79-FM-23
(Supersedes 78-FM-29)

JSC-16026
(Supersedes JSC-14235)

STS-7
Flight Feasibility Assessment

(NASA-TM-81091) SHUTTLE PROGRAM. STS-7 FEASIBILITY ASSESSMENT: IUS/TDRS-A (NASA) 63 p HC A04/MF A01 CSCL 22A

N80-27406

Unclas
G3/16 24452

IUS/TDRS-A

Mission and Planning Analysis Division

July 1979

NASA
National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

79FM23

79-FM-23
(Supersedes 78-FM-29)

JSC-16026
(Supersedes JSC-14235)

SHUTTLE PROGRAM

STS-7 Flight Feasibility Assessment

IUS/TDRS-A

By Flight Planning Branch

Approved: Harold D Beck
Edgar C. Lineberry, Chief
Flight Planning Branch

Approved: Ronald L. Berry
Ronald L. Berry, Chief
Mission Planning and Analysis Division

Mission Planning and Analysis Division

National Aeronautics and Space Administration

Lyndon B. Johnson Space Center

Houston, Texas

July 1979

ACKNOWLEDGMENT

The following Mission Planning and Analysis Division (MPAD) organizations and individuals have contributed to the development and documentation of this STS-7 Flight Feasibility Assessment document either directly or by providing input and consultation.

Responsibility	Name	Mail	Phone
MPAD flight cointegrator	Jerome Bell	FM2	4346
	Max Kilbourne	FM2	4401
TDRSS requirements and interface	Jerome Bell	FM2	4346
Propulsive consumables	Don Nelson	FM15	4907
Nonpropulsive consumables	Harry Kolkhorst	FM2	3278
	Chuck Pace	FM2	3278
Deorbit	Dallas Ives	FM4	6347
Attitude and pointing time line	Dave Scheffman	FM2	3278
	Rocky Duncan	FM2	3278
	Brody McCafferty	FM2	3278
Ground navigation	W. Wollenhaupt	FM8	9751
	J. C. Currie	FM8	3921
Ascent performance	John McNeely	FM4	5954
	Gus Babb	FM2	4401
Onorbit dispersion	Allen Dupont	FM2	5276
Entry	R. Moore	FM4	4401

In addition, MPAD wishes to express gratitude for contributions made by individuals in the following areas:

Gonzalo Montoya (MDTSCO): Guidelines and groundrules, flight design annex
Ted Guillory (FOD): Crew activities
Don Lewis (FOD): Crew activities
Sandy Price (MDTSCO): Documentation using FDS/Daconics system
Bob Culpepper (MDTSCO): Documentation using FDS/Daconics system
Lex Allen (MDTSCO): Document integration, IUS performance, and activities time line
Dick Paulson (MDTSCO): IUS performance
Larry Guderian (MDTSCO): Attitude and pointing time line
Arshad Mian (MDTSCO): Attitude and pointing time line
Rick Berry (MDTSCO): Propulsive consumables
Sam Wilson (TRW): Separation maneuver
Courtney Wright (Kentron): Launch window

Virginia A. Duke (Kentron): Launch window
Sherry Fries (Kentron): Launch window
Tom Locke (MDTSCO): Reentry
Gary Zoerner (MDTSCO): Ascent
M. Hazelrigs (MDTSCO): Crew activities
Linda Langston (MDTSCO): Ascent

CONTENTS

Section		Page
1.0	INTRODUCTION	1
2.0	ACRONYMS	2
3.0	GUIDELINES AND GROUNDRULES	5
3.1	GENERAL FLIGHT REQUIREMENTS	5
4.0	FLIGHT DESIGN ASSESSMENT FOR STS-7	9
4.1	LAUNCH WINDOW ANALYSIS	9
4.1.1	TDRS-A Launch Window Requirements and Constraints	9
4.1.2	Orbiter Launch Window Requirements and Constraints	9
4.1.3	Integrated STS-7 Launch Window	10
4.2	ASCENT PERFORMANCE	11
4.3	FLIGHT DURATION	12
4.3.1	Ascending Node Deployment Requirement	12
4.3.2	Contingency Payload Bay Door Opening Requirement	12
4.3.3	Crew Work/Rest Cycle	12
4.3.4	Onorbit Maneuver Requirements	13
4.4	ATMOSPHERIC DESCENT	14
4.5	SEPARATION SEQUENCE ASSESSMENT	15
4.5.1	Performance	15
4.5.2	Evaluation of Potential Damage to Orbiter Windows and Tiles	15
4.6	ATTITUDE AND POINTING CONSTRAINTS	16
4.6.1	Compliance With TDRS Thermal Constraints	17
4.6.1.1	Cumulative Time in Non-ZLV Attitude While the Payload is Stowed	17
4.6.1.2	Cumulative Time in Non-ZLV Attitude While the IUS is Elevated	17
4.6.1.3	Compliance with Solar Constraints	17
4.6.1.4	Compliance With Deployment Constraints	18
4.6.1.5	Assessment of Backup Opportunities	18
4.6.2	Compliance With TDRS RF Communication Requirements	18
4.6.3	Compliance With IUS RF Requirements	19

CONTENTS

Section		Page
4.6.4	Attitude Compatibility Between TDRS and IUS RF Requirements	19
4.7	IUS ATTITUDE INITIALIZATION REQUIREMENT	20
4.7.1	Impact on TDRS RF Checkout Operations	20
4.7.2	Impact on Backup Deployment	20
4.7.3	Impact on State Vector Initialization	20
4.7.4	Ascending Node Injection Requirement	21
4.8	ASCENDING NODE INJECTION REQUIREMENT	22
4.8.1	Night Deployment Requirements	22
4.8.2	Performance Requirements	22
4.8.2.1	OMS Requirements	22
4.8.2.2	RCS	23
4.8.3	Proximity Operations Requirements	23
4.8.4	TDRS/IUS Design	23
4.9	ORBITER COMPATIBILITY	24
4.10	PROPULSIVE CONSUMABLES	25
4.11	NONPROPULSIVE CONSUMABLES	26
4.12	NAVIGATION	27
4.12.1	Early Return Contingency	27
4.12.2	IUS/TDRS Deployment	27
4.12.3	Deorbit	27
5.0	REFERENCES	28

TABLES

Table		Page
I	CURRENT SRM PARTICLE DAMAGE LIMITS FOR STANDARD SEPARATION SEQUENCE DESIGN	29
II	MINIMUM RCS PROPELLANT BUDGET	30
III	OMS PROPELLANT BUDGET	31
IV	ORBITER MASS PROPERTIES DURING THE MISSION	32
V	STS-7 TDRS COMPATIBILITY ASSESSMENT	33
VI	STS-7 COMPATIBILITY ASSESSMENT	34

FIGURES

Figure		Page
1	STS-7 launch window	
	(a) TDRS descending node injection	35
	(b) TDRS ascending node injection	36
	(c) Orbiter abort lighting	37
	(d) Launch window composite	38
2	Deorbit performance requirements for 53° west descending node injection	39
3	Entry interface conditions for STS-7 conceptual profile	40
4	Effect of IUS pitch angle on hi-temp tile erosion	41
5	Effect of IUS pitch angle on hi-temp tile breakage . . .	42
6	Attitude and pointing	
	(a) Deep space facing of the Orbiter payload bay for different operations	43
	(b) Total deep space facing with raised tilt table is 44 minutes	44
	(c) Position of Sun in Orbiter body blockage while maneuvering from -ZLV to deployment attitude	45
	(d) Position of AGO in TDRS antenna beam for two different inertial attitudes	46
	(e) 45° field of view	47
	(f) Assumed hemispherical omni field of view	48
	(g) Position of HAW in IUS omni antenna FOV and relative to the body blockage	50
	(h) Overlap of FOV for TDRS and IUS omni antennas. . . .	51
7	Deorbit ΔV requirements for ascending node injection opportunity	52
8	Nonpropulsive consumables	
	(a) Flight 7 TDRS - potable H_2O profile	53
	(b) Payload bay door opening time line for ascent . . .	54
	(c) Shuttle payload bay closing time line descent . . .	55

1.0 INTRODUCTION

The Space Transportation System (STS) Flight Assignment Manifest (ref. 1) has scheduled the first tracking and data relay satellite system (TDRSS) spacecraft (TDRS-A) for a February 27, 1981 launch on STS-7.

This flight design document has been developed by the Mission Planning and Analysis Division (MPAD) in support of the TDRS-A cargo integration review scheduled for June 13, 1979. It is the companion document of the STS-7 Conceptual Flight Profile (CFP) (ref. 2).

This STS-7 Flight Feasibility Assessment (FFA), along with the STS-7 CFP, is intended to provide a base from which the various design, operation, and integration elements associated with TDRS-A can perform mission planning and analysis. The STS-7 FFA identifies conflicts, issues and concerns associated with the integrated flight design requirements and constraints.

Questions concerning this document should be addressed to Jerome Bell, Flight Planning Branch (FM2).

For questions relating to specific disciplines, the appropriate personnel identified in the acknowledgement may be contacted.

2.0 ACRONYMS

AFSCF	Air Force satellite control facility
AFO	abort from orbit
AOA	abort once around
AOS	acquisition of signal
APU	auxiliary power units
ASE	airborne support equipment
ATCS	active thermal control system
CFP	conceptual flight profile
c.g.	center of gravity
CIR	cargo integration review
Δt	time increment
ΔV	incremental velocity
DOD	Department of Defense
EAFB	Edwards Air Force Base
EDT	eastern daylight time
EPDC	electrical power distribution and control
ET	external tank
EVA	extravehicular activity
FCP	fuel cell power plant
FTR	flight test requirements
FWD	foward
GET	ground elapsed time
GMT	Greenwich mean time
GPC	general purpose computer
GSTDN	ground spaceflight tracking and data network

ha	apogee altitude
hp	perigee altitude
IMU	inertial measurement unit
IUS	inertial upper stage
JSC	Johnson Space Center
KSC	Kennedy Space Center
LH	local horizontal
LOPT	landing opportunity
LOS	loss of signal
LV	local vertical
LVLH	local vertical/local horizontal
MECO	main-engine cutoff
MPAD	Mission Planning and Analysis Division
MPS	main propulsion subsystem
NPC	nonpropulsive consumables
OA	Orbiter after
OMS	orbital maneuvering system
OMS-1	first OMS maneuver
OMS-2	second OMS maneuver
OP	Orbiter prior
PET	phase elapsed time
PI	payload integrator
PIP	payload integration plan
PLBD	payload bay doors
PROP	propellant
psf	pounds per square foot

PTC	passive thermal control
q_{max}	maximum dynamic pressure
RCS	reaction control system (primary)
RF	radio frequency
RMS	remote manipulator system
RTLS	return-to-launch site
RTS	remote tracking stations
SPIDPO	Shuttle payload integration and development program office
SRB	solid rocket booster
SRM-1	IUS stage-1 solid rocket motor
SRM-2	IUS stage-2 solid rocket motor
SSME	Space Shuttle main engine
ST	star tracker
STS	Space Transportation System
SV	Shuttle vehicle
TBD	to be determined
TCS	thermal control system
TDRS	tracking and data relay satellite
TDRS-A	first TDRS spacecraft
TDRSS	tracking and data relay satellite system
TVCS	thrust vector control system
VRCS	vernier reaction control system
WTR	Western Test Range
-ZLV	payload-bay-to-Earth attitude

3.0 GUIDELINES AND GROUNDRULES

3.1 GENERAL FLIGHT REQUIREMENTS

a. The launch date is February 27, 1981.

b. Nominal end-of-mission shall be planned for 2 days.

c. The nominal post-Orbiter maneuvering system-2 (OMS-2) parking orbit is a 150-n. mi. circular one.

d. At the time of deployment, the minimum parking orbit shall be the equivalent of a 150-n. mi. circular orbit.

e. The nominal parking orbit inclination is 28.48 degrees.

f. The launch and landing site is Kennedy Space Center (KSC).

g. The payload complement consists of a tracking and data relay satellite (TDRS-A) spacecraft integrated on a Department of Defense (DOD) two-stage inertial upper stage (IUS), the IUS airborne support equipment (ASE), and the necessary Space Transportation System (STS) cargo-chargeable equipment required to interface the IUS vehicle with the Orbiter.

h. The crew size is four.

i. Orbiter vehicle 102 configuration per reference 2 will be used.

j. The capability shall be provided to allow a return from orbit without having to deploy the IUS/TDRS.

k. Launch window shall be selected to prevent nominal end-of-mission or abort landings from occurring prior to sunrise or later than sunset.

l. Return-to-launch site (RTLS) and abort-once-around (AOA) landings will be planned to be at KSC.

m. Provide the consumables loading to allow a landing within 7 hours GET for an abort from orbit (AFO).

n. A backup landing opportunity will be provided one revolution after nominal landing.

o. The maximum space Shuttle main-engine (SSME) thrust for nominal ascent is 100 percent; for aborts, the maximum thrust is 109 percent.

p. Lift-off, end-of-mission, and abort landing payload weights are per the Payload Data Annex to the TDRS Payload Integration Plan (PIP).

q. The payload bay doors (PLBD) are to be opened as soon as operationally convenient after OMS-2; however, keeping the PLBD closed for up to 3 hours postlaunch shall not preclude continuation of the mission.

r. The TDRS command and telemetry links must be checked out onorbit prior to deployment. The nominal path will be: Ground spaceflight tracking and data network (GSTDN), Orbiter, payload interrogator, and TDRS.

s. One opportunity shall be provided for a direct TDRS to GSTDN radio frequency (RF) check prior to deployment. This is a contingency operation.

t. When the PLBD are open, the Orbiter will fly a payload bay to Earth (-ZLV) attitude except during the following activities:

  (1) All Orbiter inertial measurement unit (IMU) alinements

  (2) TDRS/STDN direct RF check

  (3) IUS attitude initialization

  (4) IUS/TDRS deployment operation

  (5) Preentry thermal conditioning, as required

u. The nominal geosynchronous placement is longitude 53° W.

v. The maximum payload allowance will be based on two-sigma flight performance reserve loading for AOA.

w. There will be four potable water tanks available for cooling using the flash evaporator. Also, one additional waste water tank can be used for additional cooling during aborts and contingencies. The potable water tanks will be 95-percent full for normal entry.

x. For nonpropulsive consumables budgeting, the following contingencies will be considered:

  (1) A 24-hour hold without reservice

  (2) The worst case of the following:

    (a) Cabin puncture

    (b) One extravehicular activity (EVA)

    (c) Last deorbit opportunity on mission extension day

    (d) One cabin repressurization

    (e) Deorbit one orbit late

y. Computation and communications required to develop and transmit a ground navigation state vector and Orbiter maneuver include the following:

   (1) Tracking passes over at least three stations distributed during one complete revolution are required to acquire enough data for computing an accurate ground navigation state vector.

   (2) Two additional tracking passes are required to provide backup and maintain navigation accuracy in the event of tracking station loss during one of the passes in (1) above. These backup passes may be located either before, after, or before and after the tracking interval in (1) above.

   (3) All station passes should be above 3-degree ground station elevation.

   (4) Fifteen minutes are required for ground computation of state vector.

   (5) Twenty minutes are to be allocated for computation of the Orbiter maneuver and uplink pads given the above state vector as input.

   (6) One primary and one backup station pass are required for uplinking the state vector and/or maneuver data.

z. When possible, deorbit should be executed on a path that allows tracking by a station between deorbit cutoff and entry interface. This station pass must be at a minimum of 14-degree elevation.

aa. Propellant loading for attitude control shall be planned on the basis of using primary RCS only. The resulting propellant loading will be needed in the event of a failure of the vernier RCS.

bb. The IUS flight operations requirements and constraints are as presented to the Shuttle Payload Integration and Development Program Office (SPIDPO) at the Johnson Space Center (JSC) April 17, 1979 and documented in a letter from Col. Shaffer (IUS Program Director) to G. Lunney (Manager) SPIDPO.

cc. The TDRS flight requirements and constraints are as defined in the TDRS PIP, April 19, 1979.

dd. The detailed TDRS/IUS data required for flight design implementation are as defined in the TDRS/IUS PIP annexes.

ee. The Orbiter separation sequence will be designed in accordance with the criteria and philosophy contained in formal briefings to STS management (refs. 3 and 4).

ff. Nine hundred-n. mi. crossrange operational capability for landing will be assumed.

gg. The solid rocket booster (SRB) configuration is the TC-121-78 and uses the Western Test Range (WTR) burn rate.

hh. There is no SRB ignition delay.

ii. SSME propellant line screens are assumed to be removed for this flight.

jj. The abort decision lag time is zero.

4.0 FLIGHT DESIGN ASSESSMENT FOR STS-7

4.1 LAUNCH WINDOW ANALYSIS

4.1.1 TDRS-A Launch Window Requirements and Constraints

Figures 1(a) and 1(b) translate TDRS-A launch window requirements and constraints, as defined in the TDRS PIP, into Orbiter lift-off time requirements. Each individual TDRS requirement and constraint are shown. Figure 1(a) is for descending and figure 1(b) for ascending node injection opportunities, respectively. (The 25.5 degree constraint between the geosynchronous orbit plane and the ecliptic plane is not violated for a target orbit inclination of 2 degrees or less. It does not impact the STS-7 launch window). Figures 1(a) and 1(b) show also that the requirement for a right ascension of the ascending node between 270 and 290 degrees defines, for both injection opportunities, a TDRS launch window independent from the other launch window constraints.

