TRW

Total Ozone Mapping Spectrometer Earth Probe (TOMS-EP)

Critical Design Review Data Package

Day 3
5 August 1992

CDRL No. SE-22
Contract No. NAS5-31488

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TOMS-EP CDR Agenda
Day 1 3 August 1992

Time	Subject	Presenter
8:00	**Mission Objectives**	
8:30	**Project Overview**	D. Stager
	PDR Actions/Open Issues	
	Subcontractors	R. Hlavaty
	Performance Assurance Implementation	E. Starr
9:30	**Key Requirements Vs. Capabilities**	B. Dobrotin
10:30	**System Implementation**	
	System Description	B. Dobrotin
	System Design Integration:	
	Mechanical Integration	D. Nicolson
	Electrical Integration, Command and Telemetry	W. Jhang
12:00	LUNCH	
1:00	**Interfaces:**	
	Launch Vehicle Interfaces and Integration	J. Giglio
	Spacecraft Bus to Instrument	B. Dobrotin
	Spacecraft/Ground	T. Watson
2:30	**Spacecraft Modes/Redundancy Management**	L. Fesq
3:30	**System Performance**	
	Mass Properties	L. Petty
	Alignment Budgets	W. Akle
	Electrical Power Energy Balance	D. Muleady

TOMS-EP CDR Agenda
Day 2 4 August 1992

Time	Subject	Presenter
8:00	**TRW Eagle Test Bed (ETB) - M2 High Bay**	T. Petersen
	Subsystem Design and Verification	
9:00	Structure and Mechanisms Subsystem (SMS)	J. Castan
10:00	Thermal Subsystem	D. Wanous
11:00	Orbit Adjust Subsystem (OAS)	A. Alicastro
12:00	LUNCH	
1:00	Communications and Data Handling Subsystem (C&DHS)	J. Kinney
2:00	Electrical Power & Distribution Subsystem (EPDS)	S. Foroozan
3:00	Attitude Control and Determination Subsystem (ACDS)	H. Schmeichel
4:00	Flight Software	D. Stuart

TOMS-EP CDR Agenda
Day 3 5 August 1992

Time	Subject	Presenter
8:00	**System Verification**	B. Dobrotin
8:30	Spacecraft Verification	J. Giglio
9:30	EMC/EMI Verification	R. Bal
	Spacecraft Integration, Test, Launch and Mission Operations	
10:30	System Integration, Test and Launch	J. Durschinger
12:00	LUNCH	
1:00	Mission Operations	T. Watson
2:00	**Performance Assurance**	E. Starr
2:15	Reliability/FMEA	W. Woerner
2:40	System Safety	D. McGraw
3:10	Contamination Control	K. Henderson
3:40	Materials and Processes	M. Hirsch
4:05	EEE Parts	G. Penney
4:50	Hardware Quality Assurance	L. Irwin
5:15	Software Quality Assurance	G. Walsh

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TOMS-EP
System Verification

B. Dobrotin

Verification Objective

- Assure that the TOMS-EP hardware and software meet the requirements of the system specification per NASA/GSFC GEVS

- Presentation of TRW approach is in three parts:
  - That which is done on ETB
  - Total spacecraft verification program
  - EMC/EMI details

Eagle Test Bed Verification Approach

- Verify at most cost effective level of assembly
- Verify on Eagle Test Bed instead of Spacecraft System I&T
- Thorough ETB integration and checkout provide assurance of successful TOMS-EP verification

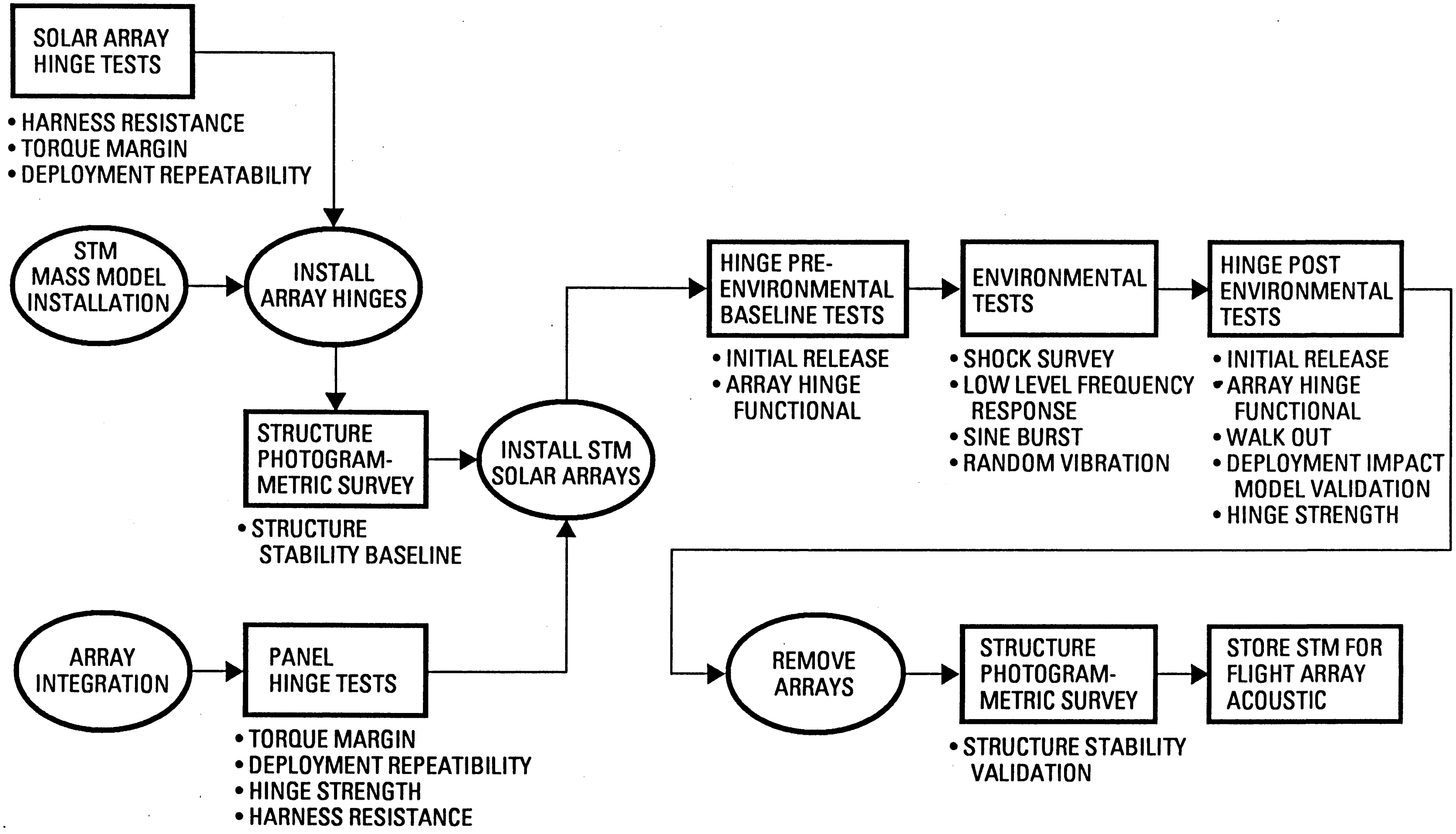
TOMS-EP Eagle Test Bed Use

- STM qualification to TOMS-EP structural requirements
  - TRW funded
- Verify subsystem operation prior to I&T
  - TFS verification (include LFBT)
  - SAR operational verification
  - EMC testing

TOMS-EP Structural Verification

- Structural dynamic loads analyses, verification data
- Initial separation shock environment data
- Array hinge performance verification data
- Solar array structural performance verification data
- Alignment stability data

Structural Test Model (STM) Test Flow



SOLAR ARRAY HINGE TESTS

- HARNESS RESISTANCE
- TORQUE MARGIN
- DEPLOYMENT REPEATABILITY

STM MASS MODEL INSTALLATION

INSTALL ARRAY HINGES

STRUCTURE PHOTOGRAM-METRIC SURVEY

- STRUCTURE STABILITY BASELINE

ARRAY INTEGRATION

PANEL HINGE TESTS

- TORQUE MARGIN
- DEPLOYMENT REPEATIBILITY
- HINGE STRENGTH
- HARNESS RESISTANCE

INSTALL STM SOLAR ARRAYS

HINGE PRE-ENVIRONMENTAL BASELINE TESTS

- INITIAL RELEASE
- ARRAY HINGE FUNCTIONAL

ENVIRONMENTAL TESTS

- SHOCK SURVEY
- LOW LEVEL FREQUENCY RESPONSE
- SINE BURST
- RANDOM VIBRATION

HINGE POST ENVIRONMENTAL TESTS

- INITIAL RELEASE
- ARRAY HINGE FUNCTIONAL
- WALK OUT
- DEPLOYMENT IMPACT MODEL VALIDATION
- HINGE STRENGTH

REMOVE ARRAYS

STRUCTURE PHOTOGRAM-METRIC SURVEY

- STRUCTURE STABILITY VALIDATION

STORE STM FOR FLIGHT ARRAY ACOUSTIC

TOMS-EP/ETB Subsystem Verification

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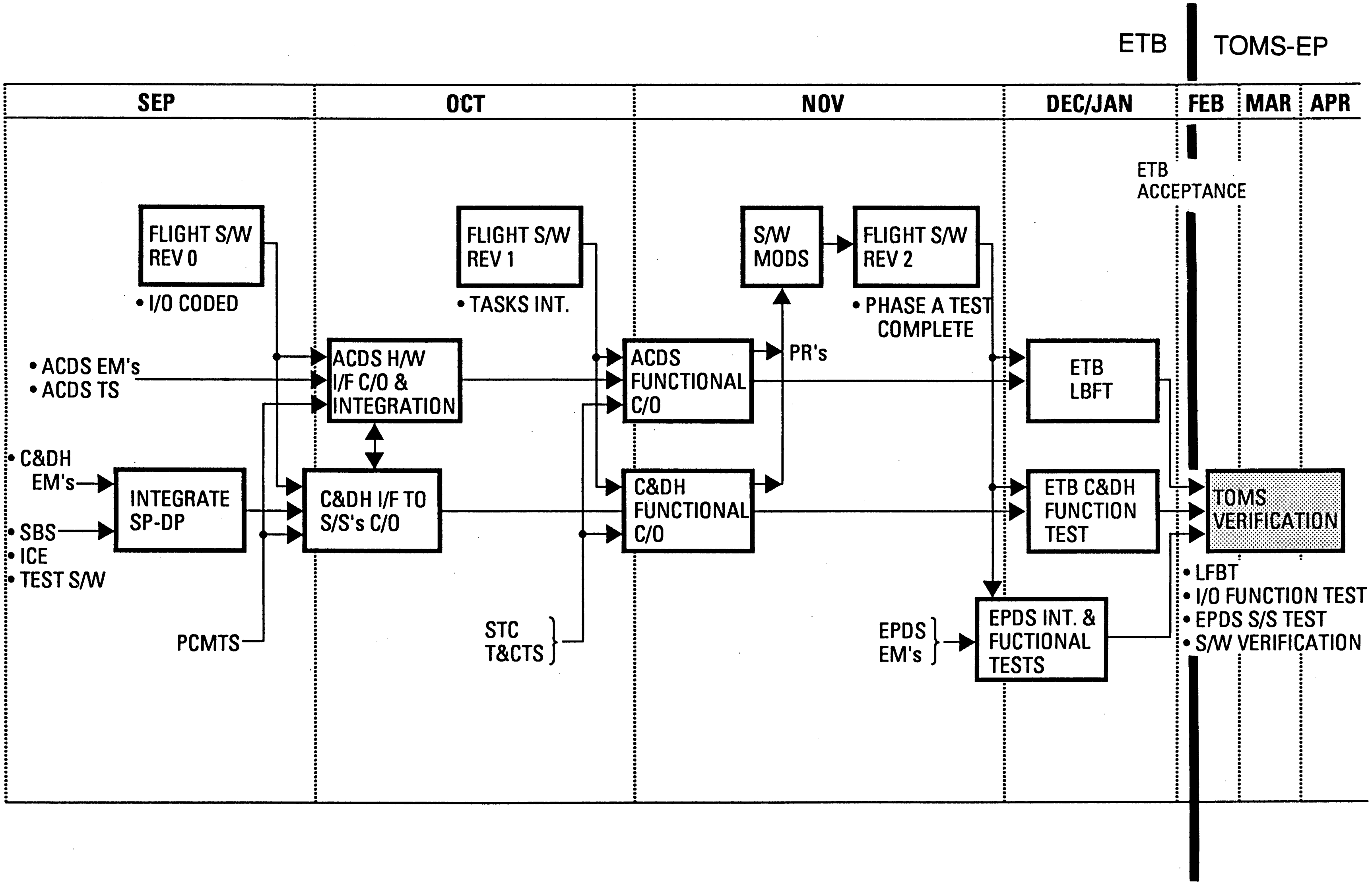
- ACDS LFBT
  - Verification is to simulation results
- EPDS Dynamic Performance Verification
  - Verifies integrated operation:

    Hardware: ARM

    Software: Charge control
- TFS øB Verification
  - Verification to Software Requirements Specification
  - Primary focus on hardware/software integration

ETB Integration Testing Provides High Confidence for TOMS-EP Verification



TOMS-EP/ETB EMC Testing

- Perform all conducted emissions testing on ETB
- Specific tests:
  - Primary bus ripple
  - Equipment switching transients
  - Conducted susceptibility
- Provides characterization of noise on power and signal lines
  - Validation of SEMCAP analysis

TOMS-EP
Spacecraft Verification

John Giglio

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VERIFICATION OBJECTIVE:

- ASSURE THAT THE TOMS-EP HARDWARE AND SOFTWARE MEET THE REQUIREMENTS OF THE SPECIFICATIONS

VERIFICATION APPROACH

- VERIFY PROTOFLIGHT HARDWARE
- VERIFY AT MOST COST EFFECTIVE LEVEL OF ASSEMBLY
- GAIN EARLY DESIGN CONFIDENCE BY USING EAGLE TEST BED
- USE PREVIOUSLY QUALIFIED AND FLOWN HARDWARE WHERE POSSIBLE

VERIFICATION METHODOLOGY

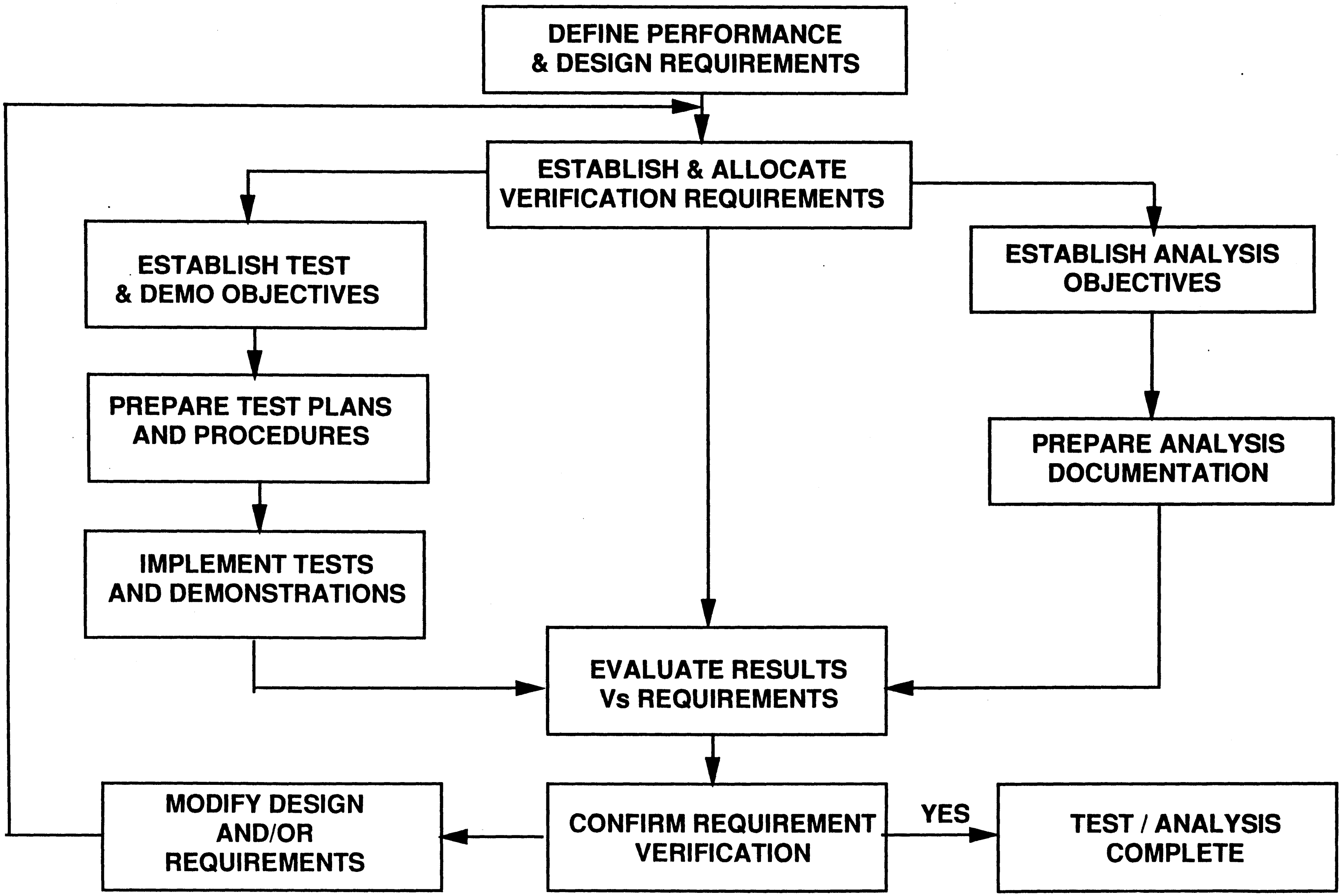
- ESTABLISH AND FLOWDOWN VERIFICATION REQUIREMENTS

- DEFINE METHODS FOR VERIFICATION OF REQUIREMENTS
  - TEST
  - ANALYSIS
  - DEMONSTRATION
  - INSPECTION

- DOCUMENT VERIFICATION METHODS IN VERIFICATION MATRICIES IN APPROPRIATE SPECIFICATIONS

- ESTABLISH VERIFICATION REQUIREMENTS TRACEABILITY TO SUPPORT S/C SELL-OFF

Verification Process Flow



DEFINE PERFORMANCE & DESIGN REQUIREMENTS

ESTABLISH & ALLOCATE VERIFICATION REQUIREMENTS

ESTABLISH TEST & DEMO OBJECTIVES

PREPARE TEST PLANS AND PROCEDURES

IMPLEMENT TESTS AND DEMONSTRATIONS

ESTABLISH ANALYSIS OBJECTIVES

PREPARE ANALYSIS DOCUMENTATION

EVALUATE RESULTS Vs REQUIREMENTS

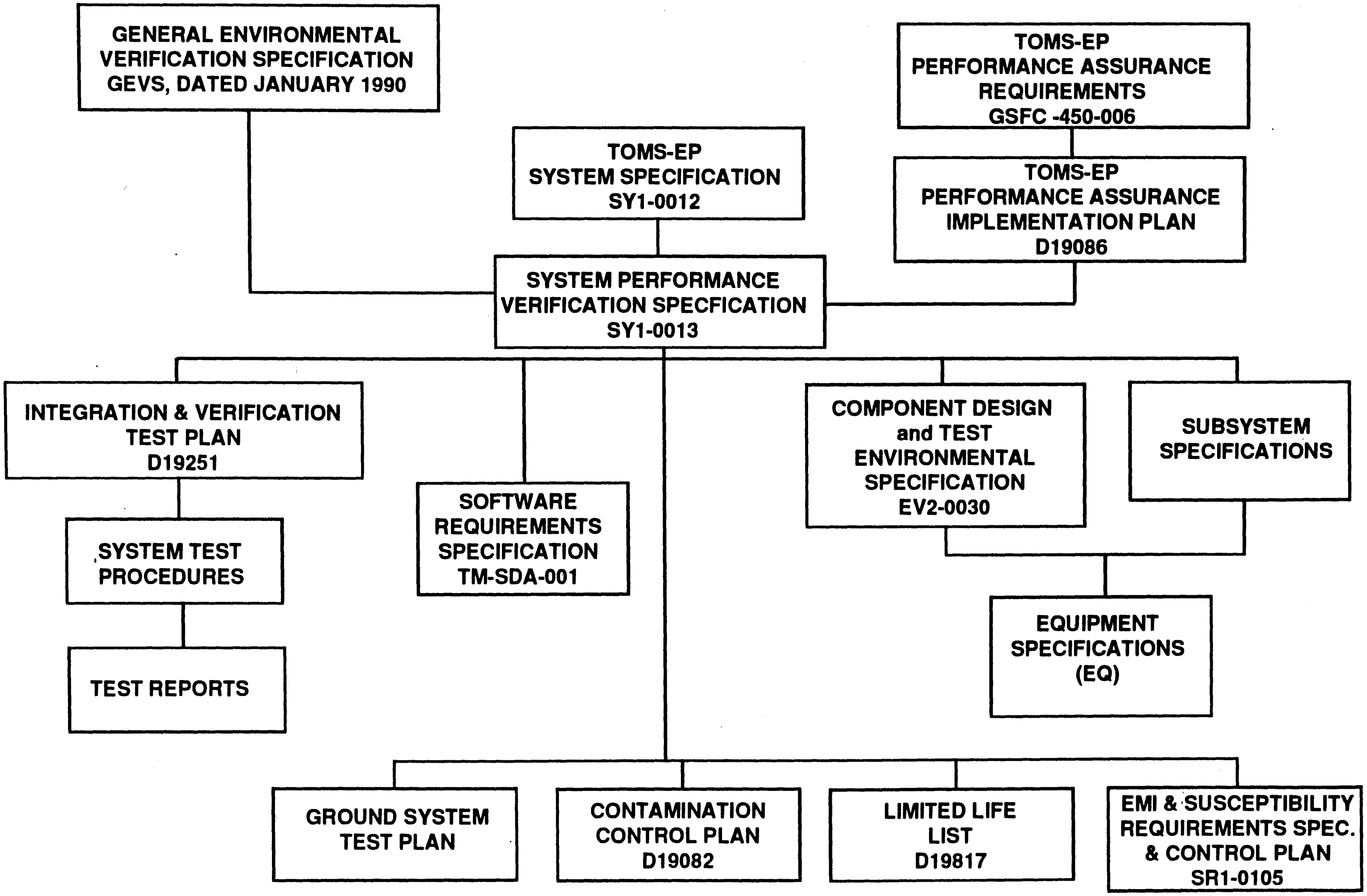
CONFIRM REQUIREMENT VERIFICATION

YES

TEST / ANALYSIS COMPLETE

MODIFY DESIGN AND/OR REQUIREMENTS

Verification Requirements Flowdown



GENERAL ENVIRONMENTAL
VERIFICATION SPECIFICATION
GEVS, DATED JANUARY 1990

TOMS-EP
SYSTEM SPECIFICATION
SY1-0012

TOMS-EP
PERFORMANCE ASSURANCE
REQUIREMENTS
GSFC -450-006

TOMS-EP
PERFORMANCE ASSURANCE
IMPLEMENTATION PLAN
D19086

SYSTEM PERFORMANCE
VERIFICATION SPECFICATION
SY1-0013

INTEGRATION & VERIFICATION
TEST PLAN
D19251

SYSTEM TEST
PROCEDURES

TEST REPORTS

SOFTWARE
REQUIREMENTS
SPECIFICATION
TM-SDA-001

COMPONENT DESIGN
and TEST
ENVIRONMENTAL
SPECIFICATION
EV2-0030

SUBSYSTEM
SPECIFICATIONS

EQUIPMENT
SPECIFICATIONS
(EQ)

