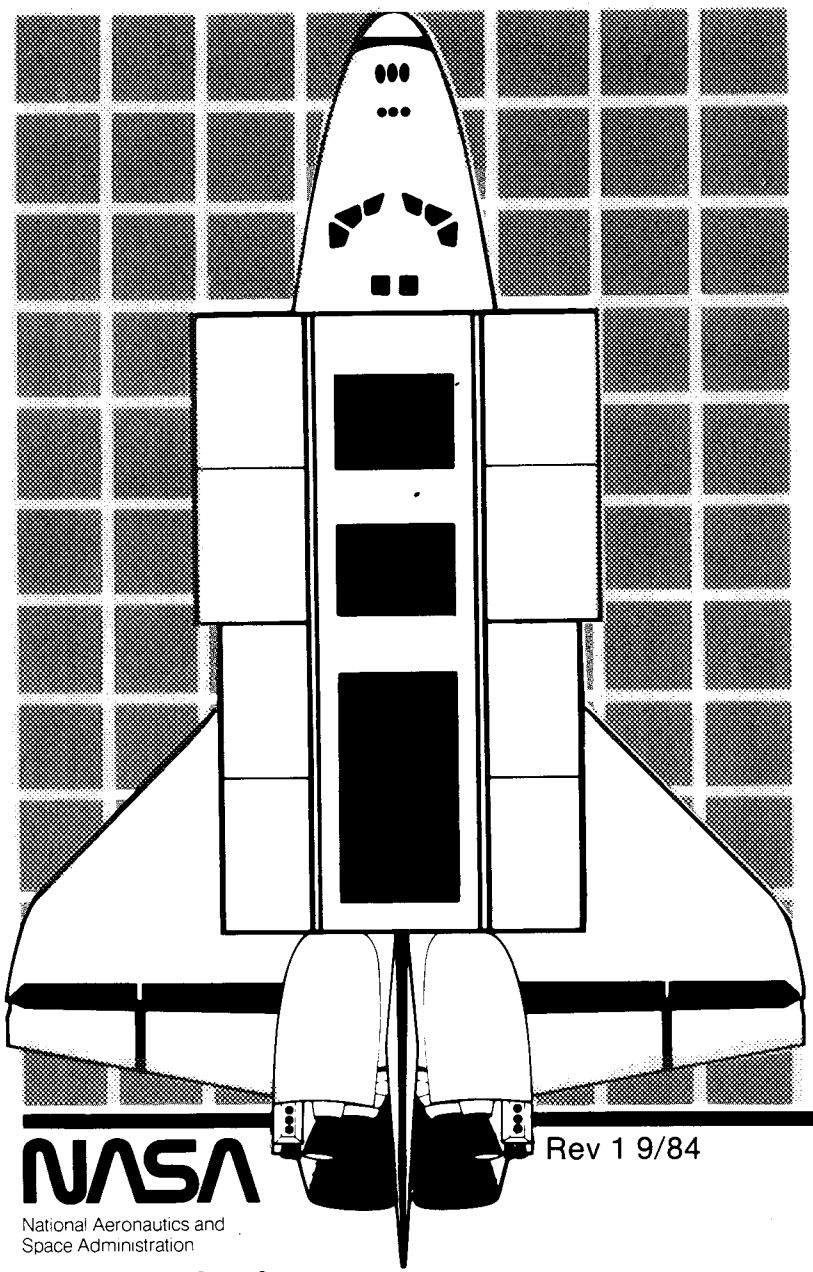
NASA-TM-108267



SPACE SHUTTLE PAYLOAD

JSC-20052
VOLUME 9

7N-16-TM
168522
p. 41

DESIGN AND DEVELOPMENT

(NASA-TM-108267) SPACE SHUTTLE PAYLOAD DESIGN AND DEVELOPMENT. VOLUME 9: THERMAL INTERFACES AND REQUIREMENTS (NASA) 41 p

N94-70373

Unclas

Z9/16 0168522

THERMAL INTERFACES AND REQUIREMENTS

Rev 1 9/84

NASA
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center

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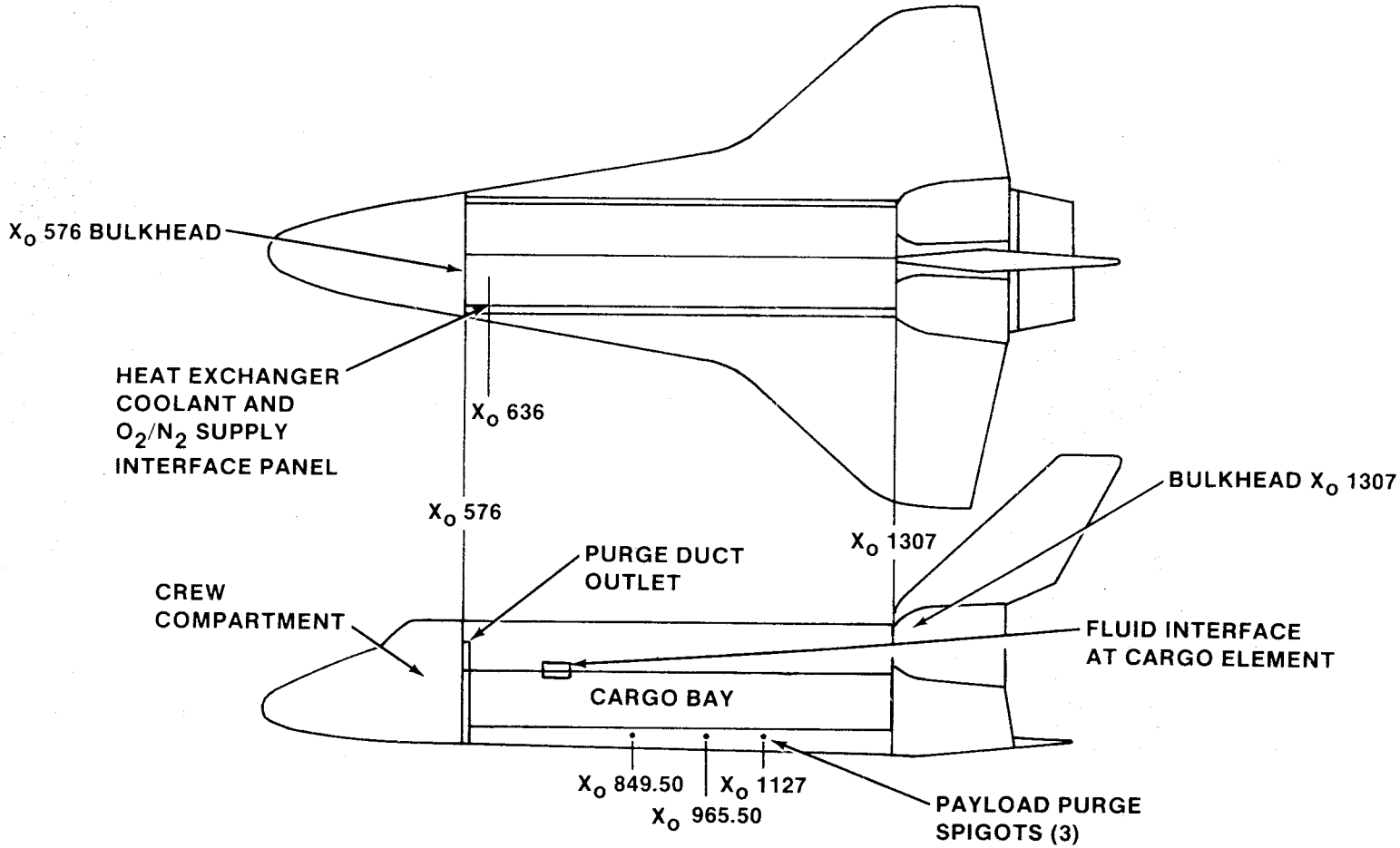
STANDARD AND OPTIONAL SERVICES

S-84-01469

- STANDARD SERVICES
  - ORBITER THERMAL MODELS
  - GENERAL CARGO BAY PRELAUNCH PURGE (MANIFOLD AT FORWARD BULKHEAD)
  - GENERAL CARGO BAY POSTLANDING PURGE AT PRIMARY AND SECONDARY LANDING SITES BUT NOT CONTINGENCY LANDING SITES
  - FLIGHT VERIFICATION ANALYSIS/ASSESSMENT
  - MIDDECK ANALYSIS/ASSESSMENT
- OPTIONAL SERVICES
  - DEDICATED SPIGOT PURGE DUCTING FROM ORBITER CARGO BAY SPIGOT TO CARGO ELEMENT AIRBORNE SUPPORT EQUIPMENT
  - DEDICATED LIQUID COOLING TUBING FROM ORBITER CARGO BAY HEAT EXCHANGER TO CARGO ELEMENT STANDARD INTERFACE PANEL (ONLY FORWARD-MOST CARGO ELEMENT)
  - INTEGRATION DESIGN THERMAL ANALYSIS
  - AFT FLIGHT DECK SUCTION COOLING DUCT

SHUTTLE ORBITER PAYLOAD THERMAL INTERFACE LOCATIONS

S-84-01834



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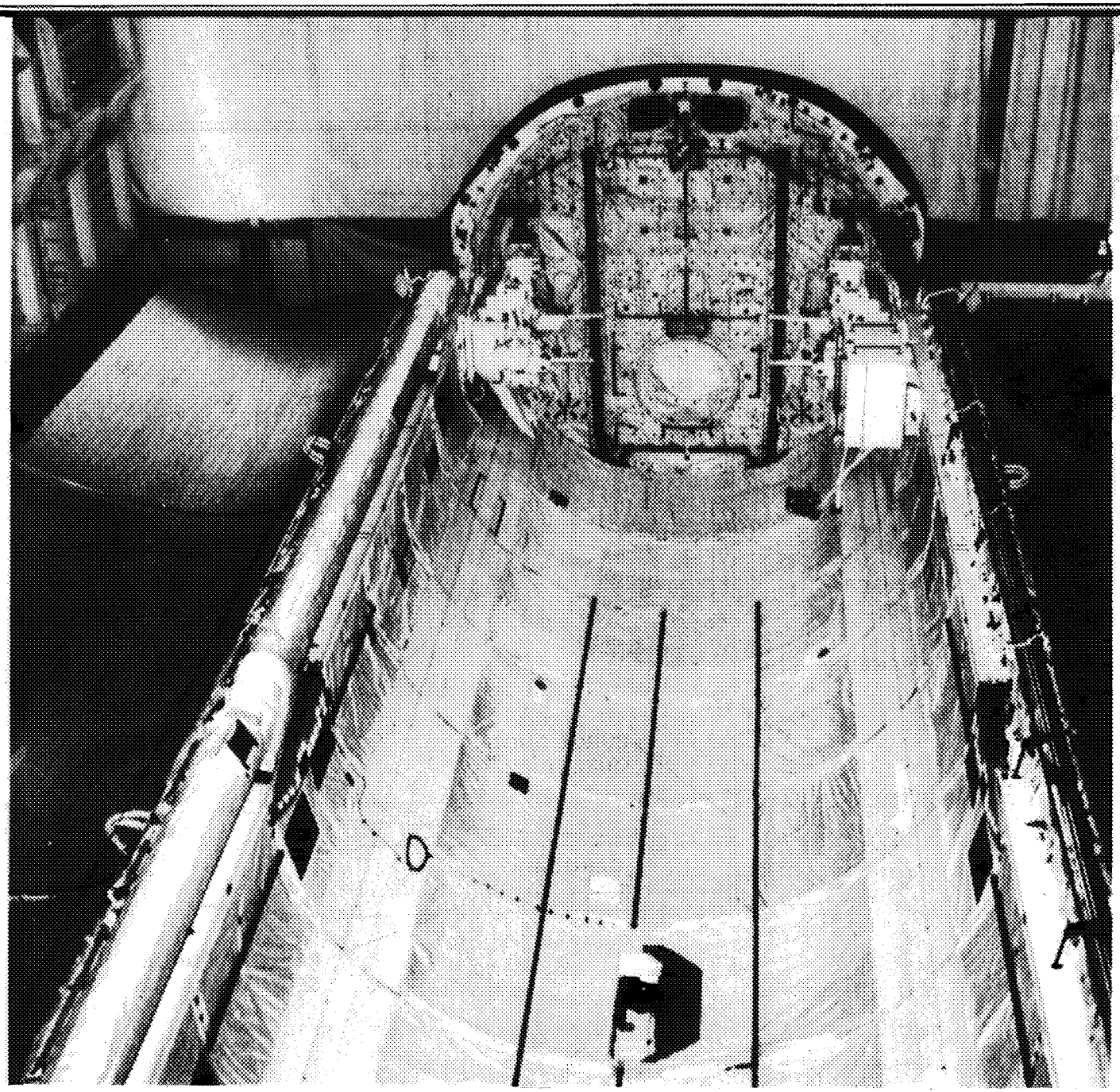

