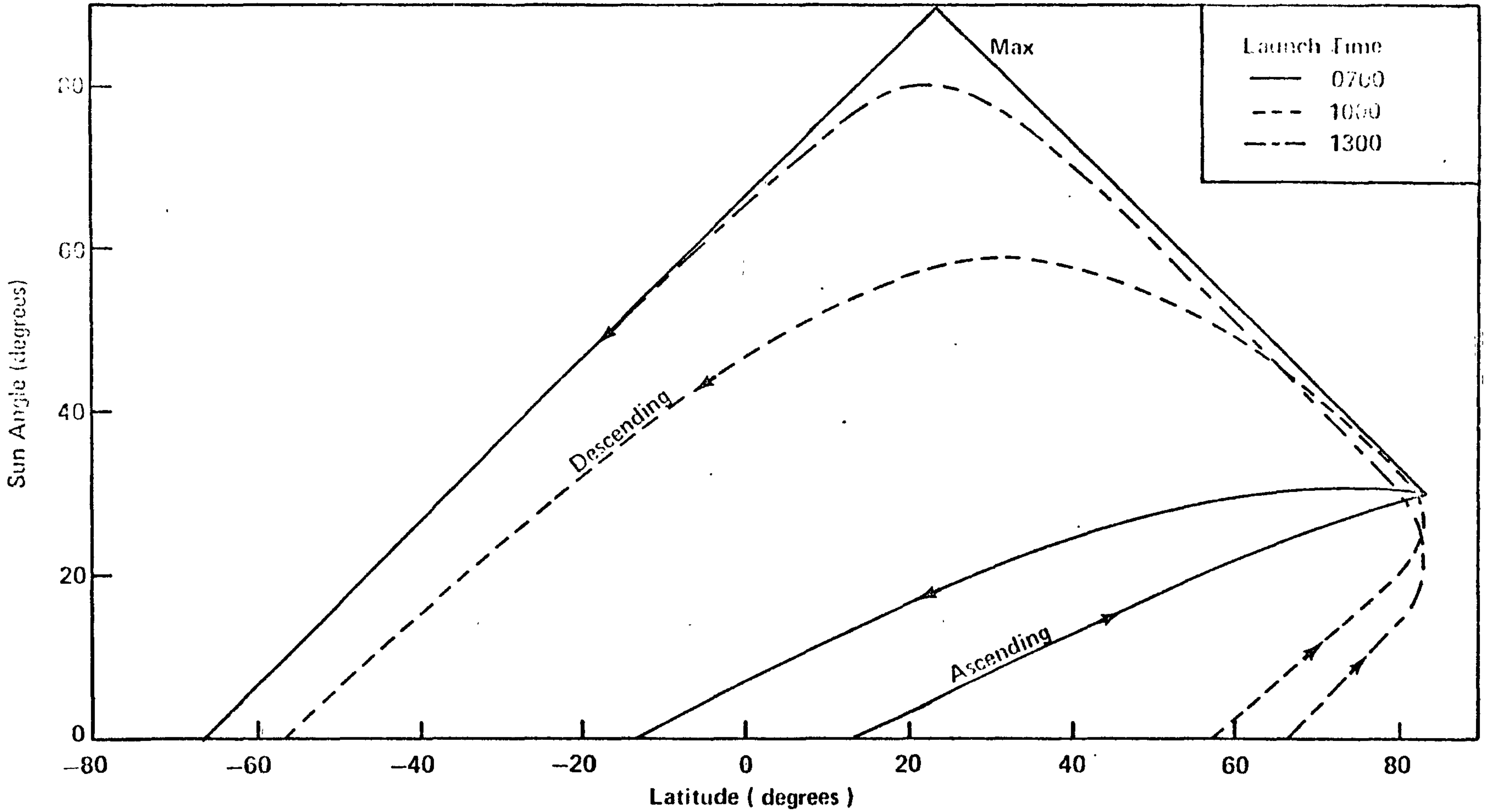


FIGURE 3-8 -- SUN ELEVATION ANGLE PROFILE FOR VARIOUS LAUNCH TIMES (i = 96.4°, SUMMER SOLSTICE)

For inclinations lower than 96.4 degrees, the precession rate of the orbit plane causes significant changes in the sun angle profile during a mission as shown in Figures 3-9 and 3-10 for 57- and 75-degree inclination orbits, respectively. Furthermore, the westerly motion of the orbiter results in a wide range of local viewing times. The magnitude of these effects for various orbital inclinations are given in Table 3-2. Figures 3-11 to 3-15 illustrate sun angle profiles for various inclinations and launch days.

ACCESS CLOSURE

For search requirements, it is desirable to have photographic opportunities in all areas of interest as frequently as possible. The closure period is the minimum time required to access, on the descending portion of the orbit, every point on the earth's surface within the latitude bounds defined by the inclination. A necessary and sufficient condition for a near-circular orbit to close is that all points on the equator be accessed. The width of the access swath, projected along the equator, depends on the imaging altitude, inclination, and obliquity limits as shown in Table 3-3. In general, the orbital swath at the equator is substantially less than the distance that the earth rotates during the orbit and closure is achieved by swaths traced on successive days filling in the gaps between swaths traced on successive orbits. Orbits that require long times to close and are therefore undesirable, have periods such that the number of orbits per day can be written in the form

$$1440/T = N - I/J$$

where T is the orbital period in minutes, and N, I, and J are integers with $I < J$. Such reasonant orbits provide repeating coverage after J days and should be avoided so that all areas are accessed uniformly.[2] It is noted, however, that orbital decay and adjustment alter the period and substantially change the closure pattern[3]. Figures 3-16 to 3-24 illustrate closure times for various orbits. In the figures, the solid line denotes the closure time at the equator; the other lines denote the closure times at various latitudes as indicated by the legend. The resonances predicted in Table 3-4 can be seen clearly for the 96.4-degree inclination orbit.

[2] For $J > 7$, repeating coverage occurs after closure and thus these orbits are not undesirable.

[3] HEXAGON orbit adjust maneuvers occur every two to three days, raise apogee by 5 to 8 NM, and increase the period by 10 to 20 seconds.

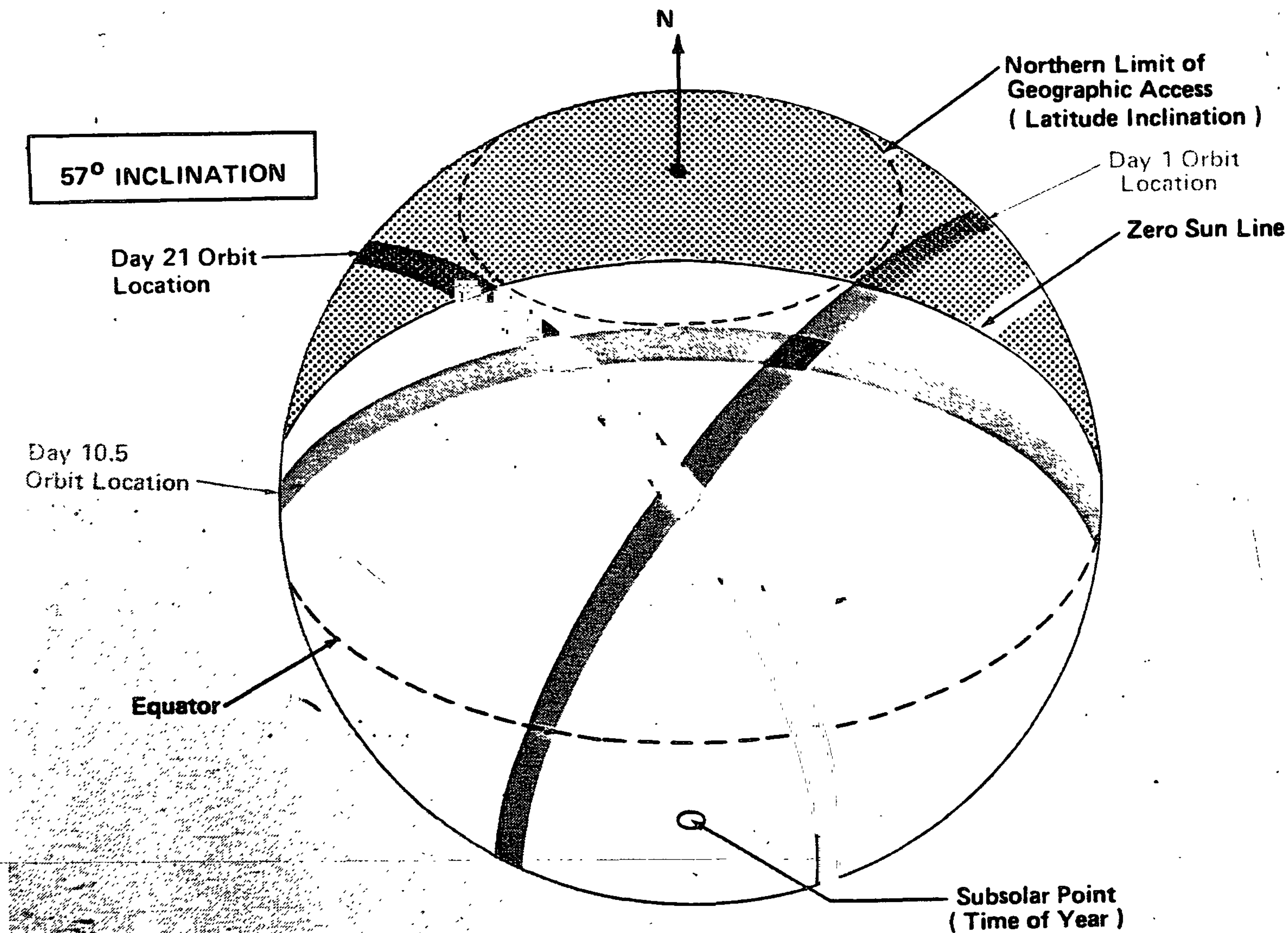


FIGURE 3-9 Illumination Constraints (i = 57°, Winter Solstice)

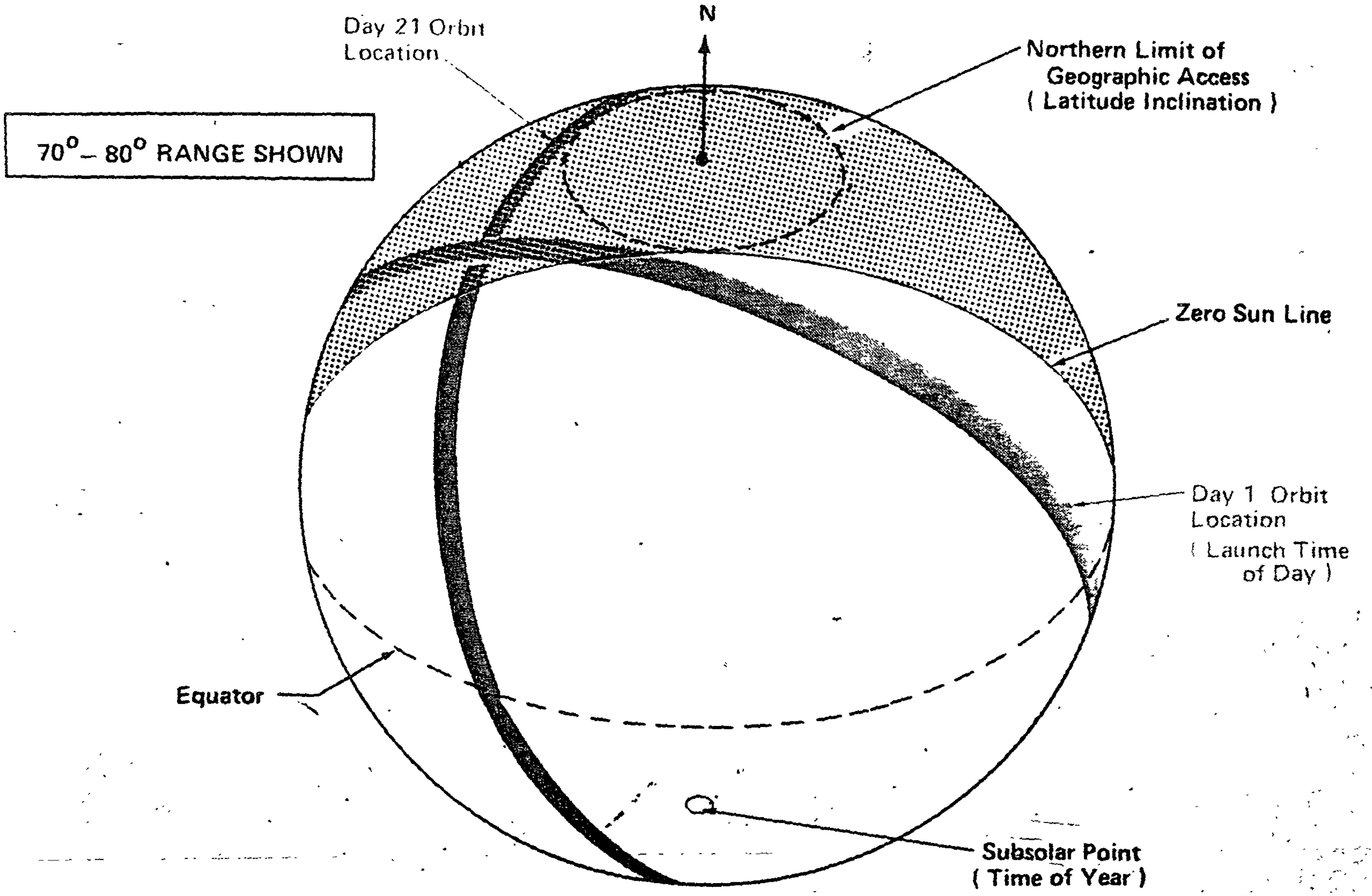


FIGURE 3-10 Illumination Constraints (i = 75°, Winter Solstice)

TABLE 3-2 - SECULAR CHANGES FOR VARIOUS ORBITS

Inclination (Deg)	Perigee X Apogee[1] (NM)	Semi-Major Axis (NM)	Period (Minutes)	Node Rate (Minutes/Day)	Perigee Rate (Deg/Day)	Local Time Difference on Descending Orbit T(45°N) - T(Eq.) (Minutes)
97	95 x 130	3549.6	88.41	.41	4.17 (north)	- 28 (earlier)
97	95 x 140	3554.6	88.59	.38	4.15	- 28
97	95 x 150	3559.6	88.78	.36	4.13	- 28
96.35	95 x 140	3554.6	88.59	0	4.19	- 26
90	95 x 140	3554.6	88.59	- 3.98	4.48	0
85	95 x 120	3546.6	88.30	- 7.13	4.34	20 (later)
80	95 x 120	3546.6	88.30	-10.26	3.84	41
75	95 x 105	3539.1	88.02	-13.40	3.03	63
75	95 x 120	3546.6	88.30	-13.33	3.01	63
75	95 x 135	3554.1	88.58	-13.26	2.99	63
63.43	95 x 120	3546.6	88.30	-20.14	0	121
57	95 x 105	3539.1	88.02	-23.81	-2.20 (south)	164

[1] For all orbits, perigee and apogee are approximate and for description only; the computations in the table are based on semi-major axis, eccentricity and inclination

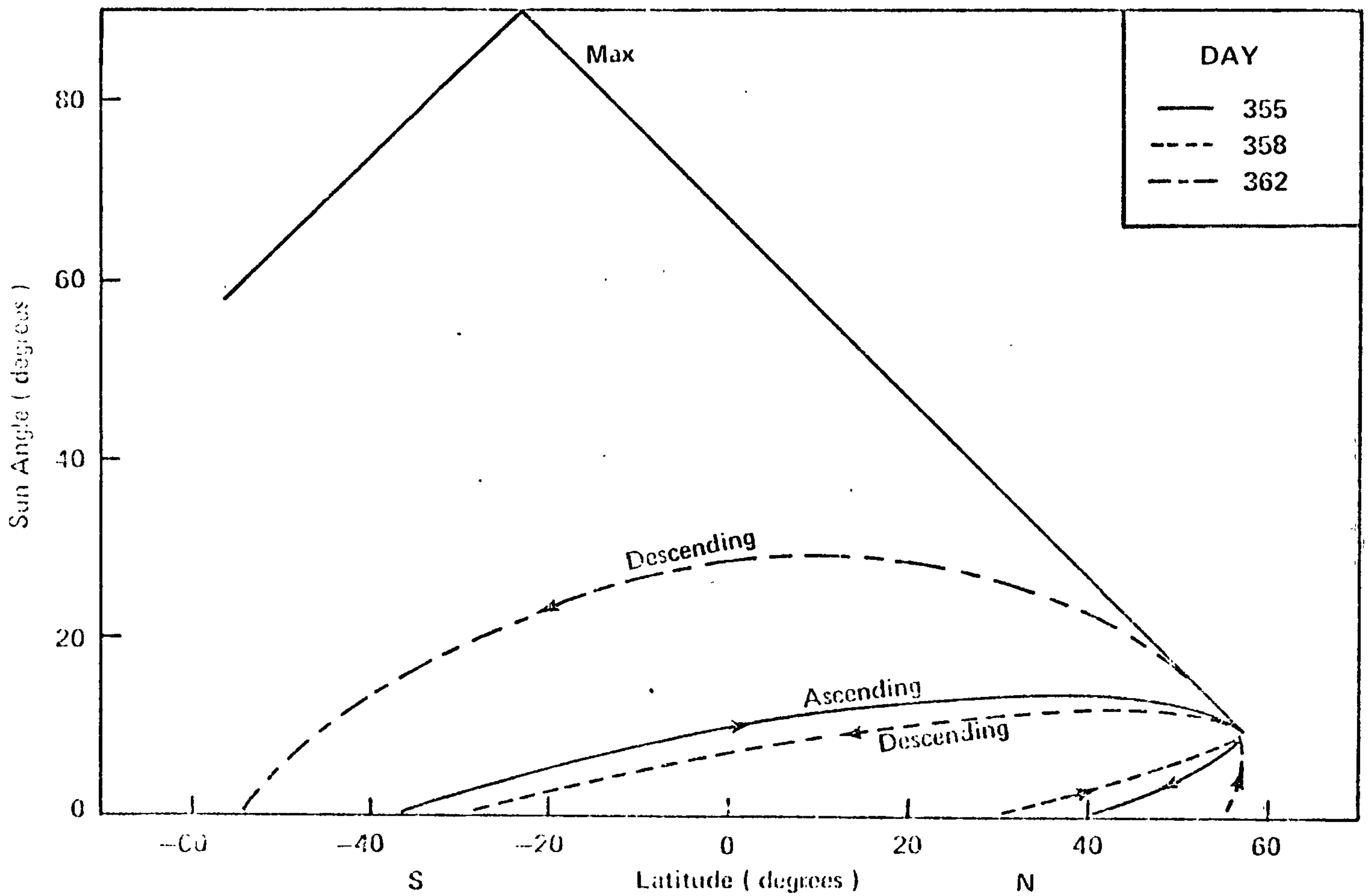


FIGURE 3-11--SUN ELEVATION ANGLE PROFILE FOR VARIOUS LAUNCH TIMES
(INCLINATION = 57°, LAUNCH TIME = 05:30 LOCAL)