GROUND SYSTEM
TEST PLAN

CONTAMINATION
CONTROL PLAN
D19082

LIMITED LIFE
LIST
D19817

EMI & SUSCEPTIBILITY
REQUIREMENTS SPEC.
& CONTROL PLAN
SR1-0105

VERIFICATION TOOLS

- SYSTEM VERIFICATION MATRIX (APPENDIX B, SY1-0013)
  DEFINES VERIFICATION METHODS AND RESPONSIBILITIES
- VERIFICATION TEST MATRIX (SY1-0013 AND IV&T PLAN D19251)
  DEFINES SYSTEM AND COMPONENT LEVEL TEST REQUIREMENTS
- VERIFICATION TRACEABILITY MATRIX (DATABASE MAINTAINED BY SE)
  (TO BE COMPLETED 45 DAYS AFTER CDR)
  DEFINES VERIFICATION REQUIREMENTS AND METHODS TRACEABILITY
- GEVS TO TOMS-EP TRACEABILITY MATRIX (APPENDIX A, SY1-0013)
  PROVIDES TRACEABILITY OF REQUIREMENTS AND APPROACH FOR VERIFICATION

System Verification Matrix Example

SY1-0012 Paragraph No.	SY1-0012 Paragraph Title	Verification Method				Traceability To GSFC 450-005	Verification Documentation
		T	A	I	D		
3	REQUIREMENTS					Title only	
3.1	ITEM DEFINITION					Definition	
3.1.1	Prime Item Diagram					Description	
3.1.2	Spacecraft Bus Interfaces					Title only	
3.1.2.1	TOMS-EP to SELV Intfc Requirements			x		5.1.1, 7.0	Inspection of records
3.1.2.1.1	Spacecraft Envelope			x		5.1.1, 7.1	Inspection of interface drawings
3.1.2.1.2	Umbilical Interface			x		5.1.1, 7.2	Inspection of drawings
3.1.2.1.3	Payload Attach Fitting (PAF)			x		6.1.1, 7.1	Inspection of drawings
3.1.2.1.4	Launch and Separation Loads	X	x			6.1.2	Test, loads analysis
3.1.2.1.5	Spacecraft Stowed Balance	x	x			6.1.3	Mass properties analysis - weight and balance test
3.1.2.1.6	Separation Conditions		x			5.1.1, 7.3	Spacecraft Mode Definition D19829
3.1.2.1.7	Spacecraft Separation Signal			x		5.1.1	Inspection of interface drawings
3.1.2.1.8	Spacecraft to SELV Ops. Interfaces	X	X	X		5.1.1	Pegasus to S/C ICD
3.1.2.2	TOMS Instrument Interfaces			x		4.1.2, 5.1.12	Inspection of drawings, ICDs, specifications
3.1.2.2.1	Pointing		x			5.2.1, 5.2.2, 5.2.3	Alignment Budgets D19254
3.1.2.2.2	Instrument FOVs		x			5.2.4	Alignment Budgets D19254
3.1.2.2.3	Instrument Power State	x	x	x		4.1.6, 6.2.4	Mode Description (D19829), s/w test, instr test
3.1.2.2.4	Sun Avoidance	x	x			4.1.7	Software testing, Mode Description
3.1.2.2.5	Instrument Weight and CG		x			6.1.3	Structural analysis, mass properties analysis
3.1.2.2.6	Instrument-to-Spacecraft Alignment	x				5.2.2	Installation/alignment
3.1.2.2.7	Instrument Access			x		5.2.5	Inspection of drawings
3.1.2.2.8	Instrument Mechanical Accomodation			x		5.2	Inspection of drawings
3.1.2.2.9	Instrument Power Requirements	x	x			6.2.2, 6.2.3	Integration test, power analysis
3.1.2.2.10	Instrument Thermal Requirements		x			6.3 a & b	Thermal analysis
3.1.2.2.11	Instrument Command and Telemetry	x	x			5.1.5, 6.4.1	Software testing, C&DH analysis
3.1.2.2.12	Magnetics	x	x			8.3	EMC analysis, EMC test
3.1.2.3	Flt Segment to Gnd Segment Interface	x	x			4.1.4, 9.5, 6.5.1.2	Comm analysis, End-to-end test
3.1.2.3.1	Ground-to-Space Command Format	x				4.1.4	End-to-end test
3.1.2.3.2	Space-to-Ground Telemetry Formats	x				4.1.4	End-to-end test
3.1.2.3.3	Space-to-Ground Ops. Interfaces	x				4.1.4	End-to-end test
3.1.2.4	POCC GSE/Spacecraft GSE Interfaces	x				4.1.4, 9.4	End-to-end test

Verification Test Matrix Example

- DOCUMENTED IN SY1-0013 AND FLOWED DOWN TO IV&T PLAN D19251

LEGEND

LEVEL OF ASSEMBLY:
S/C - SPACECRAFT
I - INSTRUMENT
S - SUBSYSTEM
C - COMPONENT

UNIT TYPE:
PT - PROTOTYPE
PF - PROTOFLIGHT
F - FLIGHT
S - SPARE
EM - ENGRG. MODEL

QUALIFICATION STATUS:
1. COMPLETE QUALIFICATION REQUIRED
2. PARTIAL QUALIFICATION REQUIRED (SEE REMARKS)
3. QUALIFIED BY USE ON PRIOR PROGRAM (SEE REMARKS)
4. OTHERWISE QUALIFIED (SEE REMARKS)
5. QUALIFIED ON TOMS-EP
N/A NOT APPLICABLE

HARDWARE SPECIFICATION						QUALIFICATION TESTS													
LEVEL OF ASSY	ITEM	S/N	UNIT TYPE	SUPPLIER	QUAL STATUS	FUNCTIONAL	EMC/EMI (REFER TO NOTE 1)	ACOUSTICS	VIBRATION (3Axis Random)	LOW LEVEL VIBRATION	PYRO SHOCK (ACTUATIONS)	SINE BURST	THERMAL VACUUM (CYCLES)	THERMAL BALANCE S/C Level	THERMAL CYCLES (MINIMUM)	PROOF	LEAK	BURN-IN (REFER TO NOTE 2)	HOT FIRE
S/C	SPACECRAFT (SEE NOTE 3)	FLT-1	PF	TRW/GFE	1	X	X		X		2	X	6	X			X		
S	STRUCTURAL TEST MODEL	STM	PT	TRW	1					X		X							
C	SOLAR ARRAY HINGE ASSEMBLY	STM	PT	TRW	1	X													
C	ALL SOLAR ARRAY HINGE ASSY. FLIGHT UNI	FLT-1	F		5														
C	SOLAR ARRAY RELEASE MECHANISMS	FLT-1	F		1	X			X						16				

GEVS Traceability Matrix Example (Appendix A, SY1-0013)

LEGEND:
X - COMPLIANCE
E - EXCEPTION, WAIVER REQUIRED

NOTES:
1- NO ANALYSIS OR TEST PLANNED
2-ANALYSIS ONLY, NO TESTING PLANNED

GEVS Reqmt. Para. Number	TITLE	SY1-0013 Reference No.	EV2-0030 Reference No.	Level of Verif System	Subsystem	Structural Test Model	Component	Eagle Test Bed	COMMENTS	REFERENCE DOCUMENTS
2.3.3	Limited Performance Tests	4.3.1	1.2.1.3	X			X			
2.3.4	Failure Free Performance	4.5	N/A	X						D119251
2.3.5	Limited Life Electrical Elements	4.6	3.1.6				X		Limited life items are defined in D19817	D19817 (CDRL PA-12)
2.4	Structural & Mechanical Verif.								Introduction	
2.4.1	Structural Loads Qualification								Discussion	
2.4.1.1	Analysis	4.1	N/A	X		X			Finite Element Model & STM Testing	CDRL SS1-0021
2.4.1.2	Modal Survey	4.7.2	N/A			X			Limited Response Test	
2.4.1.3	Design Strength Qual Test	4.7.3	N/A	x		x			Sine Burst and Selected Pull Testing	
2.4.1.4	Structural Reliability	4.7.4	N/A	X					Sine Burst	
							X		Fracture Mechanics Aanalysis OAS Tank	
2.4.1.5	Acceptance Requirements			X						
2.4.2	Vibroacoustics Qualification	3.1.4	3.1.3.2	(E)			X		Acoustic on Solar Array Only	
2.4.2.1	Fatigue Life Considerations								Not Applicable	
2.4.2.2	Payload Acoustic Test	3.1.4, 4.7	3.1.3.2	(E)			X		Solar Array Only	
2.4.2.3	Payload Vibration Tests	3.1.4, 4.7	4.3	X						
2.4.2.3 (a)	Lift-Off Random Vibration	3.1.4, 4.7	4.3	X						
2.4.2.3 (b)	Additional Vibration Testing								Not Required	
2.4.2.3 (c)	Performance	4.7.5.1	4.3	X			X			
2.4.2.4	Subsystem Vibroacoustic Tests								Not Required	
2.4.2.5	Component Vibroacoustic Tests								Introduction	
2.4.2.5 (a)	Random Vibration	3.3	3.1.3.1				X			
2.4.2.5 (b)	Acoustic Test	3.3	3.1.3.2	(E)			X		Solar Array Only	
2.4.2.5 (c)	Additional Vibration Testing								Not Required	
2.4.2.5 (d)	Performance	4.7.5.1	4.3				X			
2.4.2.6	Acceptance Requirements		3.1.3.1, 3.1.3.2				X			
.	Retest of Reflight Hardware								Not Applicable	
2.4..3	Mechanical Shock Verification								Introduction	
2.4.3.1	Subsystem Mechanical Shock Tests	N/A	N/A	X					S/C level per GEVS paragraph 2.4.3.2	
2.4.3.1 (a)	Self-Induced Shock	N/A	N/A	X					S/C level per GEVS paragraph 2.4.3.2	
2.4.3.1 (b)	Externally Induced Shock	N/A	N/A	X					S/C level per GEVS paragraph 2.4.3.2	
2.4.3.1 (c)	STS Shock Environment								Not Applicable	
2.4.3.1 (d)	Test Setup	N/A	N/A	X					S/C level per GEVS paragraph 2.4.3.2	
2.4.3.1 (e)	Performance	N/A	N/A	X					S/C level per GEVS paragraph 2.4.3.2	

Major Verification Analyses

- STRUCTUARAL DYNAMIC MODEL (VALIDATED ON STM)
- THERMAL ANALYTICAL MODEL (VALIDATED BY SPACECRAFT THERMAL BALANCE)
- COMMAND and DATA HANDLING ANALYSIS
- ATTITUDE CONTROL and DETERMINATION ANALYSIS
- ORBITAL ADJUST SUBSYSTEM ANALYSIS
- ALIGNMENT ANALYSIS
- CONTAMINATION ANALYSIS
- EMC ANALYSIS
- SAFETY ANALYSIS (CURRENTLY ACCIDENT RISK ASSESSMENT ANALYSIS)

Environmental Design Requirements

- **Minimum Natural Frequencies**
  - SPACECRAFT > 20 Hz (PEGASUS REQUIREMENT)
  - COMPONENTS LESS THAN 30 POUNDS > 100 Hz (DERIVED)
  - COMPONENTS GREATER THAN 30 POUNDS > 40 Hz (DERIVED)
  - SOLAR ARRAY (STOWED) > 22 Hz (DERIVED)

- **Acoustics**

(DERIVED)

Frequency (Hz)	1/3 Octave Sound Pressure Level (dB)
Overall	134.2

- **Design Limit Loads Derived From Pegasus Interface Loads Specified In Contract**