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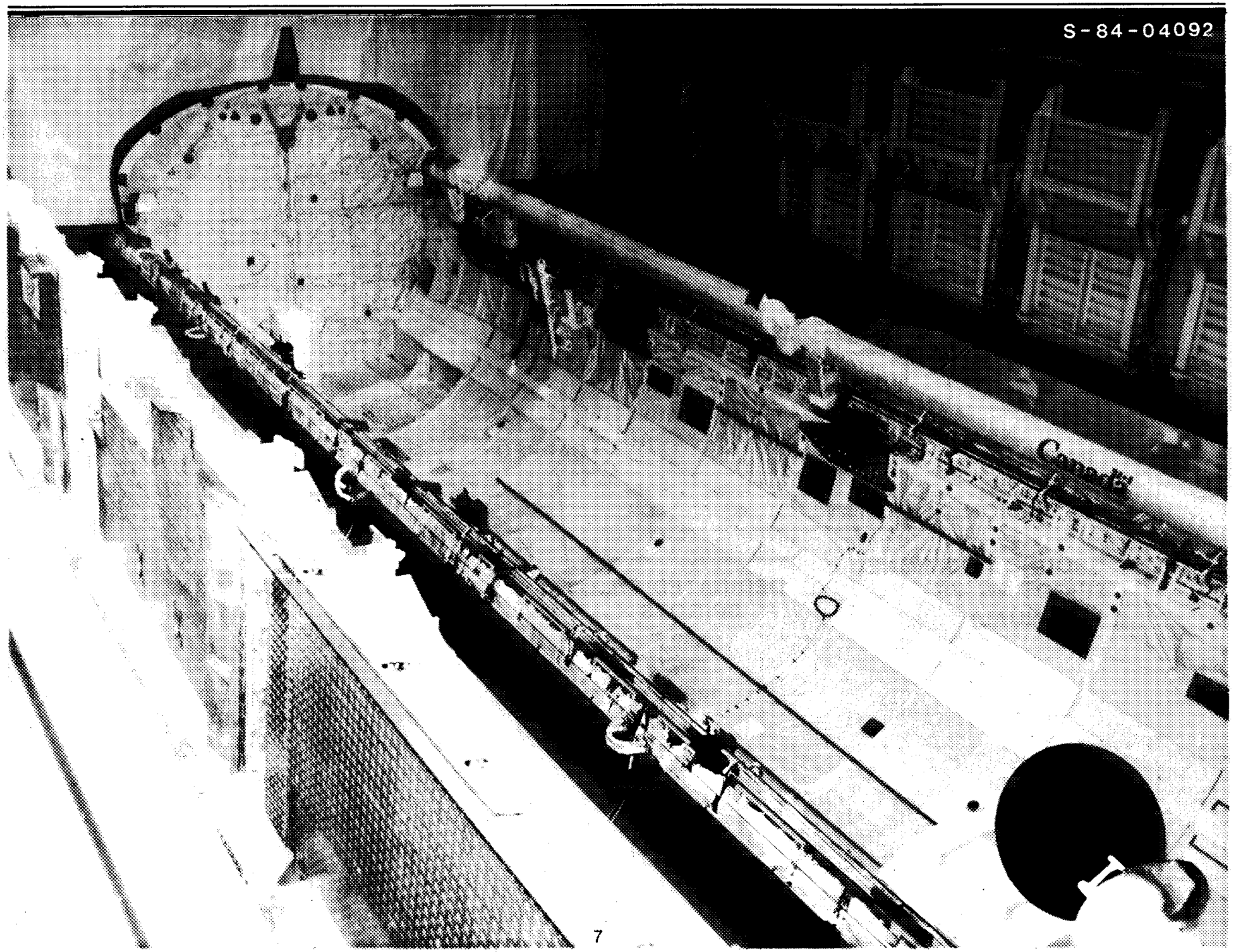
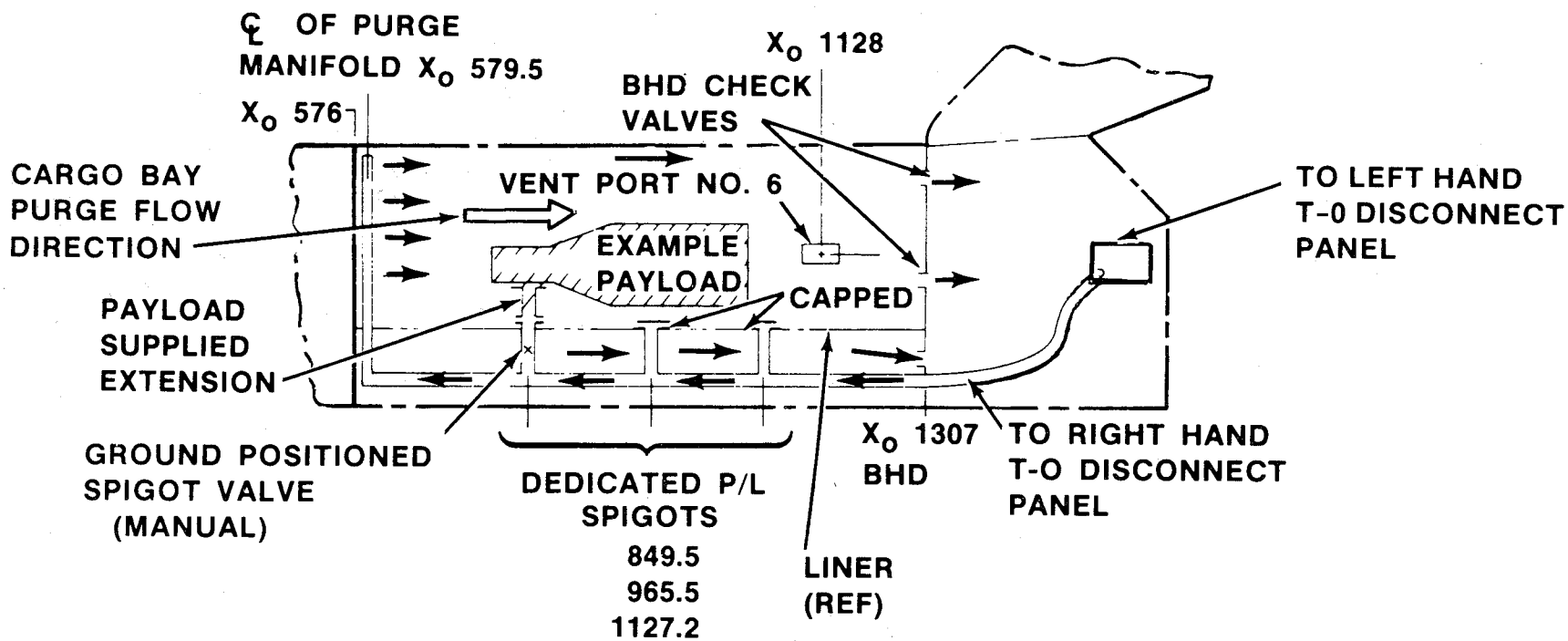


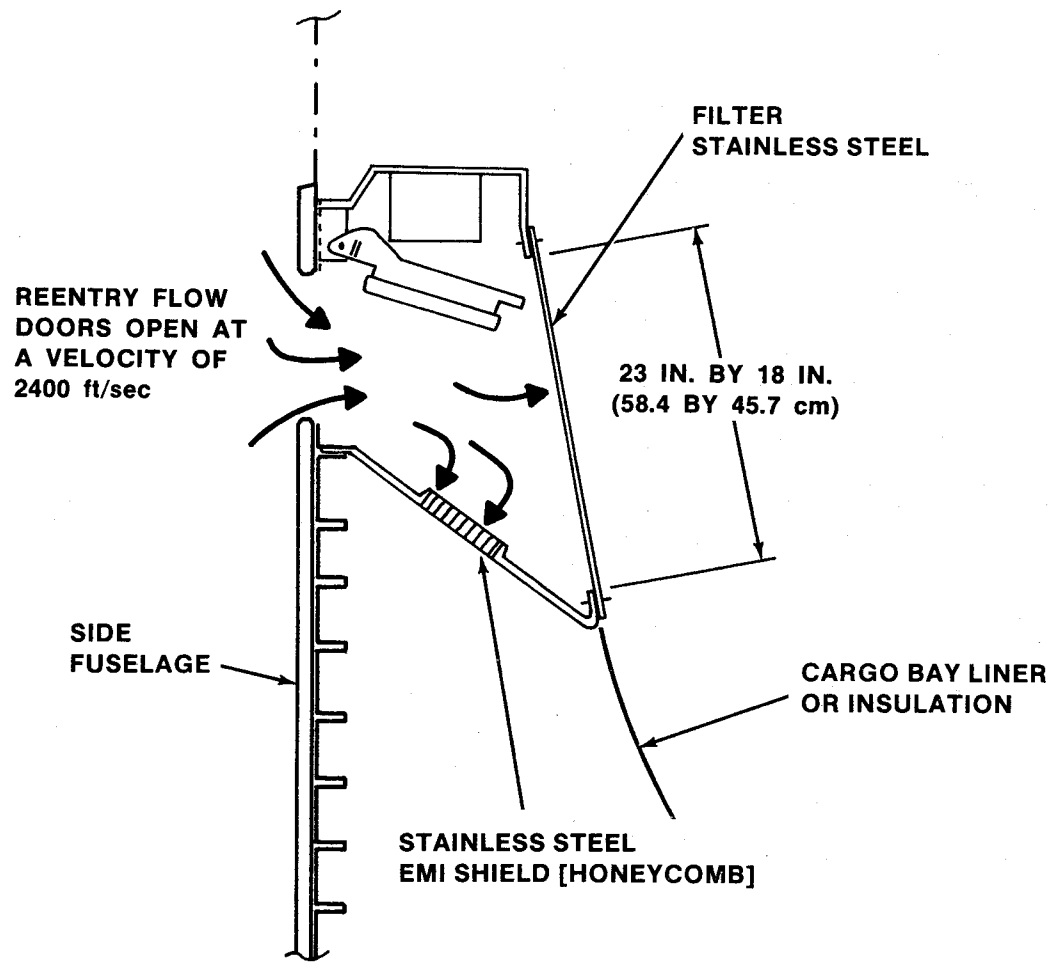
CARGO PURGE SUBSYSTEM

S-84-01851



S-84-01875

PAYLOAD BAY VENT CROSS SECTION



S-84-01484

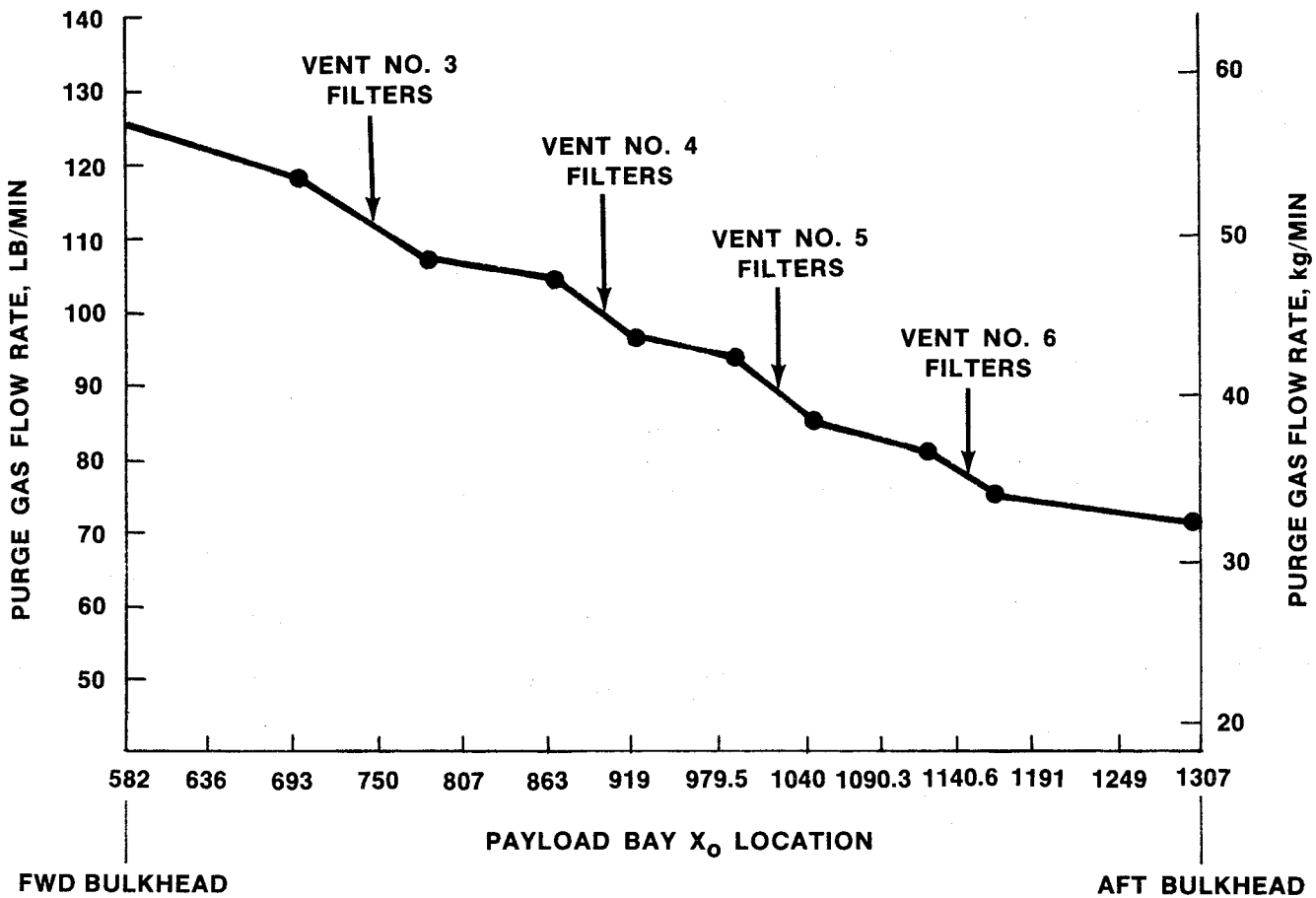
ORBITER/CARGO ACTIVE THERMAL CONTROL INTERFACE CHARACTERISTICS

- PRELAUNCH
  - GENERAL CARGO BAY PURGE 45-100° F (7.2-37.8° C) CONTROLLABLE TO ±2° F (±1.1° C)
  - OPTIONAL DEDICATED SPIGOTS — FLOW 0-100 LB/MIN (0-45.4 kg/MIN) THROUGH EACH SPIGOT WITH TOTAL SPIGOT FLOW OF 150 LB/MIN (68 kg/MIN) — TEMPERATURE SAME AS GENERAL BAY PURGE
  - OPTIONAL CARGO BAY HEAT EXCHANGER — MAXIMUM CAPACITY 5200 BTU/HR (1523.6 WATTS) (AVAILABLE TO PAYLOAD BASED ON LOAD FACTOR)
- ON-ORBIT
  - OPTIONAL CARGO BAY HEAT EXCHANGER
    - MAXIMUM CAPACITY AVAILABLE 29 000 BTU/HR (8496.9 WATTS) WITH RADIATOR KIT (AVAILABLE TO PAYLOAD BASED ON LOAD FACTOR)