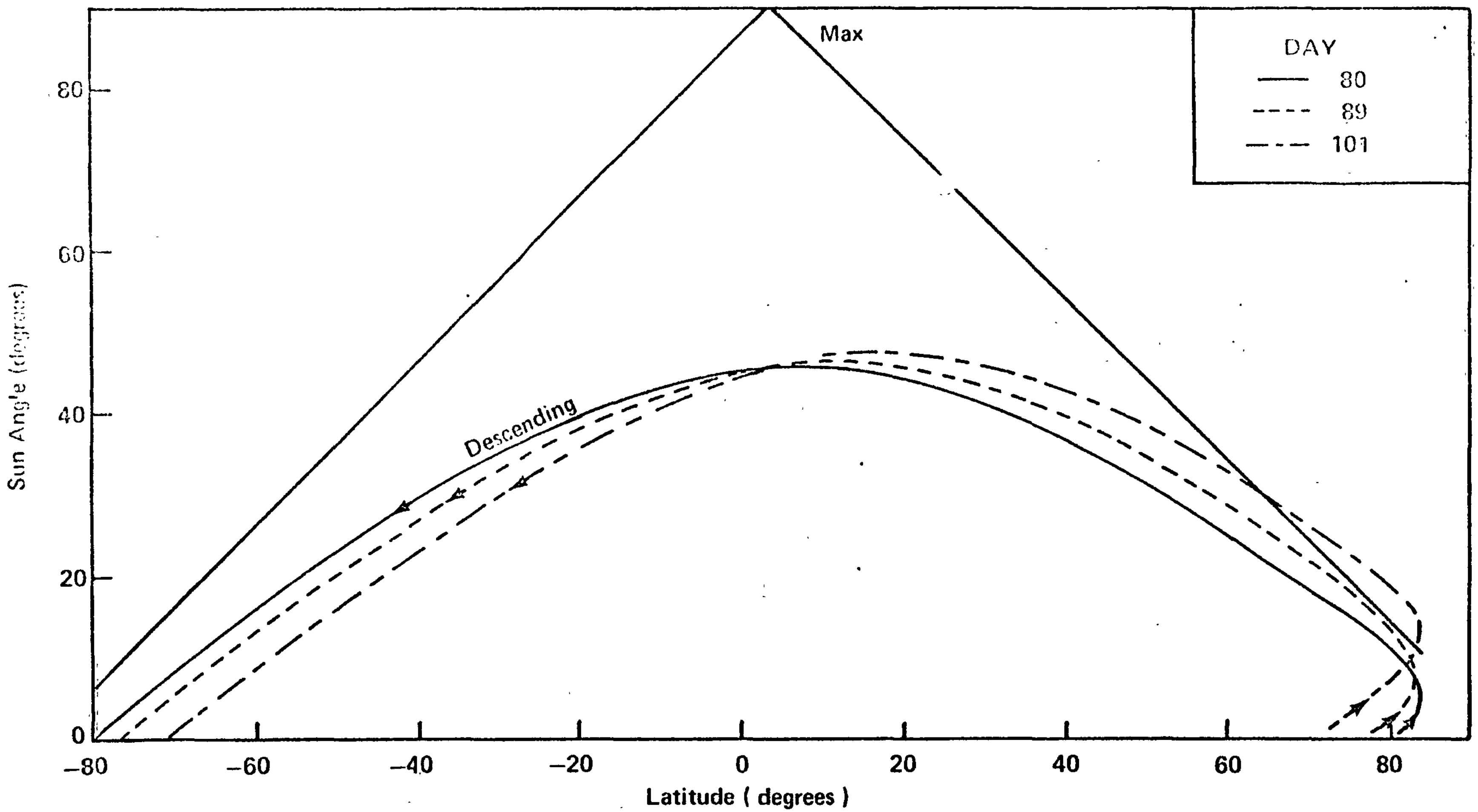


FIGURE 3-12 -- SUN ELEVATION ANGLE PROFILE VERSUS TIME
(i = 75°, T = 15:45)

(b)(1)
(b)(3) 10 USC ⊥ 424

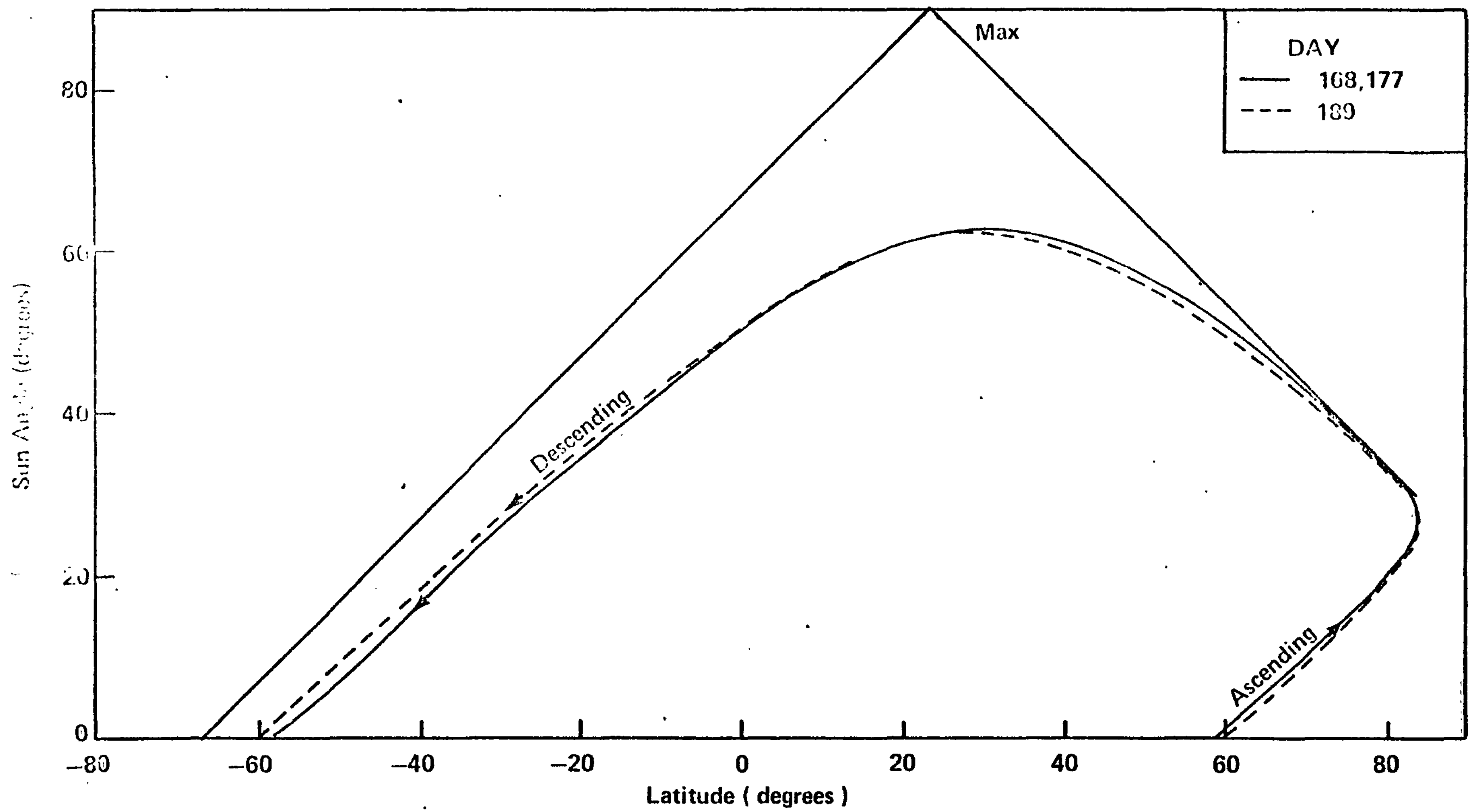


FIGURE 3-13 -- SUN ELEVATION ANGLE PROFILE VERSUS TIME
(i = 75°, T = 15:00)

HANDLE VIA BYEMAN (b)(1)
KEYHOLE CONTROL SYSTEMS ONLY (b)(3) 10 USC ⊥ 424

(b)(1)
(b)(3) 10 USC ⊥ 424

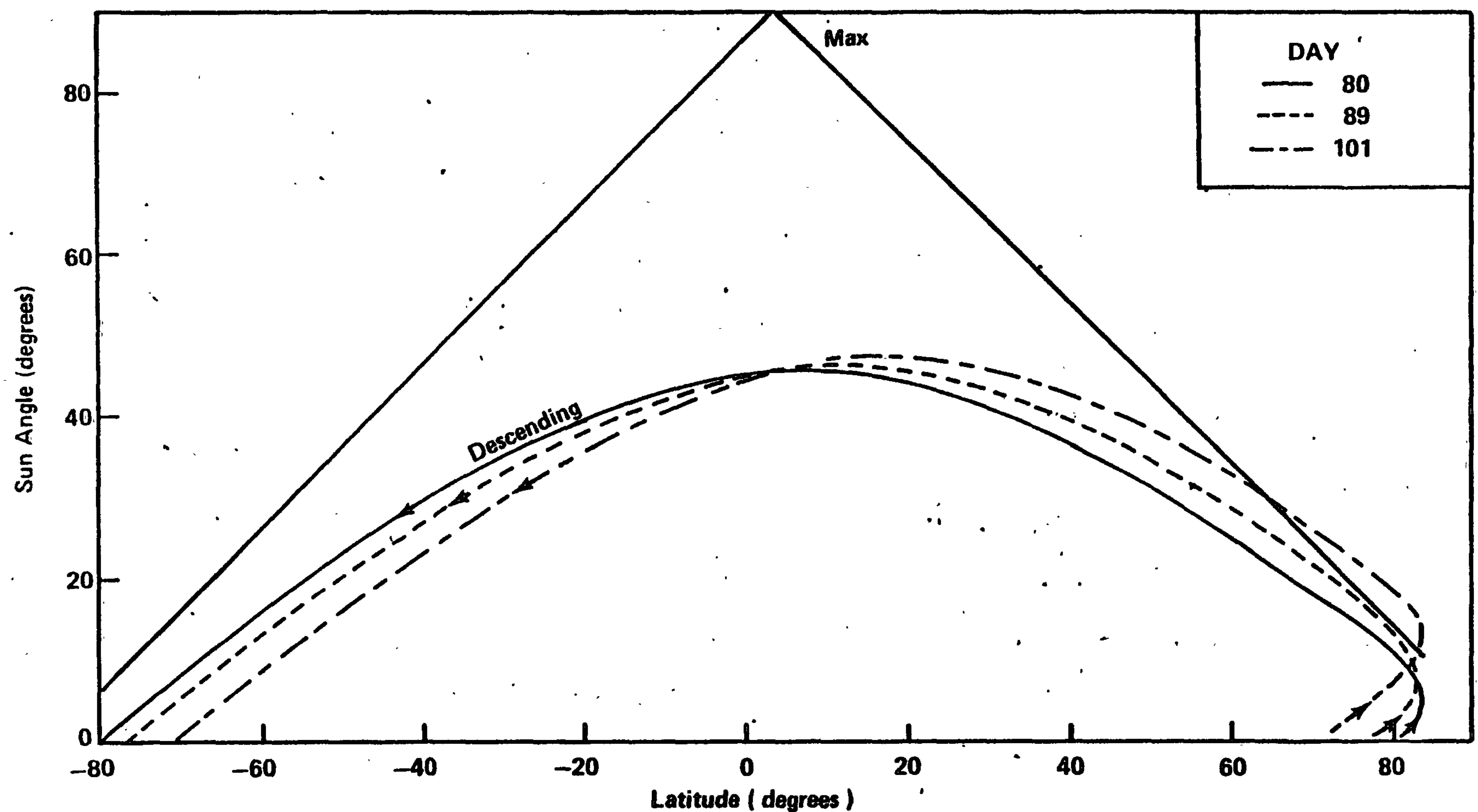


FIGURE 3-14 -- SUN ELEVATION ANGLE PROFILE VERSUS TIME
(i = 96.4°, T = 09:30)

HANDLE VIA BYEM[redacted]ALENT-
KEYHOLE CONTROL (b)(1) (b)(3) 10 USC ⊥ 424

(b)(1)
(b)(3) 10 USC 424

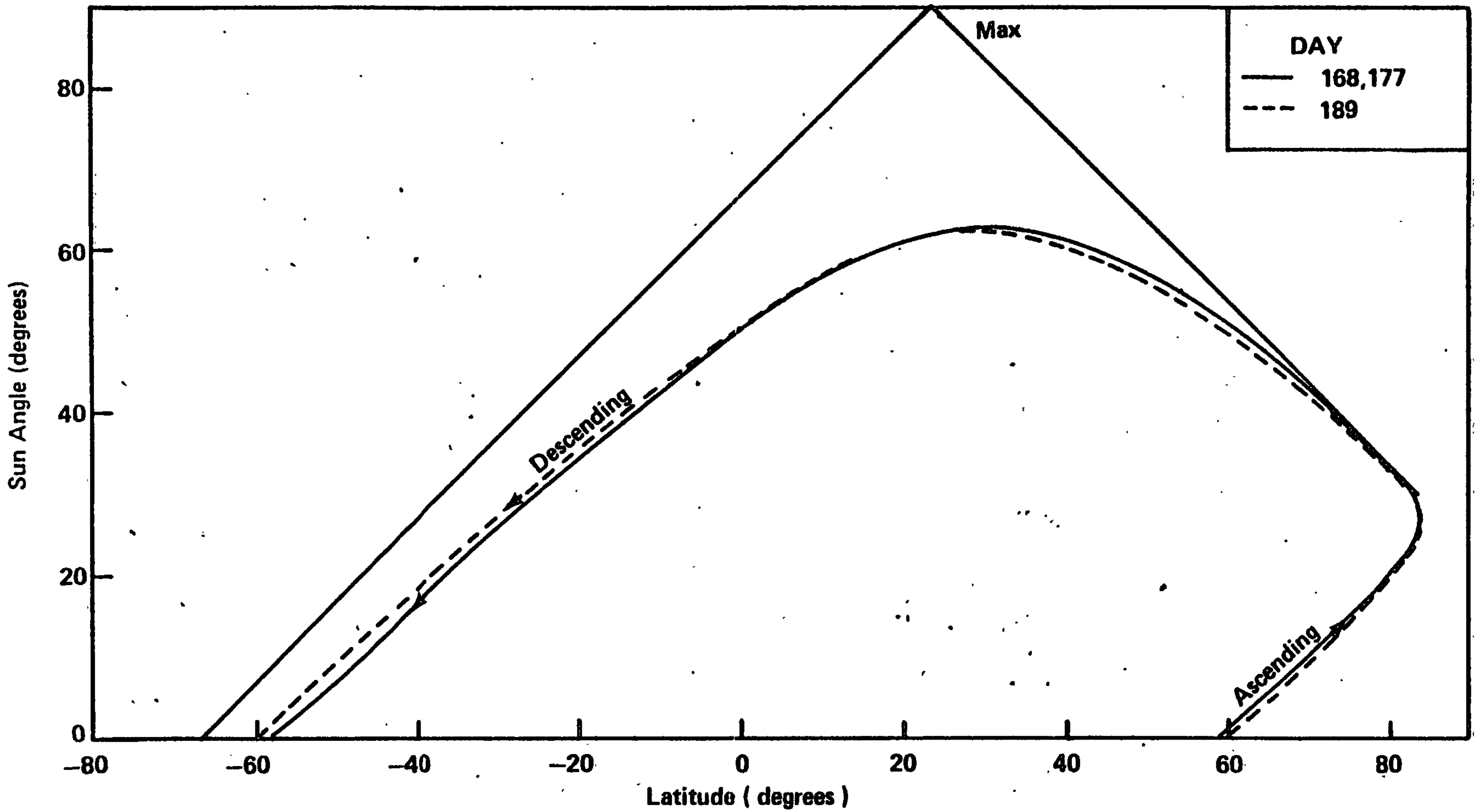


FIGURE 3-15 -- SUN ELEVATION ANGLE PROFILE VERSUS TIME
(i = 96.4°, T = 10:15)

HANDLE VIA BYEMA (b)(1) ENT-
KEYHOLE CONTROL (b)(3) 10 USC 424

TABLE 3-3 SWATH WIDTHS AS A FUNCTION OF OBLIQUITY ANGLE

SWATH WIDTH (NM)

ALT. (NM)	i = 57°				i = 75°				i = 96.4°			
	15°	30°	45°	60°	15°	30°	45°	60°	15°	30°	45°	60°
90	57.5	123.9	214.6	371.7	49.9	107.6	186.3	322.7	48.5	104.6	181.1	313.7
95	60.7	130.8	226.5	392.4	52.7	113.6	196.7	340.7	51.2	110.4	191.2	331.2
100	63.9	137.7	238.5	413.2	55.5	119.6	207.1	358.7	54.0	116.3	201.3	348.7
105	67.1	144.5	250.4	433.6	58.3	125.5	217.4	376.5	56.7	122.0	211.4	366.0
110	70.3	151.5	262.4	454.5	61.0	131.5	227.8	394.6	59.3	127.8	221.5	383.6
120	76.7	165.2	286.2	495.7	66.6	143.5	248.5	430.4	64.7	139.5	241.6	418.4
130	83.0	179.0	310.0	537.1	72.1	155.4	269.2	466.3	70.1	151.1	261.7	453.3
140	89.5	192.8	333.9	578.3	77.7	167.4	289.9	502.1	75.5	162.7	281.8	488.1

TABLE 3-4 -- RESONANT ORBITS

Semi-Major Axis (NM)	Period (Minutes)	I	J	Orbits/Day 17-I/J	Apogee (NM) (Perigee = 95 NM at 60° N)
3533.4	87.8049	3	5	16.4000	101.2
3543.0	88.1633	2	3	16.3333	120.4
3550.0	88.4211	5	7	16.2857	134.4
3555.2	88.6154	3	4	16.2500	144.8
3562.5	88.8889	4	5	16.2000	159.4
3567.4	89.0722	5	6	16.1667	169.2
3570.9	89.2035	6	7	16.1429	176.2
3592.1	90.0000	1	1	16.0000	218.6

(Keplerian) based on unperturbed period — need to modify based on nodal period.