The final TDRS-A placement longitude is required to be between longitudes 55°W and 99°W. For the descending node case, a launch window that opens at 19:20:28 GMT and closes at 20:16:33 GMT will provide three consecutive deployment opportunities. For the ascending node case, a launch window that opens at 19:34:35 GMT and closes at 20:32:32 GMT provides two consecutive deployment opportunities. A launch window compatible with all deployment opportunities under consideration will require a lift-off between 19:34:35 and 20:16:33 GMT.

The maximum right ascension of the ascending node compatible with both descending and ascending injection opportunities for a February 27th launch is about 245.5 degrees. This coincides with a lift-off at the closing of the launch window associated with the 25-degree nadir constraint for an ascending node injection.

4.1.2 Orbiter Launch Window Requirements and Constraints

The only STS-7 Orbiter constraint identified to date is for landing to occur during daylight hours. A definition of the landing time and landing site is required to convert this landing constraint into lift-off time requirements. Figure 1(c) shows the Orbiter lift-off time requirements.

Landings resulting from launch aborts (RTLS and AOA) are assumed to occur at KSC. Launch abort landings are nominally constrained to occur between 30 minutes after sunrise and 30 minutes prior to sunset. This limits launch to occur between 12:19:24 and 21:21:12 GMT for a February 27th launch day. If required, the launch window may be expanded by permitting landings as early as sunrise or as late as sunset. Launch window open is defined by the RTLS landing time while the AOA landing time defines the launch window close.

The capability must also be provided for return after OMS-2 in the event the payload bay doors cannot be opened. Navigation support requirements based on GSTDN (without an operational TDRS) and the constraint that the Orbiter APU's cannot be restarted for 3 hours precludes landing opportunities on the second orbit; i.e., deorbit one revolution beyond OMS-2 with subsequent landing at about 3 hours. For landings from the third orbit (about 4.9 hours GET, which coincides with the maximum water loading capability), the crossrange to KSC is about 1000 n. mi. This exceeds the 900-n. mi. capability of the Orbiter, necessitating a landing at an alternate site. Figure 1(c) shows the daylight landing launch window constraints for landing at Northrup and Edwards. It is seen that an EAFB landing provides for a launch time 46 minutes later in the day than the Northrup landing site. Planning EAFB as the landing site for the post OMS-2 abort maximizes the launch window and also accommodates the desirable landing lighting margin of 30 minutes. Use of Northrup would reduce the launch window duration by a minimum of 12 minutes and would also entail a reduction in the daylight remaining at the time of landing.

The nominal landing is not shown on figure 1(c) because, at present, it is not thought to be a factor. Nominal and backup landing opportunities can be selected prior to 24 and 48 hours GET, which implies landing earlier in the day than launch occurred. In fact, the daylight landing constraint is estimated to exclude only one landing opportunity to KSC within the 2-day flight. The latest deorbit opportunity for landing during the first day in conjunction with a lift-off at the close of the TDRS launch window will occur at night.

4.1.3 Integrated STS-7 Launch Window

The composite STS-7 launch window is shown in figure 1(d). Summarized on this figure is the acceptable launch window for TDRS-A ascending node injection, TDRS descending node injection, Orbiter landing lighting, and the integrated STS-7 launch window. The launch time (between 19:34:35 and 20:16:33 GMT on February 27, 1981) satisfies all the launch window requirements and constraints.

4.2 ASCENT PERFORMANCE

TBS

4.3 FLIGHT DURATION

Landing opportunities, satisfying the Orbiter crossrange constraint occur on multiples of every 22 through 24 hours following launch. The mission duration is dependent on how requirements for ascending node deployment, contingency payload bay door opening, the crew work/rest cycle and onorbit maneuvering can be met.

4.3.1 Ascending Node Deployment Requirement

The flight requirement to provide an ascending node backup deployment opportunity requires Orbiter activities associated with IUS/TDRS operations to continue through approximately 23 hours 42 minutes GET - IUS first-stage ignition. The latest planned first-day deorbit back to KSC, allowing for a backup deorbit opportunity on the following orbit, occurs at approximately 24 hours 50 minutes GET. Assuming (a) 2 to 4 hours for deorbit preparation; (b) a quiescent coast phase prior to deorbit once the predeorbit tracking and state vector determination operations are initiated; and (c) the deorbit tracking arc is initiated a minimum of about 2.5 hours prior to deorbit to satisfy data acquisition, processing and uplink requirements, landing within approximately 24 hours after launch is incompatible with an ascending node deployment. These constraints necessitate landings when the prime landing site is next accessible - during the 48-hour GET time frame.

4.3.2 Contingency Payload Bay Door Opening Requirement

The requirement to accommodate a delayed payload bay door opening (contingency or otherwise) for up to 3 hours past launch will deplete the Orbiter water for cooling to a level that could impact mission duration. Under the guideline that the four potable water tanks and the wastewater tank are to be full prior to nominal deorbit, fuel cell water will need to be generated onorbit to refill the tanks. The quantity of water produced and the rate at which it is replenished is a function of when the payload doors are opened, the radiator performance, the power level being utilized, and the orbital attitude time line. It could, therefore, require more than 24 hours GET to produce sufficient water for cooling to support the nominal deorbit and contingency landing operations required for the flight.

4.3.3 Crew Work/Rest Cycle

The TDRS longitude placement requirement provides a maximum, for a 1-day mission, of about 15 hours between nominal (the first) deployment at 10 hours GET and deorbit. Requirements to provide backup deployment opportunities on subsequent revolutions could reduce the available time interval to 12 hours. Within the 12 to 15 hours available, postdeployment proximity operations, crew sleep period, meals, and predeorbit activities must occur. The feasibility of a 1-day flight must be assessed relative to the impact on the crew work/rest cycle requirements.

4.3.4 Onorbit Maneuver Requirements

Deorbit opportunities associated with a 1-day flight could potentially require an additional 30- to 50-fps ΔV. (fig. 2). This assessment is based on the assumption that crew work/rest cycle constraints will preclude the deorbit opportunity being selected based on minimum ΔV criteria. Instead, maximizing the time between deployment and deorbit for accomplishing all postdeployment/predeorbit activities will dictate the selection. The deorbit time for a 2-day flight can presumably be selected based on minimum ΔV deorbit requirements, with the crew-related activities worked around the deorbit time. The additional ΔV requirement for a 1-day flight may be accommodated within required RCS loadings available provided the minimum loading (as defined by system constraints) adequately exceed the nominal flight requirements.

Analysis is being done to assess modifications to the separation maneuver. These modifications will not require additional propellant loading nor violate the criteria for selection of deorbit time.

4.4 ATMOSPHERIC DESCENT

Based on an assumed nominal entry weight of 188 000 pounds, a center of gravity (c.g.) location (in nominal X, Y, Z entry coordinates) of 1102.8, 0.5, and 372.5, respectively, an entry weight of 230 000 pounds for an intact abort, and the TPS design limits defined for STS-6, both the heavy and light weight atmospheric descents for STS-7 are feasible. A 900-n.mi. crossrange capability is available for a c.g. up to approximately 67 percent of the body length in the intact abort entry case. Shifts of the c.g. past that point would have to be accommodated at the expense of crossrange capability because of TPS design limits required for this flight.

Entry interface target lines for nominal and intact abort entries are presented in figure 3. The indicated target points represent a Hohmann transfer from a 150-n. mi. circular parking orbit for both the heavy and lightweight vehicle. The difference in the target line for the two entry configurations, represent a 10-fps difference in deorbit ΔV; 280 fps are required for the 230 000-pound vehicle, and 270 fps are required for the 188 000-pound vehicle.

4.5 SEPARATION SEQUENCE ASSESSMENT

4.5.1 Performance

No performance penalty is incurred with the nominal separation sequence. The abort from orbit following OMS-2 dictates the OMS propellant required for deorbit. The quantity of propellant required to return with the TDRS/IUS onboard provides a ΔV capability on the order of 50 fps greater than that required when the payload is deployed. In addition, abort from orbit requires approximately 25 fps greater deorbit ΔV than the nominal mission. An abort from orbit with the TDRS/IUS onboard, then, will require an additional OMS ΔV capability of approximately 75 fps. The separation maneuver requires a ΔV of about 70 fps. Thus, the separation sequence can use the excess ΔV required for this abort case without impacting the OMS loading requirements.

4.5.2 Evaluation of Potential Damage to Orbiter Windows and Tiles

Based on the window and thermal tile damage budgets currently being used for standard separation sequence design (table I), the potential of 49 breaks per square foot for Orbiter windows exposed to the SRM exhaust particle flux was calculated. This value is almost 700 times greater than the per-firing limit shown in table I, and five times greater, than the lifetime window breakage limit. Therefore, it is imperative that the windows be shielded from the SRM exhaust plume. This is accomplished by pointing the Orbiter's underside at the IUS prior to SRM-1 ignition and maintaining that attitude long enough after burnout to allow for the finite flight time of the impinging particles.

Other than the windows, only the Orbiter's high-temperature tiles will be exposed to a significant flux of exhaust particles during, and immediately after, the SRM-1 burn. The high-temperature tile breakage potential is 0.0008 breaks per square foot for the nominal case, and the corresponding erosion potential is 0.033 percent. These values are well within the current per-firing limits. Figures 4 and 5 indicate that a significant deviation of the IUS attitude could cause the per-firing trajectory design limits on high-temperature tile erosion and breakage, respectively, to be exceeded by factors of about 1.1 and 2.1. Such a deviation is not likely to occur, and even if it should, it is believed that the resulting damage would not be great enough to represent a flight safety hazard or a very serious Orbiter maintenance problem.

4.6 ATTITUDE AND POINTING CONSTRAINTS

The attitude and pointing profile for this Shuttle flight is unique because it supports the deployment of the first tracking and data relay satellite (TDRS) to be placed in geostationary orbit by an inertial upper stage (IUS). There are numerous Orbiter and payload/systems operational and hardware-related requirements and constraints that must be considered in the design of this profile, and each requirement and constraint must be implicitly satisfied by the attitude time line. For this flight, both the TDRS and the attached IUS impose attitude requirements on the Orbiter that serve as drivers to the design of the STS-7 profile. There are three basic payload-related attitude profile design drivers.

First, the TDRS is thermally sensitive and must be protected from exposure to the Sun as well as from long-duration exposure to deep space. Hence, prior to and at deployment, the Orbiter attitudes must be selected to satisfy these constraints. The IUS is also thermally sensitive, but the TDRS thermal sensitivity far exceeds that of the IUS.

Second, both the TDRS and IUS communications requirements must be met. Prior to deployment, the TDRS is required to communicate with a spacecraft tracking and data network (STDN) ground station (either through the payload interrogator (PI) or directly) to verify the radio frequency (RF) link. Similarly, direct IUS communications with an Air Force satellite/spacecraft control facility (AFSCF) remote tracking site (RTS) is required to verify the IUS command link. After deployment, the IUS is required to perform autoantenna selection to maintain a command link with the Orbiter, and the Orbiter must assume an attitude to point its S-band payload antenna toward the IUS until the IUS is out of communication/tracking range.

Third, the IUS requires a very accurate initial attitude and state vector. The initial IUS attitude and state vector are obtained via the Orbiter/payload interface. That attitude is refined via star scan operations supported by Orbiter attitude maneuvers, and the state vector is transferred to the IUS from the Orbiter as soon as possible after uplink and attitude initialization. To ensure that the state is not degraded by uncompensated translational velocity changes because of uncoupled control thruster firings, attitude maneuvers must be minimized after state vector transfer.

Another significant attitude constraint is imposed on the Orbiter by the IUS. That is, the Orbiter must assume a "window protection attitude" during the IUS SRM-1 burn to avoid damage of the Orbiter windows by aluminum oxide and carbon particles.

After IUS transfer, the Orbiter attitude constraints are not significantly different from other STS flights. The attitude profile for the remainder of onorbit stay time will consist of an Orbiter thermally benign attitude periodically interrupted by routine inertial measurement unit (IMU) alinements.

4.6.1 Compliance With TDRS Thermal Constraints

The base attitude profile selected for this flight consists of a -Z local vertical attitude hold (-ZLV). This attitude satisfies both Orbiter and payload thermal constraints. However, deviations from this base profile are required to support Orbiter IMU alinements and IUS IMU alinements via star scanning operations/maneuvers. Other deviations from this base attitude are required to support TDRS/IUS communications, deployment and tracking.

4.6.1.1 Cumulative Time in Non-ZLV Attitude While the Payload is Stowed

TDRS thermal constraints permit a maximum of 90 minutes of cumulative deep space facing. However, both IMU alinements and star scan operations require the payload bay (-Z axis) to be pointed towards deep space. Prior to deployment, two Orbiter IMU alinements and two IUS star scan operations are required. The cumulative time required by these operations is shown in figure 6(a). As the figure illustrates, the total deep space pointing required by these operations is about 87 minutes, assuming that a nominal IMU alinement requires 15 minutes. Thus, the 90 minutes deep space pointing constraint is not violated for IUS stowed.

4.6.1.2 Cumulative Time in Non-ZLV Attitude While the IUS is Elevated

Due to IUS power limitations, the Orbiter is not allowed to point the payload bay towards deep space for more than 2.5 hours, while the IUS is elevated. Figure 6(b) shows the impact of holding the deployment attitude on the deep space facing constraint. In doing so, the Orbiter -Z axis sweeps away from the nadir towards the horizon in 28 minutes, after which it points towards deep space for 44 minutes until the IUS is ejected. The total time in non-ZLV attitude while the IUS is elevated is 65 minutes. The figure indicates that this pointing constraint is not violated.

4.6.1.3 Compliance With Solar Constraints

The primary Orbiter attitude requirement is to point the payload bay towards the center of the Earth (-ZLV $\pm$ 2 degrees). This attitude satisfies the TDRS Sun-in-bay constraint when stowed. All attitude maneuvers (IMU alinements, star scan operations) are performed in darkness to ensure solar constraints are met.

When the IUS tilt table is elevated, the Orbiter maintains inertial hold in the deployment attitude, at which Orbiter body blockage shields the TDRS from the Sun. If the TDRS RF check via the PI fails at HAW, then a maneuver to and from a backup RF-check attitude at AGO must be performed (in darkness).

4.6.1.4 Compliance With Deployment Constraints

The deployment attitude is defined by pointing the Orbiter body vector

pitch (P) = 238 degrees
yaw (Y) = 0 degrees

towards the Sun. Before ejection of the IUS, the tilt table is elevated to 58 degrees so that the IUS -X axis points towards the Sun. The deployment attitude thus provides the maximum solar shadowing that can be achieved from the Orbiter body. Figure 6(c) shows the position of the Sun relative to the body blockage when the Orbiter maneuvers from -ZLV to deployment attitude and holds that attitude until ejection of IUS/TDRS. The figure illustrates that in deployment attitude the TDRS is always shielded from the Sun by the body blockage. Also, the deployment attitude is compatible with the OMS prethrust attitude alinement for the separation maneuver.

4.6.1.5 Assessment of Backup Opportunities

If the TDRS RF check via PI fails over HAW, then the Orbiter must maneuver to another attitude for the backup RF check via AGO. Maneuvering to and from this attitude requires a substantial amount of time because of the large eigenangle between the two attitudes. This maneuver could take much longer if there is a requirement to use vernier reaction control system (VRCS) jets because of the elevated tilt table structural constraints. Also, degradation of state vector accuracy may be expected because of these maneuvers.

Cumulative deep space viewing of 87 minutes (stowed) and 44 minutes (elevated) is consumed by the nominal attitude profile. Therefore, no more IMU alinements and star scan operations can be accommodated within the budget. However, the IUS can be kept elevated for another orbit to meet contingencies without violating the 2.5 hours deep space pointing constraint.

4.6.2 Compliance With TDRS RF Communication Requirements

The antenna field of view (FOV) as stated in the PIP is ±20 degrees about the TDRS +Z axis. This FOV is not capable of providing STDN tracking for more than 3 minutes in a ZLV or inertial attitude under the best conditions. Thus, any STDN tracking requirement in effect implies the use of the Earth target-tracking option of the universal pointing function.

The actual antenna pattern can be modeled as a cone with a 110- by 79-degree elliptical cross section. The centerline of the antenna is defined by the body vector (P = 35 degrees Y = 325 degrees) when the tilt table is elevated 29 degrees. This FOV can be utilized to provide approximately 5 minutes of tracking coverage in an inertial attitude. The coverage time can be increased by using a biased LVLH hold. Figure 6(d) shows how a STDN station (AGO) sweeps through the antenna FOV throughout the station pass. The antenna FOV shown is in the body coordinate system.

4.6.3 Compliance With IUS RF Requirements

The stated antenna FOV is ± 45 degrees. The centerline of the antenna lies along the body vector (P = 119 deg, Y = 33 deg) when the IUS is elevated to 29 degrees.