CARGO BAY PURGE GAS FLOW DISTRIBUTION

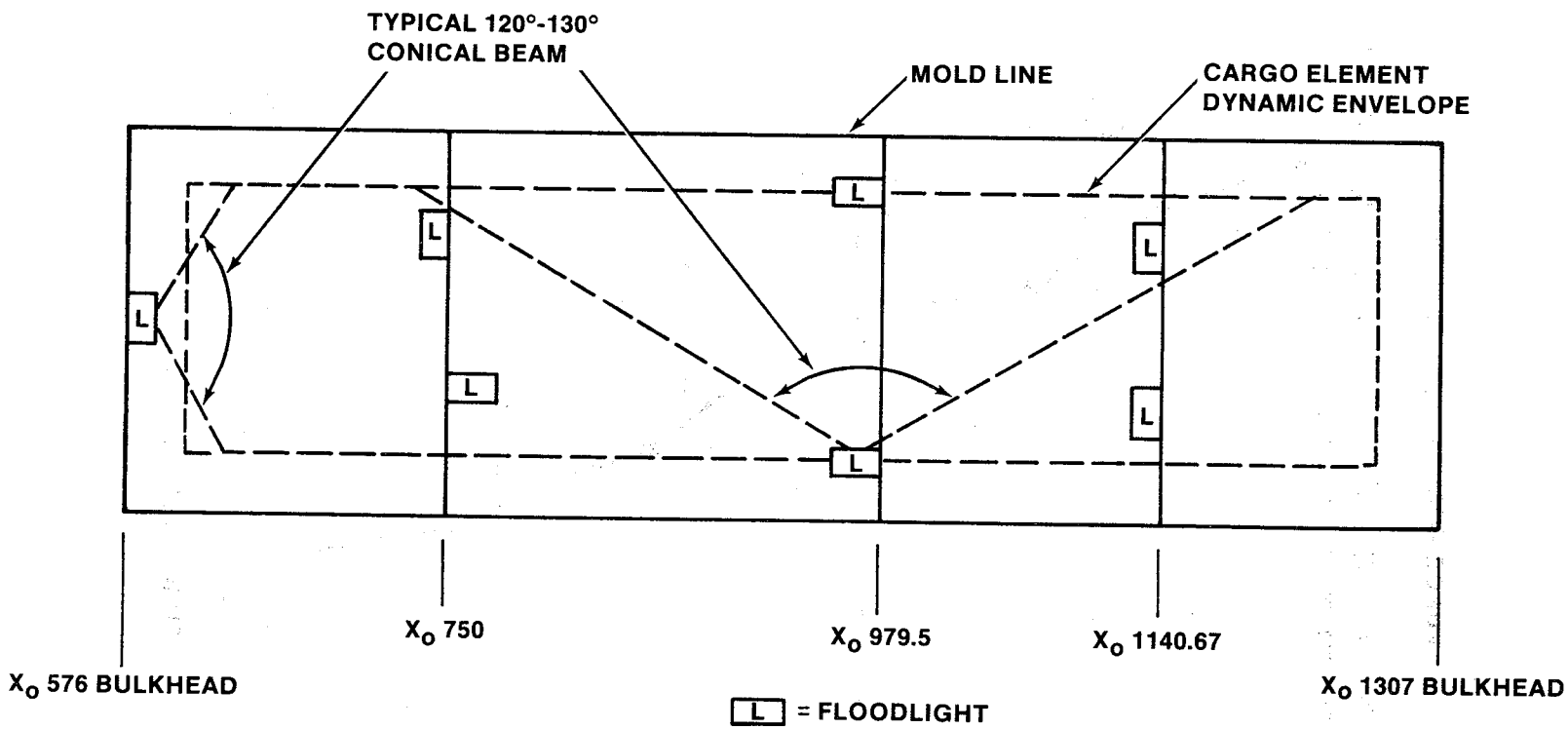
S-84-01842

TYPICAL, LOW FLOW RATE PURGE, NO SPIGOT FLOW



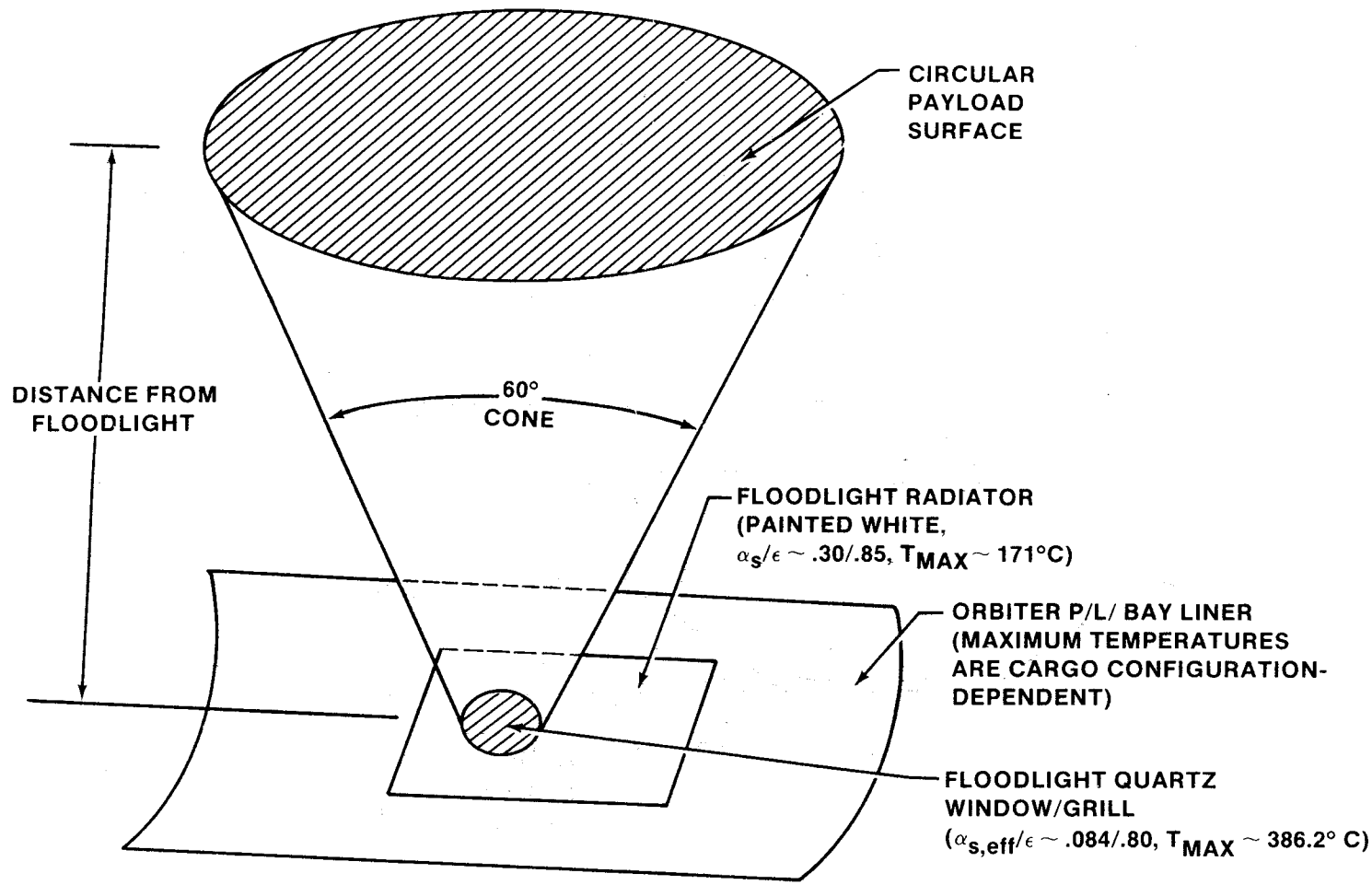
CARGO BAY LIGHTING LOCATIONS

S-84-01843



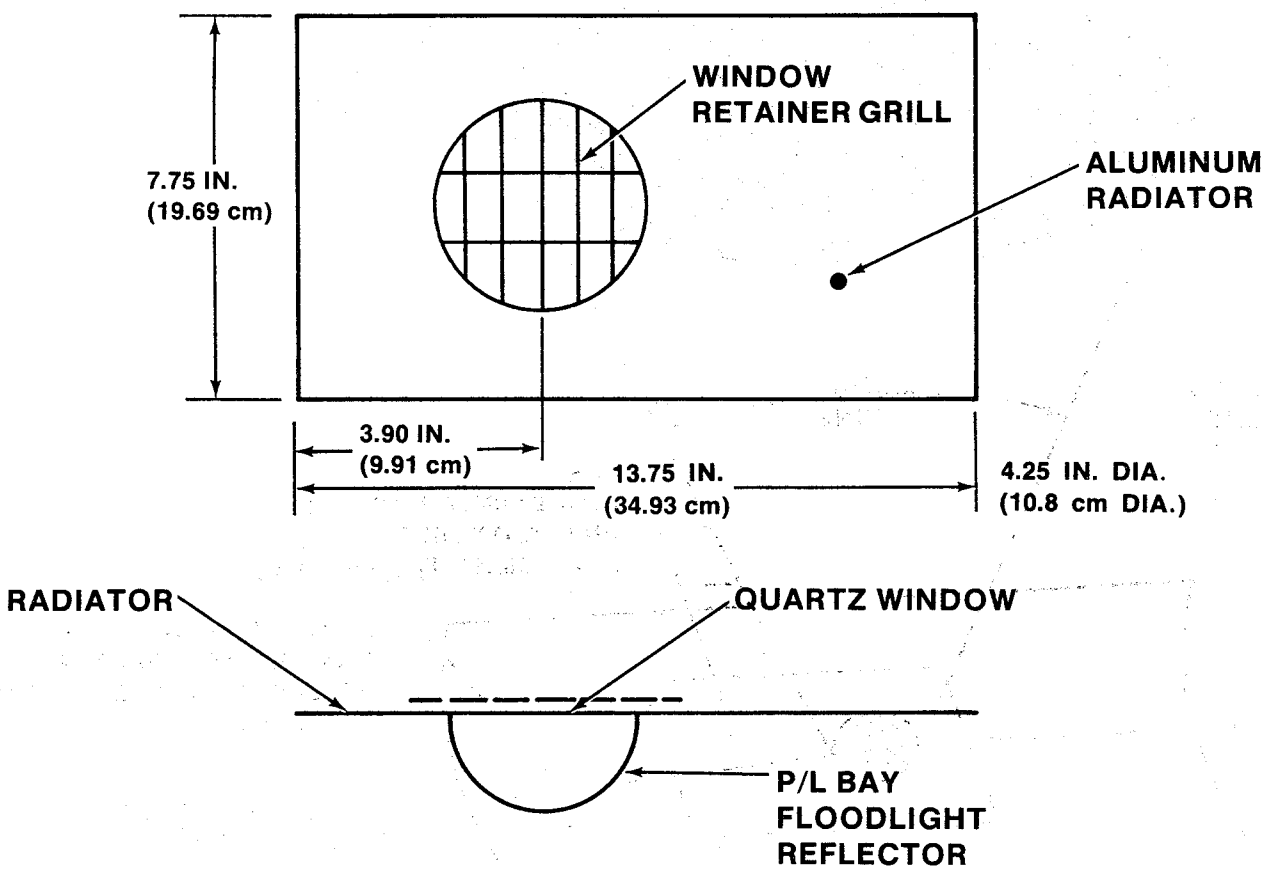
P/L BAY FLOODLIGHTS THERMAL CONFIGURATION/CHARACTERISTICS