(2 to 4 seconds longer)

HANDLE VIA BYEMAN TALENT-KEYHOLE CONTROL SYSTEMS ONLY

(b)(1)
(b)(3) 10 USC ⊥ 424

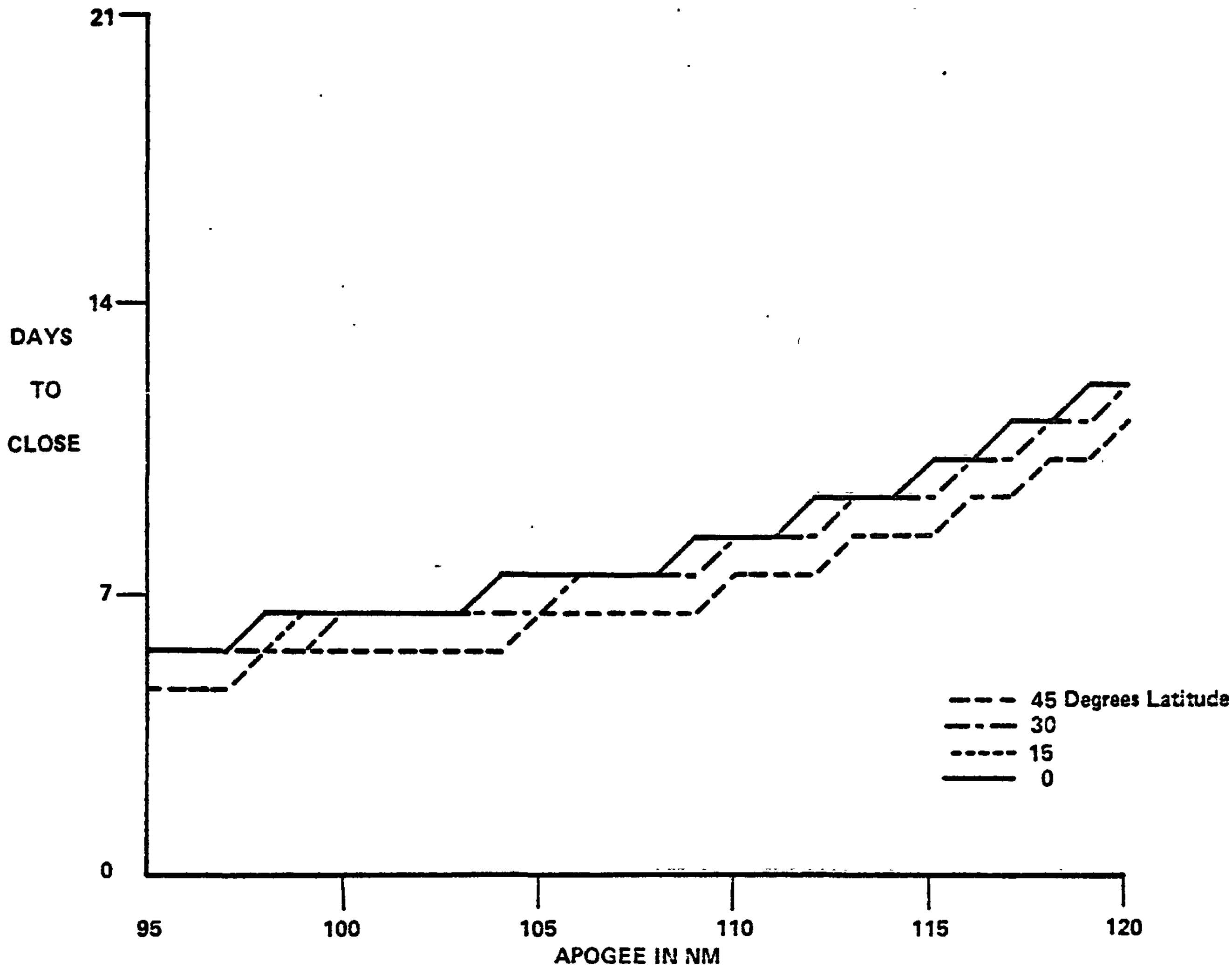


FIGURE 3-16 -- CLOSURE TIMES VERSUS APOGEE
(i = 57°, PERIGEE = 95 NM)

HANDLE VIA BYEMAN TALENT
KEYHOLE C(b)(1)OL SYSTEMS
ONLY
(b)(3) 10 USC ⊥ 424

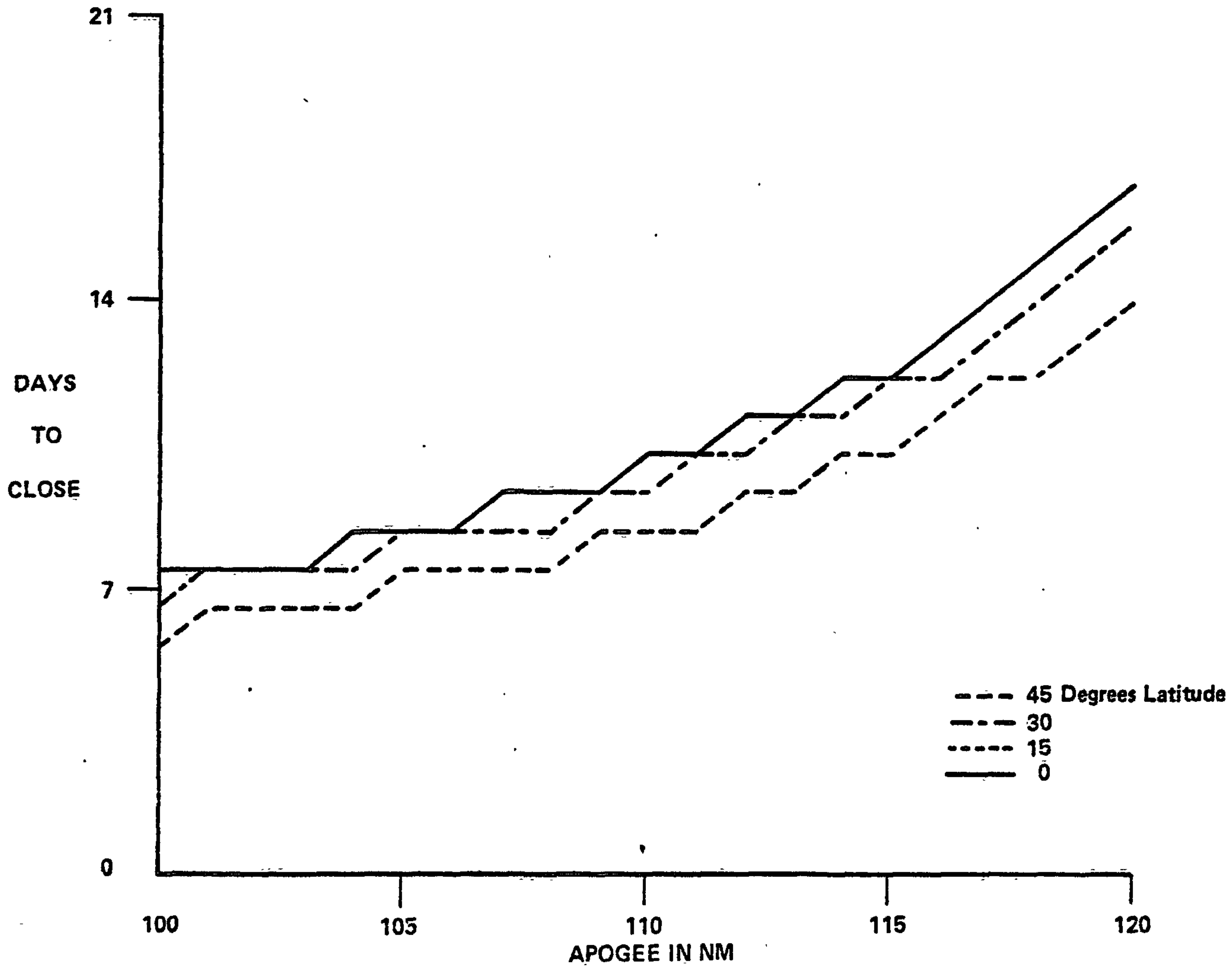


FIGURE 3-17 -- CLOSURE TIMES VERSUS APOGEE
(i = 57°, PERIGEE = 100 NM)

~~TOP SECRET~~ HEXAGON 20053

(b)(1)
(b)(3) 10 USC ⊥ 424

Approved for Release: 2017/02/08 C05094782

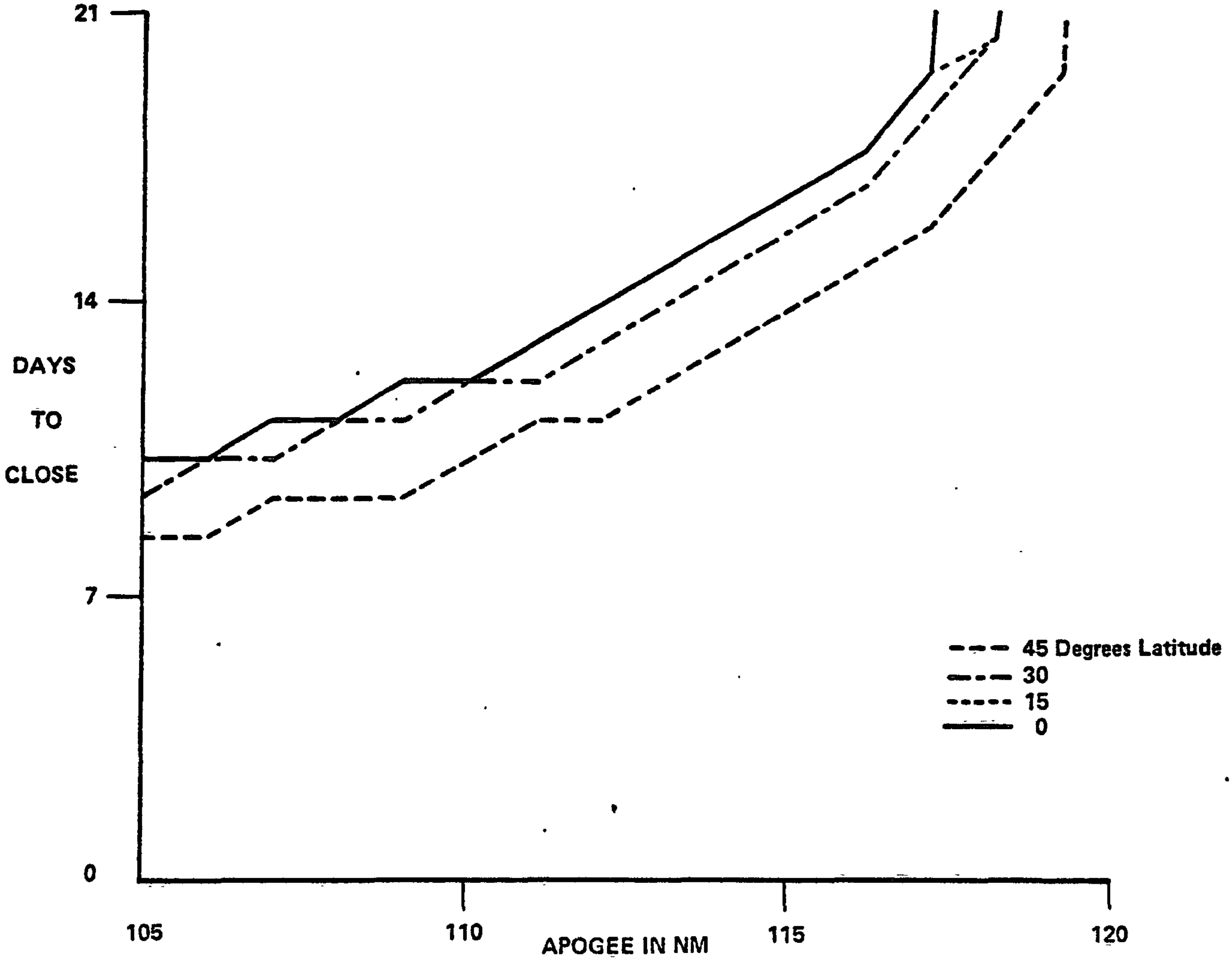


FIGURE 3-18 -- CLOSURE TIMES VERSUS APOGEE
(i = 57°, PERIGEE = 105 NM)

~~TOP SECRET~~ HEXAGON 20053

(b)(1)
(b)(3) 10 USC ⊥ 424

Approved for Release: 2017/02/08 C05094782

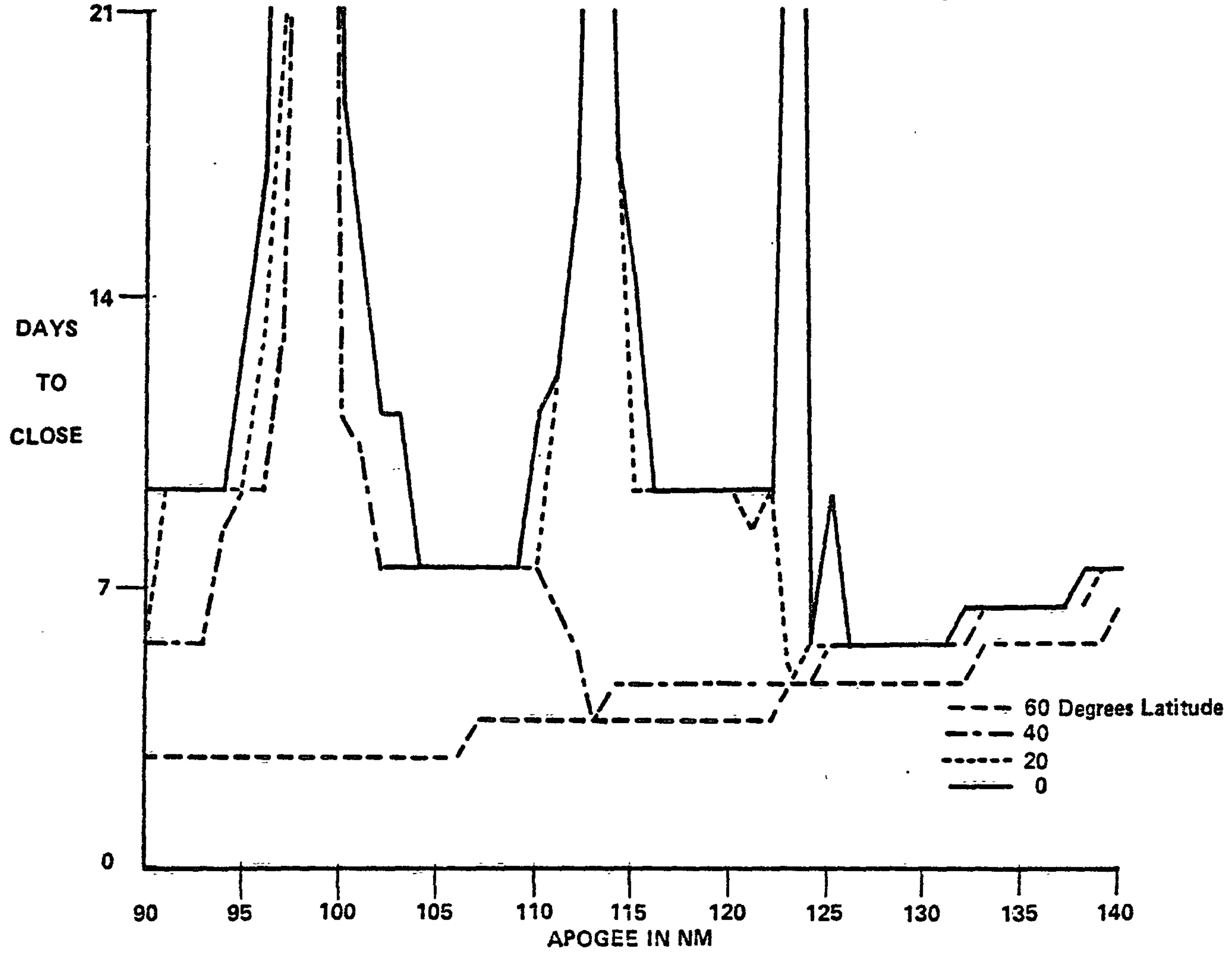


FIGURE 3-19 -- CLOSURE TIMES VERSUS APOGEE
(i = 75°, PERIGEE = 90 NM)

(b)(1)
(b)(3) 10 USC ⊥ 424

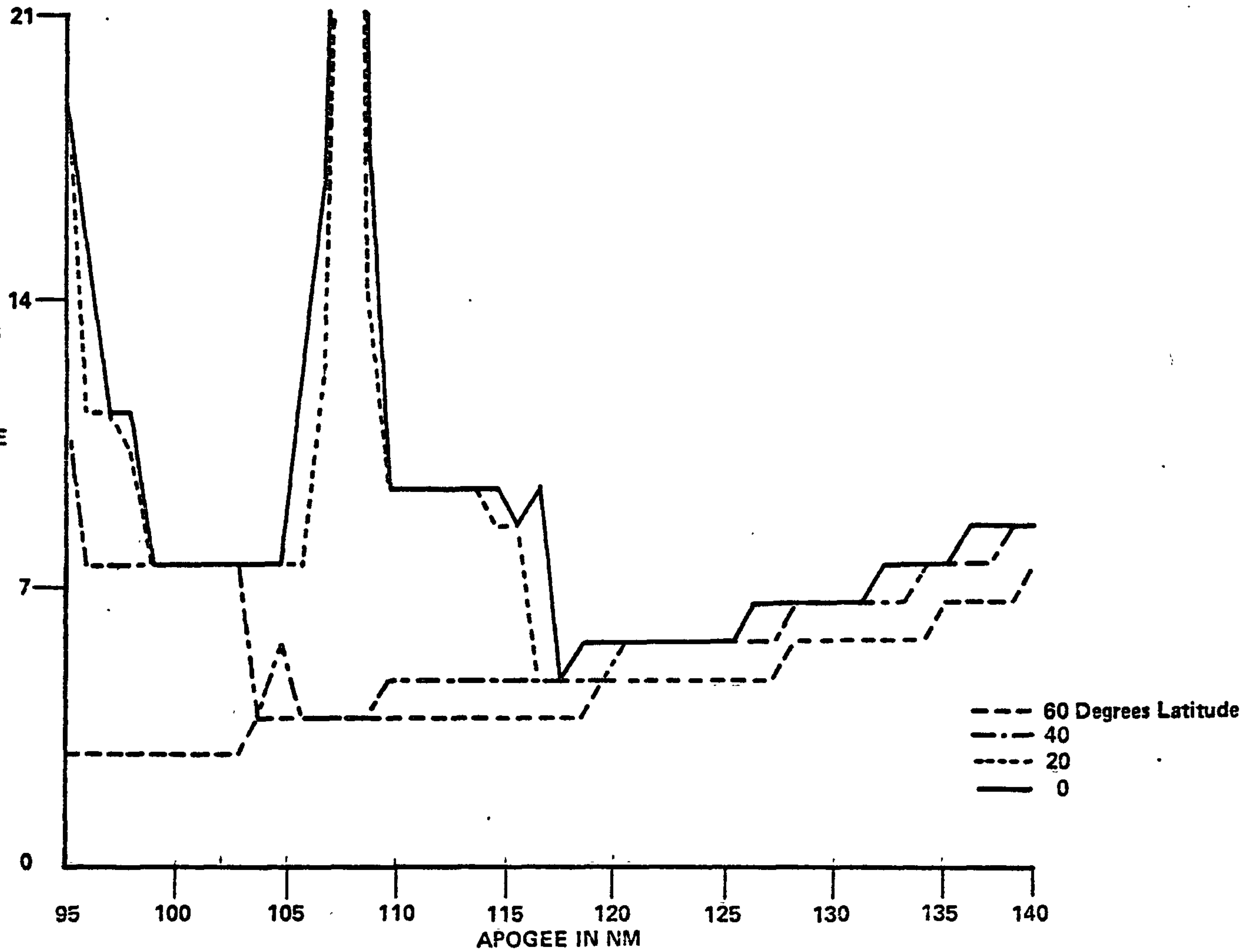


FIGURE 3-20 Closure Times Versus Apogee (i = 75°, Perigee = 95 NM)