For the IUS RF check, the Orbiter must maneuver to keep an RTS within the antenna FOV throughout the station pass. Figure 6(e) shows the IUS RF communication opportunities for the above FOV when the Orbiter is in a ZLV attitude. The figure illustrates that the 45 degrees FOV is essentially incompatible with ZLV attitude operations. Because the 45 degrees FOV IUS omni antenna is associated with RTS passes that occur in daylight, IUS RF communication requirements in general cannot be satisfied with this FOV.

The assumed antenna FOV is ±80 degrees and can provide complete coverage in an inertial attitude. Figure 6(f) shows the coverage times available for different RTS stations when the Orbiter is in a ZLV attitude. The complete coverage provided by the assumed FOV of ±80 degrees is obvious from the figure. Figure 6(g) shows the assumed FOV in Orbiter body coordinate system. The position of HAW as it sweeps through the antenna FOV when the Orbiter is in deployment attitude is also illustrated.

4.6.4 Attitude Compatibility Between TDRS and IUS RF Requirements

The IUS and TDRS antennas are incompatible for simultaneous tracking because there is a very small overlap of FOV as shown in figure 6(h). Thus, coverage for one antenna practically implies no coverage for the other.

4.7 IUS ATTITUDE INITIALIZATION REQUIREMENT

4.7.1 Impact on TDRS RF Checkout Operations

For the deployment time selected, constraining the IUS attitude initialization to occur 45 minutes prior to deployment is incompatible with TDRS RF checkout and transmitter operations requirements. The TDRS RF activity requires the spacecraft to be elevated, while the star scan activity requires the IUS to be stowed. (This is independent of attitude requirements.) These conflicting requirements dictate that the star scan operation be performed before turning on the TDRS transmitter. Performing TDRS RF checks first would require the TDRS to be restowed after the checks, the transmitter turned off, and then repeating this TDRS event after the star scan activity has been completed and prior to deployment. In addition, the maneuver to the star scan attitude could not begin until the Orbiter is in darkness, (about 42 minutes prior to deployment at 9 hours 23 minutes GET). Allowing 3 to 6 minutes for maneuvering to star scan acquisition attitude and 10 minutes for star scan activities, then 3 to 6 minutes for maneuvering to the "correct RF checkout attitude" and 5 minutes for elevation of the tilt table to 29 degrees, 21 to 27 of the available 42 minutes of darkness are used. By this time Santiago may no longer be accessible to support the contingency RF activities (coverage of Santiago is between 9:41:41 and 9:46:23 GET) via the payload interrogator. For direct GSTDN to TDRS RF communications (presuming GSTDN coverage is available), an attitude maneuver will be required from the contingency RF attitude to deployment attitude. These maneuvers potentially require 3 to 6 minutes using the PRCS and a significantly longer time if the vernier system is used when the TDRS/IUS is elevated.

4.7.2 Impact on Backup Deployment

The 45-minute attitude initialization constraint requires that a star scan operation be performed prior to every deployment opportunity. This implies that no-go decisions based upon TDRS RF considerations (or any no-go decision made after the TDRS is elevated) will require restowage, turning off the TDRS transmitter, and possibly repeating the TDRS checkout operations after the IUS attitude initialization.

4.7.3 Impact on State Vector Initialization

The maneuvers associated with star scan operations may have a significant effect on the accuracy of the state vector transferred to the IUS, especially because there is an IUS requirement for state vector transfer after the attitude initialization operation. This concern originates from: potential uncoupled attitude control from the Orbiter RCS that could be further aggravated by potential requirements for contamination avoidance thruster inhibits; the potential state vector propagation requirements resulting from sparse ground-station tracking coverage; the frequency with which the attitude initialization is inferred to be required for backup deployment; and potential longer thrust times to achieve attitude rates that minimize time line impacts.

4.7.4 Ascending Node Injection Requirement

The 45-minute attitude initialization requirement appears incompatible (from TDRS thermal constraints) with an ascending node injection opportunity. For the launch window available, the 45 minutes prior to an ascending node deployment is in daylight, and the required star scan maneuvers may severely jeopardize the TDRS.

4.8 ASCENDING NODE INJECTION REQUIREMENT

4.8.1 Night Deployment Requirements

With a nomimal 51-minute coast between deployment and IUS ignition, ascending node deployment would occur at approximately 22 hours 49 minutes GET (IUS ignition occurs at about 23 hours 40 minutes GET) for a 68° W geosynchronous placement. OMS ignition for separation would occur at 23 hours GET. The launch window for the February 27, 1981 launch date results in onorbit sunset occurring between about 22 hours 50 minutes and 22 hours 53 minutes GET (approximately 1 to 4 minutes after deployment). Although general requirements have been stated that the Orbiter shall be capable of deployment in Earth shadow, there is a concern whether this is compatible with the present Orbiter and IUS design. The execution of the various required proximity operations activities during night side passes from deployment until the OMS separation maneuver has not been fully assessed. For the present, it is assumed desirable to have a minimum of 5 minutes of daylight remaining following the OMS separation maneuver for visual sighting of the IUS/TDRS during the initial stage of the separation trajectory. Extending the postdeployment coast to 67 minutes (sec. 4.8.2.1) would provide from 6 to 9 minutes of daylight following the OMS separation burn. This would satisfy the desired visibility requirement.

4.8.2 Performance Requirements

4.8.2.1 OMS Requirements

For the 51-minute coast between deployment and IUS ignition, the ascending node injection opportunity requires deployment to occur approximately 6 minutes prior to arrival at the descending node. The subsequent postejection 11-minute coast, prior to the OMS separation maneuver, will result in apogee of the postseparation orbit (approximately 188 n. mi.) to be in the northern hemisphere. The resulting geometry between the orbital line of apsides orientation and the landing site at the time of deorbit, will result in an increase in the ΔV required for deorbit (assuming landing occurs on the nominal revolution) of about 44 fps above the ΔV available. The ΔV requirement can be reduced by delaying deorbit. However, the requirement for a one-revolution backup deorbit opportunity in conjunction with a daylight landing, limits the nominal deorbit to occur at 47:27 GET, which is associated with about a 20-fps ΔV penalty. (For the nominal descending node injection, the geometry is reversed; i.e., apogee is located in the southern hemisphere, and the orbit is oriented in essentially near-optimum location for deorbit).

The ΔV penalty associated with the ascending node injection opportunity can be eliminated by increasing the coast time between deployment and IUS ignition to approximately 67 minutes (16 minutes longer than nominal). Again, allowing for the 11-minute coast time prior to OMS ignition for separation, the earlier deployment time (relative to IUS ignition) permits a more optimum orientation of the orbit at the time of deorbit. In addition, because the overall time between OMS separation and IUS ignition will also be increased, a 10-fps ΔV savings is realized in the Orbiter/IUS separation maneuver sequence. As in the case of the 51-minute coast time between deployment and IUS ignition, the ΔV requirement for the 67-minute case can also be reduced by delaying deorbit. However, the combined ΔV requirements for the separation and deorbit maneuvers for the 67-minute postdeployment coast will match the available capability for planned deorbit on the nominal revolution. Figure 7 illustrates the deorbit requirements for the ascending node deployment opportunity.

4.8.2.2 RCS

Deployment for the ascending node injection opportunity will increase RCS propellant required for the separation phase by an additional 99 pounds above nominal. Of that quantity, 42 pounds is consumed from the forward RCS tank and 57 pounds from the aft tank. This additional usage is based on a 51-minute coast from deployment to SRM ignition. If a 67-minute coast is used, an additional 16 pounds of RCS propellant (5 forward and 11 aft) is required as a result of the longer coast time. The majority of the additional propellant required, is due to the difference in deployment attitude and the maneuvers necessary for the OMS burn (assuming the Orbiter position at SRM-1 ignition remains fixed as behind and above). After deployment, the initial RCS translation maneuver is increased from about 3 fps (nominal) to about 6.5 fps.

4.8.3 Proximity Operations Requirements

Providing for an ascending node injection opportunity will necessitate development of additional proximity operations trajectories and procedures, and potentially require additional training. This is required primarily because at TDRS/IUS deployment, the attitude must be such that the Sun is on the TDRS/IUS -X axis. For the nominal descending node injection opportunity, the Orbiter deployment attitude requirements relative to local vertical are approximately -101 degrees pitch, -34 degrees yaw, and 200 degrees roll. For the ascending node opportunity (assuming deployment occurs 51 minutes prior to IUS ignition), the required deployment attitude is -47 degrees pitch, 3 degrees yaw, and 317 degrees roll. This difference in deployment attitude requires modified procedures in order to achieve the required attitude for the OMS maneuver, which is essentially fixed (within limits) with respect to the local vertical.

4.8.4 TDRS/IUS Design

Increasing the coast time between deployment and IUS ignition beyond 51 minutes may impact the TDRS/IUS power requirements, and thus a thermal assessment would be required.

4.9 ORBITER COMPATIBILITY

There is concern whether the TDRS/IUS flight requirements and constraints will be compatible with Orbiter capability existing at the time of the planned flight, especially in light of an accelerated OFT program. In certain areas, such as entry, the flight profile generally assumed the availability of Orbiter operational capability - the required capability having been demonstrated during the six-flight OFT program. A reduced OFT program prior to the TDRS/IUS flight may result in placards being placed on Orbiter operations. An Orbiter/TDRS/IUS compatibility assessment with respect to the integrated operations needs to be performed, particularly in the area of thermal requirements and constraints. This assessment needs to be made with respect to the proposed four-flight OFT program.

4.10 PROPULSIVE CONSUMABLES

This document presents the OMS and RCS propellant budgets for the STS-7 mission. In addition, the initial mass properties of the Orbiter component loads at lift-off are given. Finally, an Orbiter mass properties time history is shown at specific events. The tables presented are reproduced from the STS-7 CFP (ref. 2).

The RCS propellant budget shown in table II is the minimum RCS propellant usage for the mission. The forward RCS tanks are loaded at the lowest capacity allowed and show a margin of 478.1 pounds. The aft RCS tanks are loaded at greater than the minimum load allowed. Actually, the minimum total load could be reduced by the 15-pound margin shown. This was not done at the time of the study because this 15-pound difference was not considered significant in terms of making another study. However, this minimum RCS loading does not allow for any growth in the mission RCS maneuvers. Therefore, it is extremely doubtful that this minimum RCS loading philosophy will be used for the mission. It is recommended that both the forward and aft RCS tanks be full loaded for the mission.

The OMS propellant budget given in table III shows the propellant usages for two cases; Case I is the budget for the mission abort after the OMS-2 burn and Case II is the budget for the nominal mission. The primary difference between the two is that in Case I the payload is not deployed. For Case I, the onorbit OMS usage is entirely for the OMS-2 burn. In Case II, the onorbit usage is the sum of the OMS-2 burn and the payload separation burn. The OMS-1 and OMS-2 burns for both cases have the same ΔVs. The OMS deorbit ΔVs are listed in the OMS propellant budget for the two cases. Based on the OMS requirements for the mission, the current OMS load is satisfactory.

Table IV shows the initial mass properties of the Orbiter component loads. All of these values are subject to change. The RCS propellant load will probably be increased as further FTR's and maneuvers are added to the mission. The nonpropulsive consumables load will be changed as mission requirements become more clearly defined. Finally, the payload weight is subject to change.

Table V shows the Orbiter mass properties at important events during the mission for the two cases discussed above. The Orbiter mass properties at entry interface show that the X c.g. for each case is well within the allowable limits of 1083.2 and 1109.0 inches.

4.11 NONPROPULSIVE CONSUMABLES

The nonpropulsive consumables level A compatibility assessment for STS-7 has been performed. The results of this assessment are presented in table V. A water management profile is shown in figure 8, and an environmental control incompatibility/solution table is presented in table VI.

4.12 NAVIGATION

4.12.1 Early Return Contingency

In the event that either the PLBD or star tracker doors do not open, the mission must be terminated. A navigation vector cannot be provided to support a 3:25 GET landing at KSC. However, an adequate navigation vector is available to support an EAFB landing at 4:40 GET.

4.12.2 IUS/TDRS Deployment

A navigation vector can be provided to support the nominal IUS/TDRS-A deployment on orbit 8 (10:05 GET) and the backup opportunity on orbit 10. An adequate navigation vector cannot be provided to support the one-revolution later deployment on orbit 9.

For the next day ascending case deployment, a navigation vector can be provided to support IUS/TDRS deployment (22:33 GET) provided DOD C-band support is available.

4.12.3 Deorbit

Should a real-time decision be made to deorbit the first day, orbits 18 and 19 can be used for deorbit provided DOD C-band support is available. Ground navigation support is marginal for supporting a KSC landing on orbit 17. Adequate ground navigation support cannot be provided to support earlier KSC landing opportunities (orbits 15 and 16).

The nominal deorbit opportunity (orbit 31) has poor navigation support even with DOD C-band support. Very little tracking data are available above 3 degrees elevation and if Orral Valley (ORR) should fail during this critical period, navigation would not be able to provide an adequate navigation vector.

The remaining landing opportunities for second-day deorbit appear to be acceptable (from a navigation viewpoint) provided DOD C-band support is available. If this C-band support is not available, landing during orbits 33 and 34 would be preferred (from a navigation viewpoint).

5.0 REFERENCES

1. STS Flight Assignment Manifest. JSC-13000-0-6P, Apr. 30, 1979.

2. STS-7 Conceptual Flight Profile. JSC-15045, June 1979.

TABLE I.- CURRENT SRM PARTICLE DAMAGE LIMITS FOR STANDARD SEPARATION SEQUENCE DESIGN

Orbiter surface type	Erosion (percent of surface area)		Breakage (Breaks per square foot)	
	Lifetime limit	Per-firing limit[a]	Lifetime limit[b]	Per-firing limit[a]
Window	2	0.015	9.7	0.072
Low-temperature thermal protection tile	10	.074	1.6	.012
High-temperature thermal protection tile	10	.074	.9	.007

[a]Based on 135 SRM firings during lifetime.
[b]Equal to expected breakage from micrometeoroids during 421 days onorbit.

TABLE II.- MINIMUM RCS PROPELLANT BUDGET

Propellant usage, lb	Forward	After	Total
ET separation (4 fps)	57.2	114.5	171.7
Orbit trim maneuvers (15 fps)	4.5	406.3	410.8
PL separation (3.8 fps)	96.9	75.5	172.4
Additional prop for ascending node PL sep	47.0	69.0	116.0
Attitude maneuvers	425.3	956.5	1381.8
Deorbit maneuvers	.0	1181.2	1181.2
Total usable required	630.9	2803.0	3433.9
Trapped, display and control	492.0	942.0	1434.0
Total required	1122.9	3745.0	4867.9
Total load	1601.0	3760.0	5361.0
Margin[a]	478.1	15.0	493.1

[a]Maximum RCS load available = 7508 pounds.

TABLE III.- OMS PROPELLANT BUDGET

	Case I (mission with payload at landing)				Case II (mission without payload at landing)			
	V, fps	Oxidizer, lb	Fuel, lb	Total, lb	V, fps	Oxidizer, lb	Fuel, lb	Total, lb
Insertion	211	3 245	1967	5 212	211	3 245	1967	5 212
Onorbit	169	2 495	1512	4 006	238	3 319	2012	5 331
Deorbit	297	4 236	2568	6 804	273	3 185	1931	5 116
Total usable required	677	9 976	6047	16 022	722	9 749	5910	15 659
Total display and control		454	312	766		452	306	758
Total trapped		584	307	891		584	307	891
Total required		11 014	6665	17 679		10 785	6522	17 307
Total load		11 021	6679	17 700		11 021	6679	17 700

TABLE IV.– ORBITER MASS PROPERTIES DURING THE MISSION

	Case I (mission with payload at landing)				Case II (mission without payload at landing)			
	Weight, lb	X_{cg}, in.	Y_{cg}, in.	Z_{cg}, in.	Weight, lb	X_{cg}, in.	Y_{cg}, in.	Z_{cg}, in.
Lift-off	251 908.6	1119.4	-0.2	382.8	251 908.6	1119.4	-.2	282.8
OP OMS-1	251 550.8	1119.4	-.2	382.8	251 550.8	1119.4	-.2	382.8
OA OMS-1	246 338.3	1113.3	-.2	380.8	246 338.3	1113.3	-.2	380.8
OP OMS-2	240 928.3	1107.0	-.3	381.4	240 928.3	1107.0	-.3	381.4
OA OMS-2	236 921.4	1101.7	-.3	379.8	236 921.4	1101.7	-.3	379.8
OP PL deployment					235 485.6	1101.7	-.4	379.4
OA PL release					194 140.6	1113.1	.0	376.3
OP PL sep burn					193 999.7	1113.5	.0	376.2
OA PL sep burn					192 675.9	1111.3	.0	375.6
OP deorbit burn	234 261.8	1102.4	-.3	379.5	191 400.4	1112.2	.0	375.5
OA deorbit burn	227 458.1	1092.2	-.3	376.6	186 284.6	1103.1	.0	372.8
Entry interface	225 804.7	1090.7	-.3	376.0	184 631.2	1101.3	.0	372.1

OP = Orbiter prior.
OA = Orbiter after.