S-84-01819



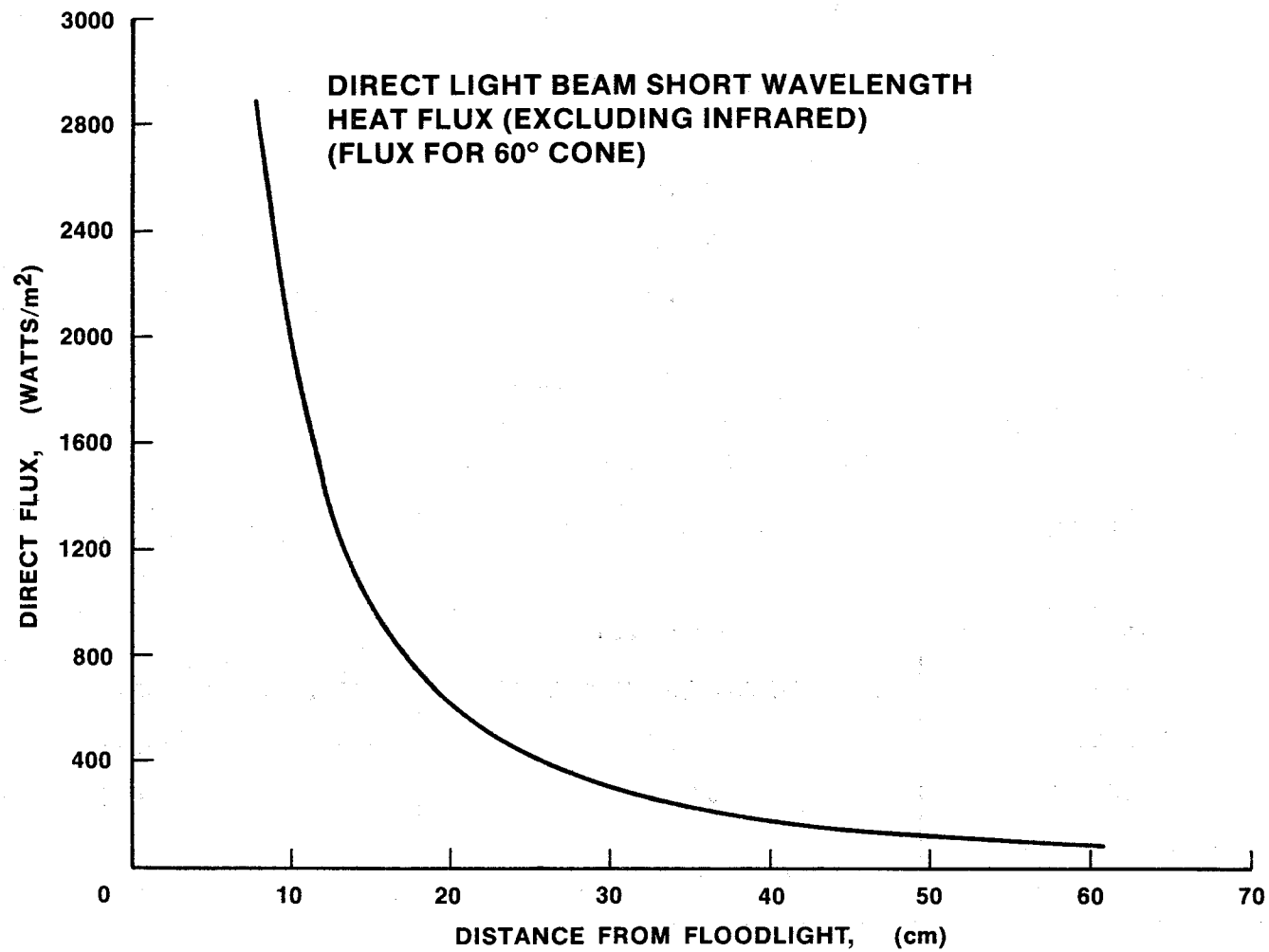
S-84-01852

P/L BAY FLOODLIGHTS
THERMAL CONFIGURATION/CHARACTERISTICS (CONT)



P/L BAY FLOODLIGHTS (CONT)

S-84-01854



STS MISSION ATTITUDE CONSTRAINTS FOR MIXED PAYLOADS

BETA ANGLES LESS THAN 60°		
ATTITUDE	REQUIRED TIME	PAYLOAD RECOVERY TIME AT +ZLV
+ZLV	CONTINUOUS	N/A
+Z SOLAR	30 MIN	PAYLOAD-PROVIDED
+Z SPACE	90 MIN	PAYLOAD-PROVIDED
PAYLOAD WORST SOLAR ANGLE	PAYLOAD-PROVIDED	PAYLOAD-PROVIDED

BETA ANGLES GREATER THAN 60°		
ATTITUDE	REQUIRED TIME	PAYLOAD RECOVERY TIME AT PTC
+PTC	CONTINUOUS	N/A
+ZLV	6 HR (FOLLOWED BY 3 HR PTC)	PAYLOAD-PROVIDED
+Z SOLAR	30 MIN	PAYLOAD-PROVIDED
+Z SPACE	90 MIN	PAYLOAD-PROVIDED
PAYLOAD WORST SOLAR ANGLE	PAYLOAD-PROVIDED	PAYLOAD-PROVIDED

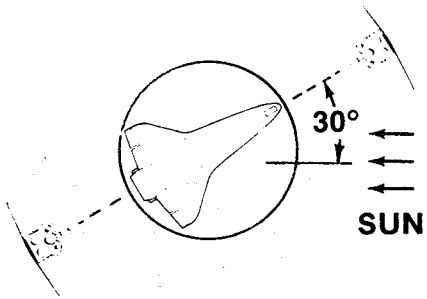
S-84-02048

STS MISSION ATTITUDE CONSTRAINTS FOR MIXED DEPLOYABLE PAYLOADS (CONT)

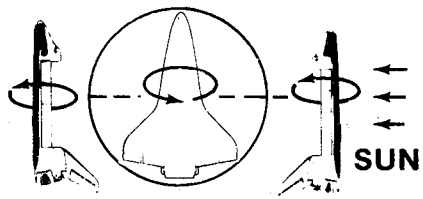
- AIRBORNE SUPPORT EQUIPMENT (ASE) REMAINING IN THE CARGO BAY AFTER DEPLOYMENT SHOULD BE COMPATIBLE WITH ORBITER ATTITUDE CONSTRAINTS DEFINED IN ICD-2-19001; HOWEVER THIS DOES NOT REQUIRE AN ACTIVE COOLING SYSTEM

ORBITER ATTITUDES

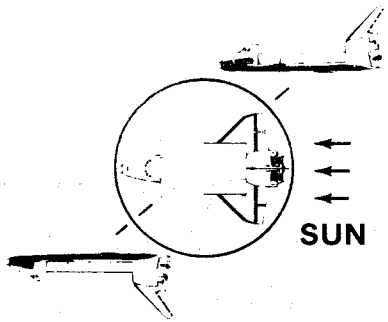
S-84-02053



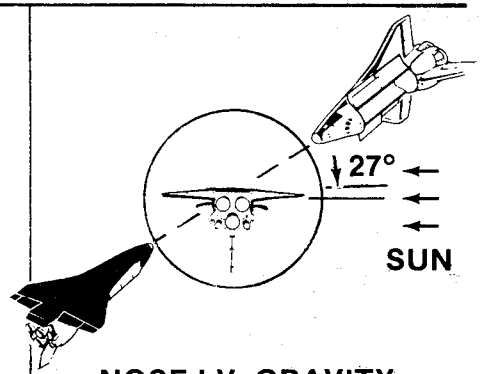
TOP LV, β = 30°
(+ZLV, -XV)



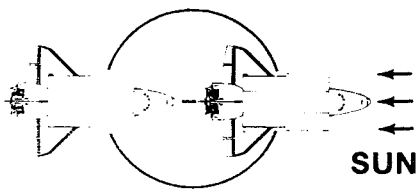
PTC, β = 0°
(X ROLL, X INERTIAL)



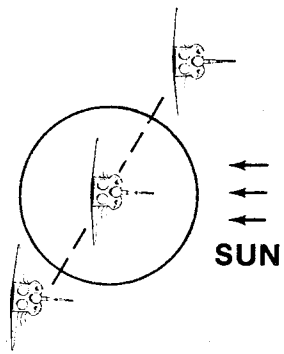
TAIL SUN, 1 REV/ORB.,
β = 45°
(+X SOLAR, +Z SPACE)



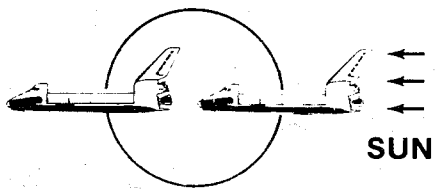
NOSE LV, GRAVITY
GRADIENT β = 30°
WING ROLL OUT ORBIT
PLANE 27° CW
(-XLV, -YV ROLL CW 27°)



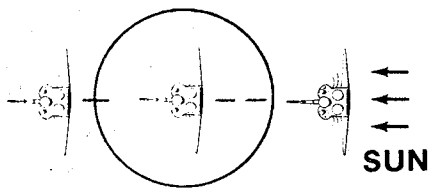
NOSE SUN, β = 0°
(-X SI, Y POP)



TOP SI, β = 60°
(+Z SI)



TAIL SI, β = 0°
(+X SI, Z POP)



BOTTOM SI, β = 0°
(-Z SI, Y POP)

THERMAL MATH MODELS (TMM)

S-84-01652

- ORBITER MODELS AVAILABLE FROM NASA
  - DETAIL ORBITER THERMAL MODEL
    - — ATMOSPHERIC MIDSECTION/CARGO BAY MODEL — ES3-77-3 REV. D
    - — ON-ORBIT OPENED CARGO BAY DOORS MODEL — ES3-76-1 REV. D
  - SIMPLIFIED ORBITER THERMAL MODEL
    - — ON-ORBIT OPENED CARGO BAY DOORS MODEL — JSC-19540 (REPLACES ES3-76-7 REV. C)
    - — ATMOSPHERIC MIDSECTION/CARGO BAY MODEL — JSC-19692 (REPLACES ES3-77-1 REV. C)
- PAYLOAD MODEL REQUIRED BY NASA
  - GUIDELINES FOR TMM DELIVERIES
    - — NASA JSC 14686
    - — MODEL SIZE
      - 300 GEOMETRIC MATH MODEL NODES FOR ENTIRE CARGO
      - 500 THERMAL MATH MODEL NODES FOR ENTIRE CARGO
      - 3000 CONDUCTORS FOR ENTIRE CARGO
      - RATIO DOWN BY PORTION OF CARGO BAY OCCUPIED

INTEGRATION ANALYSIS CYCLE

S-84-01445

PAYLOAD

FINAL DESIGN SUPPORT CYCLE

- DESIGN ANALYSIS
- EXCURSION/RECOVERY CONSTRAINTS
- PREENTRY CONDITIONING CONSTRAINTS
- SAFETY ANALYSIS

CARGO INTEGRATION REVIEW

NASA

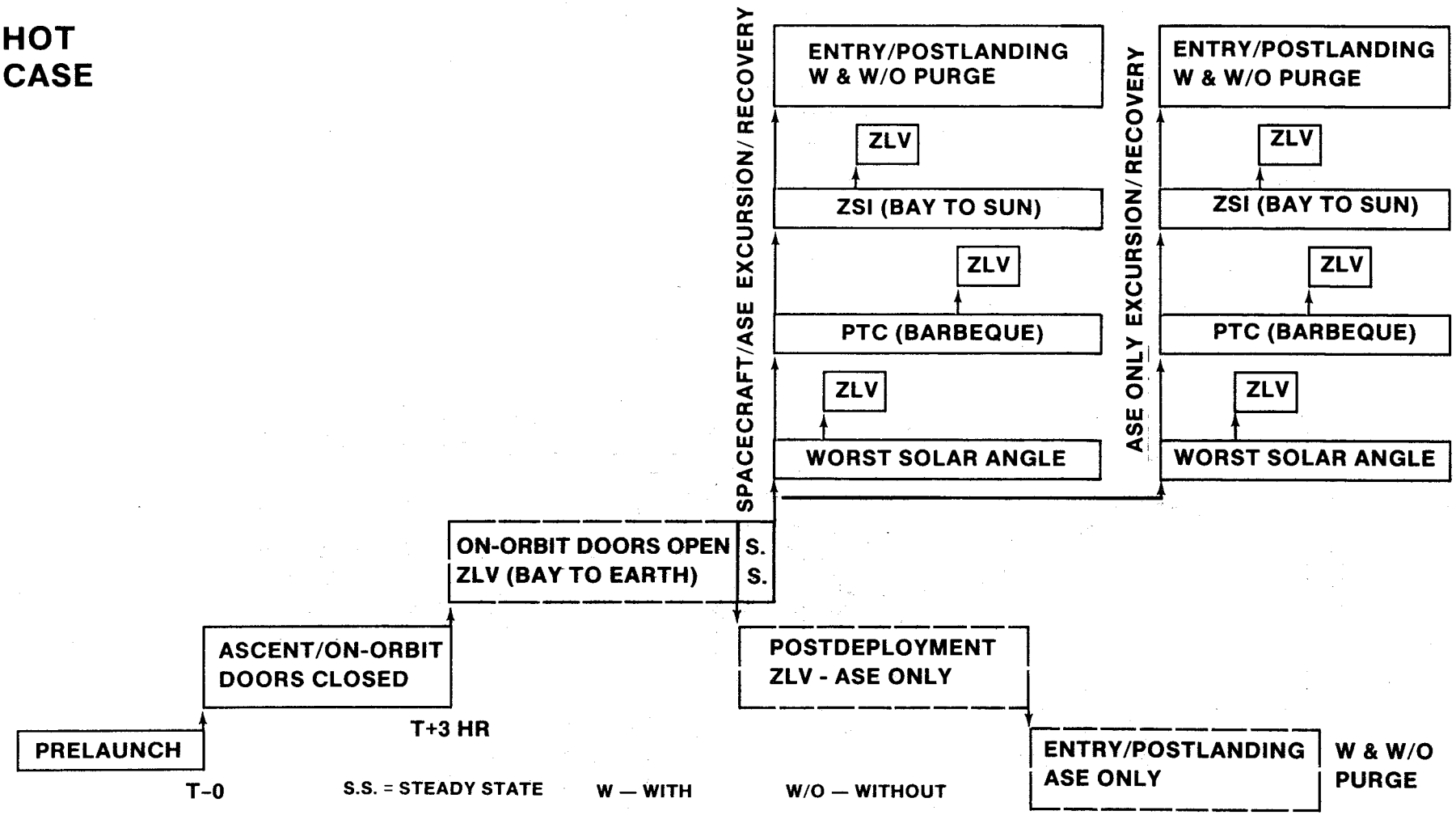
MISSION VERIFICATION CYCLE

- FINAL STS/CARGO COMPATIBILITY ANALYSIS/ASSESSMENT
- UPDATE PREVIOUS ANALYSIS IF REQUIRED
- INTERFACE VERIFICATION/ READINESS CERTIFICATION