Component and Event	Pegasus XL-C L1011 Aircraft	
	Axial, $Z_{s/c}$	Lateral
Spacecraft Structure		
Captive Flight Release (CFR)	± 1	±4.5, $-X_{s/c}$ ±1, $Y_{s/c}$
Aerodynamic Pull-up	-3.65±.35	2.4±.5, $-X_{s/c}$ ±1.5, $Y_{s/c}$
Abort Landing	±0.6	2.8±.1, $-X_{s/c}$ ±0.6, $Y_{s/c}$
1st Stage Burnout	-8.5±1	±1.2
2nd Stage Burnout	-11.5±1	±1.2
3rd Stage Burnout	-9.5±1	±1.2
Platforms		
Nadir (CFR)	± 1	±4.5, $-X_{s/c}$ ±1, $Y_{s/c}$
Middle (CFR)	± 1	±4.5, $-X_{s/c}$ ±1, $Y_{s/c}$
OAS (CFR)	± 1	±4.0, $-X_{s/c}$ ±1, $Y_{s/c}$
Powered Flight* (PF) (All Platforms)	-11.5±2.5	± 2

Environmental Design Requirements (Continued)

- Random Vibration Requirement (Revised GEVS Values For Pegasus)

Frequency (Hz)	ASD Level (G^2 / Hz)	
	Protoflight	Acceptance
20 to 100	0.005	0.0025
100 to 200	+6dB/octave	-6dB/octave
200 to 1250	0.02	0.01
1250 to 2000	-6dB/octave	-6dB/octave
Overall level	5.6 Grms	4.0 Grms

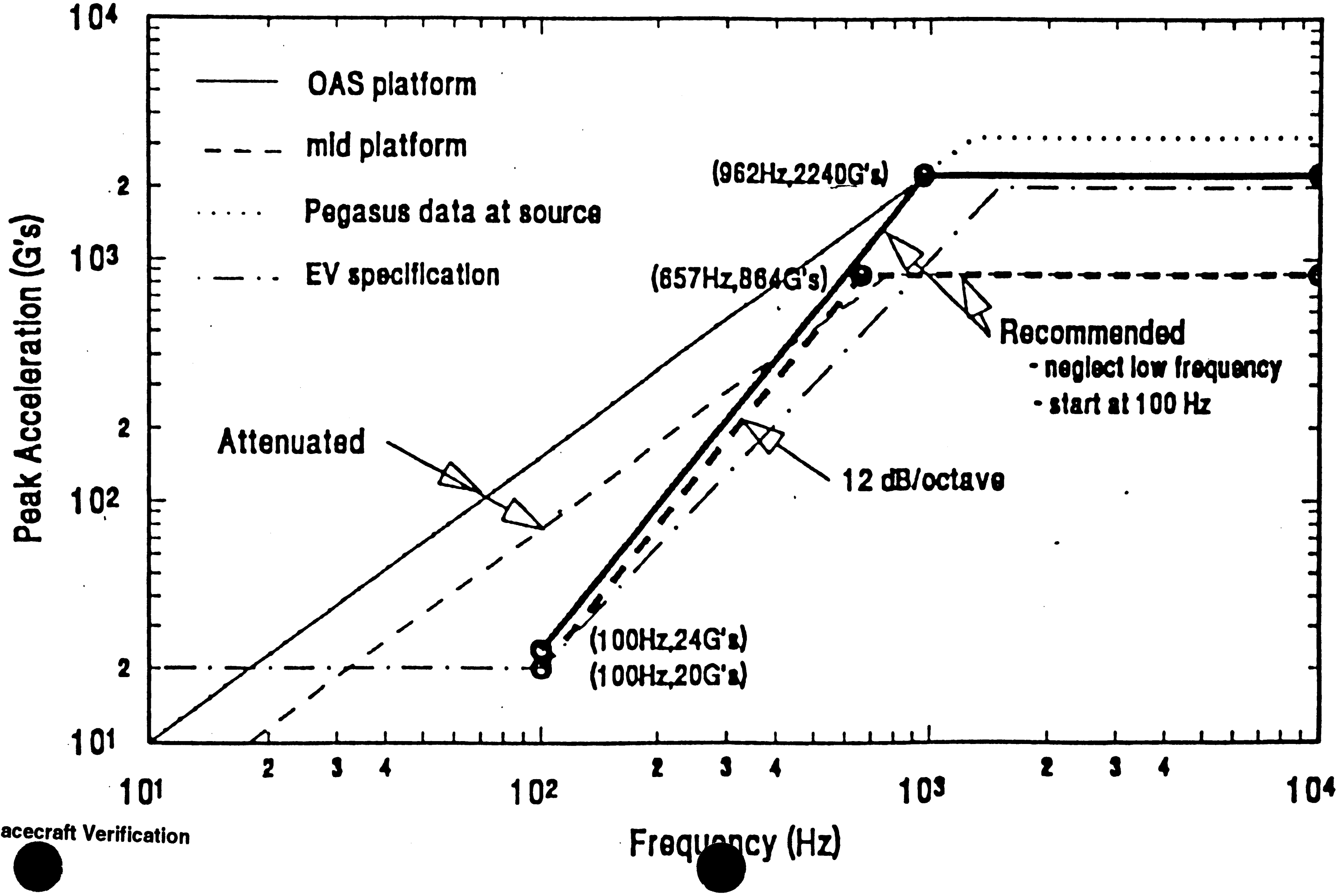
Shock Environment Issue

- CURRENT CONTRACT SHOCK ENVIRONMENT AND PEGASUS SEPARATION TEST DATA DO NOT AGREE
- ANALYSIS TO COMPARE CONTRACT VALUES AND PEGASUS TEST DATA WITH S/C ATTENUATION WAS DONE
- RESULTS INDICATE COMPONENT REQUIREMENT FOR HARDWARE ON MID-PLATFORM IS PROBABLY ACCEPTABLE
- OAS PLATFORM HAS SMALL ATTENUATION AND SHOCK TESTING ON SELECTED OAS COMPONENTS IS PLANNED
- FINAL ASSESSMENT OF PEGASUS TEST VALUES ON THE TOMS-EP DESIGN IS PENDING COMPLETION OF THE SHOCK SURVEY PLANNED FOR THE STM IN SEPTEMBER

- **Launch Vehicle Separation Shock Comparison**

TOMS Component Shock Spectra (Q=10)

Recommendation as of 7 May 92



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Component Verification Versus Requirements (EV2-0030)

Requirement	Verification
• RANDOM VIBRATION	3 AXIS - PROTOFLIGHT LEVELS
• ACOUSTICS	SOLAR ARRAY ONLY
• DESIGN STRENGTH	- ANALYSIS AT COMPONENT LEVEL - SINE BURST AT SPACECRAFT LEVEL - EQUIPMENT MUST PERFORM TO SPEC. FOLLOWING ENVIRONMENT
• THERMAL VACUUM	- 8 CYCLES RF EQUIPMENT ONLY - 6 CYCLES AT S/C LEVEL SATISFIES T/V FOR OTHER COMPONENTS
• THERMAL CYCLING	NON-RF EQUIPMENT - 16 CYCLES AMBIENT PRESSURE PROTOFLIGHT TEMPERATURES
• SHOCK	- ANALYSIS AT COMPONENT LEVEL, EXCEPT BATTERY - TEST DEFERRED TO SPACECRAFT STM SURVEY TO MINIMIZE RISK
• PERFORMANCE	- AS DEFINED BY EQ SPECIFICATIONS
• BURN-IN	- 300 HOURS OF OPERATING TIME PRIOR TO DELIVERY

Spacecraft Verification Versus GEVS Requirements

GEVS Requirement	Verification
COMPREHENSIVE PERFORMANCE TESTS	3 PLANNED - ONE AS BASELINE ONE HOT - ONE COLD DURING THERMAL VAC.
ACOUSTICS	PERFORMED ON SOLAR ARRAY ONLY. WAIVER REQUEST FOR SPACECRAFT LEVEL TEST.
RANDOM VIBRATION	3-AXIS PROTOFLIGHT LEVELS
DESIGN STRENGTH And STRUCTURAL RELIABILITY	- FIXED FREQUENCY SINE TEST OF STM FOR PRIMARY STRUCTURE - REPEATED AT SPACECRAFT LEVEL FOR FLIGHT HARDWARE
DYNAMIC MODEL VALIDATION	LOW LEVEL VIBRATION ON STM
SEPARATION SHOCK	2 FIRINGS OF TEST PAYLOAD ADAPTER SUPPLIED BY OSC
THERMAL VACUUM	- 6 CYCLES AT SPACECRAFT LEVEL - ONE CYCLE USED FOR THERMAL BALANCE TO VALIDATE THERMAL MODEL

Spacecraft Verification Versus Requirements (Continued)

GEVS Requirement	Verification
• INTERFACE ELECTRICAL TESTS	
- SPACECRAFT	PRIMARY POWER FAULT TESTING
- INSTRUMENT	S/C I/F TEST WITH INSTRUMENT SIMULATOR INSTRUMENT TEST AT ASSOCIATE CONTRACTOR WITH S/C SIMULATOR S/C LEVEL FUNCTIONAL TEST DURING I & T
- LAUNCH VEHICLE	S/C SIDE WITH EGSE IN SIMULATED PRE-LAUNCH & LAUNCH CONDITIONS
- UNIT LEVEL	UNIT TEST SETS

Mechanical Function Verification Versus GEVS Requirements

GEVS Requirement	Verification
• COMBINATION OF ANALYSIS & TEST	• KINEMATIC ANALYSIS FOR ADVERSE EFFECTS OF TOL. BUILD-UP, THERMAL DISTORTIONS, MISALIGNMENTS, STATIC/DYNAMIC DISPLACEMENTS • TESTS: HARNESS COLD TEMP RESISTANCE AND STORAGE TORQUE ANGLE MEASUREMENTS CLEARANCE VALIDATION (WALKOUT OF ARRAY THRU FULL DEPLOYMENT) NITINOL RELEASE (1ST MOTION) PRE AND POST ENVIRONMENT LOADS VERIFIED BY DYNAMIC TEST AND SELECTED PULL TEST FOR HINGE ASSEMBLY

Spacecraft Verification Versus GEVS Requirements (Continued)

GEVS Requirement	Verification
• EMC/EMI	RADIATED SUSCEPTIBILITY TESTING AT THE S/C LEVEL - CONDUCTED EMISSIONS AND SUSCEPTIBILITY AT COMPONENT LEVEL ON THE ETB - ANALYSIS AT COMPONENT LEVEL
• 100 HOURS OF FAILURE FREE PERFORMANCE	MAINTAIN SYSTEM POWERED-ON RECORDS DURING I & T
• LEAK TEST	OAS DURING I&T PROCESS

Software Verification Overview

Test Location	Test Name	Tested Items								
		HW/SW Interfaces	ACDS Functions	EPDS Functions	Software Cmds, Hardware Cmds	Stored Cmd Processing	Telemetry Processing, Playback	Fault Detection, SP Wake-up Logic	Pre-Defined RTCSs (App D)	KPD Contents (App E)
TRW/ CSEO	TFS Function-Level Test		X	X	X	X	X	X		
	TFS Verification Phase A Test				X	X	part	part		Ops part
Space Park ETB	ACDS Software Verification Test		X					part		ACDS part
	EPDS Software Verification Test			X				part		EPDS part
	TFS Verification Phase B Test	X			X		X	X		Ops part
I&T	System Test		part	part	X				X	

Major Deviations Required For GEVS Requirements

- NO ACOUSTIC TESTING AT SPACECRAFT LEVEL, SOLAR ARRAYS ONLY
- EMC TESTING VALUES TAILORED BY SR1-0105 FOR THE FOLLOWING REQUIREMENTS:
  - CE01/CEO3 (NARROWBAND AND BROADBAND)
  - RE02 (NARROWBAND AND BROADBAND)
  - CONDUCTED SUSCEPTIBILITY (POWERLINES)

  NO ANALYSIS OR TESTS ARE PLANNED FOR GEVS PARA. 2.5.4 MAGNETIC PROPERTIES EXCEPT ANALYSIS FOR STRAY MAGNETIC FIELD
- NO STRUCTURAL RELIABILTY TESTING BEING CONDUCTED ON COMPONENTS
- SINE SWEEP NOT BEING CONDUCTED ON SPACECRAFT