(b)(1)
(b)(3) 10 USC ⊥ 424

(b)(1)
(b)(3) 10 USC ⊥ 424

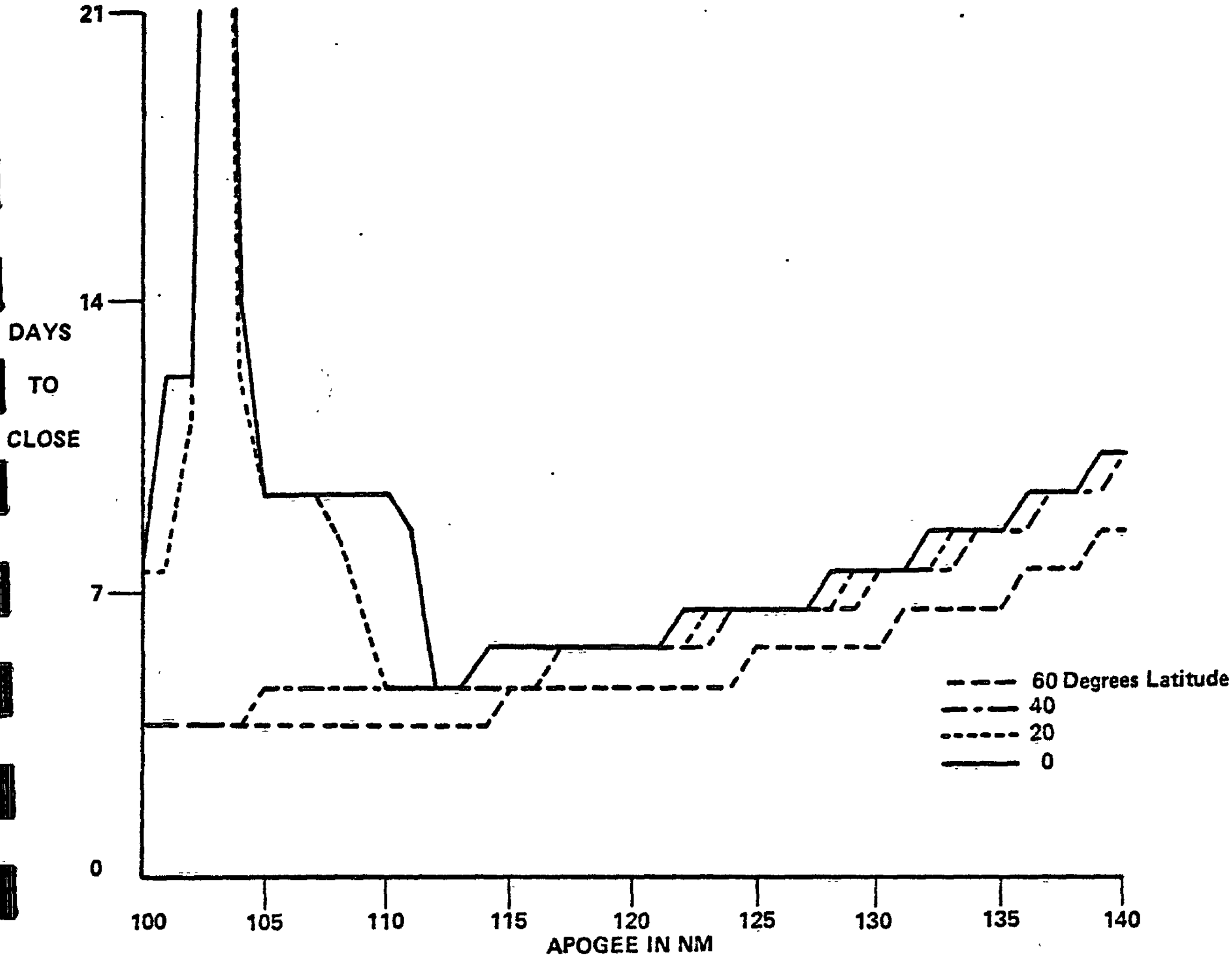


FIGURE 3-21 CLOSURE TIMES VERSUS APOGEE (i= 75°, Perigee = 100 NM)

(b)(1)
(b)(3) 10 USC ⊥ 424

(b)(1)
(b)(3) 10 USC ⊥ 424

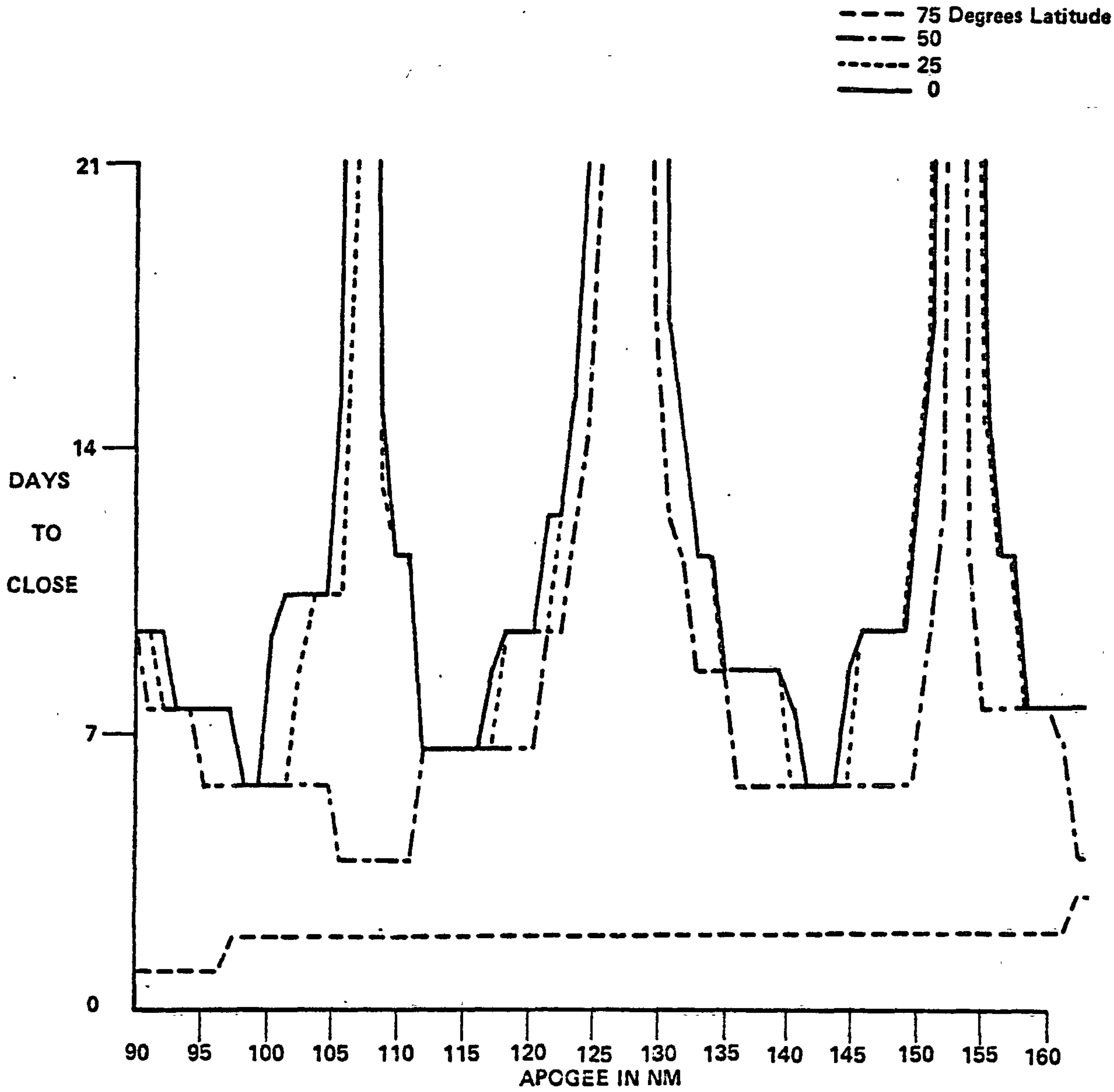


FIGURE 3-22 CLOSURE TIME VERSUS APOGEE

(i = 96.4°, PERIGEE = 90 NM)

HANDLE V(b)(1)YEMAN
TALENT-I(b)(3) 10 USC ⊥ 424
SYSTEMS ONLY

(b)(1)
(b)(3) 10 USC ⊥ 424

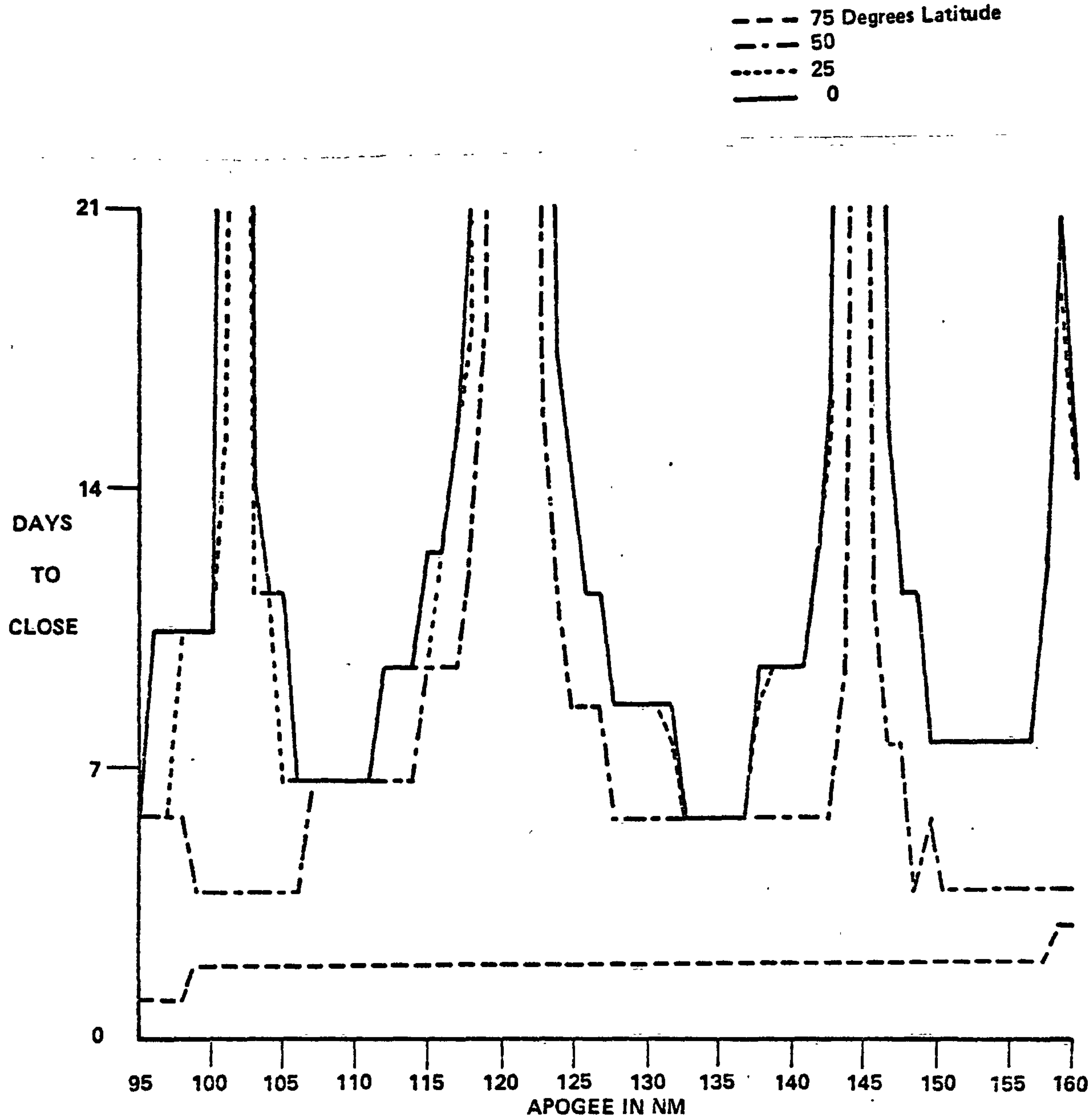


FIGURE 3-23 CLOSURE TIMES VERSUS APOGEE (i = 96.4°, Perigee = 95NM)

(b)(1)
(b)(3) 10 USC ⊥ 424

HANDLE VIA TALENT-KEYHOLE CONTROL SYSTEMS ONLY

(b)(1)
(b)(3) 10 USC ⊥ 424

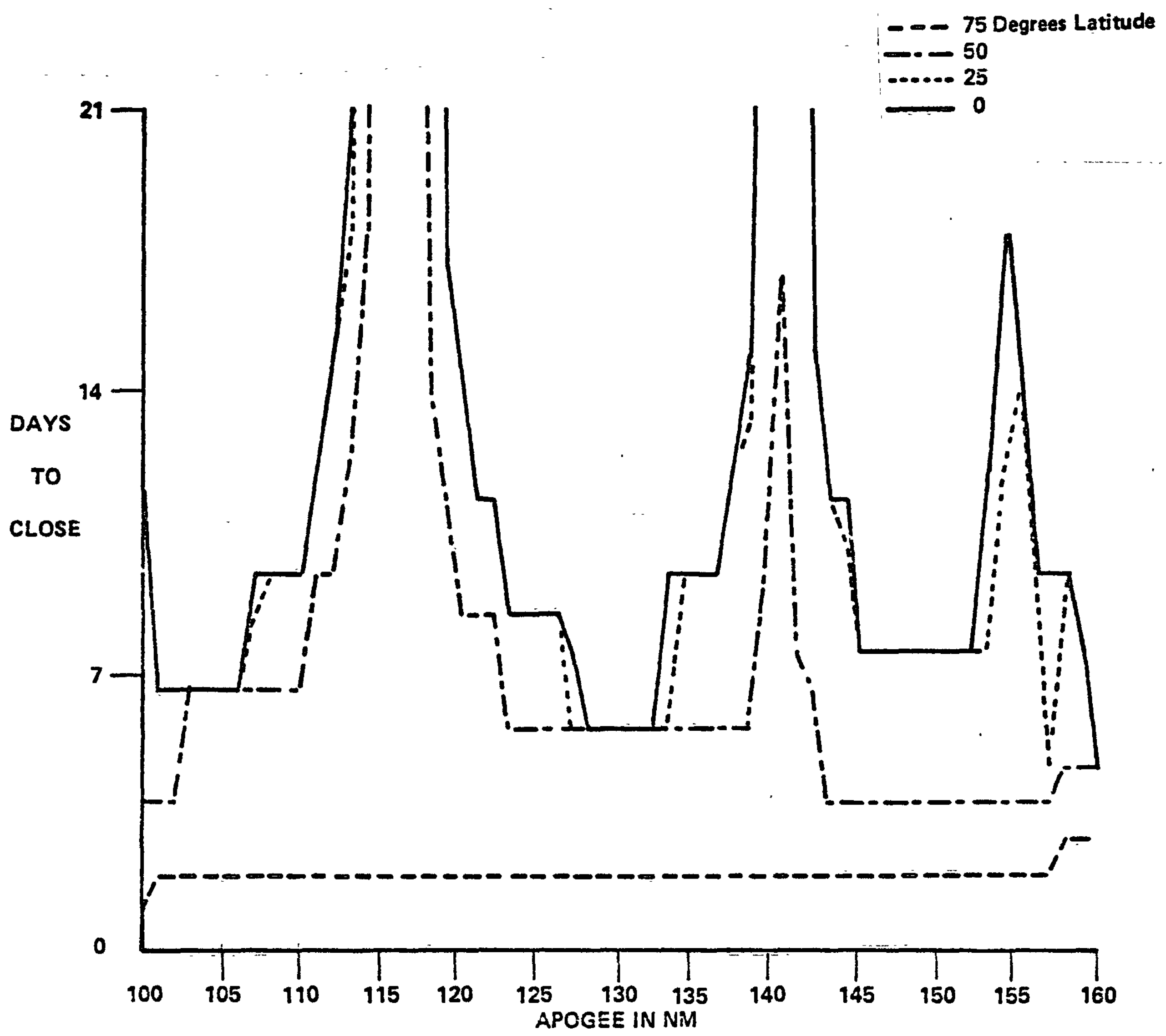


FIGURE 3-24 Closure Times Versus Apogee (i = 96.4°, Perigee = 100 NM)

HANDLE V(b)(1)BYEMAN
TALENT-K(b)(3) 10 USC ⊥ 424
SYSTEMS ONLY

ORBIT SELECTION SUMMARY

Based on the above considerations, the three orbits listed in Table 3-5 were selected as candidates for consideration in potential STS PCS operational concepts.

(1) Sun Synchronous Orbit

The sun-synchronous orbit with a 95 NM perigee and a 150 NM apogee was selected since it is the NRO Program A baseline, it accesses the entire search area, it has nearly the best illumination for imaging over the mission, and it has reasonable altitudes over the search area. This orbit may require STS thrust augmentation.

(2) 75-Degree Inclination Orbit

The 75-degree inclination orbit with a perigee of 95 NM and an apogee 120 NM was selected because it can probably be achieved with a non-thrust augmented STS and accesses most of the search area with good illumination and altitudes. The logic steps leading to the selection of this specific orbit are shown in Figure 3-25.

(3) 57-Degree Inclination Orbit

A 57-degree inclination orbit was also selected for analysis since this is the highest inclination that can be achieved from the ETR.