TYPICAL THERMAL ANALYSIS APPROACH

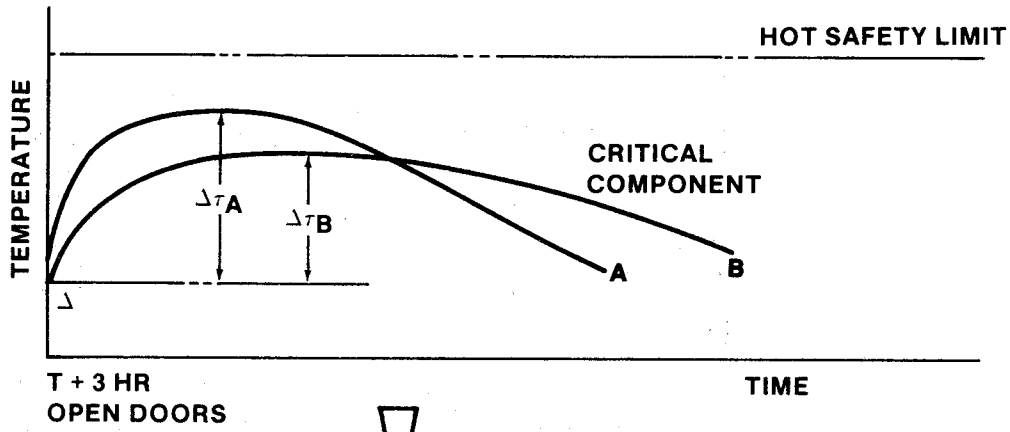
S-84-01433
Rev 1

HOT CASE

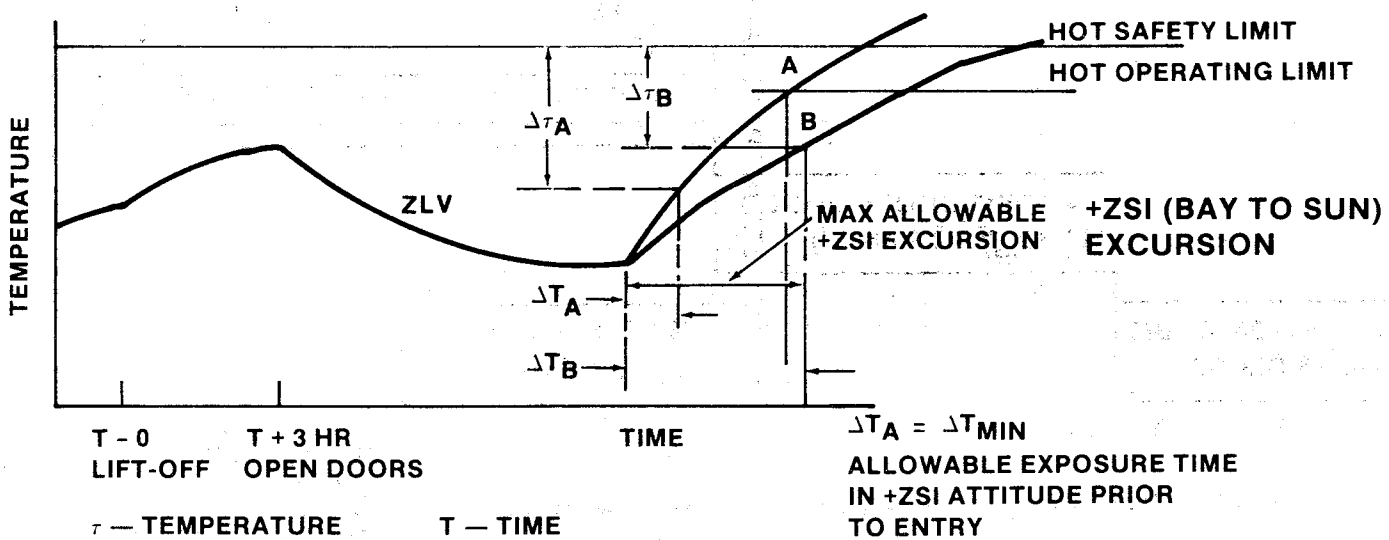


TYPICAL THERMAL ANALYSIS APPROACH — HOT CASE

S-84-01845
Rev 1



ENTRY/POSTLANDING
WITH AND WITHOUT
PURGE



+ZSI (BAY TO SUN)
EXCURSION

$\Delta T_A = \Delta T_{MIN}$
ALLOWABLE EXPOSURE TIME
IN +ZSI ATTITUDE PRIOR
TO ENTRY

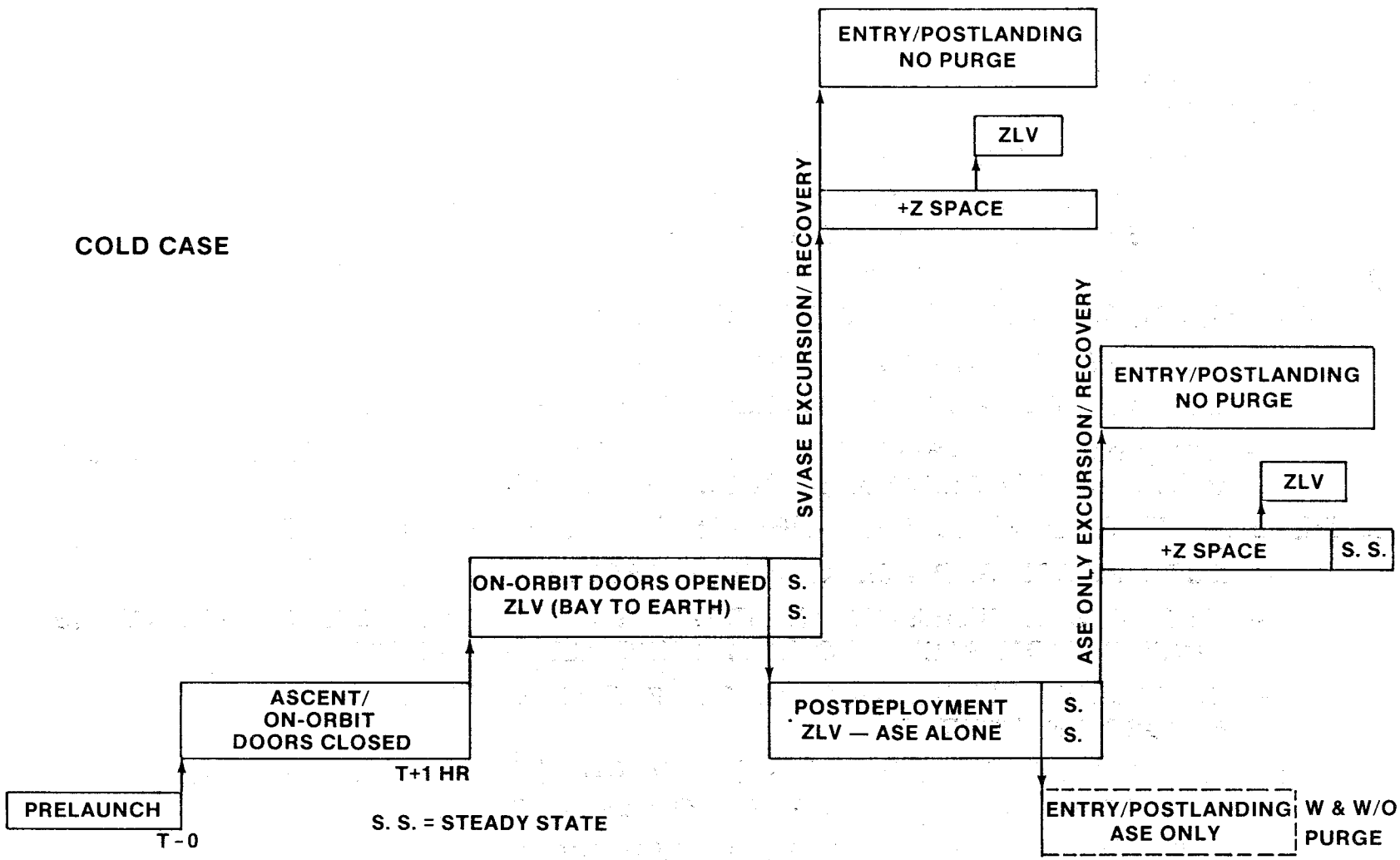
τ — TEMPERATURE T — TIME

TYPICAL THERMAL APPROACH — HOT CASE

1. PERFORM HOT EXCURSION/RECOVERY ANALYSIS TO SATISFY PIP TBD'S
   - BOTH SV/ASE AND ASE ALONE
   - USE HOT-BIASED MISSION TIMELINE AND ENVIRONMENTS TO GENERATE INITIAL CONDITIONS
2. PERFORM HOT ENTRY/POSTLANDING ANALYSIS TO DETERMINE TEMPERATURE RISE FOR EACH COMPONENT
   - BOTH SV/ASE AND ASE ALONE (IF REQUIRED)
   - USE HOTTEST POINT IN TIMELINE FOR INITIAL CONDITIONS
   - ASSUME NO PURGE AT LANDING SITE AND CONTINUE ANALYSIS UNTIL ALL TEMPERATURES BEGIN DECREASING
3. DETERMINE ALLOWABLE EXCURSION TIMES PRIOR TO ENTRY
   - BOTH SV/ASE AND ASE ALONE (IF REQUIRED)
   - USE ΔT'S GENERATED IN STEP 2 WITH EXCURSION TEMPERATURE CURVES FROM STEP 1 TO DETERMINE ALLOWABLE TIMES
   - DETERMINE THE MINIMUM ALLOWABLE TIME FOR EACH EXCURSION ATTITUDE
4. RUN ENTRY/POSTLANDING AT THE INITIAL CONDITIONS FOUND IN STEP 3 TO VERIFY MINIMUM ALLOWABLE TIMES
5. REFURBISHMENT LIMITS CAN BE ESTABLISHED SIMILARLY