Candidates For Qualification By Similarity

- THERMAL CONTROL
  - HEATERS
  - THERMOSTATS AND THERMISTORS
  - MLI
- ACDS
  - MAGNETOMETER
  - TORQUE RODS
  - FINE AND COARSE SUN SENSORS
- EPDS
  - BATTERY
- C&DH
  - GSTDN TRANSPONDER
- OAS
  - DTM SUBASSY (PARTIAL)
  - FILL & DRAIN VALVES
  - PRESSURE TRANSDUCER
  - FILTER
  - ISOLATION VALVES (PARTIAL)
  - TANK (PARTIAL)

TOMS-EP
EMI/EMC Verification

R. Bal

EMC Topics of Discussion

- EMC Objectives
- Requirements vs Capability
- EMC Status/Assessment
- EMC Verification Activities
- Problem Areas/Concerns and Resolutions

EMC Objectives

- o To achieve internal EMC between Spacecraft
  - Components
  - Subsystems
  - Instrument
- o To achieve external EMC between the Spacecraft and
  - EGSE (Electrical Ground Support Equipment)
  - LVI (Launch Vehicle Interfaces)
  - Launch Site
  - Orbital Environment

EMC Requirements Vs. Capability

Requirement	Capability	Comment/ Verification method
Primary Power Grounding/Isolation		
Primary power shall be dc isolated from chassis/structure of individual components by ≥ 1 Megohm.	Comply Except: Transponder (chassis return) MDE (30 KΩ) PCU/ARE (100 KΩ)	System impact minimal. Refer to the following for details: 1) TOMS-EP.91.500.089 2) TOMS-EP.92.500.011 3) TOMS-EP.91.500.088 4) TOMS-EP.91.500.075
Interface Requirements - Orbital Operations		
Conducted Emissions, Primary Power Lines. Interference generated by units using primary power bus shall not exceed the levels given in Figures A-1 and A-2 of the SR1-0105 Document.	Comply	Units shall comply by similarity to existing design or test. Xponder tested, Instrument, CEA and GRA unit test planned. Remaining units tested in ETB.
Radiated Emissions. Interference emanating from the equipment case or cabling shall not exceed the levels given in Figures A-4 thru A-6 of the SR1-0105	Comply	Units shall comply by similarity to existing design or test Xponder tested. Instrument and GRA test planned. Satellite Radiated Emissions test planned.

EMC Requirements Vs. Capability (Continued)

TRW

Requirement	Capability	Comment/Verification method
Conducted Susceptibility, Primary and Secondary Power Leads. Equipment operational performance shall not be degraded when subjected to conducted susceptibility signals having amplitude shown in figures A-8 and A-9.	Comply	Units shall comply by test or similarity to existing design. Transponder tested. Instrument, CEA and GRA unit test planned. Remaining units tested in ETB.
Radiated Susceptibility. Equipment operational performance shall not be degraded when subjected to the Radiated E-Field of 2 V/m from 14 KHz to 2 GHz and 5 V/m from 2 GHz to 10 GHz.	Comply	Units comply by test or similarity to existing design. Transponder tested. Instrument test planned. Radiated Susceptibility test planned at the Satellite level.
In-rush Current Transient in-rush current drawn by equipment turn-on or mode changes shall not exceed the values shown in Table 4-1 of SR1-0105.	Comply	Units comply by Test or similiarity to existing design. TAM In-rush Current is as yet TBD.

in
bay
area

3 or 4
different
positions

EMC Status/Assessment

1) The following requirements were either tailored(from MIL-STD-461 C or GEVS) or modified in the EMC Spec. since PDR.

   a) Conducted Susceptibility Requirement (CS01/CS02). Tailored to TOMS-EP design based on the Bus Impedance Analysis. Revised susceptibility requirement to 2.0 Vp-p between 30 Hz and 100 KHz (Was 9.6 Vp-p), decreasing to 0.5 Vp-p (was 2.8 Vp-p) at 20 MHz. 0.5 Vp-p between 20 MHz and 500 MHz (was 2.8 Vp-p).

   b) Secondary Power Over-voltage requirement defined:
   +5V Output: Over-voltage up to 6.2 VDC for 20 µSec.
   ±15V Output: Over-voltage up to ±18.6 VDC for upto 20 µSec.
   Over voltage requirement based on DC-DC Converter shutoff capability.

EMC Status/Assessment (Continued)

c) In-rush currents associated with equipment turn-on firmed-up Relays switching the in-rush currents meet the derating criteria set forth by MIL-STD-975 except in the VDE interface. The 10 Amp relays switches 16 A (pulse duration 6 µsec), whereas, MIL-STD -975 derating requirement is 6.1 Amps. Deviation submitted to GSFC. TAM in-rush as yet TBD.

d) Developed a "notch" for the Radiated Emissions (Narrowband and Broadband) - See Figure A-5 and A-6 in the EMC Spec. The notch was developed based on the Receiver sensitivity (-123 dBm).

EMC Status/Assessment (Continued)

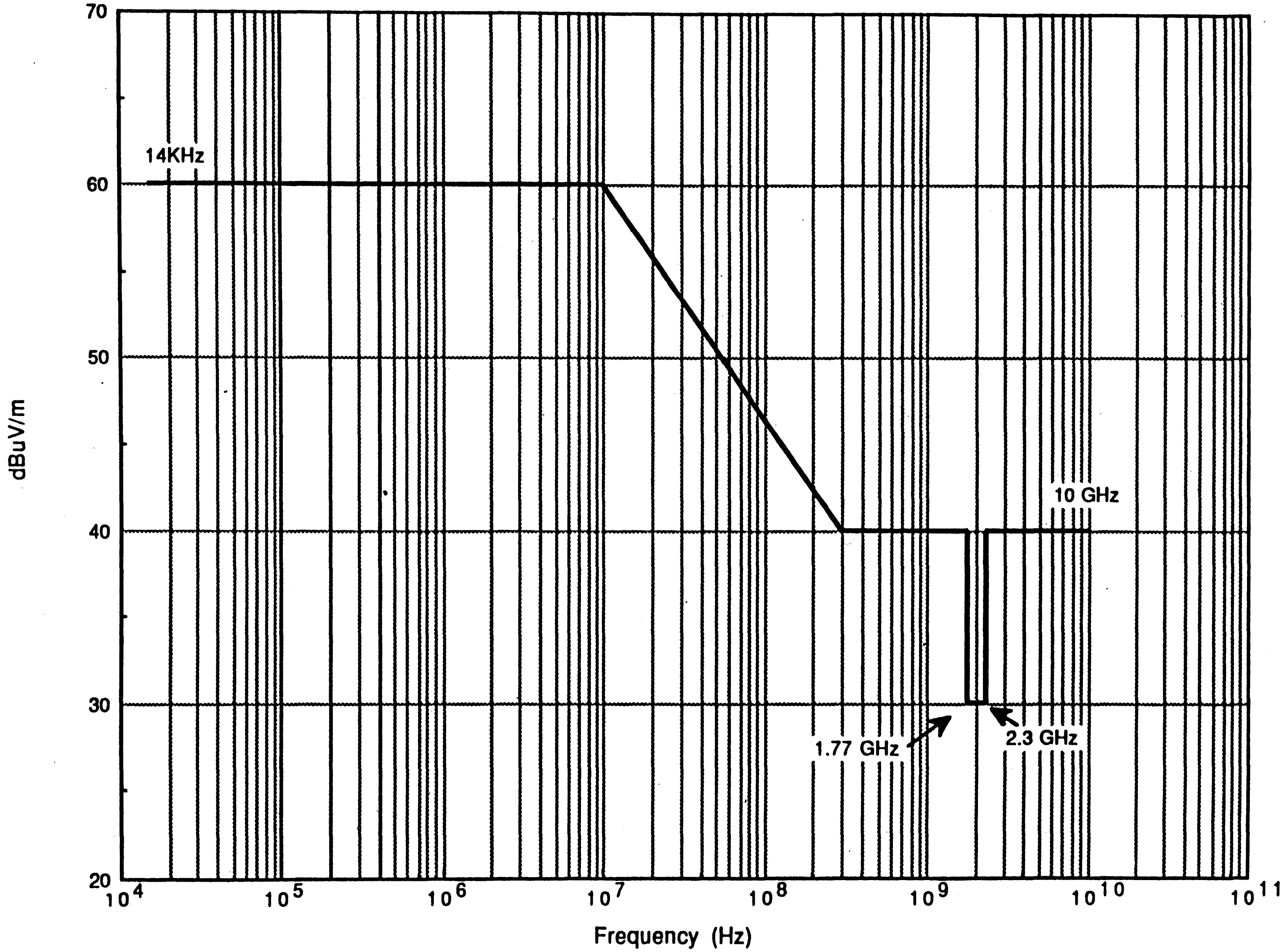


Figure A-5 RE02 Narrowband Emissions, Electric Field.

EMC Status/Assessment (Continued)

2) EGSE EMI/EMC Design Requirements and Guidelines. Detailed Grounding, Bonding, Cabling, Filtering guidelines for EGSE. (See TOMS-EP.91.500.057 for details). Highlights are:

   a) EGSE generated ripple shall be limited to 250 mVp-p and the transients above 28 VDC(overshoot) shall be limited to no more than 28 V peak (duration of less than 10 µsec).

   56V total →

   b) DC power provided by EGSE to the Spacecraft shall be grounded at the Spacecraft only (1MΩ isolation between the DC power return and chassis and other returns at the EGSE).

   c) Construct equipotential frameworks (Ground Reference Frames - Copper strips, 20 mils min. thickness and 9 inch wide), to which the spacecraft and the EGSE equipment shall be grounded).

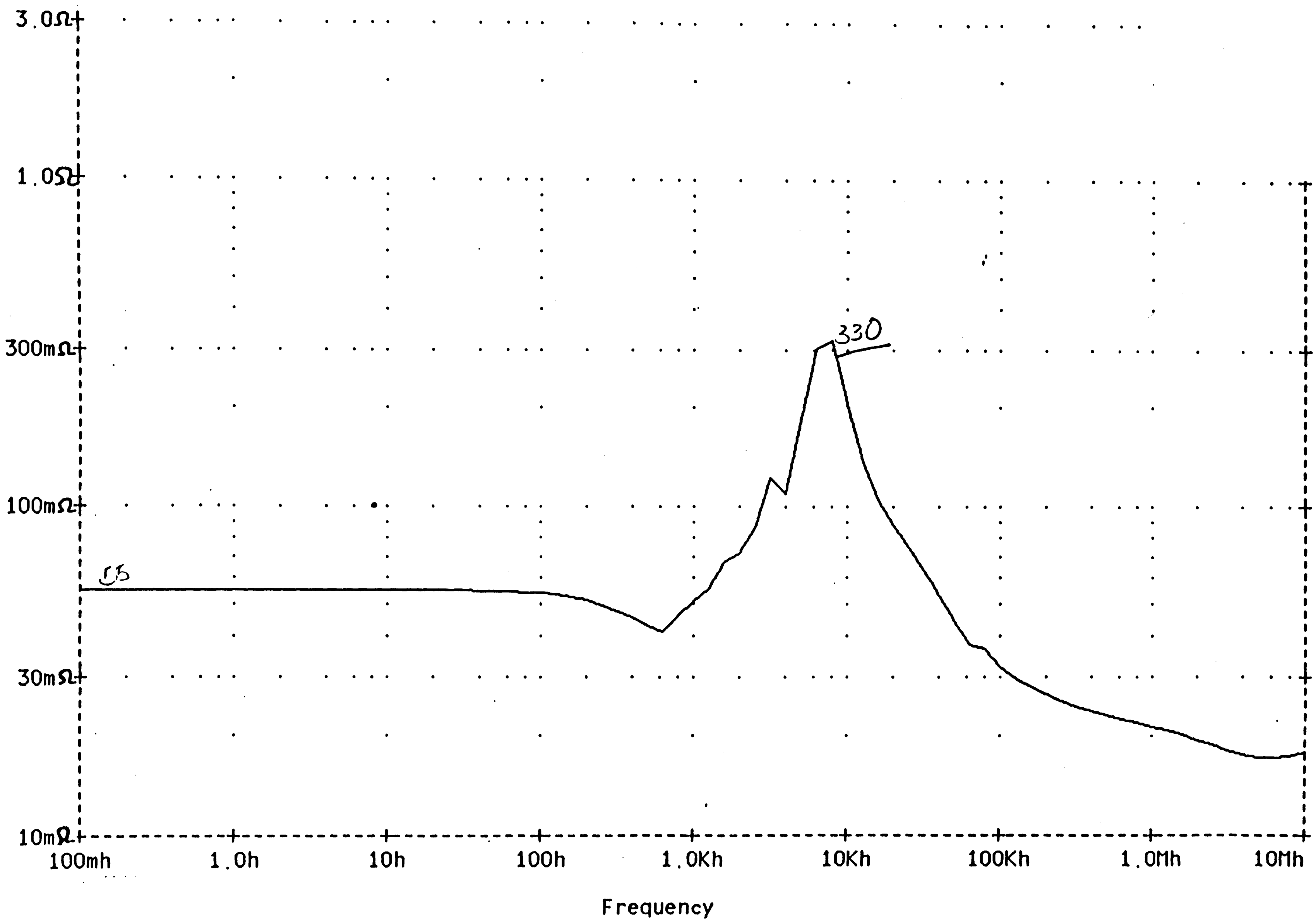
EMC Status/Assessment (Continued)

d) Power supplied by EGSE to Spacecraft shall be on twisted unshielded pair. Digital, data, commands, and state circuits shall be on shielded twisted pair etc.