TABLE V.- STS-7 TDRS COMPATIBILITY ASSESSMENT

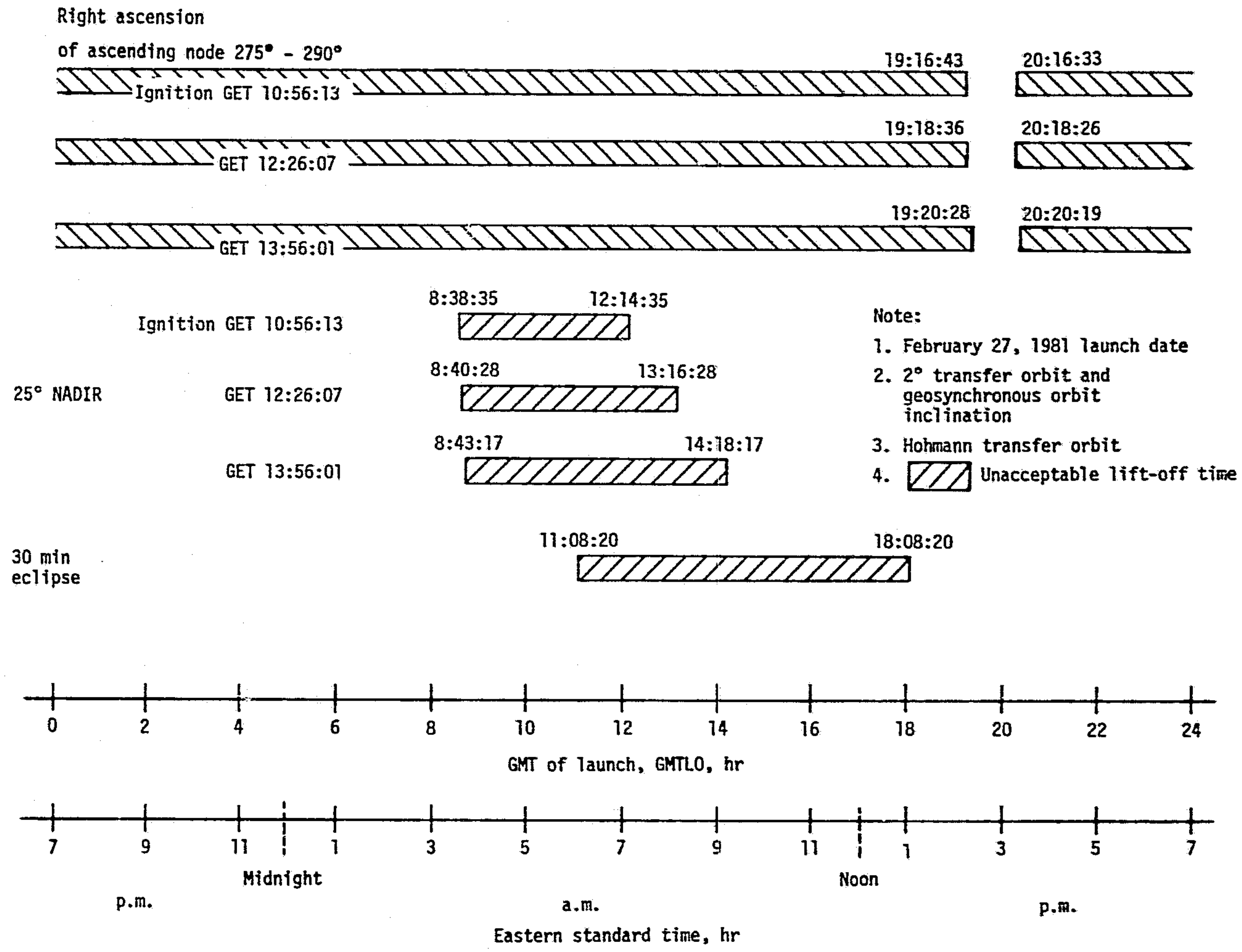
Nonpropulsive consumables

Consumables	Type of requirement	Quantity
Electrical power	Power level	18.3 kw average
	Energy	1267. kwh
	Voltage/current	Acceptable
	Fuel/cell reactants	Two tank sets
Environmental (cabin)	Air temperature	Nominal
	Air mixture	Nominal
	Humidity	Nominal
	Water loop temperature	Nominal
	Water storage	A waste water dump is required at <4 hr GET; A potable water dump is required at <28 hr GET
Active thermal control	Freon temperature	Nominal
	Radiator	Supplemental flash evaporator cooling required
	Flash evaporator water	Acceptable
	Ammonia cooling	Acceptable

TABLE VI.- STS-7 COMPATIBILITY ASSESSMENT

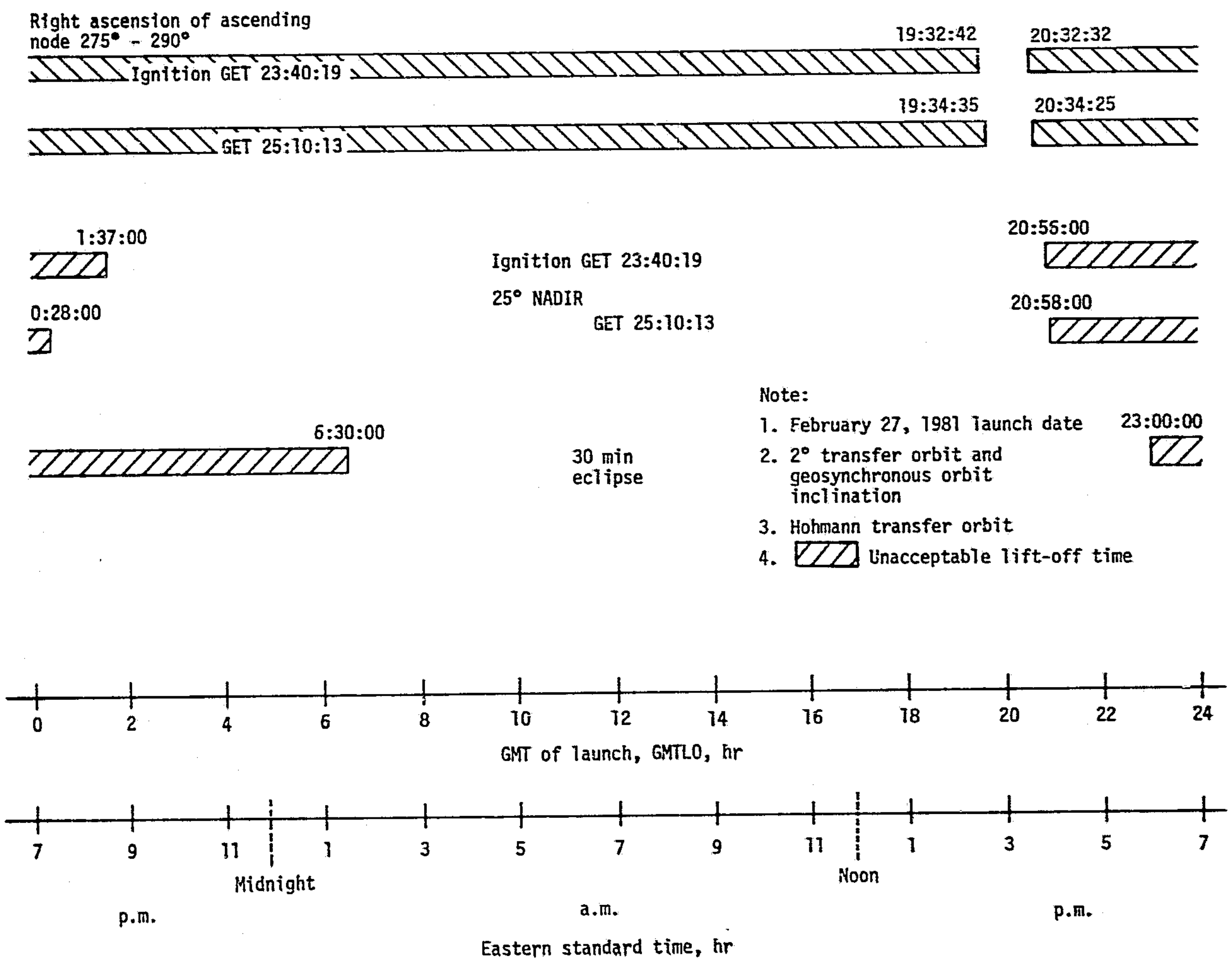
Environmental control

Incompatibility	Solution
Deployment of payload requires a period with no maneuvering; it is assumed that this precludes water dumps	Mission planning must accommodate one water dump between normal PLBD opening and T + 4-hr GET and two dumps a day during flight
If "no maneuvering periods" also require inhibiting the flash evaporator operation o Current ATCS freon temperature will have a heat sink outlet temperature >40° o Cabin and avionics bay temperature limits may be exceeded o Payload freon loop temperature may exceed limits	More detailed temperature assessment should be performed once mission requirements have matured



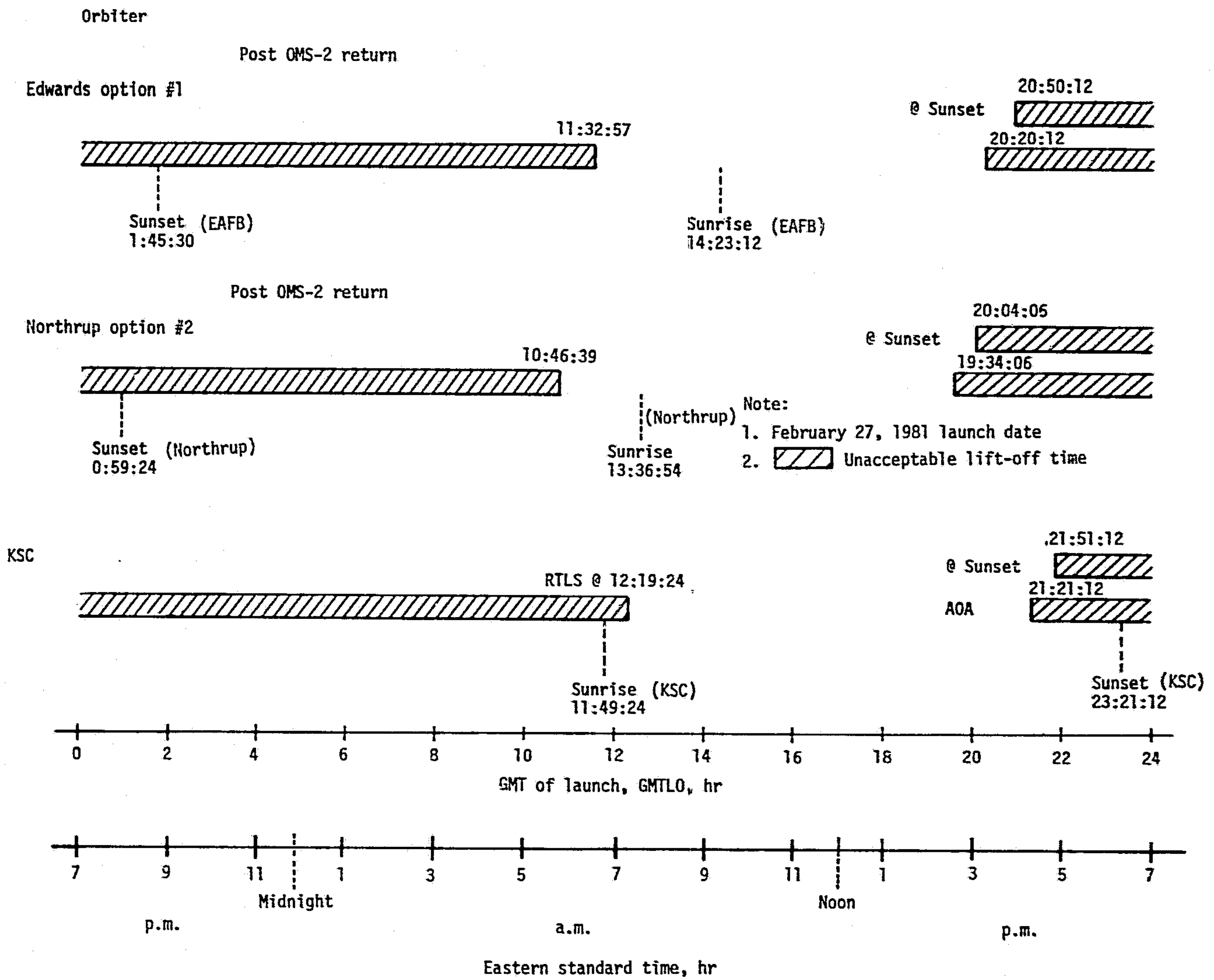
(a) TDRS descending node injection.

Figure 1.- STS-7 launch window.



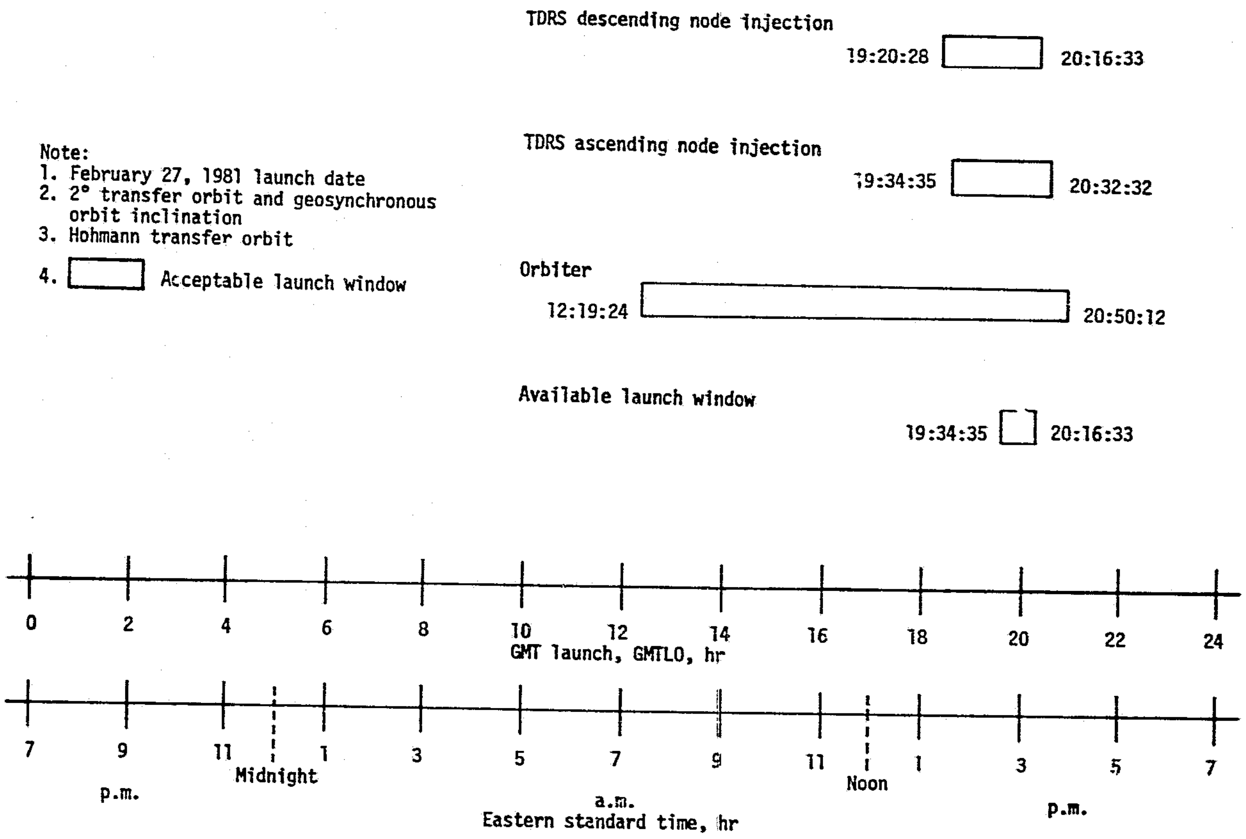
(h) TDRS ascending node injection.

Figure 1.- Continued.