LAUNCH TIME FOR SELECTED ORBITS

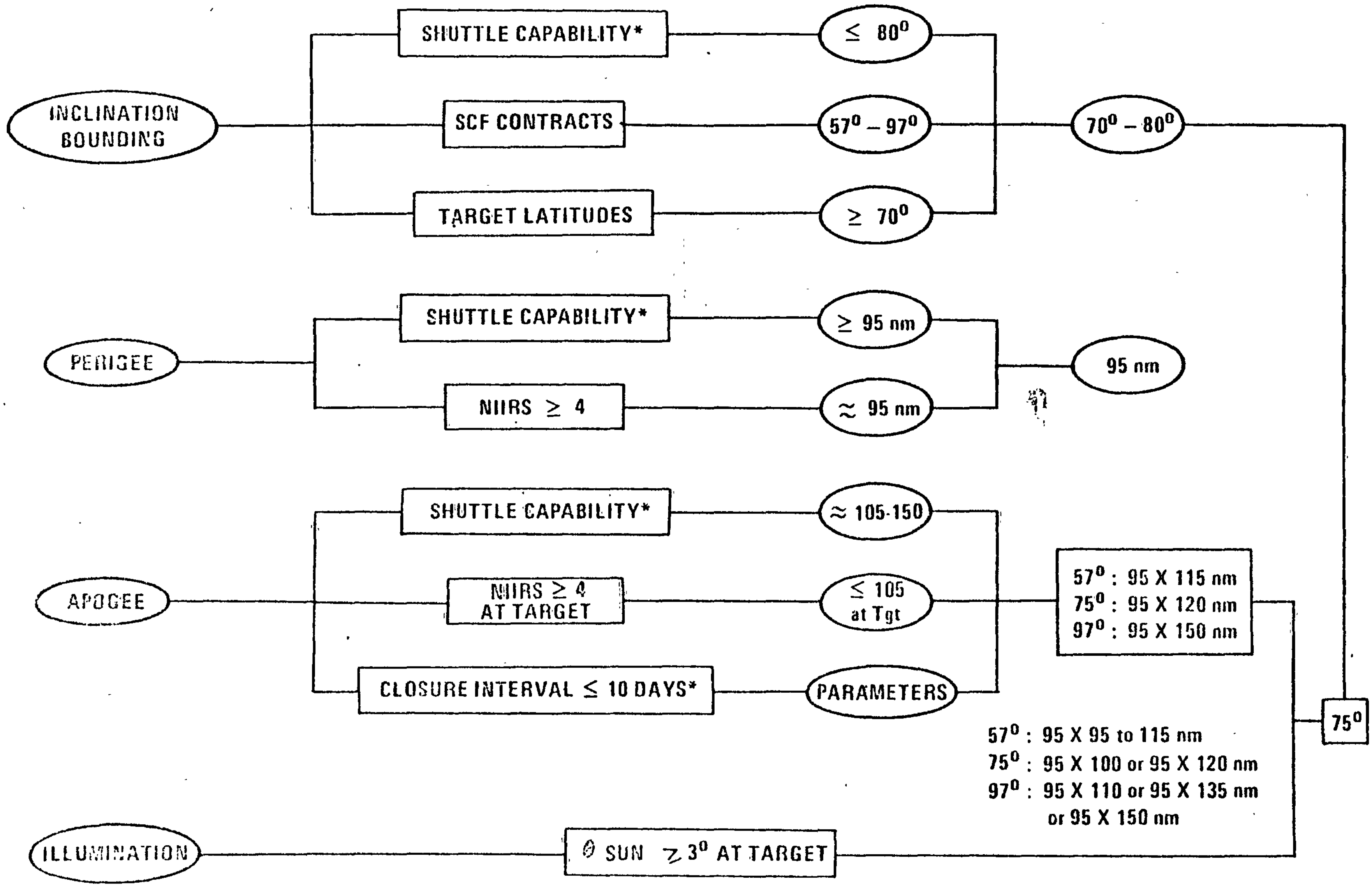
Launch time should be chosen so that the search areas are accessed at sun elevation angles above approximately 3 degrees for adequate illumination throughout the mission. At sun-synchronous inclinations, a noon mission provides the highest sun angles, but earlier missions provide additional daylight accesses on the ascending portion of the orbit from spring to fall. If illumination were the only consideration, early morning launches, 7:30 a.m. local time at the equinoxes and 10:20 a.m. local time at the summer solstice[4], would be best; however, the higher probability of haze over coastal regions during this period makes later launches somewhat more desirable. For these reasons, HEXAGON Mission 1215 was launched at 10:30 a.m. local time.

[4] A later summer launch is needed to provide accesses to 56 degrees south latitude.

TABLE 3-5 ORBIT SELECTION

INCLINATION (DEG)	PERIGEE (NM)	LATITUDE OF PERIGEE (° N. LAT.)	APOGEE (NM)	PERIOD (MINUTES)	GEODETIC PERIGEE X APOGEE (NM)	CLOSURE (DAYS) LATITUDE 0°	15°	30°	45°	60°	75°
57	95	52	115	88.13	92 x 117	11.1	11.1	10.2	9.3	-	-
75	95	40	120	88.32	92 x 123	5.6	5.7	5.7	4.7	4.7	0.1
96.4	95	60	150	88.72	93 x 149	7.6	7.6	7.6	7.6	3.8	2.0

(b)(1)
(b)(3) 10 USC ⊥ 424



* Affected by 21 Day Duration: Tentative

FIGURE 3-25 DETERMINATION OF KEY BASELINE ORBIT PARAMETERS

(b)(1)
(b)(3) 10 USC ⊥ 424

Tables 3-6 and 3-7 summarize the optimal launch times and resultant illumination profiles for 57-, 75-, and 96.4-degree inclination orbits. In the spring and summer, a slightly earlier sun-synchronous inclination launch can take advantage of ascending accesses; in fall and winter, sun angle constraints at the higher latitudes require a slightly later launch.

3.3 WEATHER ANALYSIS

Poor weather can severely degrade the collection performance of a short duration, limited access mission. Particularly affected are specials and the 2-month period target clusters which require cloud-free photography every mission. In addition, mission spacings of four months will place cells in the 4- and 6-month requirements in the demand every mission and satisfaction of portions of the requirements in these areas may also be precluded by cloud-cover that persists for the length of the mission.

An analysis of the impact of weather on collection performance was performed using historical weather data from the 3DNEPH file by simulating 1440 7-, 14-, and 21-day misssions, one each day from January 1, 1972 to December 10, 1975. The 868 12 x 18 NM WAG cells comprising the target cluster requirements were aggregated into 107 contiguous areas.

The number of days between successive accesses to the centroid of these areas was computed analytically as a function of latitude for a 75-degree inclination, 100 NM circular orbit with a ± 45-degree obliquity limit. The initial access to each area was assumed to occur at a random time within the first access period.

Figure 3-26a shows the fraction of accessed cloud-free area as a function of mission duration, averaged over all 1440 missions. For an average 7-day mission, the percentage of area accessed cloud-free ranges from 41 percent for the worst, i.e. poorest weather area, to 92 percent for the best. For an average 21-day mission, all areas are accessed at least 77 percent cloud-free.

Figure 3-26b shows the fraction of missions that return 80 percent or more of the area cloud-free as a function of mission duration. The area in the worst weather region is seen 80 percent cloud-free during only 14 percent of the

TABLE 3-6 -- OPTIMAL LAUNCH TIMES[1]

	INCLINATION		
DAY OF YEAR	SUN-SYNCHRONOUS	75°	57°
46	10:00 TO 11:30	16:45	-
80 (SPRING EQUINOX)	8:00 TO 11:00	15:45	-
168 (SUMMER SOLSTICE)	10:15	15:00[2]	-
290	10:30 TO 11:30	16:30	-
355 (WINTER SOLSTICE)	11:40	16:00	05:30[3]

[1] LOCAL TIME OF LAUNCH. SUN-SYNCHRONOUS AND 75° LAUNCHES ARE SOUTHERLY FROM THE WTR. 57° LAUNCHES ARE NORTHERLY FROM THE ETR. ALL TIMES ARE FOR 21-DAY MISSIONS UNLESS NOTED OTHERWISE.

[2] 14:00 FOR A 14-DAY MISSION

[3] 7-DAY MISSION

TABLE 3-7 Latitude Coverage for ≥3° Sun Elevation Angles

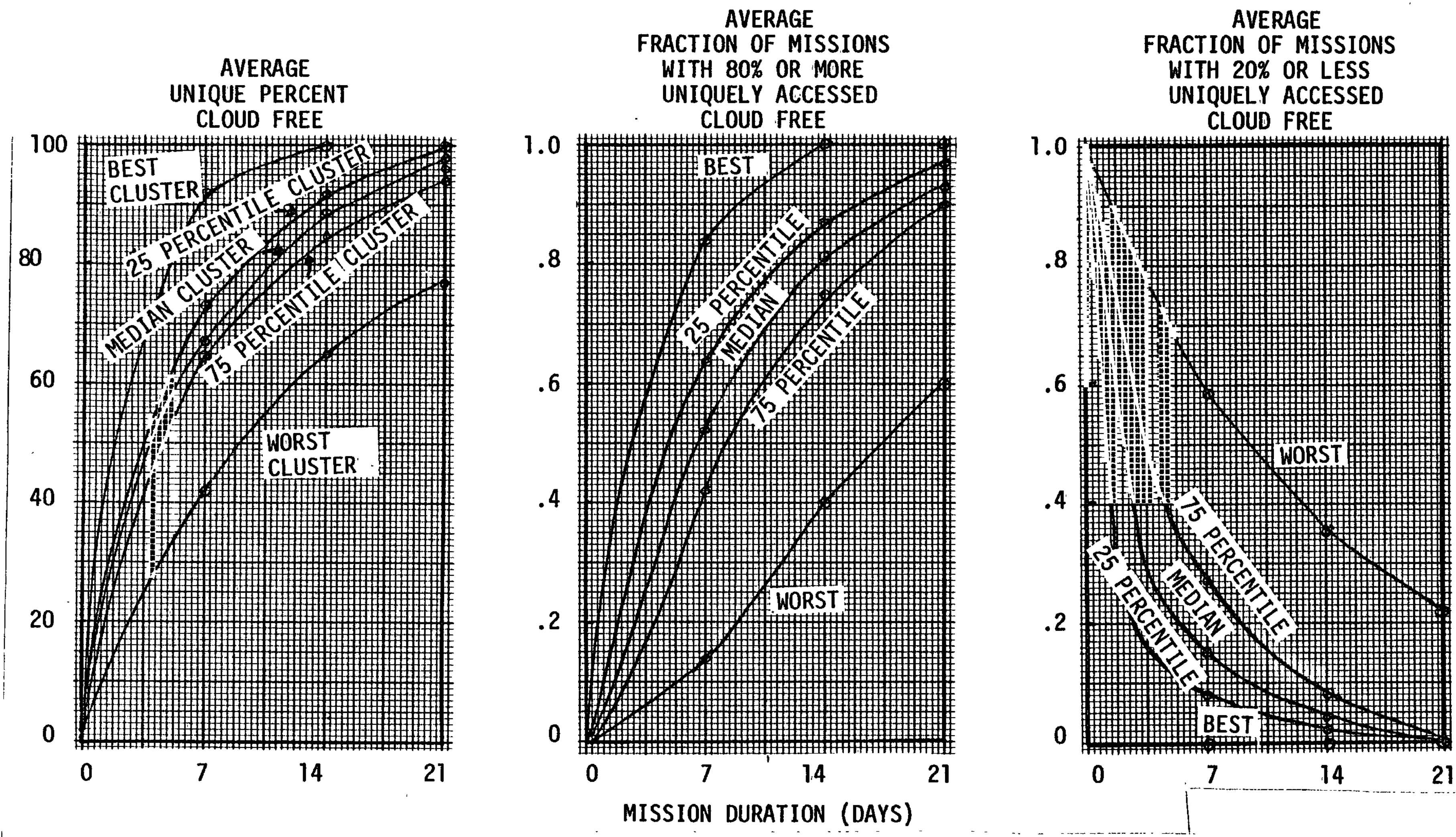
Day of Launch	96.4° Inclination[1] 10:40 Launch			75° Inclination[1] 15:20 Launch			57° Inclination[2] 05:30 Launch		
	SOM[4]	MM[4]	EOM[4]	SOM	MM	EOM	SOM	MM	EOM
46	79° D[3] to -83°	77° D to -83°	79° D to -83°	74° D to -73°	73°D to -74°	71°D to -75°	--	--	--
168	64°A to -57°	64°A to -57°	65°A to -52°	47°A to -40°	61°A to -54°	69°A to -63°	--	--	--
290	75°D to -83°	73°D to -83°	68°D to -83°	75° to -72°	72°D to -75°	63°D to -75°	--	--	--
355	--	--	--	--	--	--	-27°A to 46°D	26°A -15°D	57° -52°D

[1] 21 Day Mission

[2] 7 Day Mission

[3] A Suffix D Denotes Descending, A Ascending

[4] SOM = Start of Mission, MM = Mid-mission, EOM = End of Mission



(a) (b) (c)

BYE-10686-79
Page 53

FIGURE 3-26 Four-Year Weather Analysis of 107 2-Month Target Clusters

7-day missions and 60 percent of the 21-day missions. Half of the areas are seen 80 percent cloud-free on only 52 percent of the 7-day missions, but on 81 percent of the 14-day missions and 93 percent of the 21-day mission. Conversely, Figure 3-26c shows that all 21-day missions, but only 91 percent of 14-day missions, access three-fourths of the areas at least 20 percent cloud-free.

To summarize, a 7-day duration mission can satisfy the 80 percent status requirement for half of the target clusters only 52 percent of the time. Longer duration missions can result in a much higher status, 81 or 93 percent, for 14- or 21-day missions respectively. Individual special search requirements and specific requirements elsewhere are similarly affected.

Performance against relatively small requirements that must be satisfied during one mission improves substantially with mission duration.

3.4 COLLECTION TARGETING STRATEGY

The collection requirements and capabilities of the STS PCS are similar to the current HEXAGON; thus, the mission planning and collection strategies should be similar to those used operationally for HEXAGON. The present HAMPER planning software and 'TUNITY targeting software can and should be used to plan and target the STS PCS. Only relatively minor modifications would be required to support the studied STS PCS operating concepts.

Imaging operations are selected based on the value of the cells contained within the operation. Cell value is defined as the [redacted] This value function, similiar to that used for HEXAGON, includes required NIIRS in the probability computation and additional thresholds for altitude and slant range to bias the system towards the higher quality imagery requirements projected for 1985. The use of a slant range threshold prevents value from being assigned to cells accessed with a low probability of NIIRS requirement satisfaction. Since all of the orbits analyzed always accessed the required areas with reasonable slant ranges and altitudes, these thresholds were not used.

For the current study, targeting control parameters, e.g., cell weights, weather and age thresholds, were manually established for each of 67 requirements cell groups (RCG's) on a trial and error basis over a number of simulations. This approach results in performance data that are both slightly conservative, because the RCG control parameters are not optimized, and somewhat misleading, because under satisfaction of requirements in some regions is hidden by over satisfaction in other regions within an RCG. These effects are discussed more fully in Section 4.

4.0 SELECTED OPERATING CONCEPTS AND PERFORMANCE ANALYSIS RESULTS

This section identifies the operating concepts selected for detailed performance analysis via simulation, outlines the methodology and describes the software tools used to conduct the simulations, and summarizes the simulation results.

4.1 SELECTED OPERATING CONCEPTS

Three operating concepts were selected for detailed analysis via simulation. The NRO Program A baseline concept is to fly three missions per year in the HEXAGON orbit, 96.4 degrees inclination, 95 x 150 NM. The second concept is to fly three missions per year at a lower, 75-degree, inclination orbit; search areas above 75 degrees north latitude would be targeted by [redacted]. This lower inclination was selected as the baseline for this study because a preliminary analysis of the STS payload capacity indicated that a 21-day mission at a sun-synchronous inclination might require thrust augmentation. The third concept is a 7-day, 57-degree inclination winter mission from the Eastern Test Range. This mission would test the STS PCS concept and fill the projected 145-day gaps in search system coverage between HEXAGON missions prior to the termination of the HEXAGON program.

4.2 SIMULATION APPROACH

The simulations were conducted in two phases. In the first phase, a first-order model simulator (FOAM) was used to approximate the performance of the Program A baseline concept as a function of various targeting parameters. A set of targeting parameters that provided satisfactory collection performance for this concept was identified, and, in the second phase, the high fidelity operational HEXAGON simulator (HSIM) was used to obtain performance data for all of the selected operating concepts.

4.2.1 STUDY TOOL DESCRIPTION

The first-order analysis model (FOAM) simulator was developed to permit rapid-turnaround parametric studies of system performance. The FOAM simulator uses precise access data, the cell value function described in Section 3.4, and a photographic opportunity region or decision element (DE) that extends 40 seconds in-track and ± 45 degrees in obliquity. The value of each DE is computed as the sum of the photographic value of the individual cells within the DE and compared with a threshold value. The entire area contained within the DE is photographed if its value exceeds the threshold. Film use is controlled by automatically adjusting the DE value threshold to expend the total film load during the mission.

The cumulative probability of success is updated for each cell, after each photographic attempt, based on assessed weather (using the 1972 to 1975 3DNEPH historical weather file) and the probability of achieving the required NIIRS value. The Program A slant range NIIRS model is used to predict the probability of NIIRS quality satisfaction for each cell. Control parameters are manually assigned at the RCG level, i.e. value function parameters are assigned separately to each of the 67 area requirements.

The NIIRS model, with a random number generator and verified weather, are used to compute a posteriori cell photographic accomplishment. FOAM provides detailed measures of mission accomplishment at the RCG level as well as aggregate measures by country code and collection period.

The two basic limitations of the FOAM program are the requirement for manual selection of control parameters and the 40-second DE selection logic. Control parameter optimization in a STS PCS operational environment is envisioned as a HAMPER-like function. For the current study, however, the modest computational requirements of FOAM, 20 minutes of CPU time and 700K bytes of core per mission, permitted iterative manual parameter selection.

After the RCG control parameters were established using FOAM, the high-fidelity HEXAGON simulator (HSIM) was used to estimate system performance more accurately. A constant set of control parameters were used for all orbital inclinations and mission durations. Both HSIM and FOAM use the same weather data, access data, and value function; however, HSIM uses the operational HEXAGON dynamic programming algorithm to select operations on a per rev basis. A value per film use marginal efficiency threshold is adjusted to satisfy the film budget.

An HSIM output post-processor was designed to provide detailed measures of accomplishment on a mission and mission series level. These measures include half-, once-, and twice-due COMIREX status versus time by RCG, geographic region and collection period.

4.2.2 SIMULATION CASES AND CONDITIONS

The simulations performed in support of the STS PCS study consisted of the following 10 cases[5]:

(1) F 97-21C - A 2-year, 6-mission simulation of the Program A baseline concept performance using the 1972 and 1973 3DNEPH historical weather data. This case was simulated for current requirements and used the FOAM simulator to establish a nominal set of targeting parameters. The initial status, i.e. the date-last-seen for currently required cells, was taken from the HEXAGON 1214 end-of-mission status. The cells composing the projected new requirements were initialized with zero status. All missions used 160K feet of stereo film, 50 percent more than the assumed PCS load for standing search[6], to compensate for the elementary FOAM selection logic.

(2) F 97-14C - The conditions for this case and F 97-21C are the same except for the mission duration which was reduced from 21 to 14 days to provide a quantitative estimate of the effect of mission duration on system performance.

(3) F 97-21A - A series of 21-day missions directed against the projected 1985 search requirements. This case was run to establish a nominal set of targeting parameters for the new requirements.

(4) F 97-14A - A series of 14-day missions directed against the projected 1985 search requirements.

---

[5] The case name consists of a prefix letter (F for FOAM, H for HSIM), the inclination in degrees, the mission duration in days, and a suffix letter (C for current requirements, A for all projected requirements, ANC for all requirements except target clusters).