3) Bus Impedance Characterization (TOMS-EP.92.500.024). The bus impedance varies from a minimum of 55 mΩ to a maximum of 330 mΩ between 0.1 Hz and 100 KHz. Bus Impedance results were utilized in conjunction with the Conducted Emissions requirements to tailor the Conducted Susceptibility requirement.

A maximum of 330 mΩ (Bus Z at 10 KHz) and a maximum of 2.2 Amps p-p (Conducted Emissions-RSS of 10 loads at 10 KHz) results in a noise level of 0.74 Vp-p. The Conducted Susceptibility level was set at 2 Vp-p which provides a design margin of 8dB).

TOMS-EP Bus Impedance



EMC Verification Activities

1) SEMCAP ANALYSIS

Completed SEMCAP (Specification Electro-Magnetic Compatibility Analysis Program). SEMCAP is a Air Force/NASA approved code. The objective is to analytically verify EMISMs (Electromagnetic Interference Safety Margins) between signal interfaces, that is , ensure that the present design (cable type, twisting shielding and layout) provides ample margin from cable-to-cable coupled noise.

SEMCAP uses electromagnetic field equations and capacitive/inductive coupling equations to calculate the cross-coupling between an energy source (Generator) and a potentially susceptible interface (Receptor).

EMC Verification Activities (Continued)

Modeled 10 Receptors and 4 Generators to represent majority of the satellite interface types. Receptors and Generator are as follows:

Receptors

1. GRA Current Telemetry
2. DSE Relay Status Tlm
3. EPDS WDT- Pulse Output
4. ADE Readout Enable
5. Special Command I/F
6. MDE Analog Cmd
7. MDE Motor Current Tlm
8. Serial Tlm (Data)
9. IRSA-SCE Infrared I/F
10. IRSA-SCE Infrared I/F

Generators

1. Serial Telemetry Clock (Steady state noise generator)
2. OAS Heater turn-on (Transient noise generator)
3. Serial Telemetry Data (Steady state noise generator)
4. Motor Drive Current (Steady state noise generator)

EMC Verification Activities (Continued)

Table below shows the margin in dB for the modeled interfaces for both the steady state and Transient cases.

Receptors	Steady-State Margin (dB) (RSS)	Transient Margin (dB)
1. GRA Current Telemetry	13	-36
2. DSE Relay Status Tlm	65	18
3. EPDS WDT- Pulse Output	60	16
4. ADE Readout Enable	70	26
5. Special Command I/F	57	14
6. MDE Analog Cmd	56	14
7. MDE Motor Current Tlm	17	-33
8. Serial Tlm (Data)	90	55
9. IRSA-SCE I/F- Infrared sig	21	07
10. IRSA-SCE I/F-BDC sig	20	20

EMC Verification Activities (Continued)

Results

Steady State Operations: Analysis shows that ample positive margin exists on all receptors for the steady state operations. For example, a 13 dB margin (RSS) exists on the GRA Current telemetry. This means the following:

Threshold of sensitivity for GRA Current Telemetry was established as 20 mV(minimum resolution step size for a 8-bit telemetry word). The noise from all steady-state generators adds upto 4.6 mV (RSS), thus providing a 13 dB margin.

Transient Effects: For transient event (heater turn-on) a negative margin exists on the GRA current telemetry (-36 dB) and the MDE Motor Current Telemetry (-33 dB). Such one time erroneous telemetry values would be ignored, that is, time averaging of these parameters is required.

EMC Verification Activities (Continued)

2) Magnetic Analysis.

  a) The DC Magnetic field at the Instrument is 0.64 Gauss (requirement is 1 Gauss). DC Magnetic field levels at the Instrument from all spacecraft contributors listed below add up to 238 mGauss (RSS). Earth field at the TOMS-EP orbit is 400 mGauss.

1. Solar Arrays (18.3 mGauss - By Analysis)
2. Mag. Torq. (236 mGauss - By Analysis) - ON at full Current
3. Transponder (5.1 mGauss - By Analysis)
4. GRA (4 mGauss - Test Data)
5. Reaction Wheels (3 mGauss - Test Data)
6. PCU (6.9 mGauss - By Analysis)
7. Secondary Power structure currents (15.8 mGauss - By Analysis)
8. RF Switch (17.1 mGauss - Test Data)
9. Misc. leakage currents (<1 mGauss - By Analysis)

EMC Verification Activities (Continued)

b) DC Magnetic field requirement is 53 mGauss at the TAM for an earth field measurement error of 10%. DC Magnetic levels at the Triple Axis Magnetometer add upto 31.4 mGauss (RSS) from all spacecraft contributors listed below:

1. Solar Arrays (18.3 mGauss - By Analysis)
2. Mag. Torquers (2.4 mGauss - By Analysis)-Residual Field
3. Transponder (5.1 mGauss - By Analysis)
4. GRA (4 mGauss - Test Data)
5. Reaction Wheels (3 mGauss - Test Data)
6. PCU (6.9 mGauss - By Analysis)
7. Sec. Pwr structure currents (15.8 mGauss-By Analysis)
8. RF Switch (17.1 mGauss - Test Data)
9. Misc. leakage currents (<1 mGauss - By Analysis)

TAM measurement of earth's magnetic field will be software controlled to be sampled only when no current is being dumped in the torque rods.

EMC Verification Activities (Continued)

c) Calculated the Spacecraft magnetic moment to be 0.29 Am^2 (RSS) from all spacecraft contributors listed below:

1. Solar Arrays (0.081 Am^2)
2. Magnetic Torquers (0.1 Am^2)-Residual moment with Torquers off
3. Transponder (0.07 Am^2)- Transmitter-OFF
4. PCU (0.25 Am^2)
5. Secondary Power structure currents (0.05 Am^2)

With Transmitter-On the Transponder contribution is 0.33 Am^2 and the magnetic moment is 0.44 Am^2(RSS).

EMC Verification Activities (Continued)

3) System Level Tests

Perform System Level EMI/EMC Tests. Testing will be shared between the ETB and the Satellite. Testing on ETB has the following advantages:

1) Recognition and resolution of problems prior to spacecraft A&T.
2) Reduce TOMS-EP EMI/EMC Test time.

The ETB and Spacecraft EMC testing will be as follows:

- Perform the following tests on the ETB:
- Ripple Measurement on Primary Power Bus
- Equipment Turn-on and Turn-off Transients
- Conducted Susceptibility-Steady State (injection level is 6 dB higher than the ripple measured on the primary power bus above).

EMC Verification Activities (Continued)

- Conducted Susceptibility- Transient (injection level is 6 dB higher than the transients measured in the turn-on turn-off transients measured above.

- Perform the following tests on the Satellite:
- Radiated Emissions
- Radiated Susceptibility

Problem Areas/Concerns and Resolution

EMI/EMC Tests are performed on selected units only. EMC problems may be discovered during A&T, affecting schedule/cost.

Resolution:

An integrated Spacecraft level test (Conducted Emissions/Susceptibility) is planned in ETB configuration to discover and resolve EMC problems prior to spacecraft integration. Radiated Emission/Susceptibility problems could still surface at the system level.

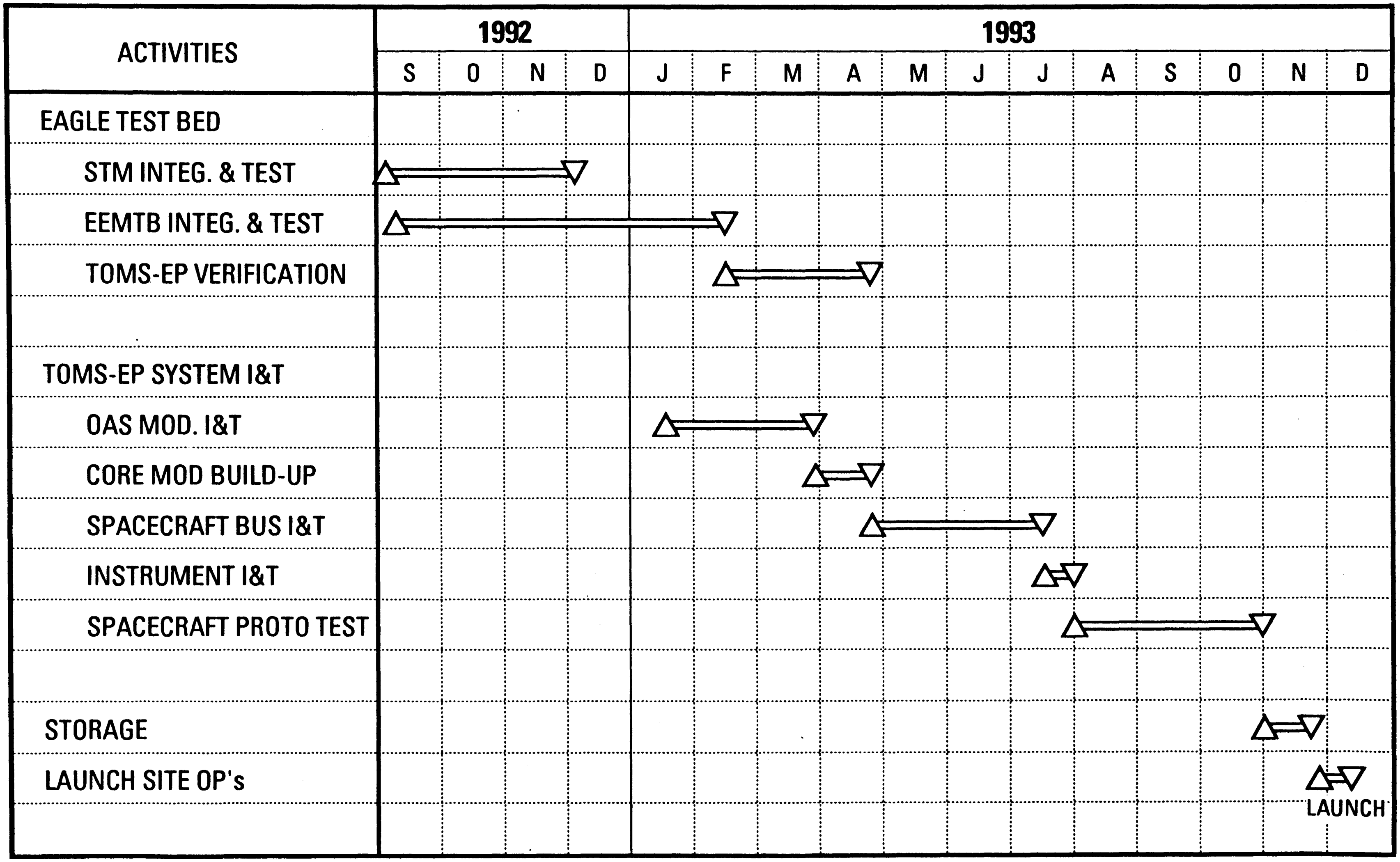
TOMS-EP
Spacecraft Integration, Test, Launch, and Mission Operations