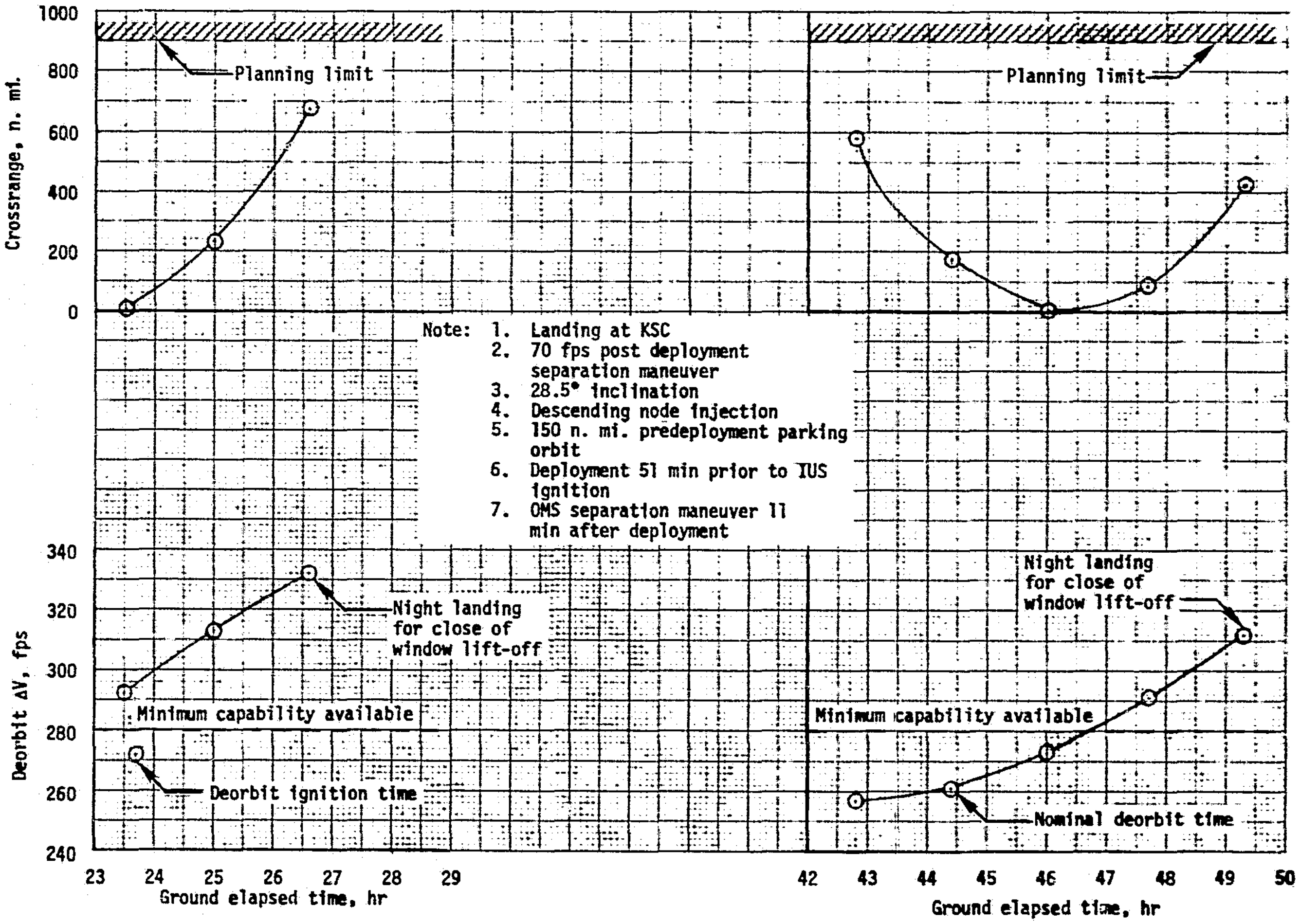
(c) Orbiter abort lighting.

Figure 1.- Continued.



(d) STS-7 launch window composite.

Figure 1.- Concluded.



(a) One day flight.

(b) Nominal two day flight.

Figure 2.- Deorbit performance requirements for 53° west descending node injection.

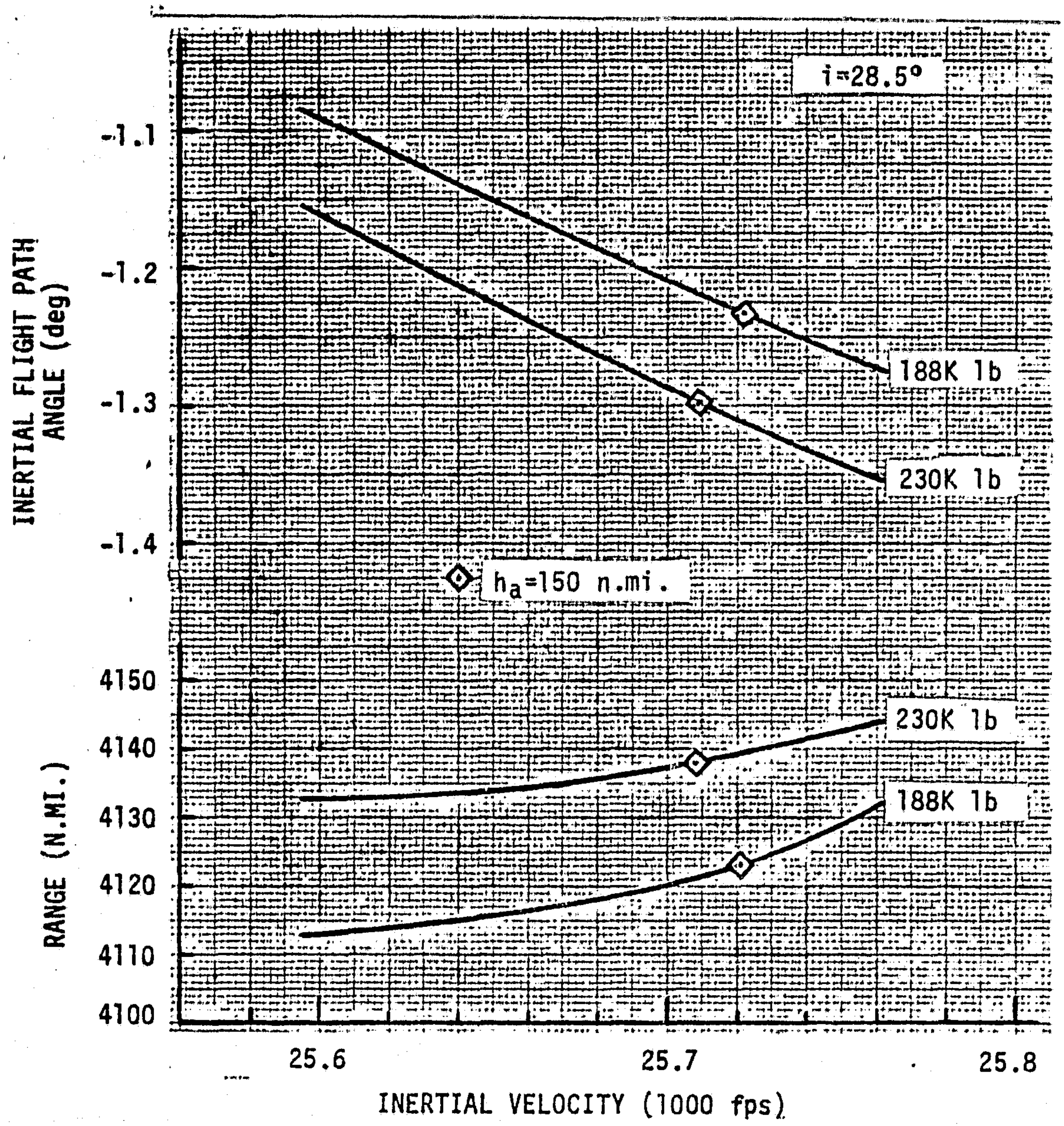


Figure 3.- Entry interface conditions for STS-7 conceptual profile.

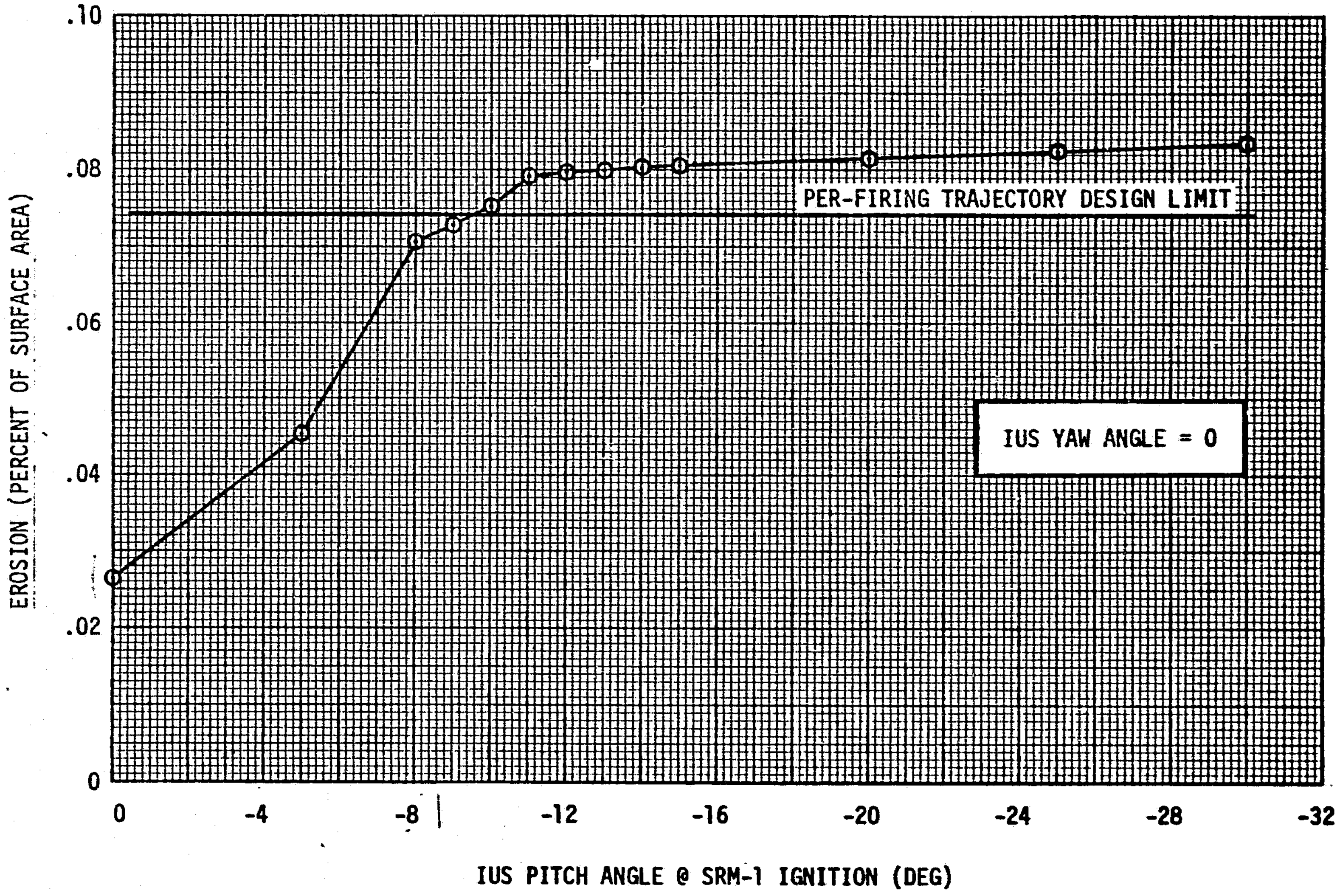


Figure 4.- Effect of IUS pitch angle on hi-temp tile erosion.

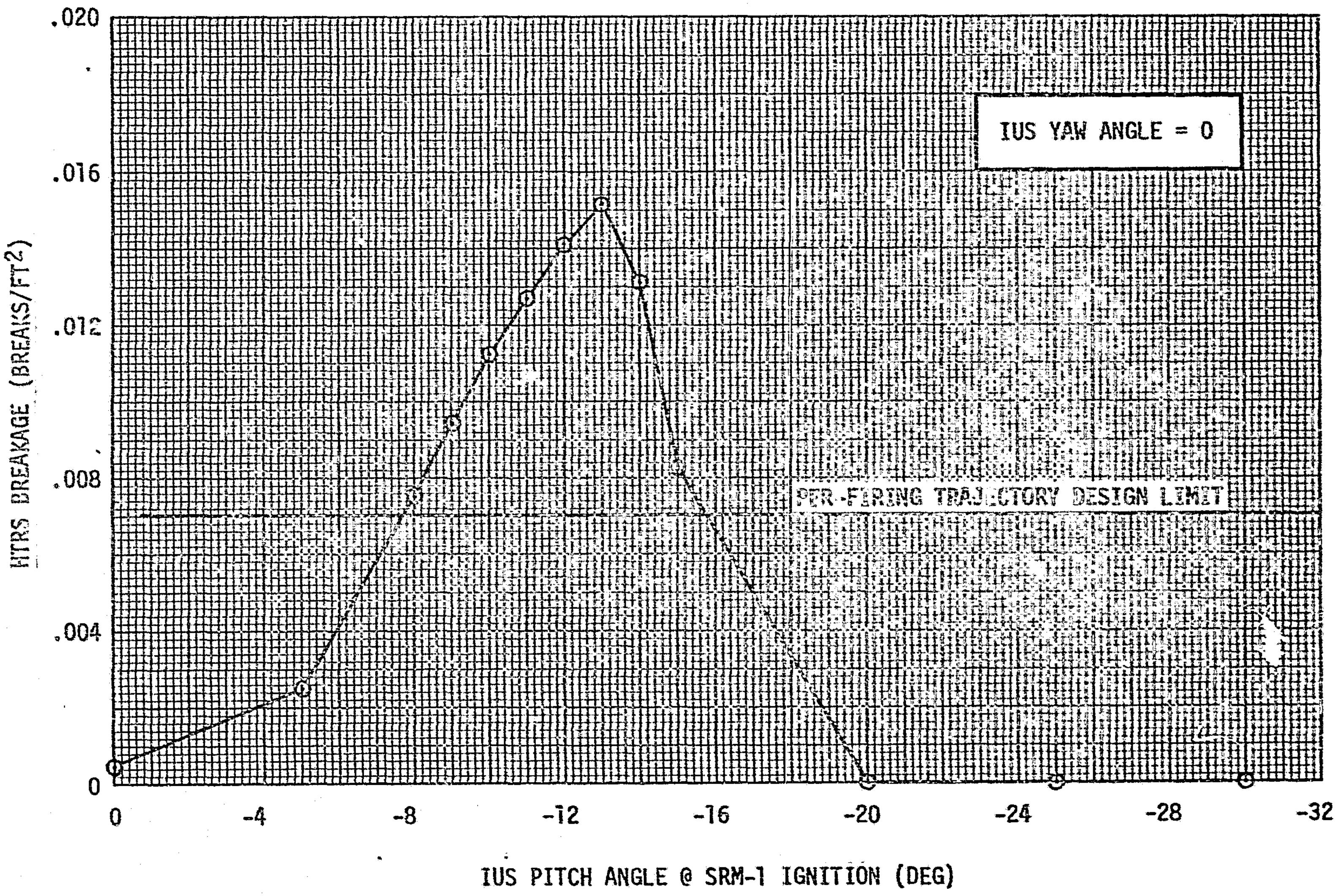
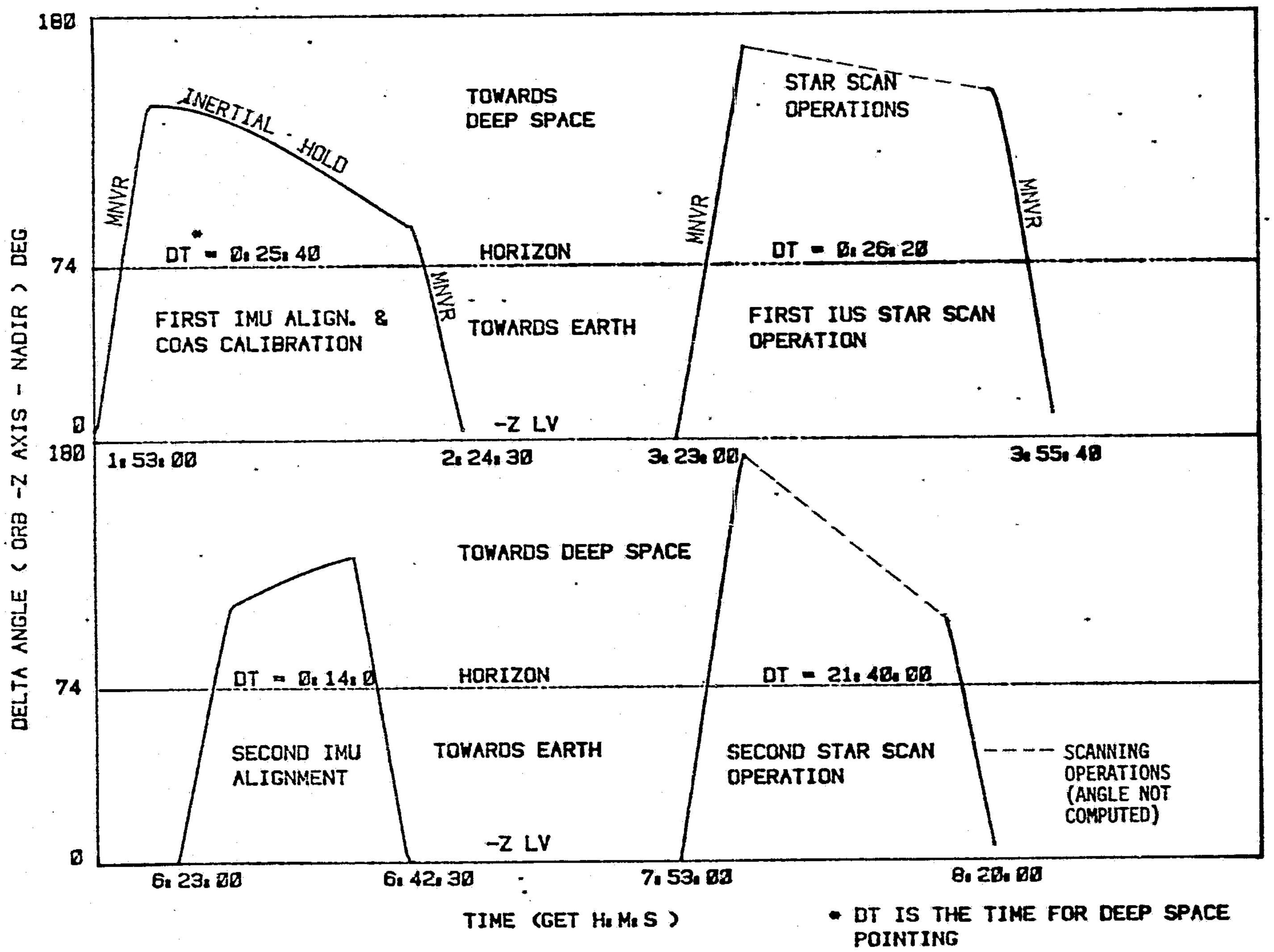
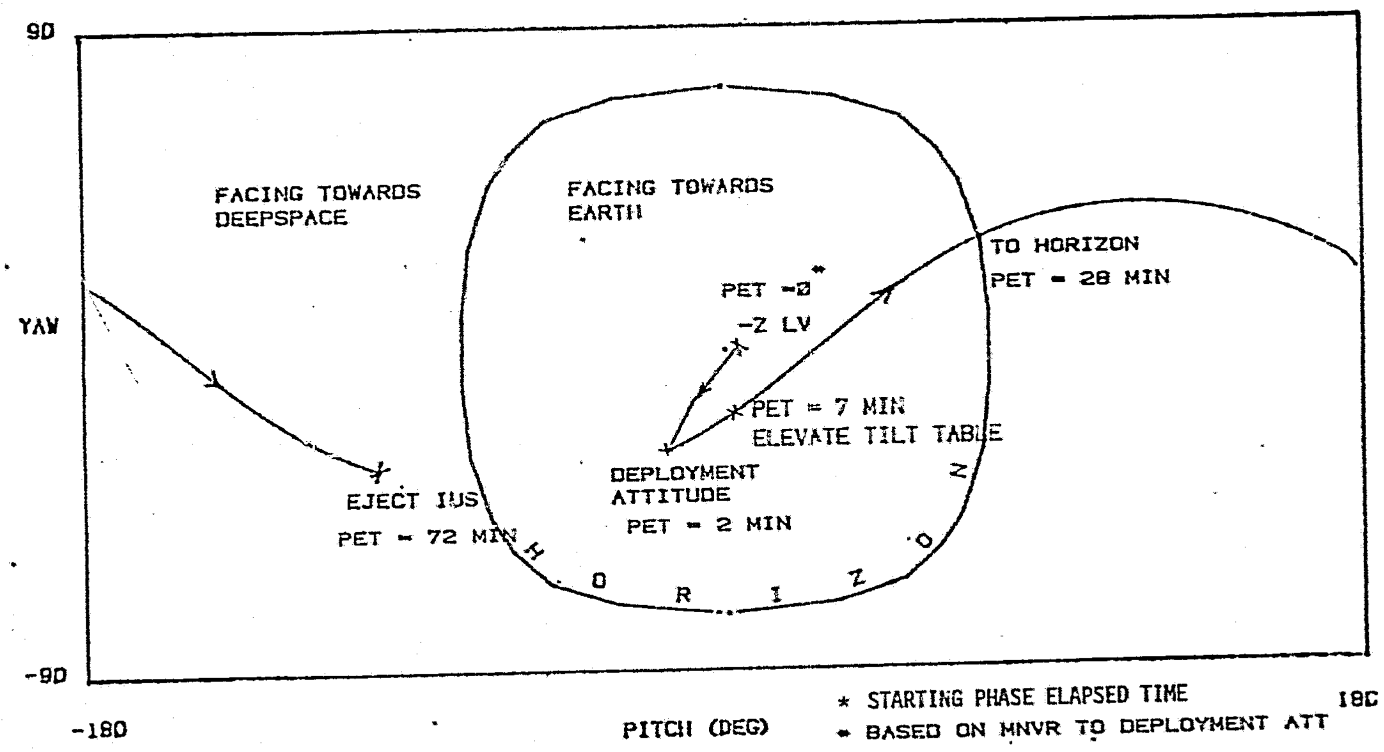