[6] The assumed PCS film load for standing search is .75 x 142K or 106.5K feet of film for each camera (see Section 3). The remainder, 35.5K feet, is budgeted for specials.

(5) F 97-14 ANC - A series of 14-day missions directed against the projected 1985 requirements with the 2-month collection period target cluster areas excluded. This case was studied because the desired age distribution of 2-month requirements cannot be maintained during the 3- to 4-month gap between missions and an alternative system, e.g. [redacted], could be tasked against the target cluster search requirements. System resources normally expended against the target custers could be redirected against the remaining requirements to improve overall system performance.

(6) H 97-21A - A 2-year, 6-mission simulation of the Program A baseline concept performance using the 1973 and 1974 3DNEPH historical weather data. This case was simulated for the projected 1985 requirements and was run using the HEXAGON simulator (HSIM). Initial cell status data for this case were obtained from the cell status data at the end of the third FOAM mission of case F 97-21A; thus, the last three missions of case F 97-21A and the first three mission of case H 97-21A may be compared directly since they correspond to the same initial conditions and weather. This comparison provides a cross-check of the validity of the two simulators. All missions used 106.5K feet of stereo film, 75 percent of the assumed PCS load.

(7) H 97-14A - A series of 14-day missions directed against the projected 1985 search requirements.

(8) H 75-21A - A 2-year, 6-mission simulation of the current study baseline concept performance - three 21-day missions per year in a 75-degree inclination, 95 x 120 NM orbit directed against the projected 1985 search requirements.

(9) H 75-14A - A series of 14-day missions in the 75-degree inclination orbit.

(10) H 57-07C - A 7-day, winter solstice mission in a 57-degree inclination orbit directed against current requirements. The mission was run against 1972, 1973, and 1974 3DNEPH historical weather data and used 35K feet of film, equivalent to a HEXAGON bucket. This case was simulated to provide performance data for an STS PCS mission flown during the winter gap between planned HEXAGON missions.

TOP SECRET HEXAGON [redacted] 20053
(b)(1)
(b)(3) 10 USC 424

Approved for Release: 2017/02/08 C05094782

Table 4-1 summarizes the simulated cases. Detailed simulation data for cases H 97-21A, H 97-14A, H 75-21A, and H 75-14A are contained in Appendix A.

4.3 SIMULATION RESULTS

FOAM RESULTS

STS PCS performance against current and projected 1985 search requirements for three 21-day, 96.4-degree inclination missions per year is shown in Table 4-2. When the system is tasked against current requirements, a comparison of the average once-due COMIREX end-of-mission (EOM) status with the 80 percent status requirement shows that, except in the target cluster areas, performance substantially exceeds the requirements. Satisfaction of the 2-month requirements is severely limited by the system's difficulty in obtaining NIIRS 5 imagery. This may be deduced from the average 92 percent XN status for the clusters. Although the EOM statuses generally meet the requirements, the half-due and once-due statuses fall below the required values between missions, particularly for the 2- and 4-month collection period groups. Age distributions are discussed more fully in the next section. When the system is tasked against the projected 1985 requirements, EOM system performance is at or near the required levels except for the 2-month requirements. It is noted, however, that the aggregate area groupings used for data display have the effect of hiding shortfalls in specific areas.

The performance of three 14-day missions per year at 96.4 degrees inclination is shown in Table 4-3 for three possible taskings, against current requirements, against 1985 requirements, and against 1985 requirements with the cluster areas tasked to another system. When tasked against either current or projected requirements, the 14-day mission series provides significantly poorer performance than the 21-day mission series in the 2- and 4-month areas, although the overall performance is only slightly poorer. The average XN or CX EOM status is reduced by 3 percent for the shorter mission tasked against current requirements, with virtually all of the loss in the

Table 4-1 Simulation Case Summary

Mission Series Designation	Inclination (Degrees)	Perigee X Apogee (NM)	Missions per year	Days per Mission	Day(s) of Launch	Time of Launch (local)	Comments
F 97-21C	96.4	95 x 150	3	21	46 168 290	10:40	Target against current requirements. Avoid Winter solstice.
F 97-14C	96.4	95 x 150	3	14	46 168 290	10:40	Use FOAM.
F 97-21A and H 97-21A	96.4	95 x 150	3	21	46 168 290	10:40	Target against 1985 requirements. Avoid Winter solstice.
F 97-14A and H 97-14A	96.4	95 x 150	3	14	46 168 290	10:40	Use FOAM and HSIM.
F 97-14 ANC	96.4	95 x 150	3	14	46 168 290	10:40	Target against 1985 requirements except for 2-mo. clusters. Avoid Winter solstice.
H 75-21A	75	95 x 120	3	21	46 168 290	15:25	Target against 1985 requirements. Avoid Winter solstice.
H 75-14A	75	95 x 120	3	14	46 168 290	15:25	
H 57-07C	57	95 x 115	1	7	355	05:30	HEXAGON gap filler from ETR. Winter solstice missions in 1981, 1982, and 1983 against current requirements.

TABLE 4- 2-- FOAM SIMULATION RESULTS. THREE 21-DAY, 96.4° INCLINATION MISSIONS PER YEAR AGAINST CURRENT AND 1985 REQUIREMENTS

MISSION	Cloud-Free (XN) EOM Status 1	2	3	4	5	6	AVG	COMIREX (CX) EOM Status 1	2	3	4	5	6	AVG
CURRENT REQUIREMENTS (F97-21C)														
All Current	93	93	96	96	93	97	95	90	90	94	94	90	94	92
Current 2 Mo	96	90	96	96	82	93	92	59	52	62	64	48	57	57
4 Mo	88	84	92	91	80	93	88	87	83	91	91	79	93	87
6 Mo	89	95	95	97	96	96	95	88	95	95	96	96	96	94
9 Mo	95	96	99	99	99	99	98	95	96	99	99	99	99	98
12 Mo	96	98	98	98	98	98	98	96	97	98	98	98	98	98
18 Mo	96	97	98	98	99	99	98	96	96	98	98	99	99	98
24 Mo	92	97	98	98	98	98	97	92	97	98	98	98	98	97
1985 REQUIREMENTS (F97-21A)														
All Current & New	57	69	77	81	80	82	82**	54	64	73	76	76	78	78**
All Current	85	82	85	90	85	89	86	82	78	82	87	81	85	83
All New	37	59	71	74	77	78	78**	34	55	67	69	73	73	73**
Current 2 Mo	94	89	95	95	81	93	91	60	51	56	63	38	52	53
4 Mo	79	69	79	82	66	83	76	77	68	79	82	65	82	76
6 Mo	78	84	80	92	89	85	85	77	84	80	92	88	84	84
9 Mo	88	86	92	95	94	95	92	87	86	92	95	94	95	92
12 Mo	88	87	87	92	90	90	89	88	87	86	92	89	90	89
18 Mo	87	81	82	89	90	89	86	87	81	81	88	90	88	86
24 Mo	80	86	87	90	87	89	87	80	86	86	90	87	89	86
New 9 Mo	49	68	78	80	81	79	80*	45	65	77	76	79	75	77*
18 Mo	23	46	62	65	71	75	75**	20	41	56	59	66	71	71**
24 Mo	18	52	63	71	78	81	81**	13	41	50	57	63	69	69**

* Average over last 4 missions
** Status at the end of mission 6

Since new requirements were initialized with no status

TABLE 4-3 FOAM SIMULATIONS RESULTS:

AVERAGE END-OF-MISSION COMIREX STATUS

MISSION SERIES DESIGNATION	ALL REQ'TS	ALL CURRENT REQ'TS	ALL NEW REQ'TS	CURRENT 2 MO	CURRENT 4 MO	CURRENT 6 MO	CURRENT 9 MO	CURRENT 12 MO	CURRENT 18 MO	CURRENT 24 MO	NEW 9 MO	NEW 18 MO	NEW 24 MO
97-21C	-	92	-	57	87	94	98	98	98	97	-	-	-
97-14C	-	89	-	40	80	91	96	97	98	97	-	-	-
97-21A	78	83	73	53	76	84	92	89	86	86	77***	71**	69**
97-14A	86	82	87	39	72	83	91	90	90	90	88***	84**	80**
97-14ANC	88	81	90	30*	70	82	90	92	92	93	92***	88**	86**

* BONUS, LAST CASE HAD NO REQUIREMENTS AGAINST CLUSTERS

** EOM SIX STATUS SINCE NEW REQUIREMENTS WERE INITIALIZED WITH NO STATUS

*** AVERAGE OVER LAST FOUR MISSIONS SINCE NEW REQUIREMENTS WERE INITIALIZED WITH NO STATUS

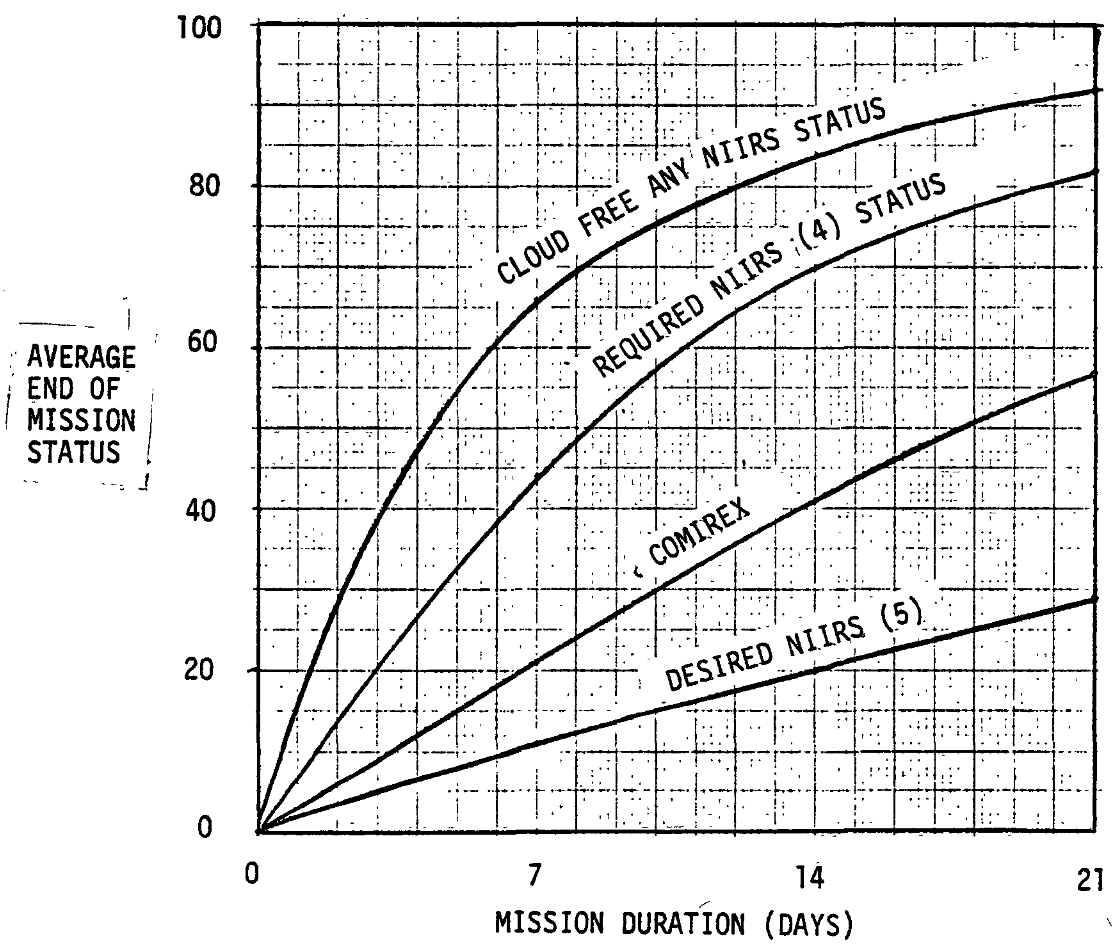
2- and 4-month collection period areas. The 17 percent reduction in the 2-month CX status is a direct result of the reduced number of opportunities to obtain NIIRS 5 photography as shown in Figure 4-1. Since both the 14- and 21-day missions use the same film load and have at least one access to every cell, gross coverage is the same in both cases but reducing the mission duration costs 15,000 SNM of NIIRS 5 imagery in the 2-month areas, 75,000 SNM of NIIRS 4 imagery in the 4-month areas, and 200,000 SNM of cloud-free imagery elsewhere. Against the 1985 requirements, the shorter mission achieves paradoxically better overall performance. This is because the change in tasking results in more film being spent taking areas with modest quality requirements and generally good weather, and less film being spent taking generally redundant, inadequate quality imagery in the 2-month areas. The average percent cloud-freeness is generally lowest for the 2- and 4-month areas and highest in the new requirement areas, as shown in Table 4-4. Stating the performance of short duration missions in terms of the aggregate status is somewhat misleading, however, because persistent cloud cover will cause very poor performance in specific areas as described in Section 3.3.

The tradeoff between film use and mission duration is shown in Figure 4-2 for the 4-month CPG's. In the figure, the solid and dashed lines denote the increase in CX status with mission duration and film load, respectively. Whereas an increase in the mission duration from 7 to 21 days substantially increases the average EOM status for a given film expenditure, a substantial increase in the film budget for 7- or 14-day missions improves the EOM status by only a small amount.

HSIM RESULTS

The results of the 96.4-degree inclination operating concept simulations were used to verify the assumed relationship between film use and the method of operation selection. The comparison between the EOM statuses in Table 4-5 shows that for the same initial conditions and same weather year, the HSIM simulator, using the HEXAGON operational selection algorithm, provides uniformly better performance (except in the 2-month requirements) and uses a third less film than the FOAM simulator described in Section 4.2.1. The agreement between the HSIM and FOAM results in Table 4-5 for the EOM status provides a cross-check of the validity of the two computer programs.

 (b)(1)
(b)(3) 10 USC 424



BYE-10686-79
Page 65

FIGURE 4-1 Average 2-Month Requirements Performance Versus Mission Duration

 (b)(1)
(b)(3) 10 USC 424

(b)(1)
(b)(3) 10 USC ⊥ 424

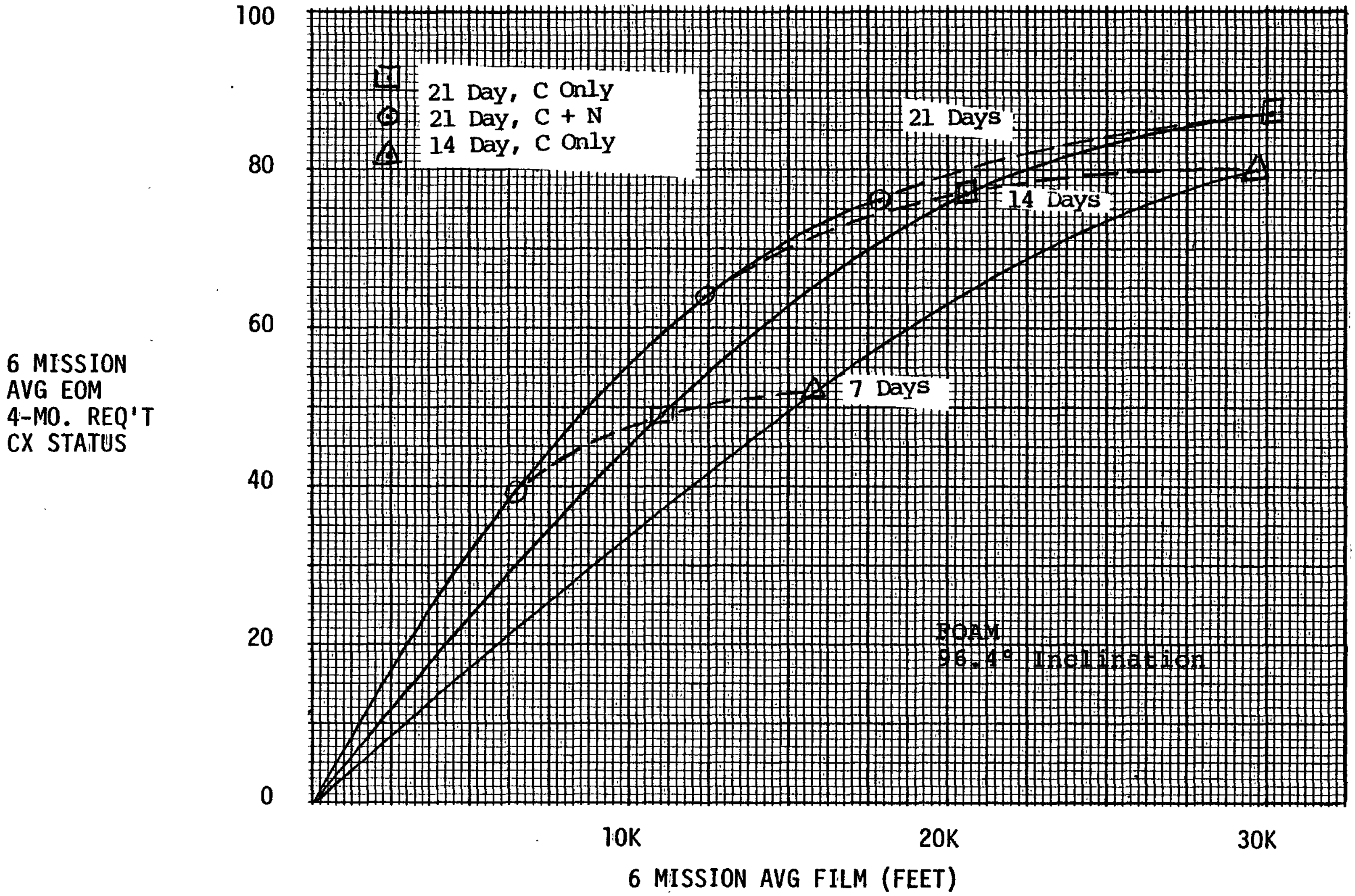
TABLE 4-4 AVERAGE PERCENT CLOUD FREENESS OF GROSS COVERAGE

MISSION SERIES DESIGNATION	ALL REQ'TS	ALL CURRENT REQ'TS	ALL NEW REQ'TS	CURRENT 2 MO	CURRENT 4 MO	CURRENT 6 MO	CURRENT 9 MO	CURRENT 12 MO	CURRENT 18 MO	CURRENT 24 MO	NEW 9 MO	NEW 12 MO	NEW 18 MO
97-21C	-	57	-	49	50	52	54	59	64	68	-	-	-
97-14C	-	56	-	48	49	51	52	57	61	60	-	-	-
[illegible]-21A	65	58	74	49	51	53	55	60	69	77	78	73	62
97-14A	65	58	74	52	52	53	55	60	68	76	78	72	61
97-14ANC	68	64	70	55	54	57	61	66	71	72	75	66	58

BYE-10686-79
Page 66

HANDLE VIA BYEMAN TALENT-KEYHOLE CONTROL SYSTEMS ONLY

(b)(1)
(b)(3) 10 USC ⊥ 424



BYE-10686-79
Page 67

FIGURE 4-2 Average 4-Month Requirements Performance Versus Mission Duration and Film Load

TABLE 4- 5 COMARISON OF FOAM AND HSIM EOM ONCE-DUE STATUS FOR 96.4°, 21 DAY MISSIONS. FOAM MISSIONS 4, 5 AND 6 COVER THE SAME PERIOD AS HSIM MISSIONS 1, 2 AND 3, RESPECTIVELY.