TOMS-EP
Spacecraft Integration, Test, and Launch Site Activities

J. Durschinger

TOMS-EP

ETB-TOMS-EP Integration and Test Schedule



M2M 92.149.15

Integration and Test Key Features

- Test equipment, key procedures, critical test software verified on ETB
- TOMS-EP engineering models verified on ETB
- Key system analysis and software verified on ETB
- TOMS-EP functional testing is structured as the second in a series
- TOMS-EP is a protoflight environmental test I&T program
- S/C bus baseline performance verified before instrument integration
- OAS S/S test performed at module level
- Factory testing assures full spacecraft/instrument functionality requiring only aliveness test at launch site

System Test Requirements Sources

Need these docs. for PE

- System assembly test and launch is performed in accordance with D19251 Integration, Verification & Test Plan, CDRL-IT-01
  - This is my bible
- IV&T plan derived from requirements in:
  - SY1-0013 System Performance Verification Specification
  - PA1P
  - Launch Vehicle ICD (IF3-0008)
  - Instrument ICD (IF3-8007)
  - Instrument Integration and Operations Plan (D19081)
  - Contamination Control Plan (D19082)
  - EMI/EMC Requirements Specification and Control Plan (SR1-0105)
  - Ground System Test Plan (D19818)

Test Program Structure is Derived from Verification Test Matrix

all tests done w/ Instr.

Requirement (SY1-0013)	Capability (D19251)
• Functional	Comprehensive performance test (CPT) • Baseline (7.3) • Hot and cold T/V (7.17) • Contents defined by requirements in SY1-0013
• One hundred hour failure free performance	Accumulated during spacecraft T/V-T/B testing
• EMC/EMI	EMC test (7.6) • Conducted test on ETB • Radiated test on TOMS-EP
• Vibration	Prototype 3 axis random vibration test (7.10)
• Pyroshock	Prototype separation and array release shock tests (7.11, 7.12) • 2 actuations

Test Program Structure is Derived from Verification Test Matrix (Continued)

Requirement (SY1-0013)	Capability (D19251)
• Sine burst	Sine burst test (7.9)
• Thermal vacuum	Thermal vacuum temperature cycling (6 cycles) (7.17) Instr. to go thru this
• Thermal balance	Thermal vacuum/thermal balance test (7.17) • Hot and cold thermal balance • Hot and cold CPT
• Leak	OAS leak test (7.1.3, 7.18)

- include a test (like a compatibility test) w/ all systems on (Instr./S/c)

Software Verification During System Test

- Software verification is performed on the ETB
  - C & DH subsystem in phase B verification tests
  - ACDS subsystem in TOMs LFBT
  - EPDS subsystem in TOMs EPDS verification tests
- Flight software is loaded into SP & DP EEPROMS using a Gulton designed loader which tests the PROMS before loading the software
- Memory dumps during the spacecraft CPTs will verify the software has not been corrupted by hardware failures during environmental testing
- Any software used in normal command and telemetry processing and for hardware interfaces will get exercised as part of the planned hardware tests in the CPT
- Critical RTCSs (ie deploy) are verified in system I & T

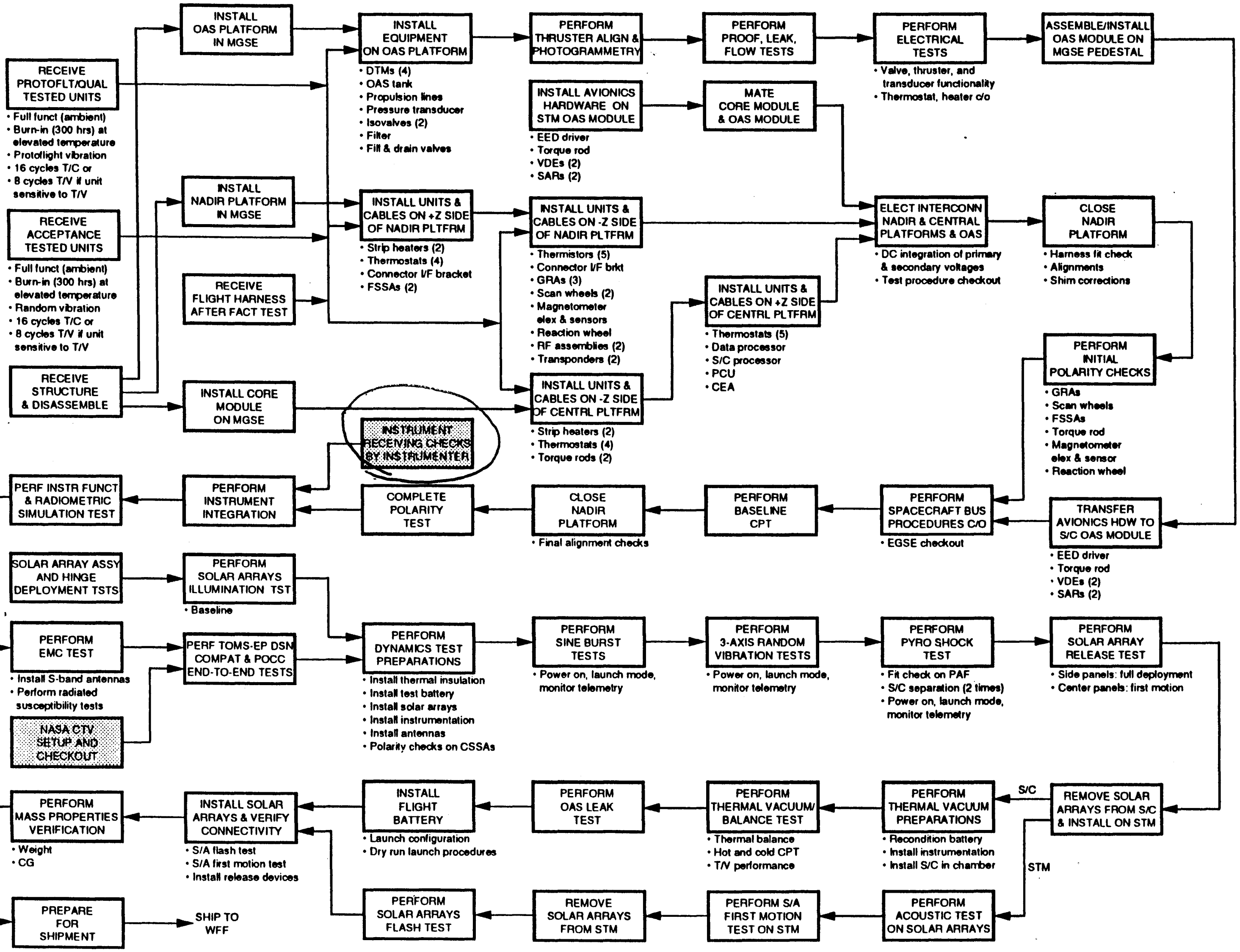
Integration and Test Plan

- Component
- Spacecraft Bus Assembly and Test
- Instrument Installation and Integration
- Protoflight Spacecraft Assembly and Test

Component Qualification and Acceptance

- Specific test requirements and qualification status for each component are contained in SY1-0013, verification test matrix
- Requirements are flowed down to individual suppliers
- Test environments for each component specified in EV2-0030
- Component functional and performance verification test requirements are specified in Section 4, Verification Requirements of the individual EQ specifications

Integration & Test Overall Flow



RECEIVE PROTOFLT/QUAL TESTED UNITS
- Full funct (ambient)
- Burn-in (300 hrs) at elevated temperature
- Protoflight vibration
- 16 cycles T/C or
- 8 cycles T/V if unit sensitive to T/V

RECEIVE ACCEPTANCE TESTED UNITS
- Full funct (ambient)
- Burn-in (300 hrs) at elevated temperature
- Random vibration
- 16 cycles T/C or
- 8 cycles T/V if unit sensitive to T/V

RECEIVE STRUCTURE & DISASSEMBLE

INSTALL OAS PLATFORM IN MGSE

INSTALL NADIR PLATFORM IN MGSE

RECEIVE FLIGHT HARNESS AFTER FACT TEST

INSTALL CORE MODULE ON MGSE

INSTALL EQUIPMENT ON OAS PLATFORM
- DTMs (4)
- OAS tank
- Propulsion lines
- Pressure transducer
- Isovalves (2)
- Filter
- Fill & drain valves

INSTALL UNITS & CABLES ON +Z SIDE OF NADIR PLTFRM
- Strip heaters (2)
- Thermostats (4)
- Connector I/F bracket
- FSSAs (2)

INSTRUMENT RECEIVING CHECKS BY INSTRUMENTER

PERFORM THRUSTER ALIGN & PHOTOGRAMMETRY

INSTALL AVIONICS HARDWARE ON STM OAS MODULE
- EED driver
- Torque rod
- VDEs (2)
- SARs (2)

INSTALL UNITS & CABLES ON -Z SIDE OF NADIR PLTFRM
- Thermistors (5)
- Connector I/F brkt
- GRAs (3)
- Scan wheels (2)
- Magnetometer elex & sensors
- Reaction wheel
- RF assemblies (2)
- Transponders (2)

INSTALL UNITS & CABLES ON -Z SIDE OF CENTRL PLTFRM
- Strip heaters (2)
- Thermostats (4)
- Torque rods (2)

PERFORM PROOF, LEAK, FLOW TESTS

MATE CORE MODULE & OAS MODULE

INSTALL UNITS & CABLES ON +Z SIDE OF CENTRL PLTFRM
- Thermostats (5)
- Data processor
- S/C processor
- PCU
- CEA

PERFORM ELECTRICAL TESTS
- Valve, thruster, and transducer functionality
- Thermostat, heater c/o

ELECT INTERCONN NADIR & CENTRAL PLATFORMS & OAS
- DC integration of primary & secondary voltages
- Test procedure checkout

ASSEMBLE/INSTALL OAS MODULE ON MGSE PEDESTAL

CLOSE NADIR PLATFORM
- Harness fit check
- Alignments
- Shim corrections

PERFORM INITIAL POLARITY CHECKS
- GRAs
- Scan wheels
- FSSAs
- Torque rod
- Magnetometer elex & sensor
- Reaction wheel

TRANSFER AVIONICS HDW TO S/C OAS MODULE
- EED driver
- Torque rod
- VDEs (2)
- SARs (2)

PERFORM SPACECRAFT BUS PROCEDURES C/O
- EGSE checkout

PERFORM BASELINE CPT

CLOSE NADIR PLATFORM
- Final alignment checks

COMPLETE POLARITY TEST

PERFORM INSTRUMENT INTEGRATION

PERF INSTR FUNCT & RADIOMETRIC SIMULATION TEST

SOLAR ARRAY ASSY AND HINGE DEPLOYMENT TSTS

PERFORM SOLAR ARRAYS ILLUMINATION TST
- Baseline

PERFORM EMC TEST
- Install S-band antennas
- Perform radiated susceptibility tests

NASA CTV SETUP AND CHECKOUT

PERF TOMS-EP DSN COMPAT & POCC END-TO-END TESTS

PERFORM DYNAMICS TEST PREPARATIONS
- Install thermal insulation
- Install test battery
- Install solar arrays
- Install instrumentation
- Install antennas
- Polarity checks on CSSAs