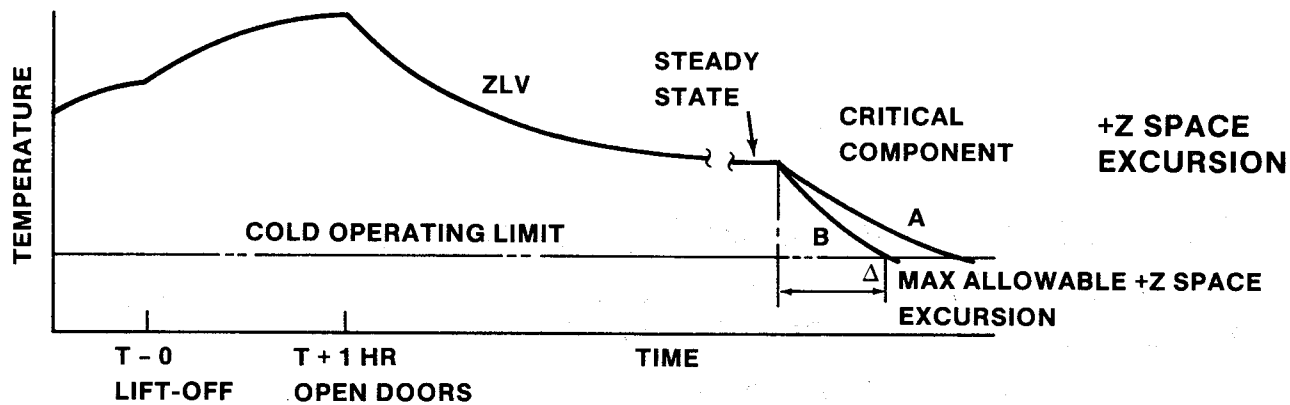
TYPICAL THERMAL ANALYSIS APPROACH

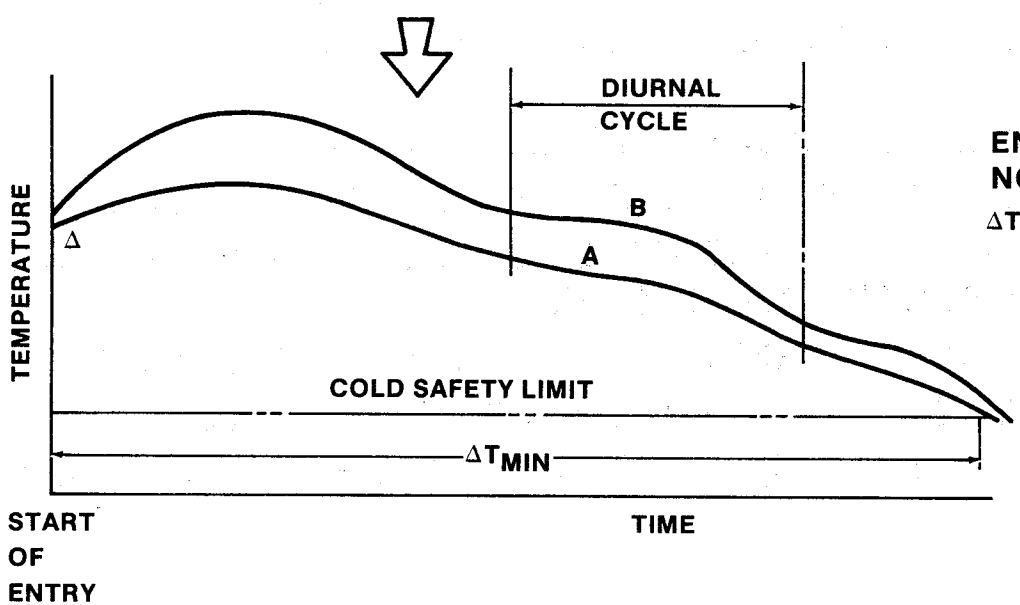
S-84-01836



TYPICAL THERMAL ANALYSIS APPROACH — COLD CASE

S-84-01827





ENTRY/POSTLANDING
NO PURGE

ΔT_{MIN} = ALLOWABLE EXPOSURE TIME TO COLD POST-LANDING ENVIRONMENT

TYPICAL THERMAL APPROACH — COLD CASE

S-84-01496

1. PERFORM COLD EXCURSION/RECOVERY ANALYSIS TO SATISFY PIP TBD'S
   - BOTH SV/ASE AND ASE ALONE (IF REQUIRED)
   - USE COLD-BIASED MISSION TIMELINE AND ENVIRONMENTS TO GENERATE INITIAL CONDITIONS
2. PERFORM COLD ENTRY/POSTLANDING ANALYSIS TO DETERMINE ALLOWABLE EXPOSURE TIME TO COLD POSTLANDING ENVIRONMENT
   - BOTH SV/ASE AND ASE ALONE (IF REQUIRED)
   - USE COLDEST POINT IN TIMELINE FOR INITIAL CONDITIONS
   - ASSUME NO PURGE AT LANDING SITE AND CONTINUE ANALYSIS UNTIL CYCLIC STEADY STATE IS REACHED
   - COLD SAFETY LIMITS EVENTUALLY WILL BE EXCEEDED
   - GROUND POWER OR WARM PURGE AIR IS REQUIRED
   - ESTABLISH LENGTH OF TIME PRIOR TO POWER/WARM AIR NEED

PREENTRY CONDITIONING CONSTRAINTS

EXAMPLE

S-84-01653
Rev 1

	ALLOWABLE EXPOSURE TIME PRIOR TO ENTRY — HOURS				
	SV AND ASE		ASE ONLY		
	REFURBISHMENT	SAFETY	REFURBISHMENT	SAFETY	
PTC					
+ZSI					
+ZLV					
WORST SOLAR ANGLE					
+Z SPACE					

ORBITER ATMOSPHERIC FLIGHT THERMAL DATA SUMMARY

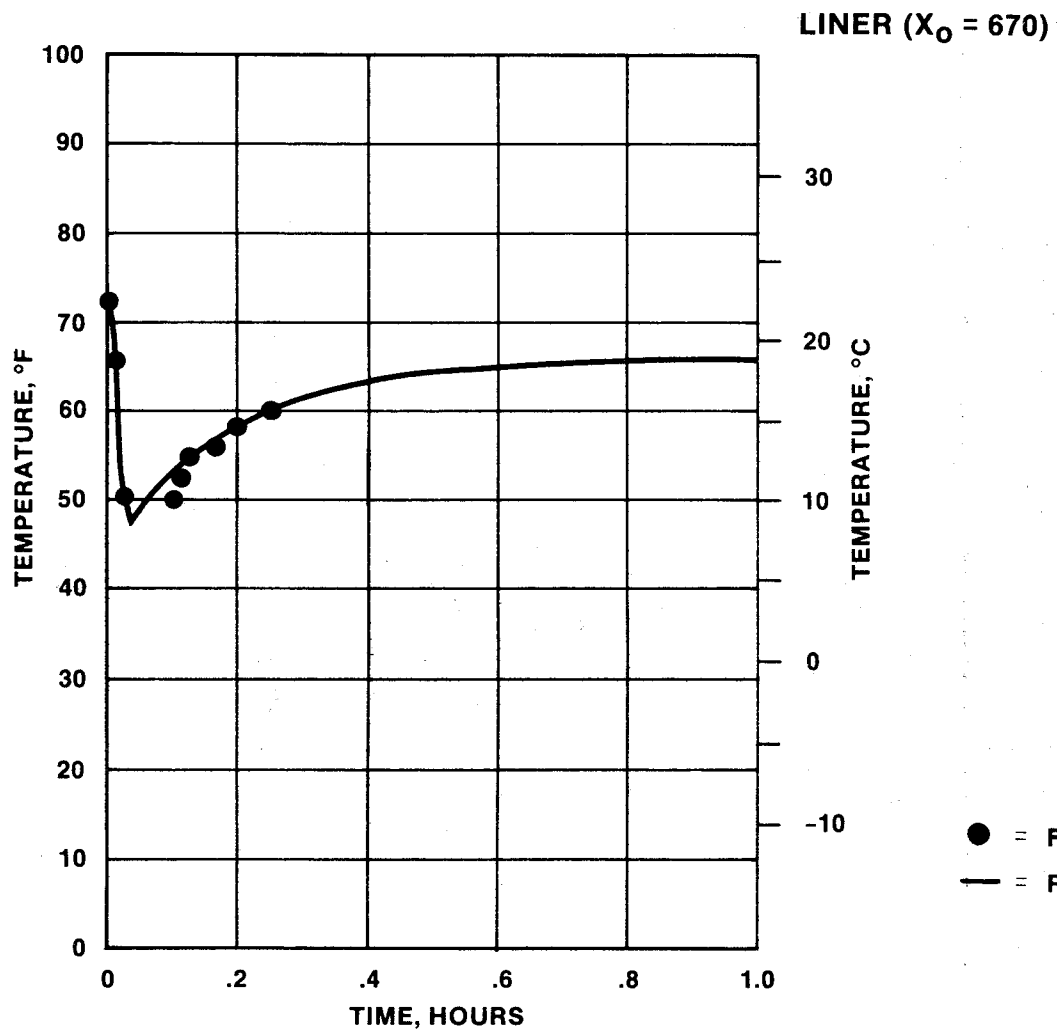
S-84-01439

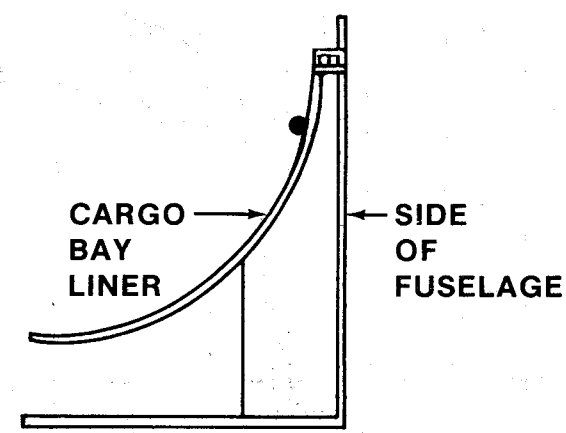
(NOMINAL CONDITIONS, NOT DESIGNED CONDITIONS)

	PRELAUNCH	ASCENT	ENTRY/POSTLANDING
PURGE	21.2 TO 26.7° C		12.8 TO 18.3° C
LINER	21.1 TO 26.7° C	10 TO 26.7° C	-17.8 TO 23.9° C
LONGERON	21.1 TO 23.9° C	21.1 TO 23.9° C	-17.8 TO 23.9° C
FITTING	21.1° C	21.1° C	-12.2 TO 23.9° C
RADIATOR	21.2 TO 23.9° C	13.9 TO 23.9° C	-20.6 TO 29.4° C
BULKHEAD	21.1 TO 26.7° C	10 to 26.7° C	-17.8 TO 23.9° C