1985 REQUIREMENTS	XN EOM STATUS						CX EOM STATUS					
	FOAM			HSIM			FOAM			HSIM		
MISSION	4	5	6	1	2	3	4	5	6	1	2	3
ALL	81	80	82	82	84	86	76	76	78	81	83	85
CURRENT	90	85	89	91	90	93	87	81	85	90	88	92
NEW	74	77	78	77	81	82	69	73	73	76	80	81
2 CURRENT	95	81	93	96	90	96	63	38	52	44	40	48
4 CURRENT	82	66	83	83	80	91	82	65	82	82	79	90
6 CURRENT	92	89	85	91	88	91	92	88	84	91	88	91
9 CURRENT	95	94	95	94	94	96	95	94	95	94	94	95
12 CURRENT	92	90	90	92	93	93	92	89	90	92	92	93
18 CURRENT	89	90	89	95	96	95	88	90	88	94	96	95
24 CURRENT	90	87	89	95	93	94	90	87	89	95	92	93
9 NEW	80	81	79	77	79	80	76	79	75	77	79	80
18 NEW	65	71	75	77	85	88	59	66	71	76	85	87
24 NEW	71	78	81	75	84	88	57	63	69	73	82	86

A necessary condition for satisfactory reconnaissance system performance is that all areas of interest be accessible. The data in Table 4-6 show that all geographic regions are accessed similarly throughout the year by the 75- and 96.4-degree inclination orbits. It is noted that, as expected, the summer missions have the same number or more accesses to all areas except South America than the spring or fall missions. The lower inclination mission provides more accesses, on the average, to the USSR. This is because the additional system time spent by the 75-degree inclination mission between 50 and 75 degrees north latitude provides more accesses than are lost because of less daylight and the complete lack of coverage above 75 degrees north latitude.

Table 4-7 presents gross and unique coverage data by geographic region for case H75-21A. Each mission returns, on the average, 25.9 MSNM of cloud-free photography, 76 percent of the global search requirements. On a per region basis, gross coverage is comparable to the area of all current requirements. Over half of the current requirements and a third of the new requirements are returned at the required NIIRS value each mission.

The performance of 21- and 14-day duration, 75- and 96.4 degree inclination missions are presented in Table 4-8. Overall average performance, except in the cluster areas, is satisfactory in all cases; the shorter mission provides significantly lower <u>average</u> status only in the 2- and 4-month collection period areas. The dependence of performance on orbital inclination is negligibly small.

Half-, once-, and twice-due XN status and CX A/R results versus time for the 75-degree, 21-day missions are shown in Figures 4-3 to 4-8. Recall that the half-, once-, and twice-due required statuses are 50, 80, and 96 percent. The cloud-free any NIIRS status in all areas approximates the COMIREX requirements throughout the 2-year period. The characteristics of the 4-month mission spacing may be clearly seen for the half-due status in Figure 4-5. Target cluster age distributions, shown in Figure 4-4 , fall considerably below the requirement that CX A/R be one. Either more frequent missions with better quality imagery or tasking by [redacted] is needed to achieve satisfaction in these areas. The 4-month and longer CPG's age distributions are satisfactory except for the half-due status in the 4- and 6-month areas. Some tasking to [redacted] would also satisfy requirements in these areas and off-load the STS PCS so that slight shortfalls in other areas, i.e. the new 9-month requirements, could be eliminated.

TABLE 4-6

MEAN DAYTIME ACCESSES PER CELL

(21-DAY MISSIONS)

	75°			97°		
RCG	FEB	JUNE	OCT	FEB	JUNE	OCT
UR- 2	5.97	7.74	5.91	5.60	5.83	5.60
UR- 4	5.92	7.71	5.84	5.47	5.75	5.46
UR- 6	6.31	8.91	6.13	5.72	6.84	5.62
UR- 9	6.63	9.54	6.41	5.91	6.78	5.84
UR-12	6.83	10.0	6.62	6.06	7.29	6.00
UR-18	9.20	18.2	8.44	7.96	12.8	7.18
UR-24	12.2	25.8	9.44	9.17	21.6	8.03
CH-2	4.09	4.12	4.09	4.10	4.10	4.10
CH-4	4.06	4.13	4.06	4.04	4.04	4.04
MG-4	5.16	5.42	5.16	4.53	4.53	4.53
EE-4	5.59	6.67	5.59	5.00	5.00	5.00
KN-2	4.37	4.37	4.37	4.11	4.11	4.11
KN-4	4.41	4.41	4.41	3.67	3.67	3.67
SE-4	2.80	2.80	2.80	3.30	3.30	3.30
CU-4	3.31	3.31	3.31	2.98	2.98	2.98
ME-2	3.80	3.80	3.80	3.80	3.80	3.80
ME-4	3.71	3.76	3.71	3.67	3.67	3.67
NS-24	3.53	3.53	3.53	3.55	3.55	3.55
SS-18	5.83	3.77	5.83	5.63	5.63	5.63

(b)(1)
(b)(3) 10 USC ⊥ 424

TABLE 4-7 AVERAGE CLOUD-FREE COVERAGE PER MISSION BY REGION (MSNM): (b)(1) (b)(3) 10 USC ⊥ 424
H 75-21A (202 SNM PER CELL)

	AREA	GROSS AREA/XN	/RN	/DN	UNIQUE AREA/XN	/RN	/DN
USSR	6.86	7.54	7.17	4.04	3.75	3.68	2.68
CHINA	2.82	3.02	2.91	1.77	1.67	1.65	1.24
MONGOLIA	0.46	0.33	0.32	0.19	0.20	0.20	0.15
E. EUROPE	0.41	0.75	0.73	0.44	0.33	0.32	0.26
KOREA	0.06	0.10	0.09	0.09	0.03	0.03	0.03
S.E.ASIA	0.24	0.16	0.15	0.09	0.11	0.11	0.08
CUBA	0.06	0.04	0.04	0.03	0.03	0.03	0.02
MIDDLE EAST	0.25	0.52	0.50	0.30	0.22	0.22	0.18
ALL CURRENT	11.16	12.46	11.91	6.95	6.34	6.24	4.64
W. EUROPE	1.16	0.33	0.32	0.20	0.26	0.25	0.16
AFRICA	8.66	6.74	6.55	3.96	3.53	3.49	2.66
NEAR EAST	1.61	1.54	1.50	0.94	0.79	0.78	0.62
FAR EAST	1.92	1.25	1.21	0.77	0.81	0.80	0.58
[redacted]	0.21	0.12	0.12	0.07	0.09	0.08	0.06
SOUTH PACIFIC	1.05	0.24	0.23	0.14	0.20	0.19	0.11
[redacted]	2.30	0.58	0.56	0.30	0.47	0.46	0.27
CENTRAL AMERICA	0.79	0.46	0.45	0.28	0.31	0.31	0.22
SOUTH AMERICA	5.27	2.15	2.08	1.12	1.39	1.36	0.90
ALL NEW	22.97	13.41	13.02	7.78	7.85	7.72	5.58
ALL REQ'TS	34.13	25.87	24.93	14.73	14.19	13.96	10.22
ALL REQ'TS PER YEAR	34.52						

HANDLE VIA BYEMAN (b)(1) (b)(3) 10 USC ⊥ 424
KEYHOLE CONTROL SYSTEMS ONLY

TABLE 4-8 HSIM SIMULATION RESULTS:
AVERAGE END-OF-MISSION COMIREX STATUS

MISSION SERIES DESIGNATION		ALL REQ'TS	ALL CURRENT REQ'TS	ALL NEW REQ'TS	CURRENT 2 MO	CURRENT 4 MO	CURRENT 6 MO	CURRENT 9 MO	CURRENT 12 MO	CURRENT 18 MO	CURRENT 24 MO	NEW 9 MO	NEW 18 MO	NEW 24 MO
H 97-21A	3/year	84	91	80	43	84	92	96	94	96	94	79	82	83
H 97-14A	3/year	84	88	81	32	77	90	96	94	96	95	79	86	88
H 75-21A	3/year	84	90	80	44	83	91	96	94	94	91	80	81	82
H 75-14A	3/year	84	88	81	31	78	91	96	94	95	92	80	85	86
H 75-21A	4/year													
H 97-07A	6/year*	70	74	68	14	58	71	85	85	84	90	71	62	76

* 35.5 K stereo/mission

BYE-10686-79
Page 72

HANDLE VIA BYEMAN TALENT-
KEYHOLE CONTROL SYSTEMS ONLY

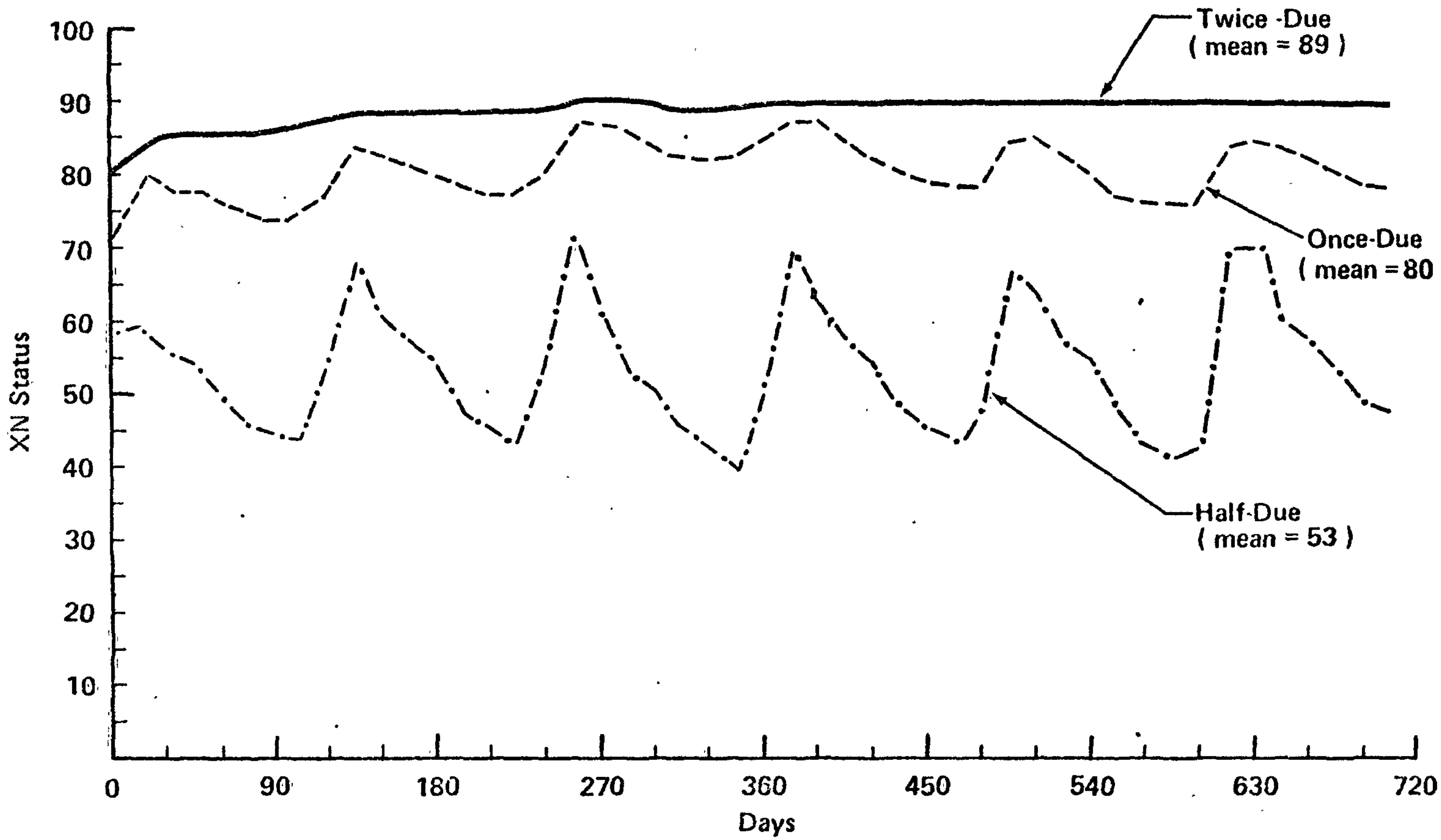


FIGURE 4-3 -- AGE DISTRIBUTIONS (i = 75 DEGREES, THREE 21-DAY MISSIONS PER YEAR, ALL REQUIREMENTS)

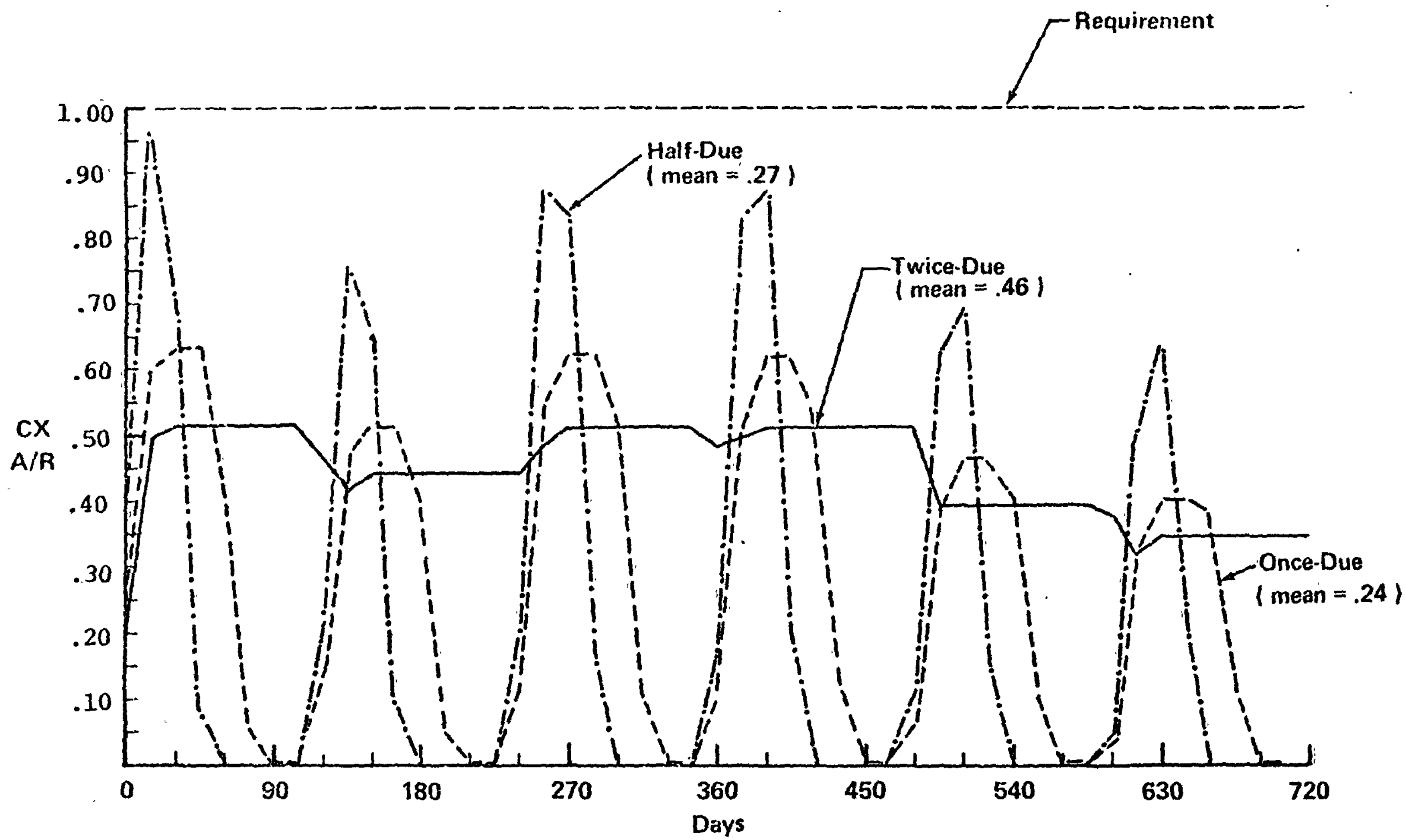


FIGURE 4-4 -- AGE DISTRIBUTIONS (i = 75 DEGREES, THREE 21-DAY MISSIONS PER YEAR, 2-MONTH PERIOD COLLECTION GROUPS)

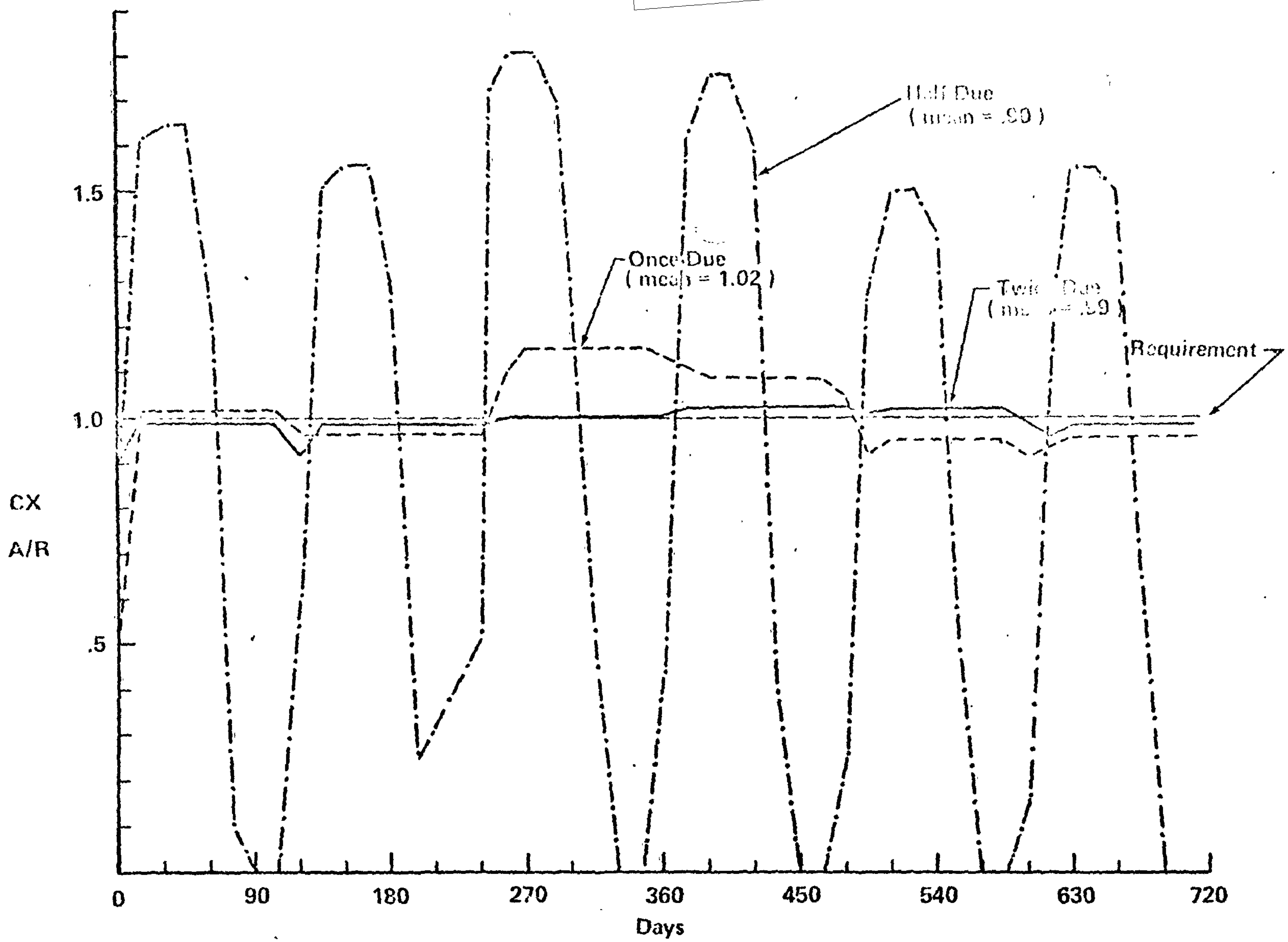


FIGURE 4-5 -- AGE DISTRIBUTIONS (i = 75 DEGREES, THREE 21-DAY MISSIONS PER YEAR, 4-MONTH PERIOD COLLECTION GROUPS)