Figure 5.- Effect of IUS pitch angle on hi-temp tile breakage.



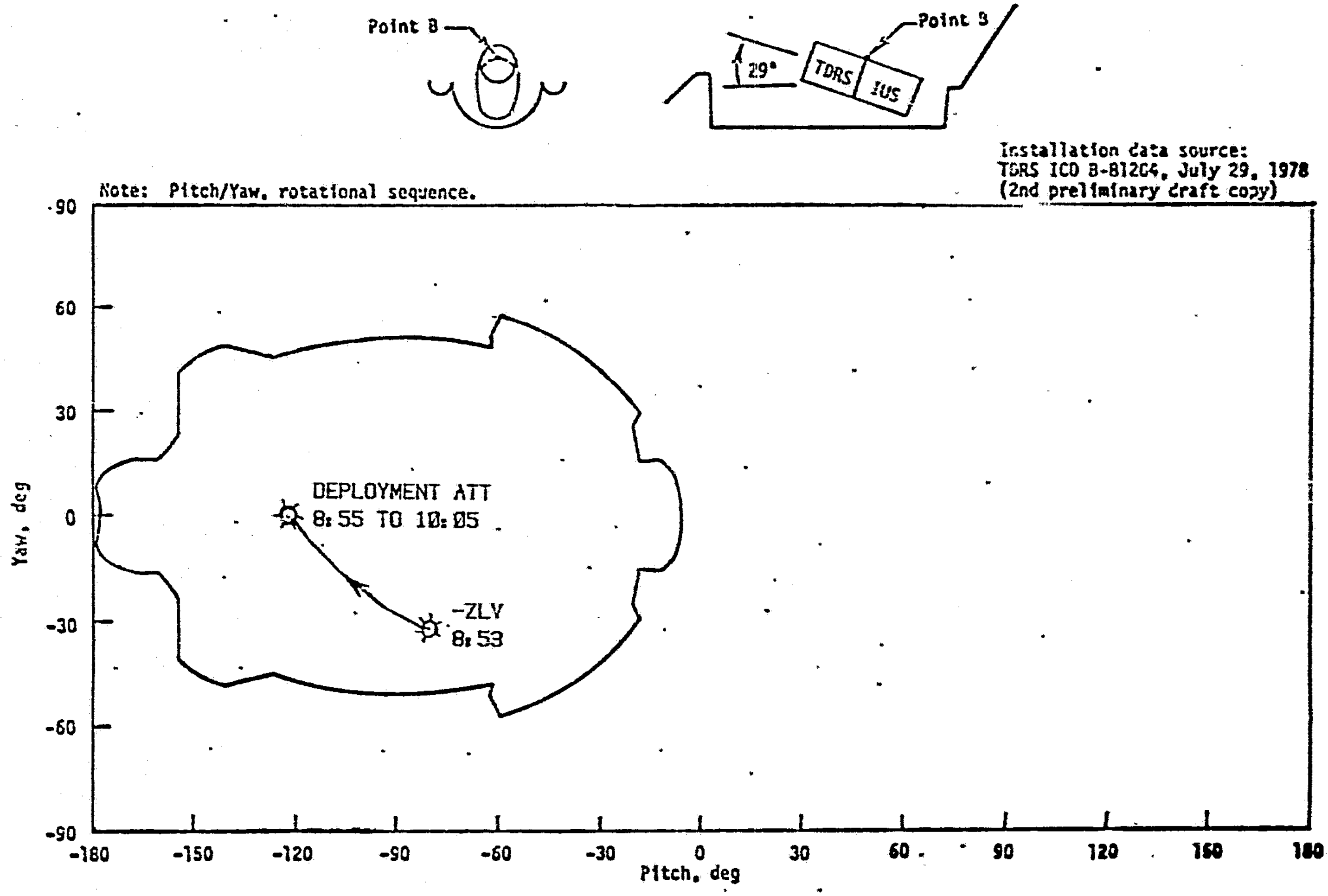
(a) Deep space facing of the Orbiter payload bay for different operations.

Figure 6.- Attitude and pointing.



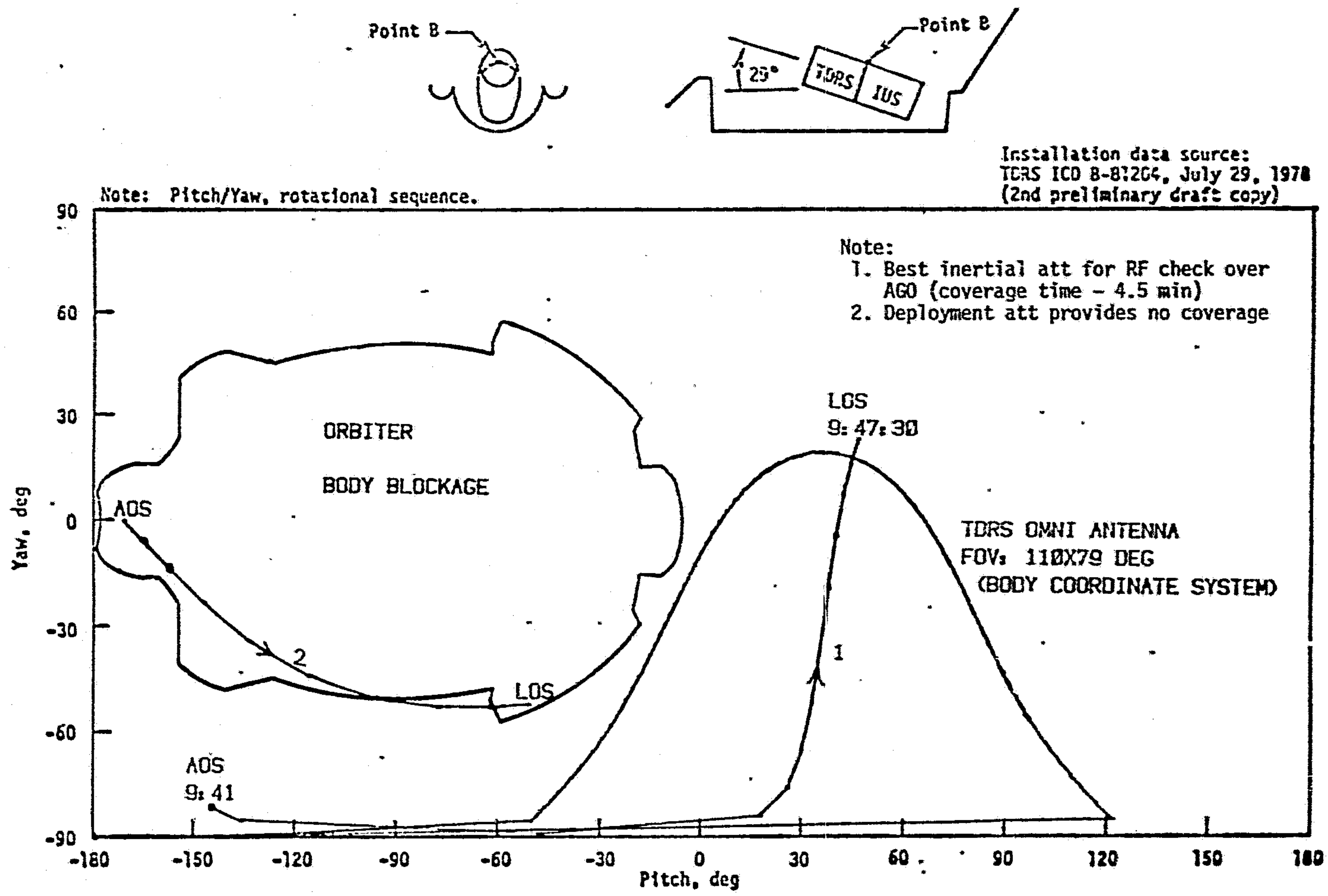
(b) Total deep space facing with raised tilt table is 44 minutes.

Figure 6.- Continued.



(c) Position of sun in Orbiter body blockage while maneuvering from -ZLV to deployment attitude.

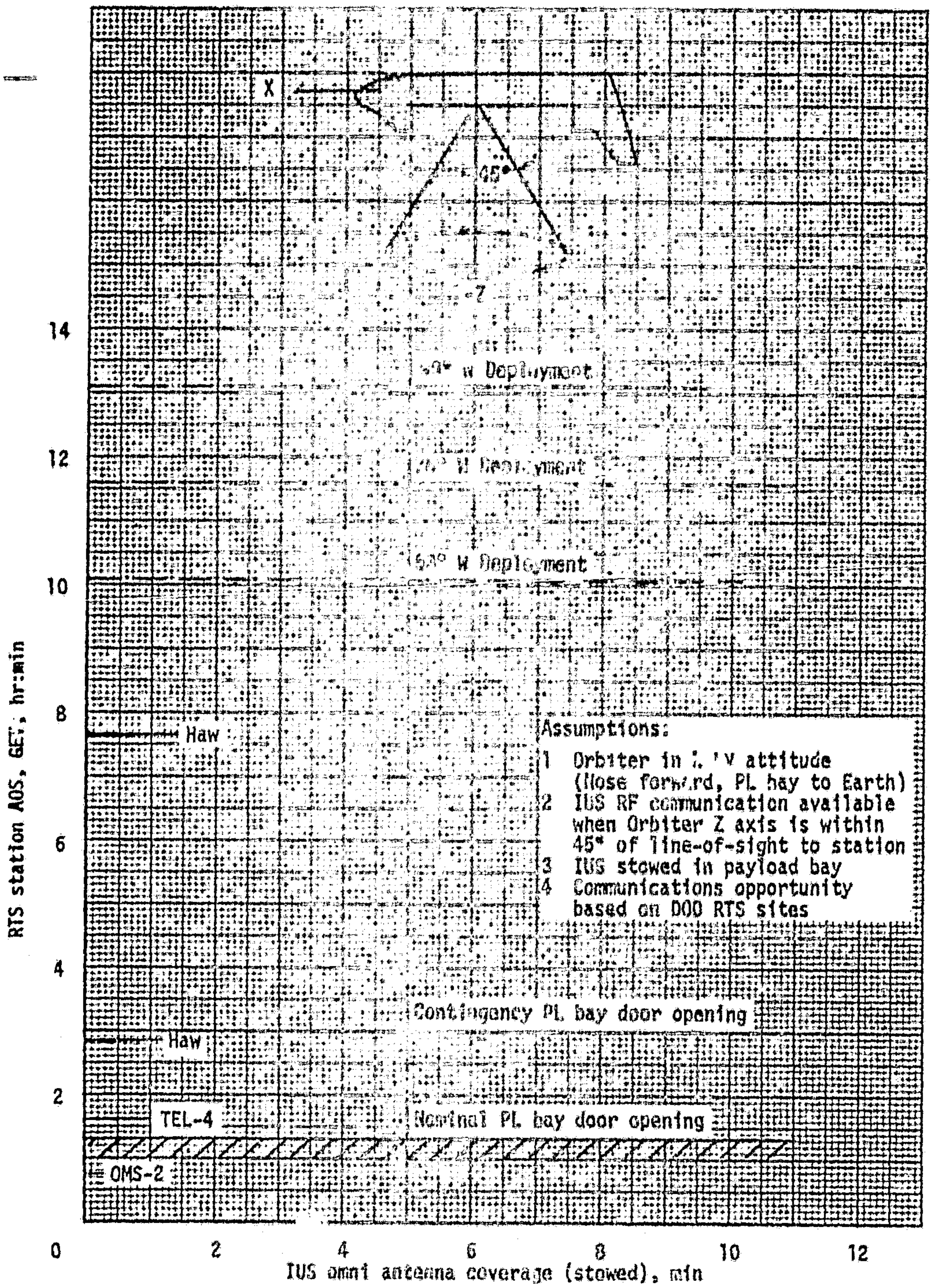
Figure 6.- Continued.



(d) Position of AGO in TDRS antenna beam for two different inertial attitudes.