STS-3 FLIGHT DATA VS. 390 NODE PREDICTIONS ASCENT

S-84-01853



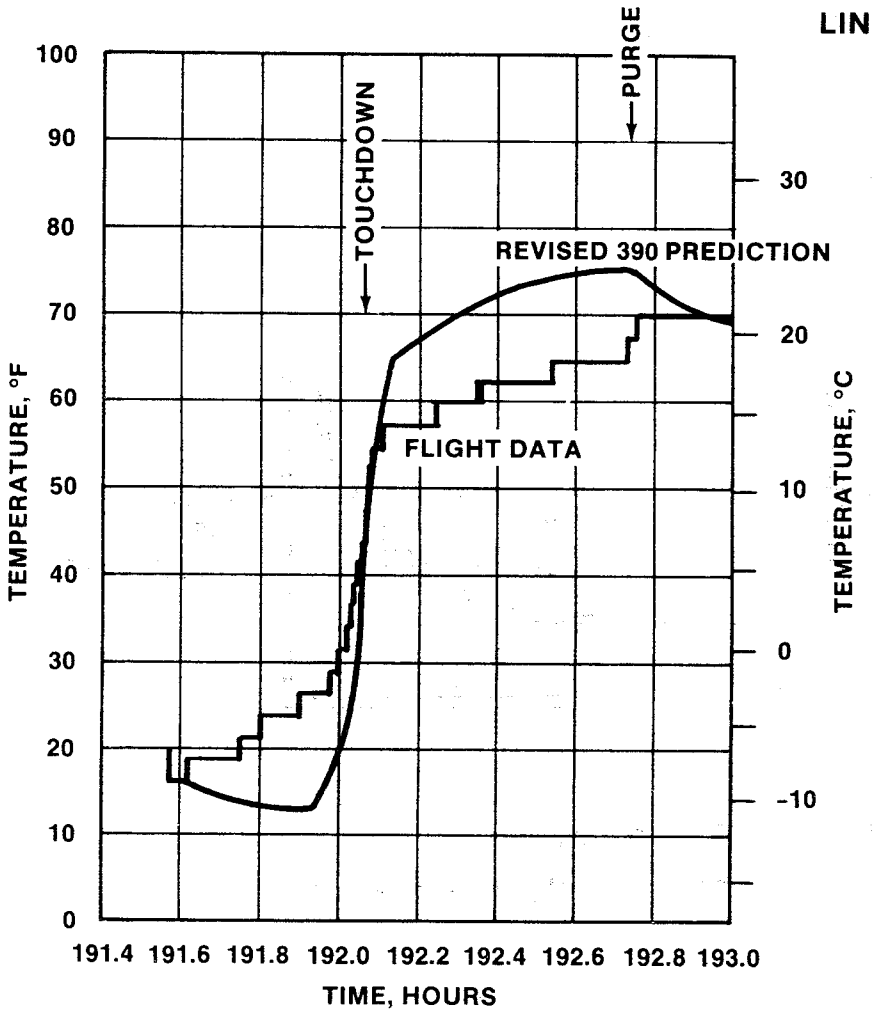


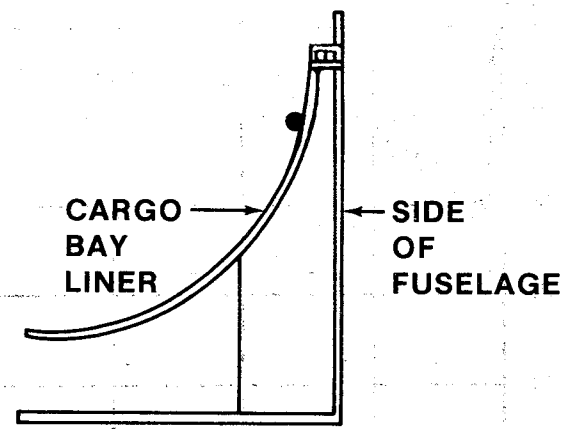
● = FLIGHT DATA

— = REVISED 390 PREDICTION

S-84-01844

STS-3 FLIGHT DATA VS. 390 NODE PREDICTIONS ENTRY





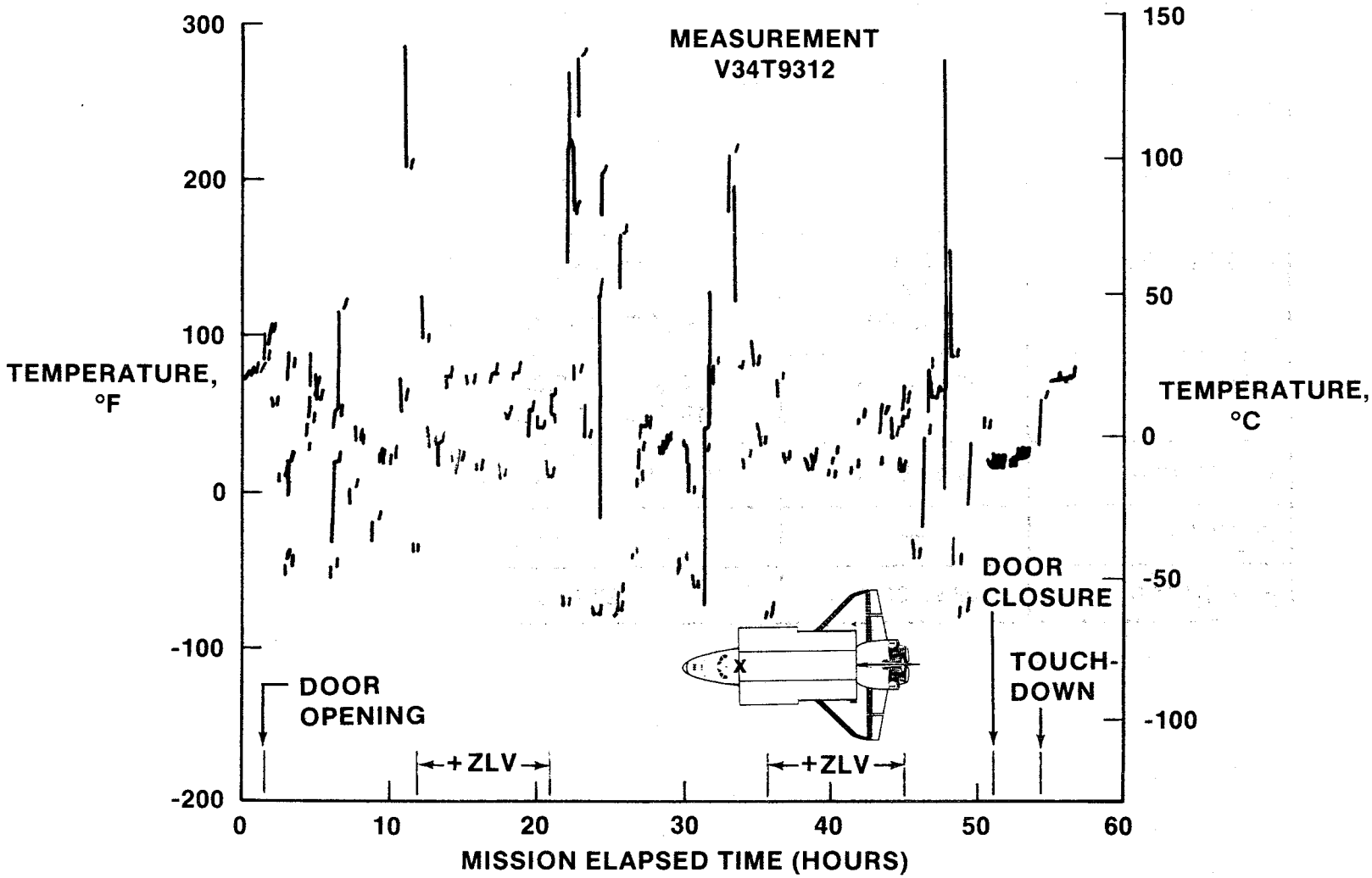
S-84-01463

ORBITER ON-ORBIT FLIGHT THERMAL DATA SUMMARY— TYPICAL DEPLOYABLE NOMINAL ENVIRONMENT

FLIGHT	STS-1	STS-2	
BETA ANGLE RANGE	-26° TO -19°	-45° TO -51°	
ORIENTATION	TOP TO EARTH	TOP TO EARTH	
		PORT	STBD
LINER	-15/26.7°C	-3.9/ 18.3°C	-12.2/ 1.7°C
LONGERON	-9.4/-6.7°C	4.4/7.1°C	-9.4/-6.7°C
FITTING	—	—	—
BULKHEAD	-28.9/-23.3°C	-17.8/37.8°C	