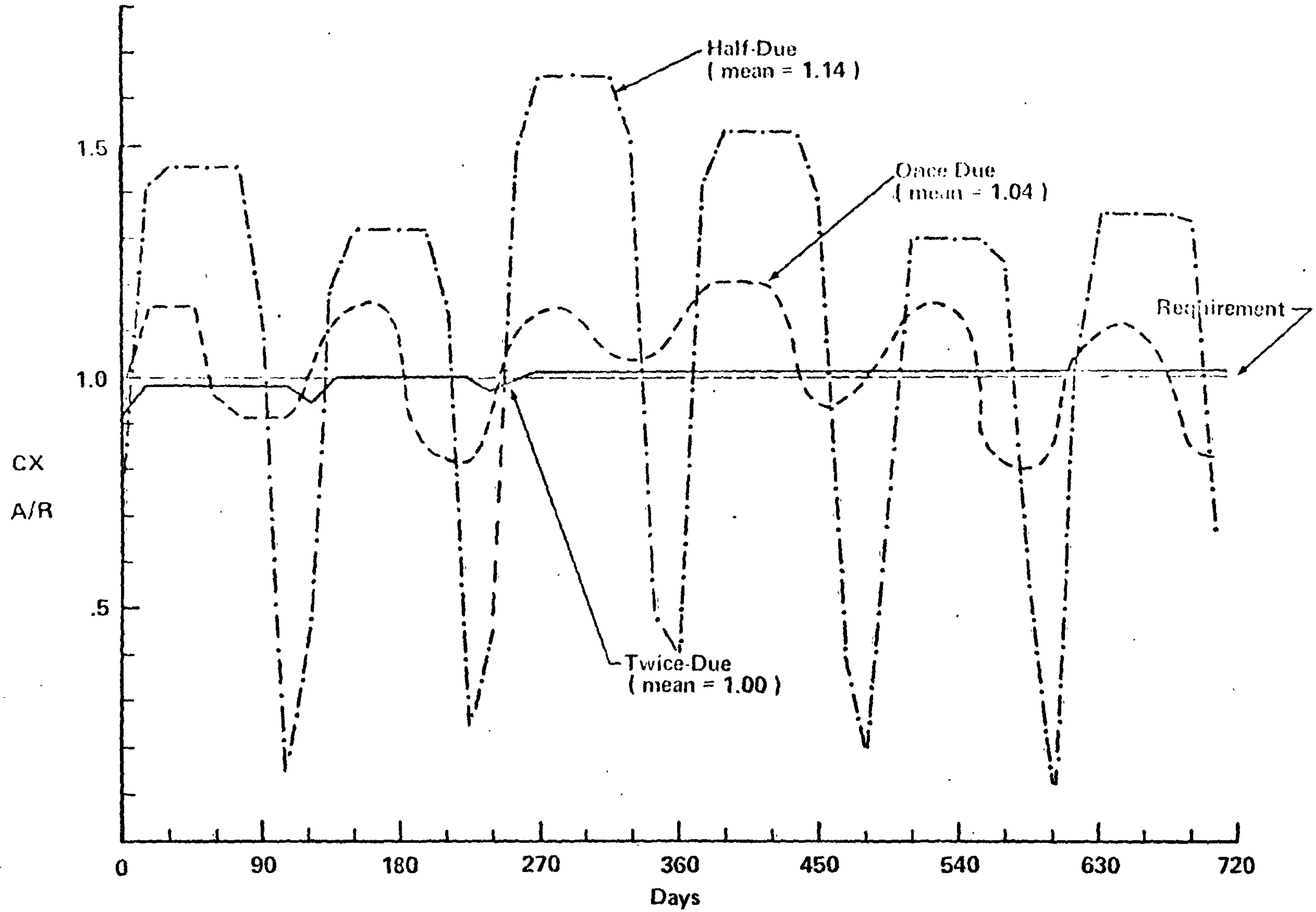


FIGURE 4- 6 -- AGE DISTRIBUTIONS (i = 75 DEGREES, THREE 21-DAY MISSIONS PER YEAR, 6-MONTH PERIOD COLLECTION GROUPS)

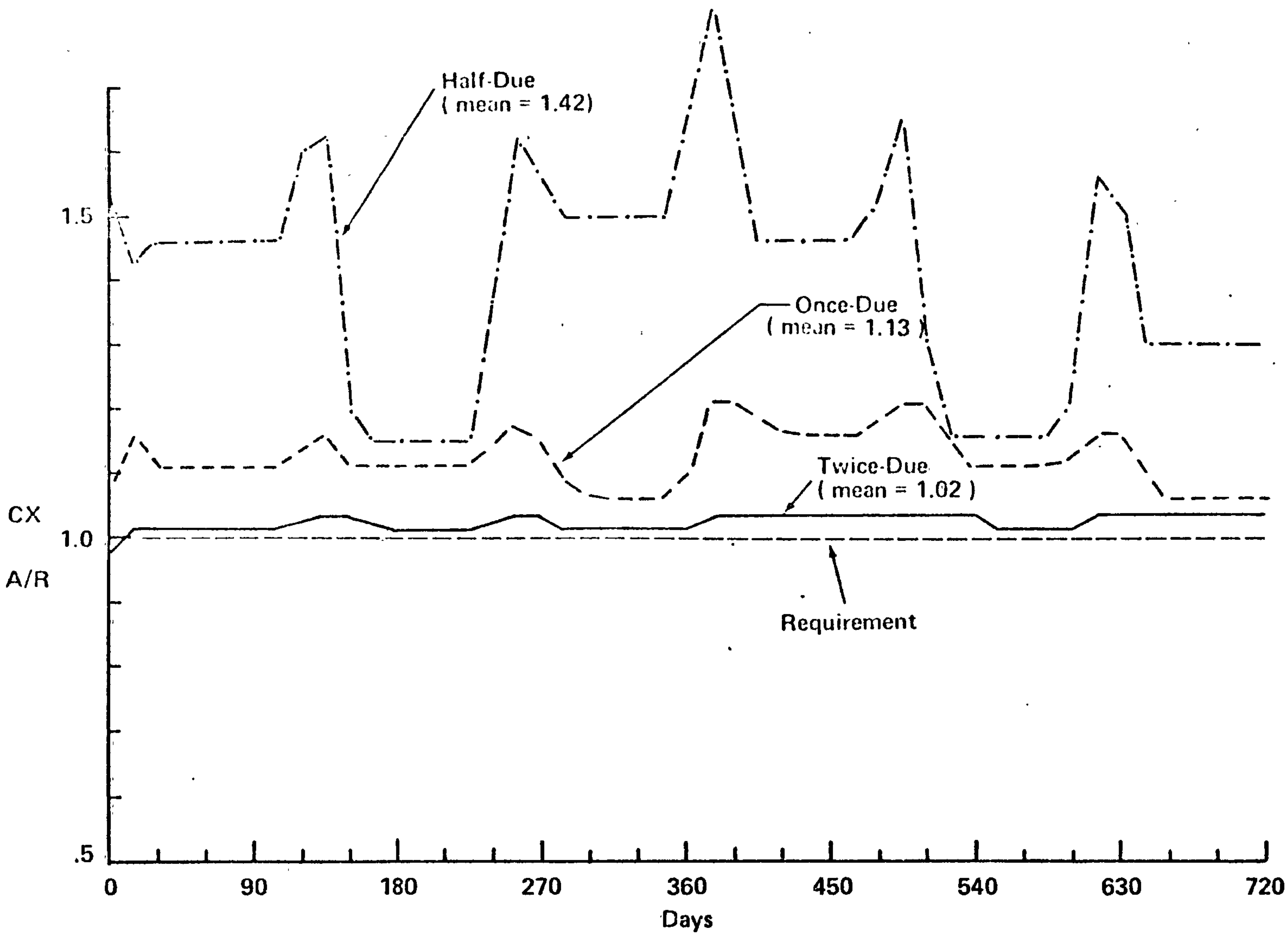


FIGURE 4- 7 -- AGE DISTRIBUTIONS (i = 75 DEGREES, THREE 21-DAY MISSIONS PER YEAR, CURRENT 9-MONTH PERIOD COLLECTION GROUPS

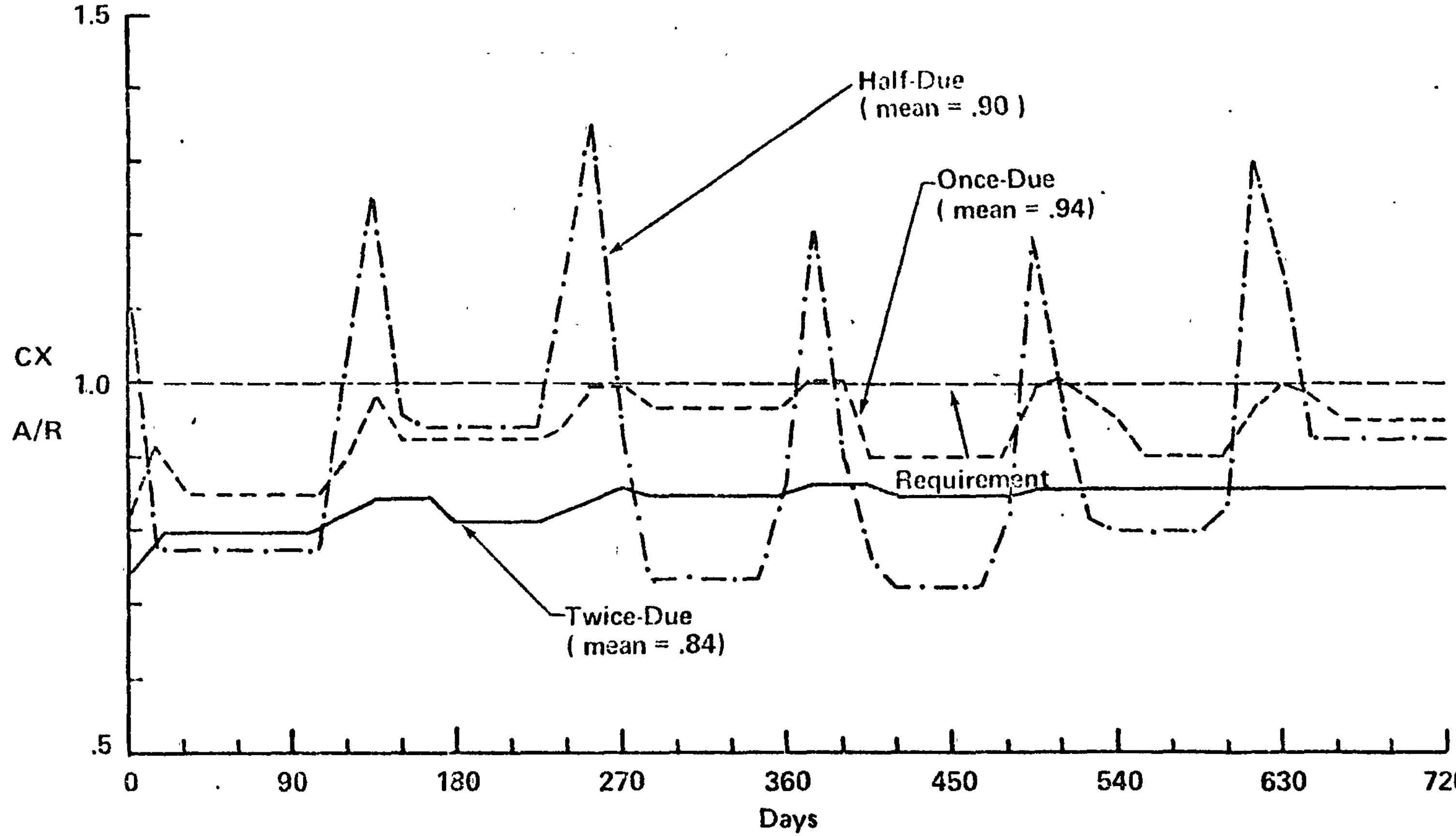


FIGURE 4- 8 -- AGE DISTRIBUTIONS (i = 75 DEGREES, THREE 21-DAY MISSIONS PER YEAR, PROJECTED NEW 9-MONTH PERIOD COLLECTION GROUPS)

The 57-degree inclination, 7-day gap-filler mission performance was simulated for three weather years as shown in Table 4-9. In each case, the date-last-seen and pre-mission status were initialized with HEXAGON Mission 1214 end-of-mission data. COMIREX status (CX) at the end of each mission, and the projected status at the start of the next HEXAGON mission, with an assumed launch date of 15 March, are tabulated. The data show that the gap-filler mission returns cloud-free photography of an average of 68 percent of the 2-month and 53 percent of the 4-month cells. It is noted that 5 to 6 percent of the 2- and 4-month cells in the Soviet Union are inaccessible to the 57-degree inclination mission.

Detailed simulation data for cases H97-14A, H97-21A, H75-14A, and H75-21A are contained in the appendices.

TOP SECRET HEXAGON [redacted] 20053

TABLE 4-9 57 DEGREE INCLINATION, 7-DAY MISSION PERFORMANCE (H 57-07C)

Collection Period Group (Months)	Total Cells (12x18 NM)	Inaccessible Cells (percent above 60°N)	Start of Mission Status @ 12/21	57°, 7 day, 35K Stereo Film, CX Once-due Status					
				1972 WX		1973 WX		1974 WX	
				EOM	NXTMSN	EOM	NXTMSN	EOM	NXTMSN
2	868	5	0	34	0	38 [28]	0	21 [30]	0
4	5261	6	5	54	52	58 [74]	55	52 [57]	50
6	3743	14	50	71	47	70 [78]	49	68 [50]	47
9	8356	20	71	80	69	82 [81]	70	78 [48]	68
12	17910	28	67	80	80	83 [79]	83	80	80
18	16880	70	79	83	82	85 [64]	83	84 [74]	82 [71]
24	2243	93	74	78	78	81 [73]	81	79	79

HANDLE VIA BYEMAN TALENT-
KEYHOLE CONTROL SYSTEMS ONLY

(b)(1)
(b)(3) 10 USC ⊥ 424

5.0 CONCLUSIONS

An in-depth study of the parameters affecting STS PCS performance was conducted. Three operational concepts were selected and their performance evaluated using a high fidelity simulator. The following conclusions summarize the simulation results:

(1) Although there are substantial shortfalls relative to specials and 2-month collection period requirements, three 21-day missions per year in a sun-synchronous orbit can provide an average, once-due CX A/R status of 0.99 against the projected 1985 requirements. More than three missions per year would result in a substantial over satisfaction of all but the 2-month collection period and special search requirements. When tasked against the current requirements, three missions per year would result in a substantial over satisfaction of all but the 2-month and special requirements.

(2) The 2-month collection period requirements can not be satisfied because the system is in orbit only 3 times during the year for 21 days each mission, and because of the low probability of NIIRS 5 imagery from the PCS.

(3) Lower inclination orbits, i.e. 75 degrees, can provide a performance comparable to that of sun-synchronous orbits.

(4) For a given film load, shorter duration missions yield only slightly poorer overall performance; however performance against specials, target clusters, and specific requirements elsewhere is degraded significantly.

(5) The 57-degree inclination mission tasked against current requirements returns cloud-free photography of about 68 percent of the 2-month and 53 percent of the 4-month areas.

6.0 RECOMMENDATIONS FOR FURTHER STUDY

A number of issues requiring further analysis have been identified during the conduct of this study and are listed below. Each of these issues should be addressed before a specific STS PCS operating concept is selected.

(1) The projected 1985 standing search area and quality requirements significantly affect STS PCS performance and the trade-offs among various operating concepts. Are the proposed COMIREX requirements in the following categories likely to change?

- the projected 1985 standing search areas
- required NIIRS 4, desired NIIRS 5, desired NIIRS percentage 50 for the 2-month collection period areas
- required NIIRS 3, desired NIIRS 4, desired NIIRS percentage 80 for all mono requirements

(2) Will the relatively few search system days on orbit per year significantly degrade area coverage related intelligence need satisfaction?

(3) What is the impact on search exploitation resources of three STS PCS missions per year, each of which returns much redundant and cloud-covered imagery?

(4) The slant range NIIRS model has known deficiencies. Would the use of a more precise NIIRS model substantially change the predicted performance in the desired NIIRS 4 and 5 areas?

(5) Will new types of film (e.g., SO315) substantially increase image quality? This could increase satisfaction of 2 month requirements, may allow mono coverage of mono requirements (with approximately a 30 percent film savings), and may allow higher perigee altitudes.

(6) The DMSP morning and afternoon satellites provide timely weather forecast and assessment data for missions at sun-synchronous inclinations. Would the loss of this data for missions in lower inclination orbits significantly degrade performance?

(7) Can a further optimization of mission parameters and models, e.g. schedule, orbital elements, value function, NIIRS model, provide significantly better performance?

(8) A detailed consideration of STS schedules and capabilities is needed to establish an optimal, cost-effective operating concept.

- Could a mix of shared and dedicated flights with various mission durations and orbital inclinations provide satisfactory, cost-effective performance?

- How many opportunities are there for shared flights given the STS payload limitations?

(9) How could the STS PCS and [redacted] be optimally tasked to satisfy together the search requirements? (b)(1) (b)(3) 10 USC 424

TOP SECRET HEXAGON [redacted] 20053 (b)(1) (b)(3) 10 USC 424

Approved for Release: 2017/02/08 C05094782