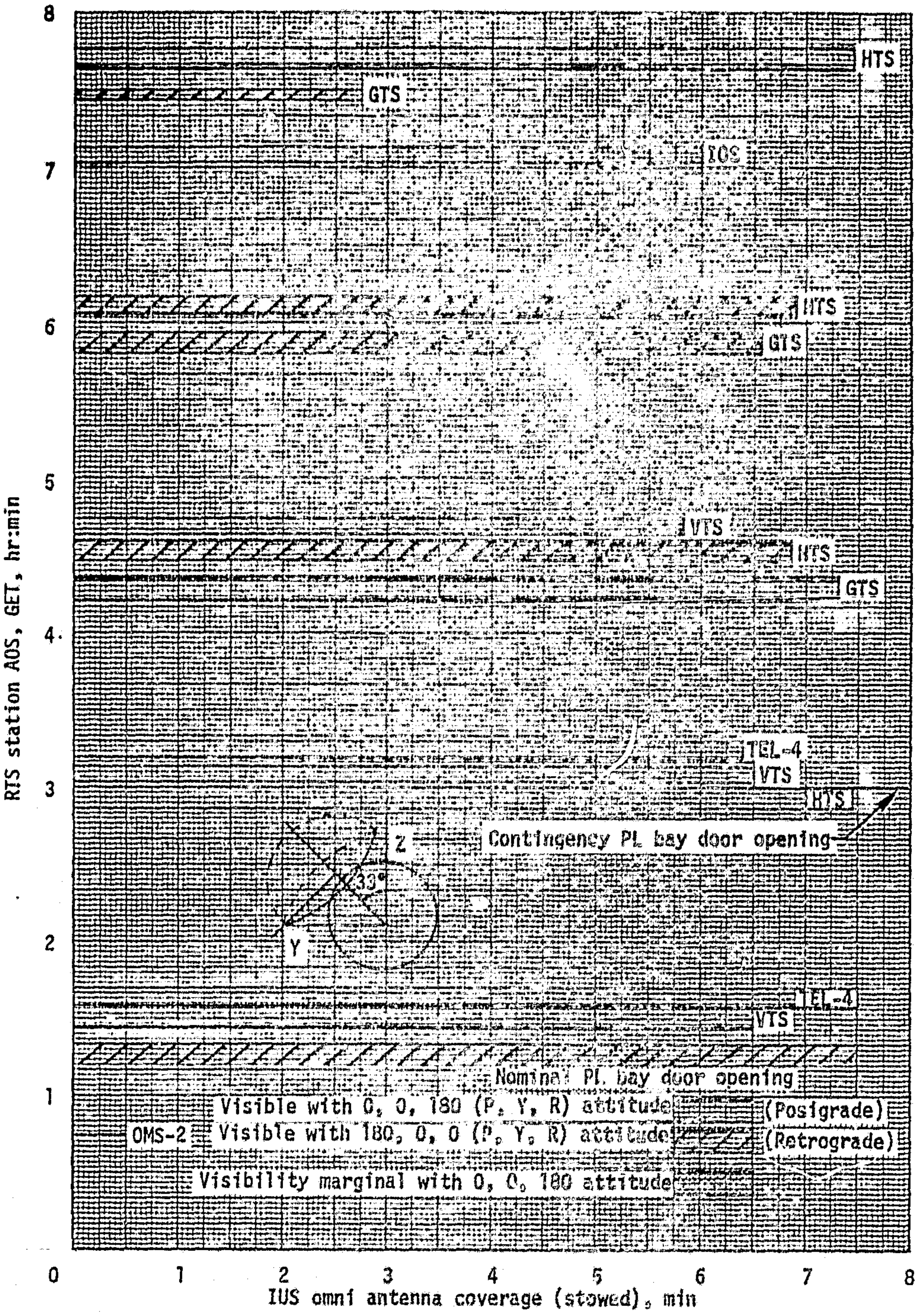
Figure 6.- Continued.

ORIGINAL PAGE IS
OF POOR QUALITY



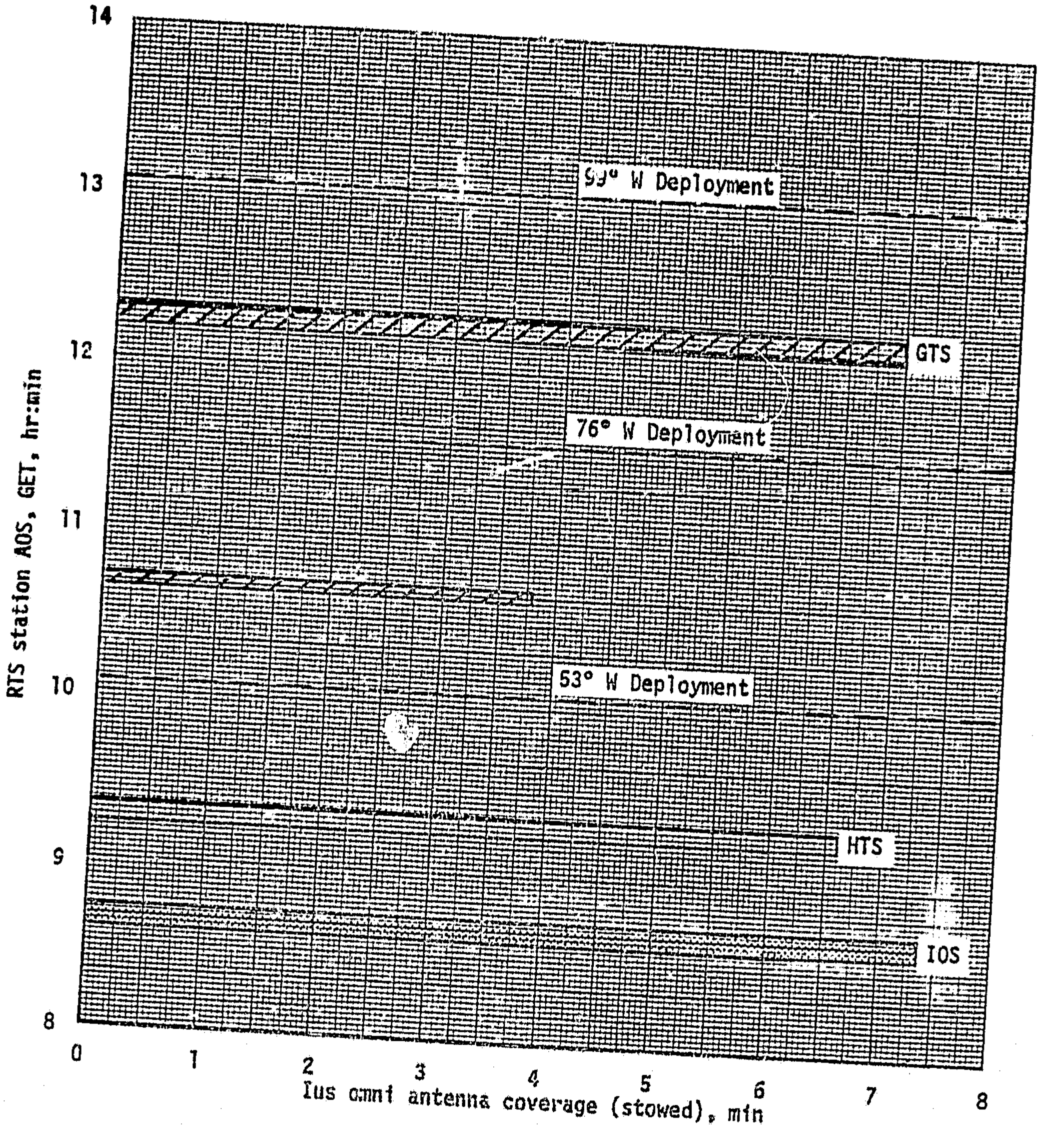
(e) 45° field of view.

Figure 6.- Continued.



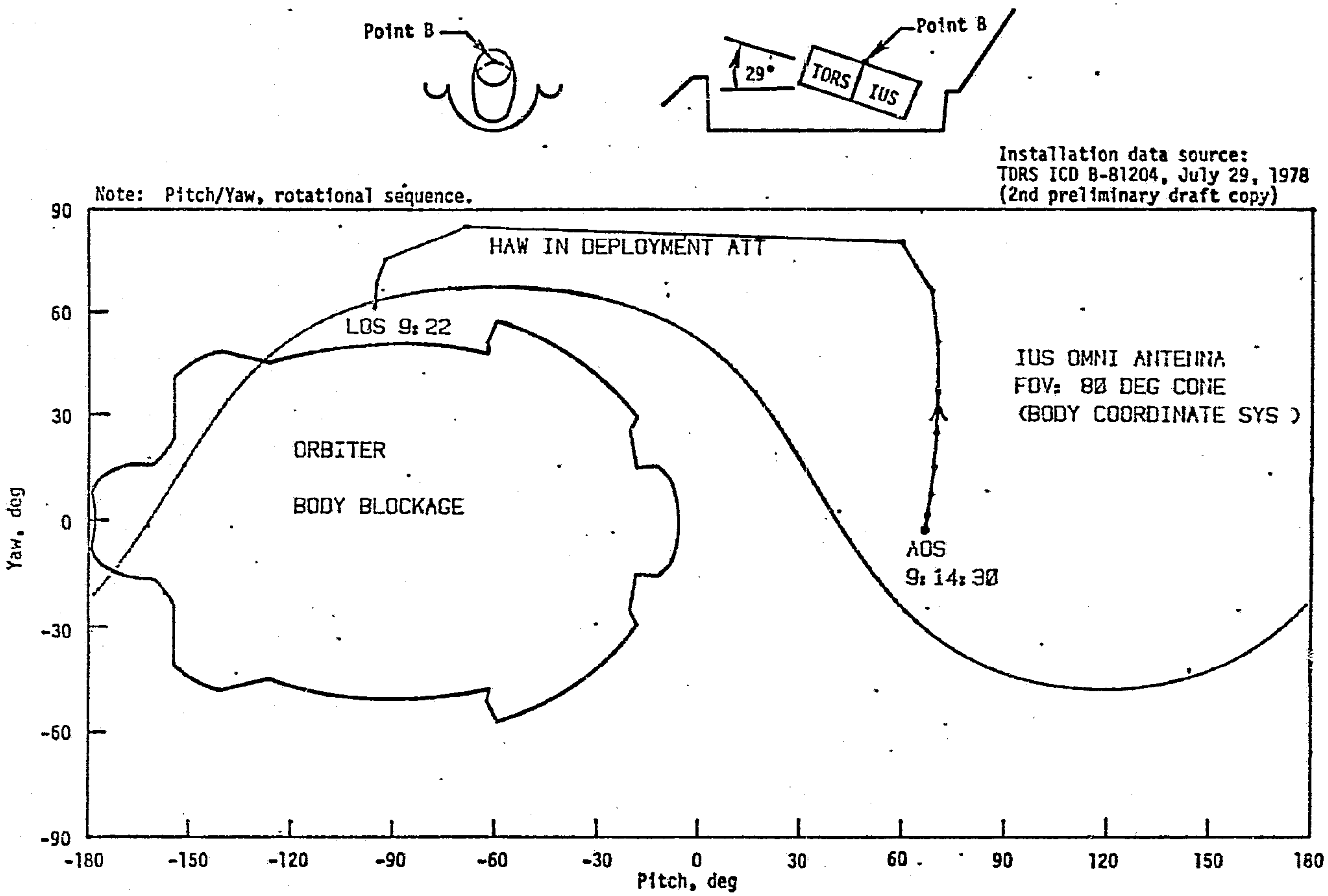
(f) Assumed hemispherical omni field of view.

Figure 6.- Continued.



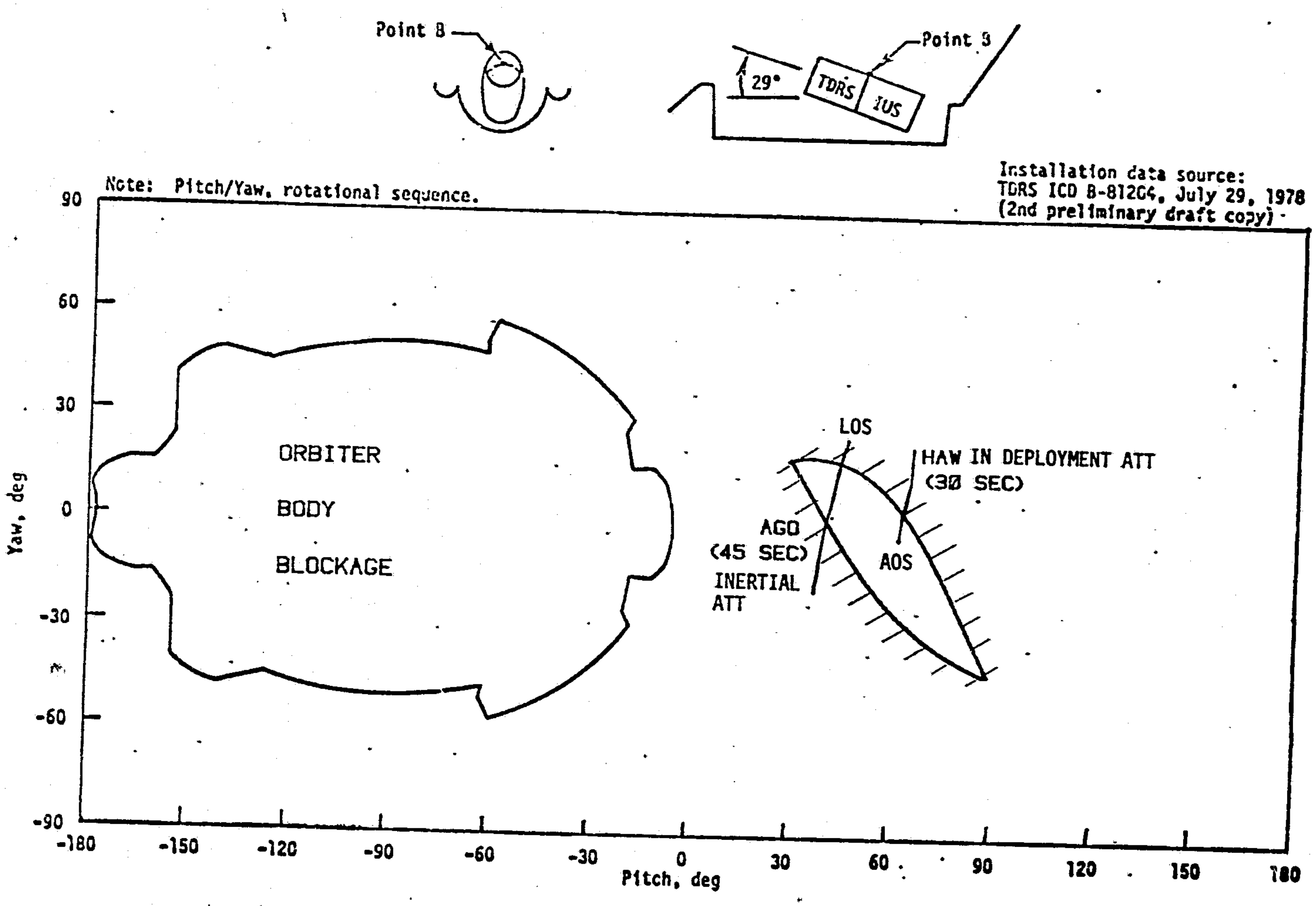
(f) Concluded.

Figure 6.- Continued.



(g) Position of HAW in IUS omni antenna FOV and relative to the body blockage.

Figure 6.- Continued.



(h) Overlap of FOV for TDRS and IUS omni antennas.

Figure 6.- Concluded.