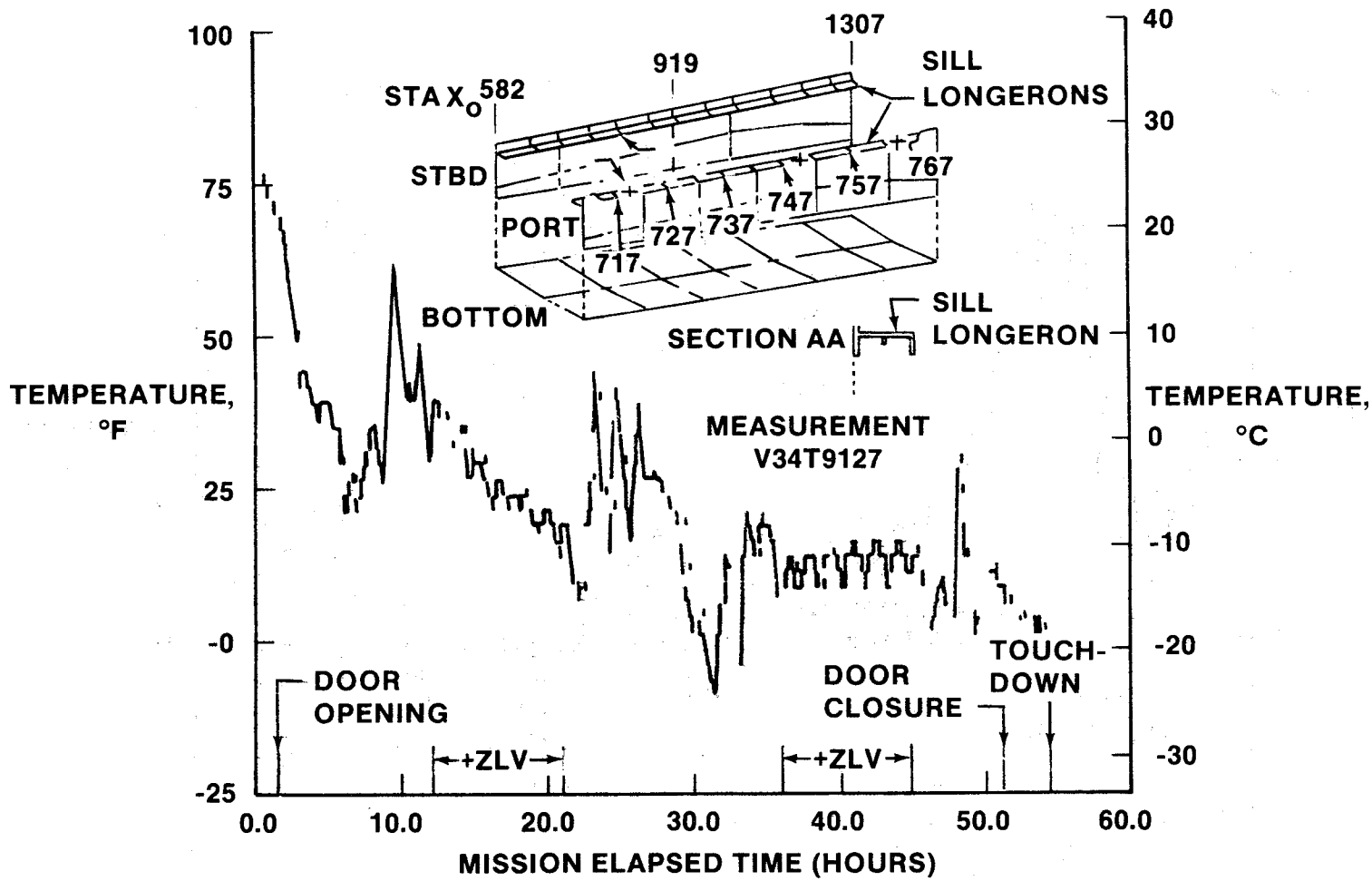
STS-1 LINER TEMPERATURE

S-84-02047



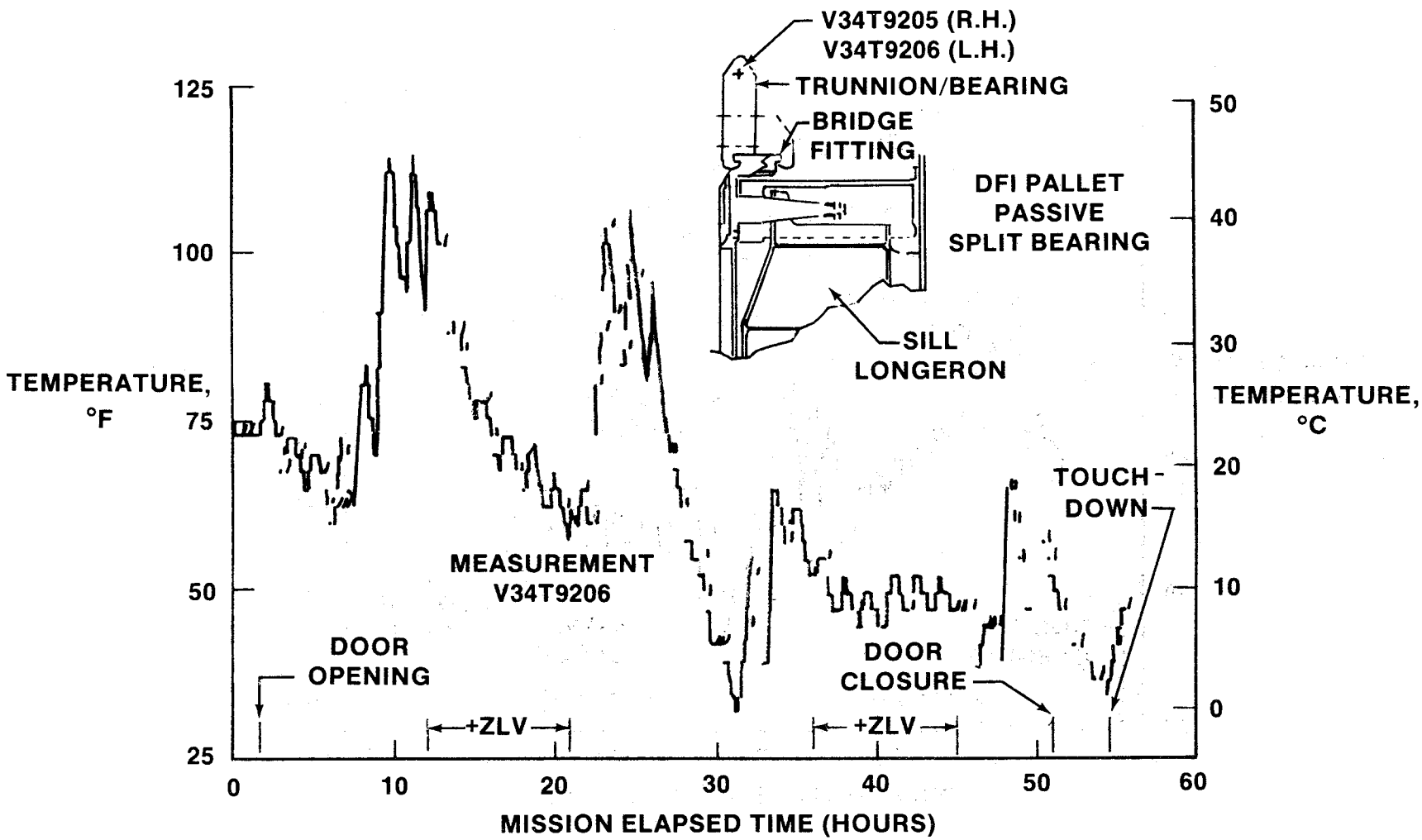
STS-1 PORT SILL LONGERON TEMPERATURE

S-84-02045



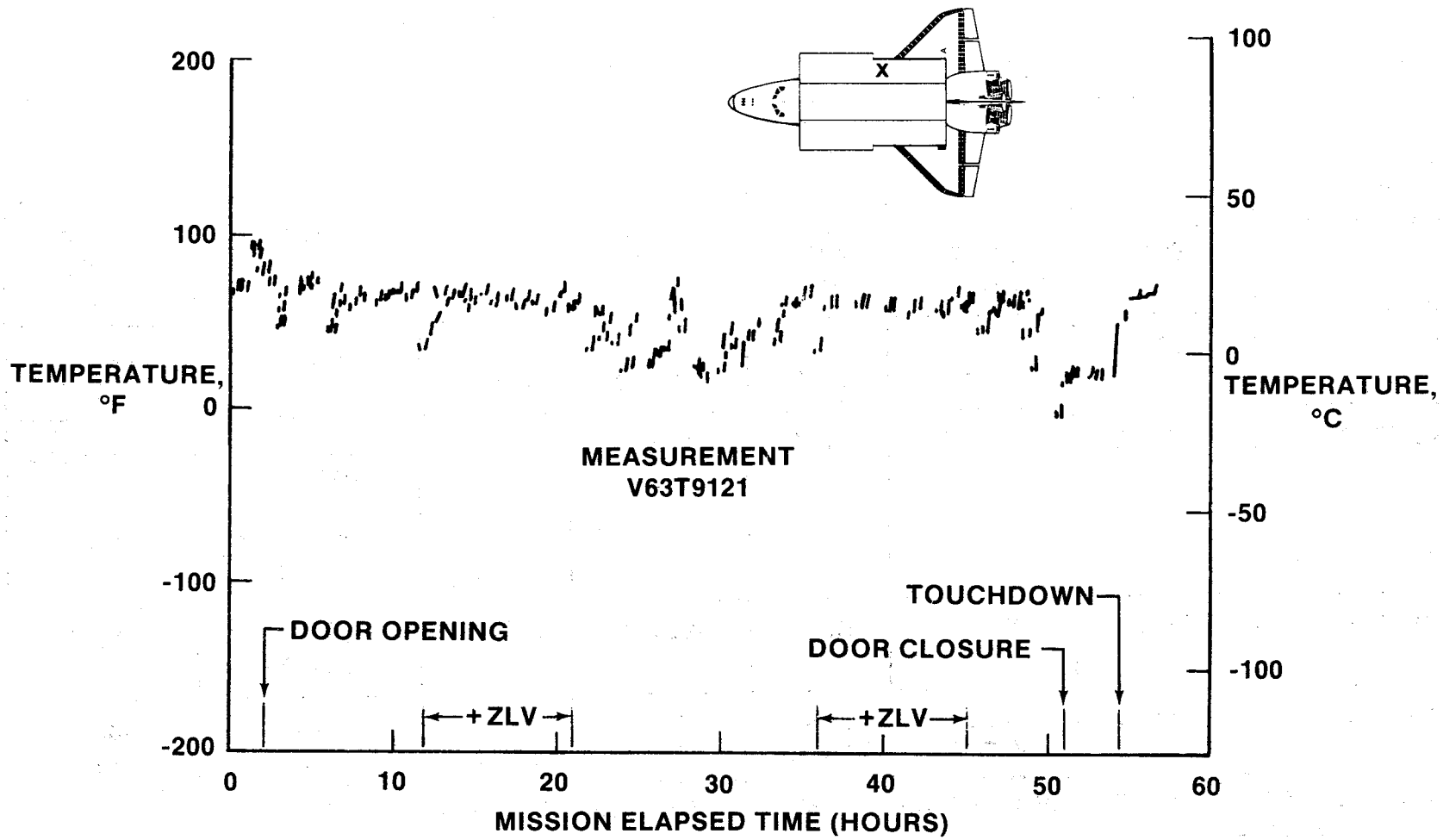
STS-1 DFI PALLET TRUNNION TEMPERATURE

S-84-02046



STS-1 RIGHT RADIATOR SURFACE TEMPERATURE

S-84-02052



ORBITER ON-ORBIT FLIGHT THERMAL DATA SUMMARY— TYPICAL EXCURSION (EXTREME) OR SORTIE ENVIRONMENTS

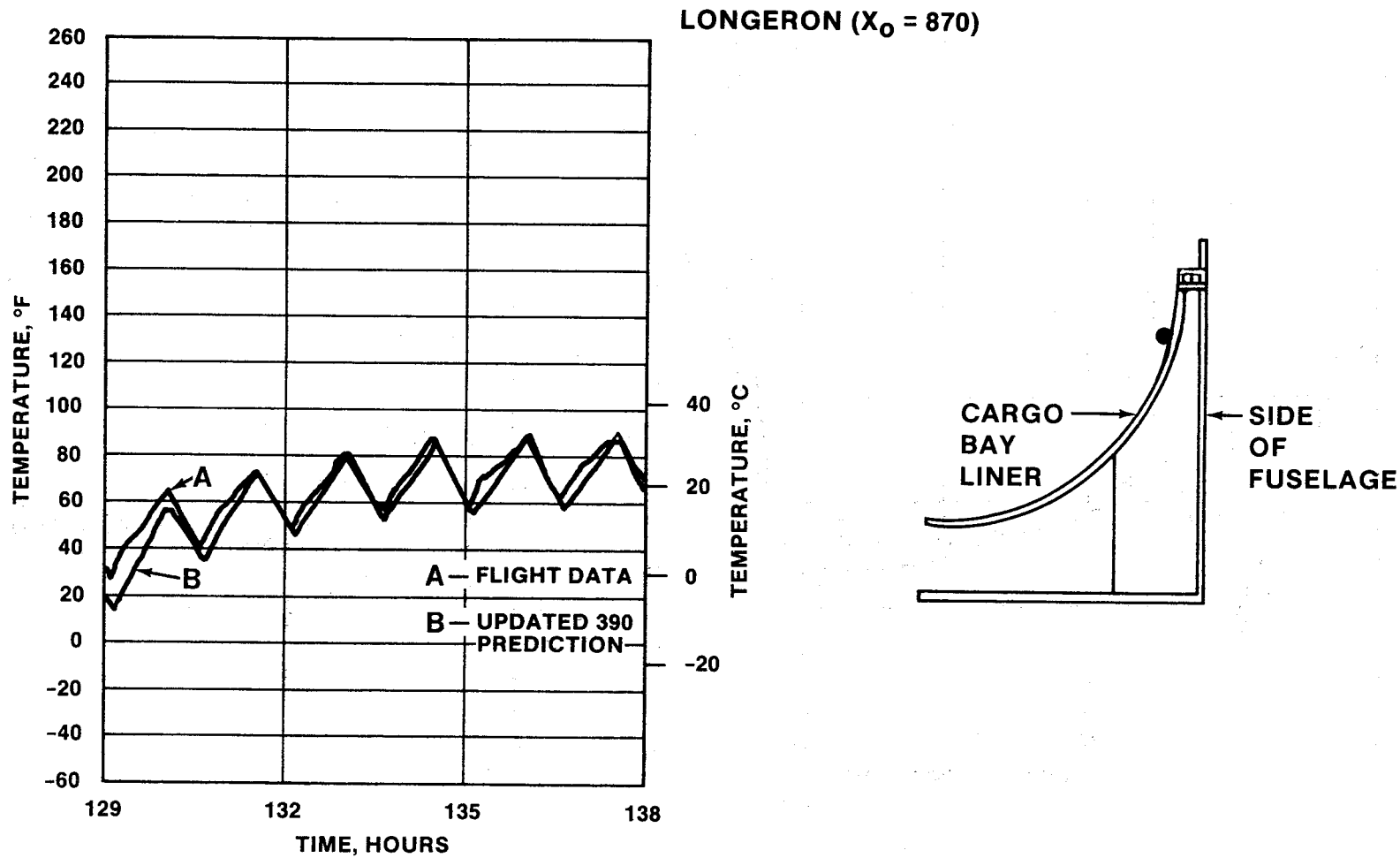
S-84-02044
Rev 1

FLIGHT	STS-3			STS-4		STS-5	
BETA ANGLE RANGE	-23° TO -36°			-1° TO -20°		-20° TO -7°	
ORIENTATION	TAIL SUN ORB RATE	NOSE SUN 2 ORB RATE	TOP SUN SI	BOTTOM SUN SI	TAIL SUN SI	STBD SUN SI	NOSE SUN SI
LINER	-102.7°C	-73.3/ 10°C	-1.1/ 127°C	-62.2/ -1.1°C	-73.3/ -6.7°C	-78.9/ -6.7°C	-23.9/ 62.2°C
LONGERON	-45.6°C	-6.7°C	37.8°C	-28.9°C	-40°C	-42.8/-37.2°C (PORT) -23.3/-17.3°C (STBD)	-40/-34.4°C -37.2°C
FITTING	-45.6°C	-28.9°C	51.7°C	-23.3°C	-37.2°C	-31.7°C (PORT)	-40°C
BULKHEAD	-84.4°C	-73.3/ -6.7°C	-17.8/ 37.8°C	-62.2/ -17.8°C	-73.3/ -1.1°C	-62.2/ -17.8°C	-62.2 -28.9°C

*MEASUREMENT REPRESENTATIVE OF RESISTANCE TEMPERATURE DEVICE BEHIND THE LINER
SI — SOLAR INERTIAL
ORB RATE ROLL ABOUT X-AXIS AT A RATE OF ONE REVOLUTION PER ORBIT

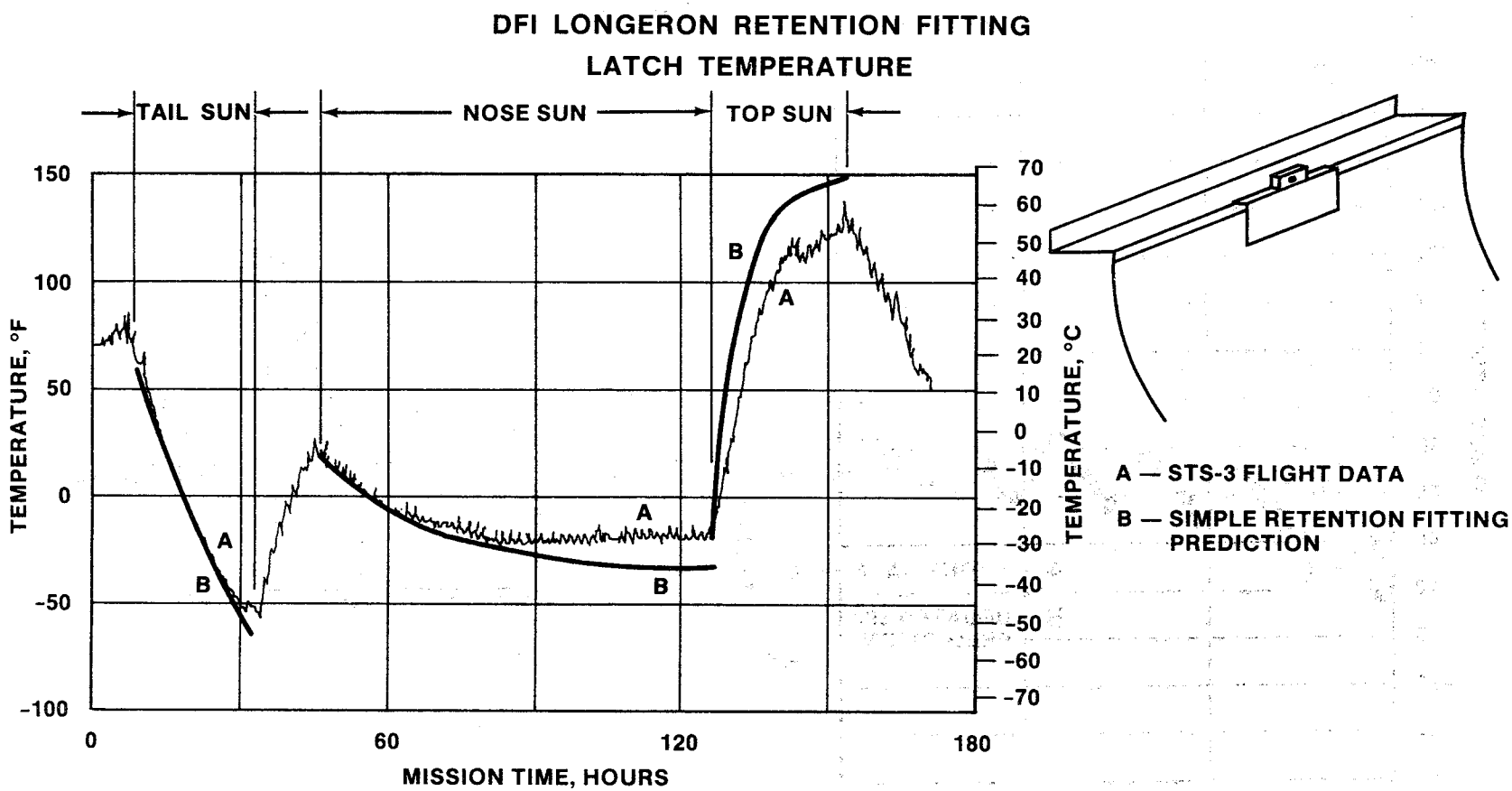
STS-3 FLIGHT DATA VS. 390 NODE PREDICTIONS TOP SUN

S-84-01835



STS-3 FLIGHT DATA VS. 390 NODE PREDICTIONS

S-84-01826



LESSONS LEARNED FROM FLIGHT AND ANALYSIS

S-84-01421

- IN ORDER TO MINIMIZE THERMAL ATTITUDE CONSTRAINTS, CONSIDER THE ORBITER CARGO BAY ENVIRONMENT EARLY IN DESIGN CYCLE FOR SUCH COMPONENTS AS
  - AIRBORNE SUPPORT EQUIPMENT
  - LOW MASS EXTERNAL SURFACES
  - HIGH α/ϵ MATERIALS
  - PROPELLANT LINES
  - PRESSURE VESSELS
  - BATTERIES
  - SOLAR ARRAYS

LESSONS LEARNED FROM FLIGHT AND ANALYSIS (CONT)

- TRANSPARENT MATERIAL, LIKE BETA CLOTH, RESULTS IN HIGHER SECOND SURFACE TEMPERATURE THAN OUTER SURFACE (BETA CLOTH) FOR SOLAR ATTITUDES
- IF LONG-TERM SOLAR ATTITUDES ARE REQUIRED, CONSIDER CLOSING OUT THE GAP BETWEEN ORBITER SILL LONGERONS AND CARGO ELEMENT WITH SOLAR SHIELD TO ELIMINATE SOLAR ENTRAPMENT BETWEEN CARGO BAY AND CARGO ELEMENT
- PREDICTED THERMAL RESPONSES FOR EXTENDED HOLD DURATIONS ARE INEXPENSIVE TO RUN IF THEY ARE ACCOMPLISHED DURING THE DESIGN RUNS

S-84-01457

RECOMMENDATIONS TO MINIMIZE THERMAL INTEGRATION COST

- MINIMIZE SPECIAL ATTITUDE CONSTRAINTS. DESIGN TO HOT AND COLD ATTITUDES INSTEAD OF POINT DESIGN
- MINIMIZE DEDICATED SPIGOT PURGE REQUIREMENTS
- MINIMIZE PAYLOAD HEAT EXCHANGER REQUIREMENTS

SUMMARY

- PASSIVE PAYLOADS ARE CONTROLLED DURING PRELAUNCH WITH THE GENERAL CARGO BAY PURGE
- ASCENT THERMAL ENVIRONMENTS HAVE LITTLE EFFECT ON PAYLOAD RESPONSE. THE PAYLOAD TEMPERATURE RESPONSE DURING ASCENT PHASE OF THE MISSION IS PRIMARILY AFFECTED BY PAYLOAD POWER DISSIPATION
- ON-ORBIT PREFERRED NOMINAL ENVIRONMENTS HAVE BEEN DEFINED FOR MIXABLE DEPLOYABLE PAYLOADS TO MINIMIZE THE ON-ORBIT THERMAL ENVIRONMENT EFFECTS
- FLIGHT DATA INDICATE THAT PLANNED NOMINAL ENTRY ENVIRONMENTS ARE BENIGN COMPARED TO DESIGN ENTRY ENVIRONMENTS

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* U.S. GOVERNMENT PRINTING OFFICE: 1984—769-013/7675