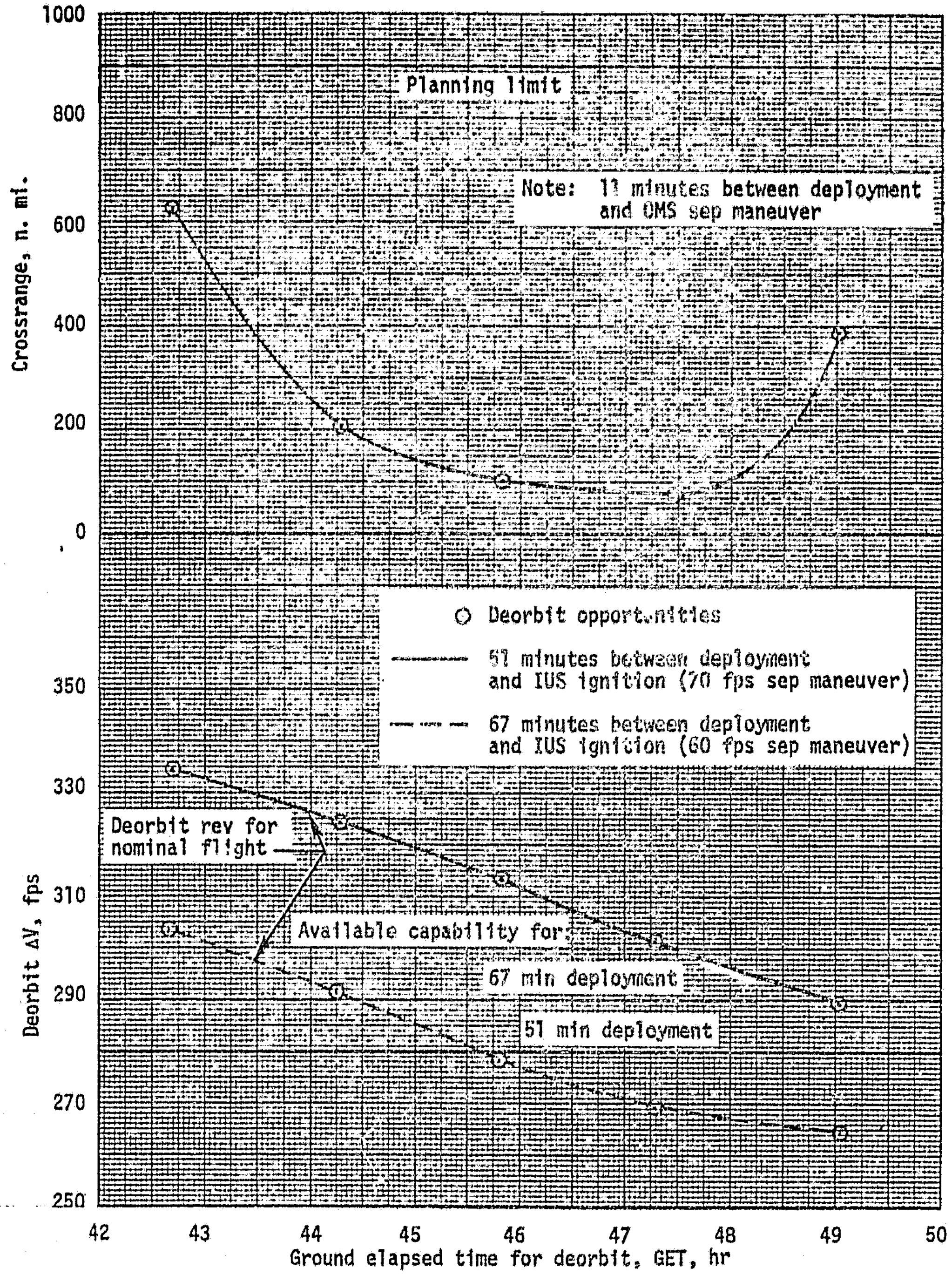
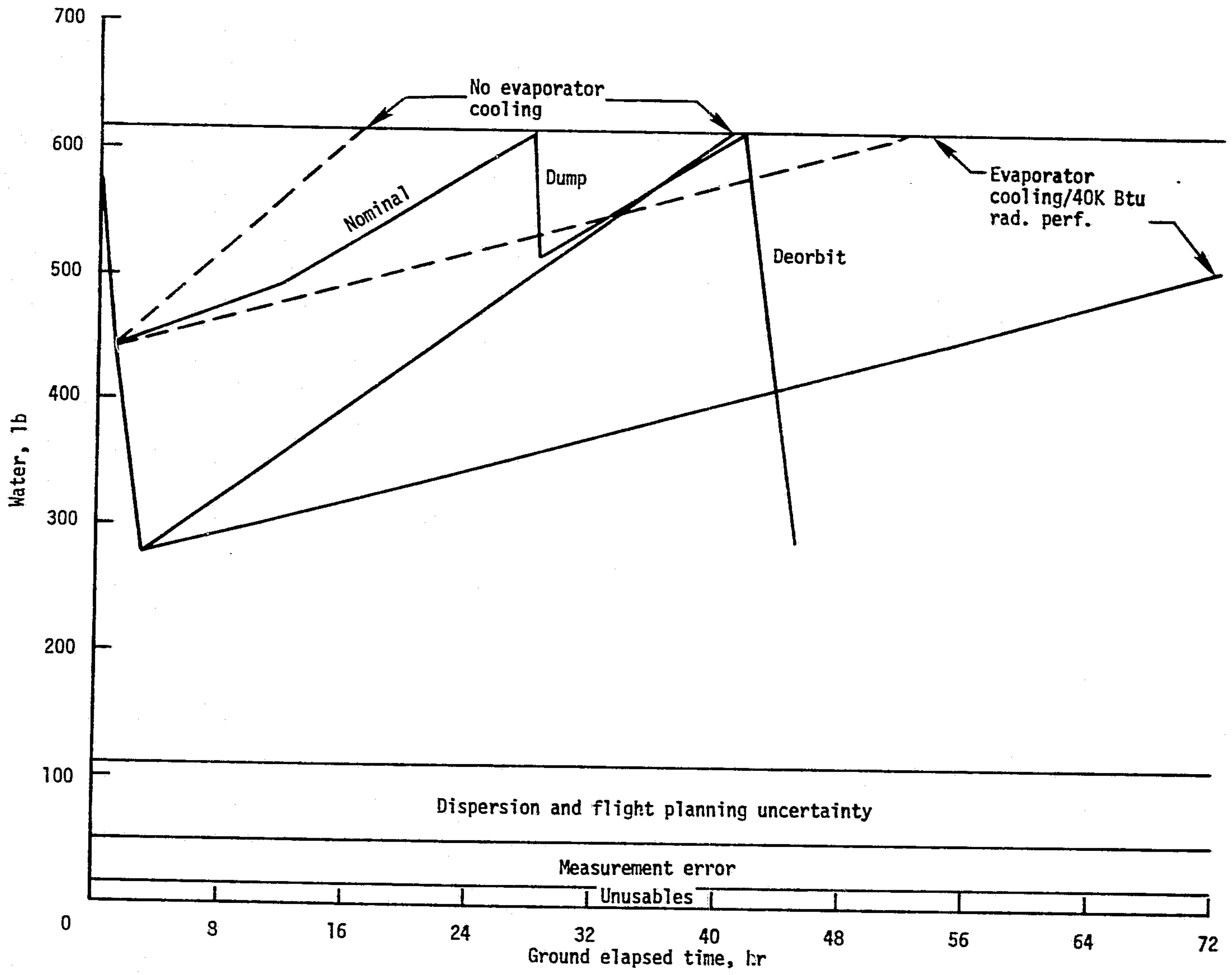
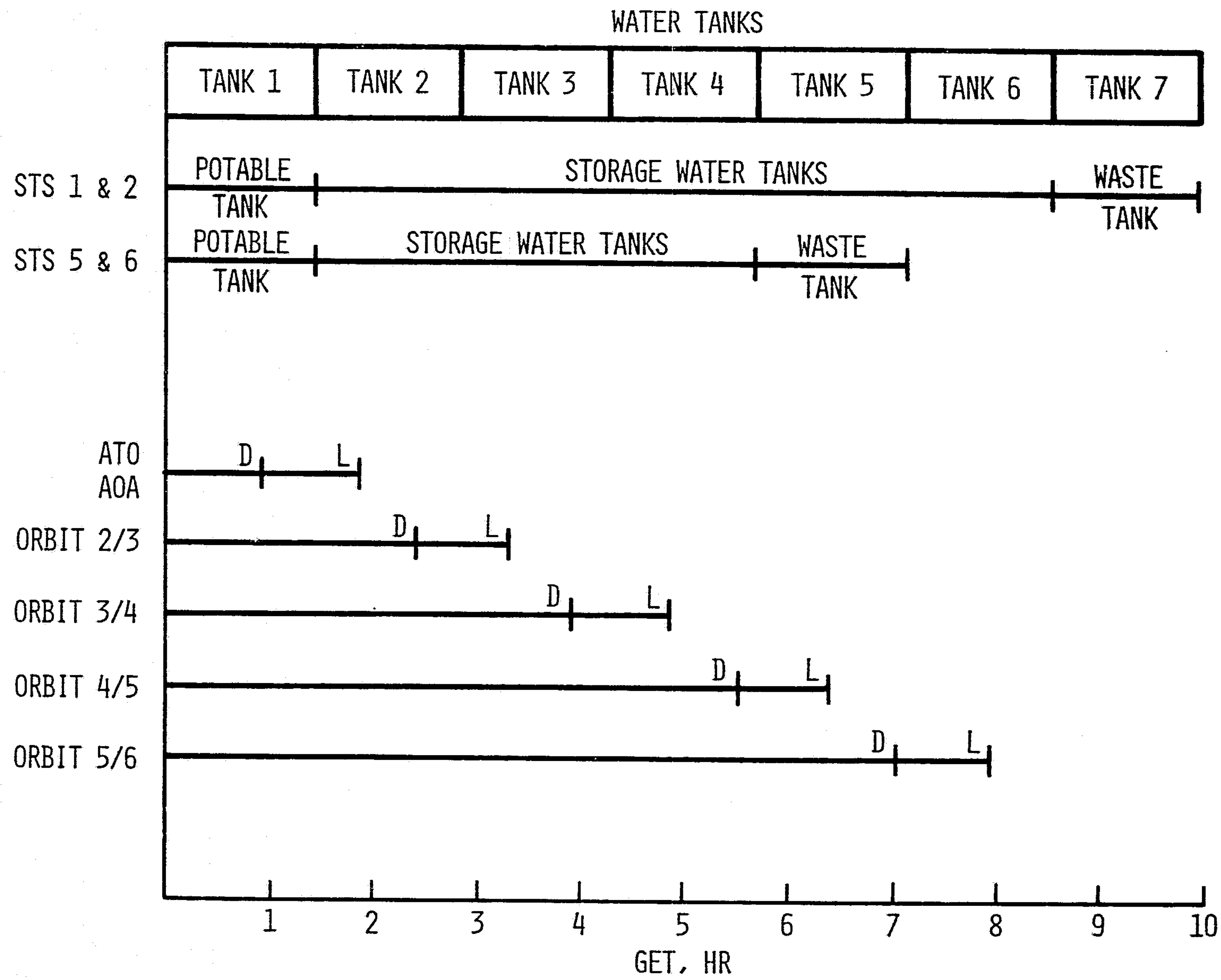


Figure 7.- Deorbit ΔV requirements for ascending node injection opportunity.



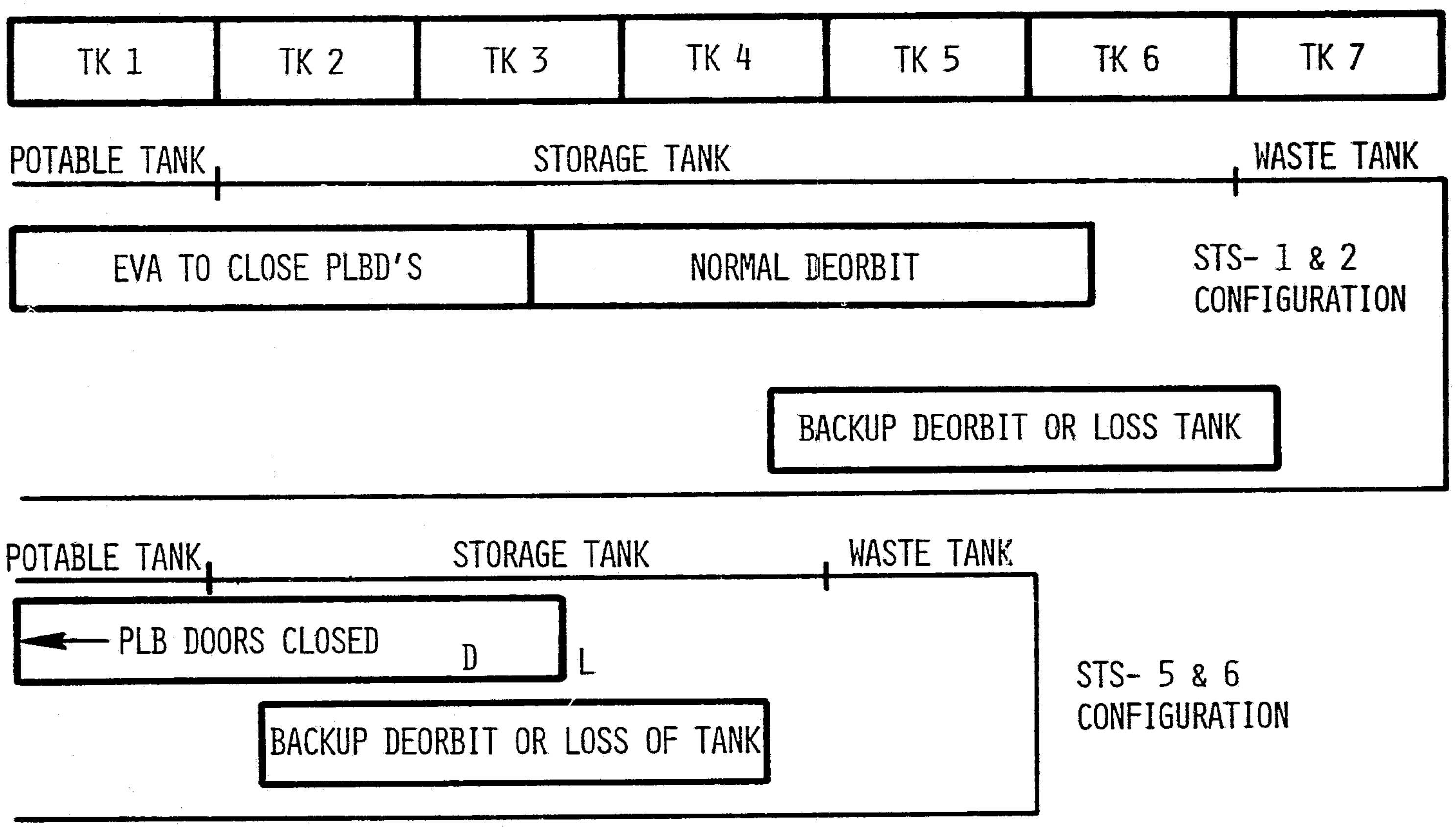
(a) Flight 7 TDRS - potable H_2O profile.

Figure 8.- Nonpropulsive consumables.



(b) Shuttle payload bay door opening timeline for ascent.

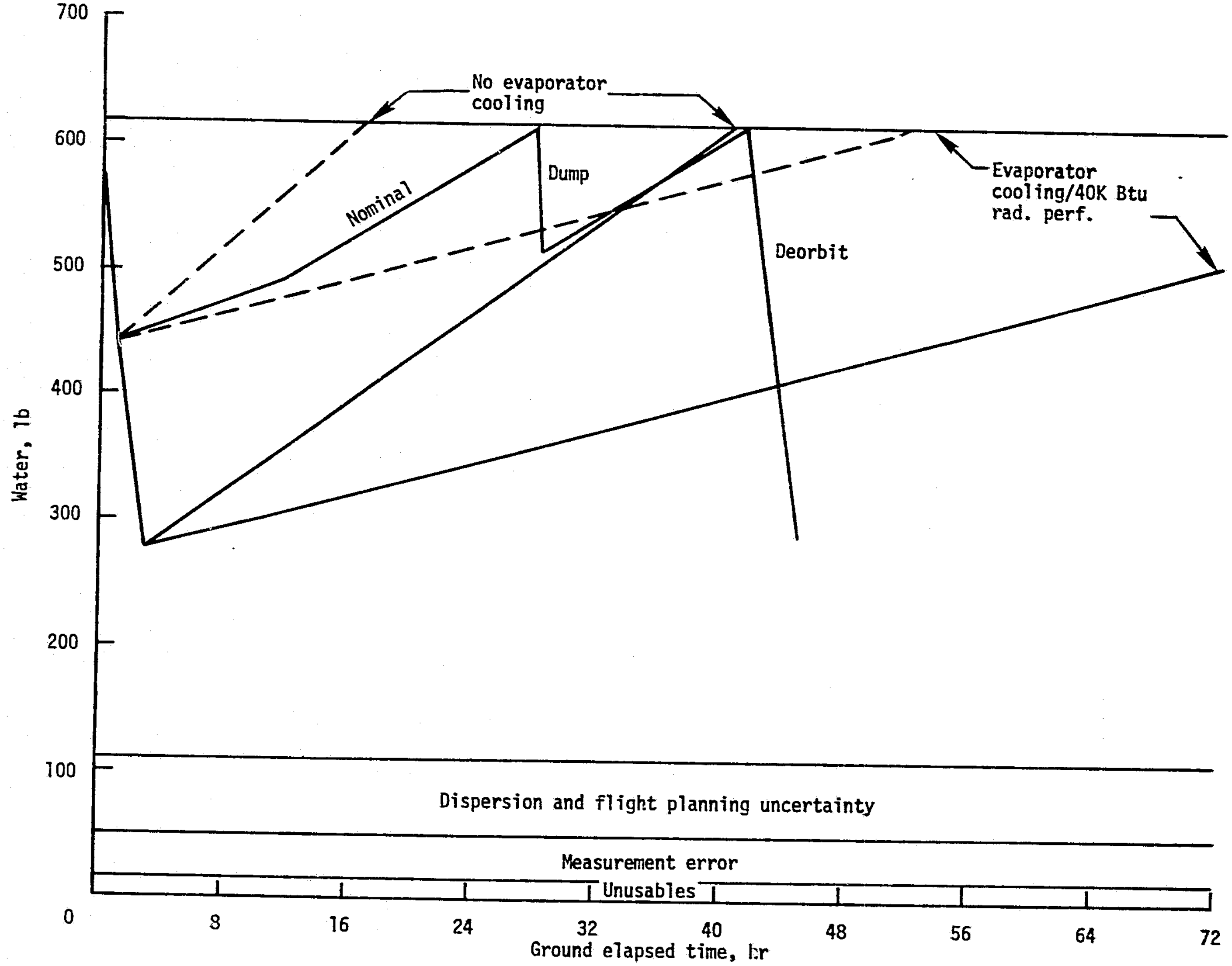
Figure 8.- Continued.



(c) Shuttle payload bay closing timeline descent.

Figure 8.- Concluded.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1979—671-014/1626



(a) Flight 7 TDRS - potable H_2O profile.

Figure 8.- Nonpropulsive consumables.