PERFORM SINE BURST TEST
- Power on, launch mode, monitor telemetry

PERFORM 3-AXIS RANDOM VIBRATION TESTS
- Power on, launch mode, monitor telemetry

PERFORM PYRO SHOCK TEST
- Fit check on PAF
- S/C separation (2 times)
- Power on, launch mode, monitor telemetry

PERFORM SOLAR ARRAY RELEASE TEST
- Side panels: full deployment
- Center panels: first motion

REMOVE SOLAR ARRAYS FROM S/C & INSTALL ON STM

S/C

PERFORM THERMAL VACUUM PREPARATIONS
- Recondition battery
- Install instrumentation
- Install S/C in chamber

PERFORM THERMAL VACUUM/ BALANCE TEST
- Thermal balance
- Hot and cold CPT
- T/V performance

PERFORM OAS LEAK TEST

INSTALL FLIGHT BATTERY
- Launch configuration
- Dry run launch procedures

STM

PERFORM ACOUSTIC TEST ON SOLAR ARRAYS

PERFORM S/A FIRST MOTION TEST ON STM

REMOVE SOLAR ARRAYS FROM STM

PERFORM SOLAR ARRAYS FLASH TEST

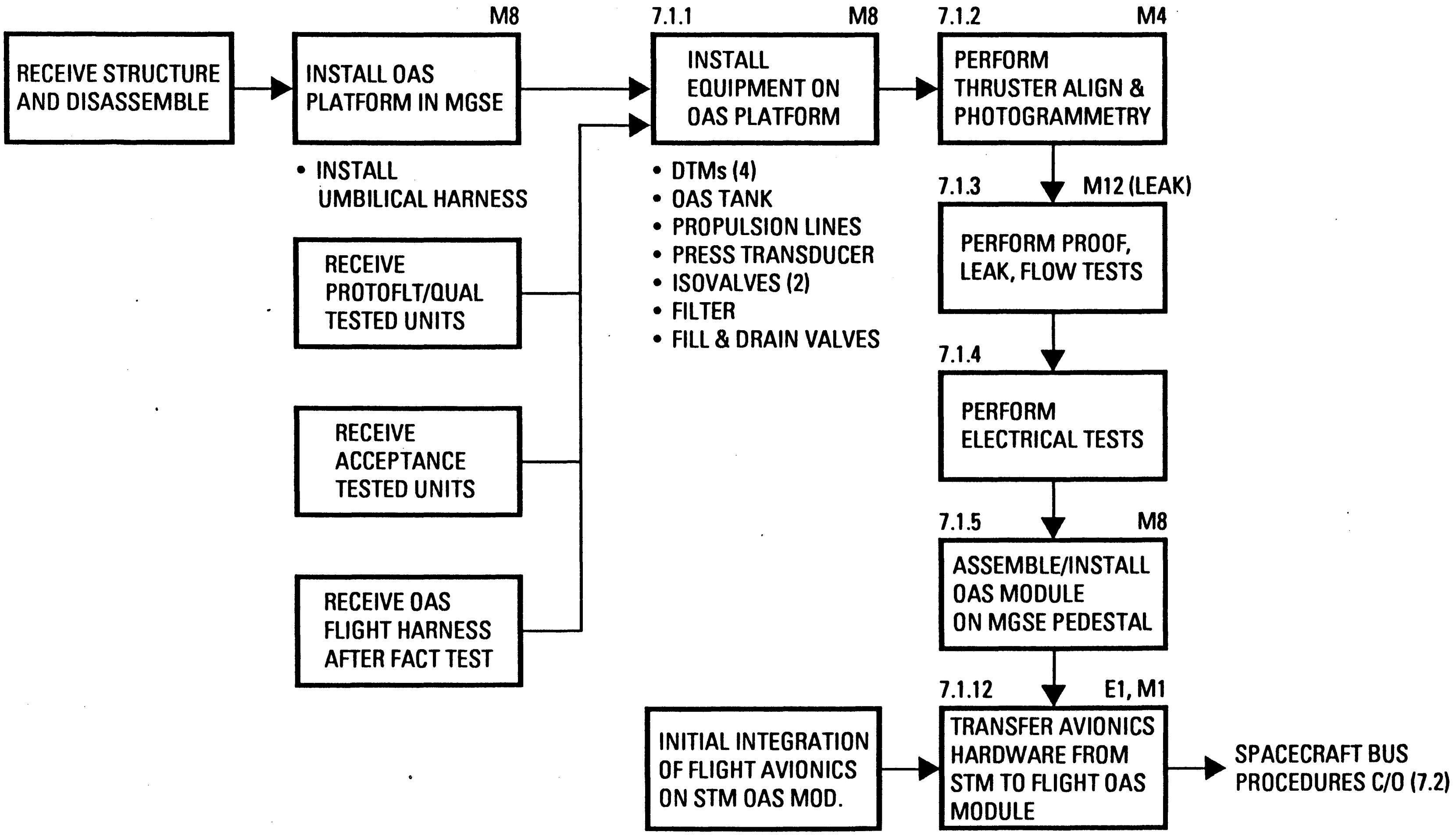
INSTALL SOLAR ARRAYS & VERIFY CONNECTIVITY
- S/A flash test
- S/A first motion test
- Install release devices

PERFORM MASS PROPERTIES VERIFICATION
- Weight
- CG

PREPARE FOR SHIPMENT

SHIP TO WFF

OAS Subsystem Assembly and Test



RECEIVE STRUCTURE AND DISASSEMBLE

M8

INSTALL OAS PLATFORM IN MGSE

- INSTALL UMBILICAL HARNESS

RECEIVE PROTOFLT/QUAL TESTED UNITS

RECEIVE ACCEPTANCE TESTED UNITS

RECEIVE OAS FLIGHT HARNESS AFTER FACT TEST

7.1.1 M8

INSTALL EQUIPMENT ON OAS PLATFORM

- DTMs (4)
- OAS TANK
- PROPULSION LINES
- PRESS TRANSDUCER
- ISOVALVES (2)
- FILTER
- FILL & DRAIN VALVES

7.1.2 M4

PERFORM THRUSTER ALIGN & PHOTOGRAMMETRY

7.1.3 M12 (LEAK)

PERFORM PROOF, LEAK, FLOW TESTS

7.1.4

PERFORM ELECTRICAL TESTS

7.1.5 M8

ASSEMBLE/INSTALL OAS MODULE ON MGSE PEDESTAL

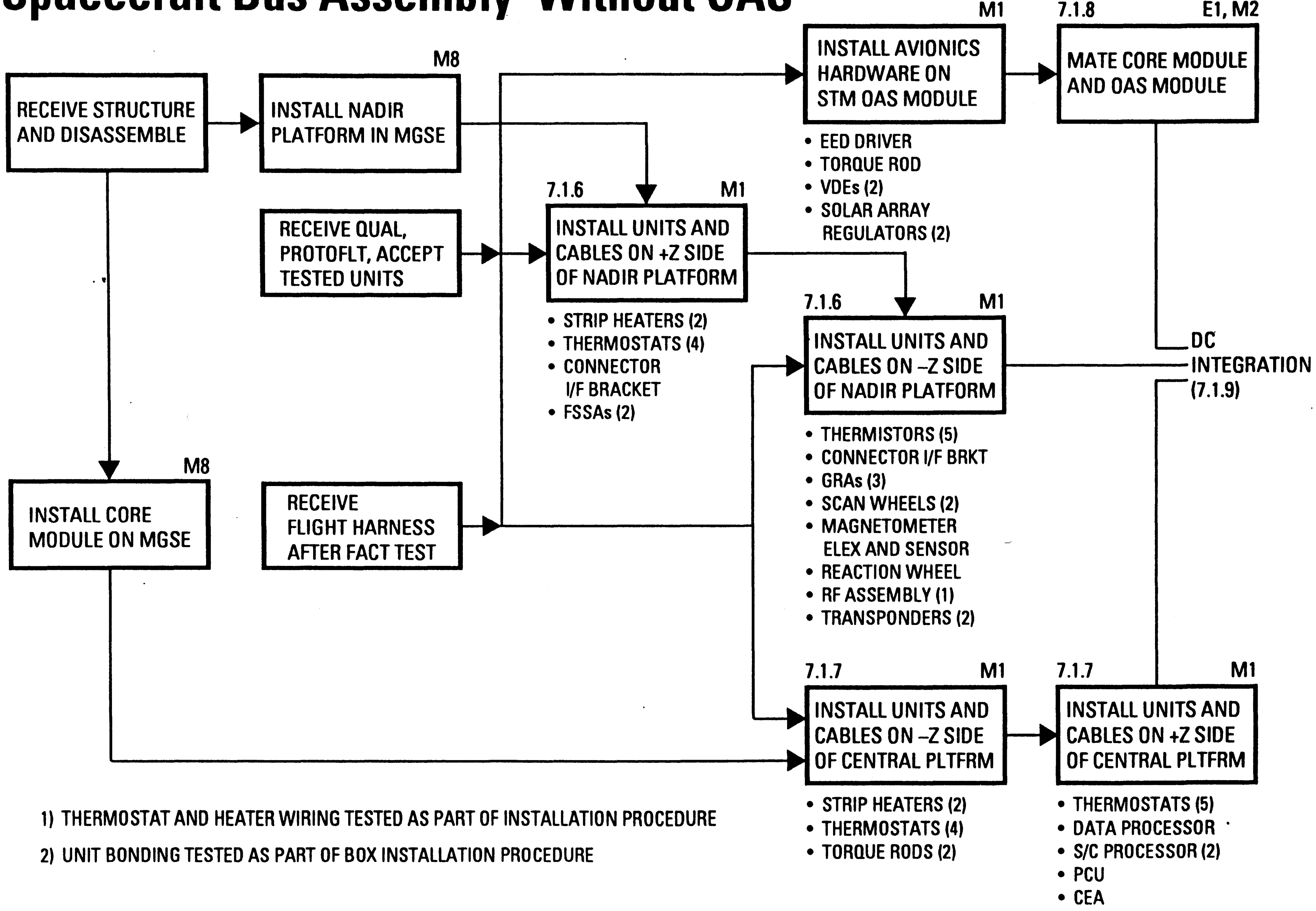
INITIAL INTEGRATION OF FLIGHT AVIONICS ON STM OAS MOD.

7.1.12 E1, M1

TRANSFER AVIONICS HARDWARE FROM STM TO FLIGHT OAS MODULE

SPACECRAFT BUS PROCEDURES C/O (7.2)

Spacecraft Bus Assembly Without OAS



RECEIVE STRUCTURE AND DISASSEMBLE

M8
INSTALL NADIR PLATFORM IN MGSE

RECEIVE QUAL, PROTOFLT, ACCEPT TESTED UNITS

7.1.6 M1
INSTALL UNITS AND CABLES ON +Z SIDE OF NADIR PLATFORM

- STRIP HEATERS (2)
- THERMOSTATS (4)
- CONNECTOR I/F BRACKET
- FSSAs (2)

M1
INSTALL AVIONICS HARDWARE ON STM OAS MODULE

- EED DRIVER
- TORQUE ROD
- VDEs (2)
- SOLAR ARRAY REGULATORS (2)

7.1.8 E1, M2
MATE CORE MODULE AND OAS MODULE

7.1.6 M1
INSTALL UNITS AND CABLES ON –Z SIDE OF NADIR PLATFORM

- THERMISTORS (5)
- CONNECTOR I/F BRKT
- GRAs (3)
- SCAN WHEELS (2)
- MAGNETOMETER ELEX AND SENSOR
- REACTION WHEEL
- RF ASSEMBLY (1)
- TRANSPONDERS (2)

DC INTEGRATION (7.1.9)

M8
INSTALL CORE MODULE ON MGSE

RECEIVE FLIGHT HARNESS AFTER FACT TEST

7.1.7 M1
INSTALL UNITS AND CABLES ON –Z SIDE OF CENTRAL PLTFRM

- STRIP HEATERS (2)
- THERMOSTATS (4)
- TORQUE RODS (2)

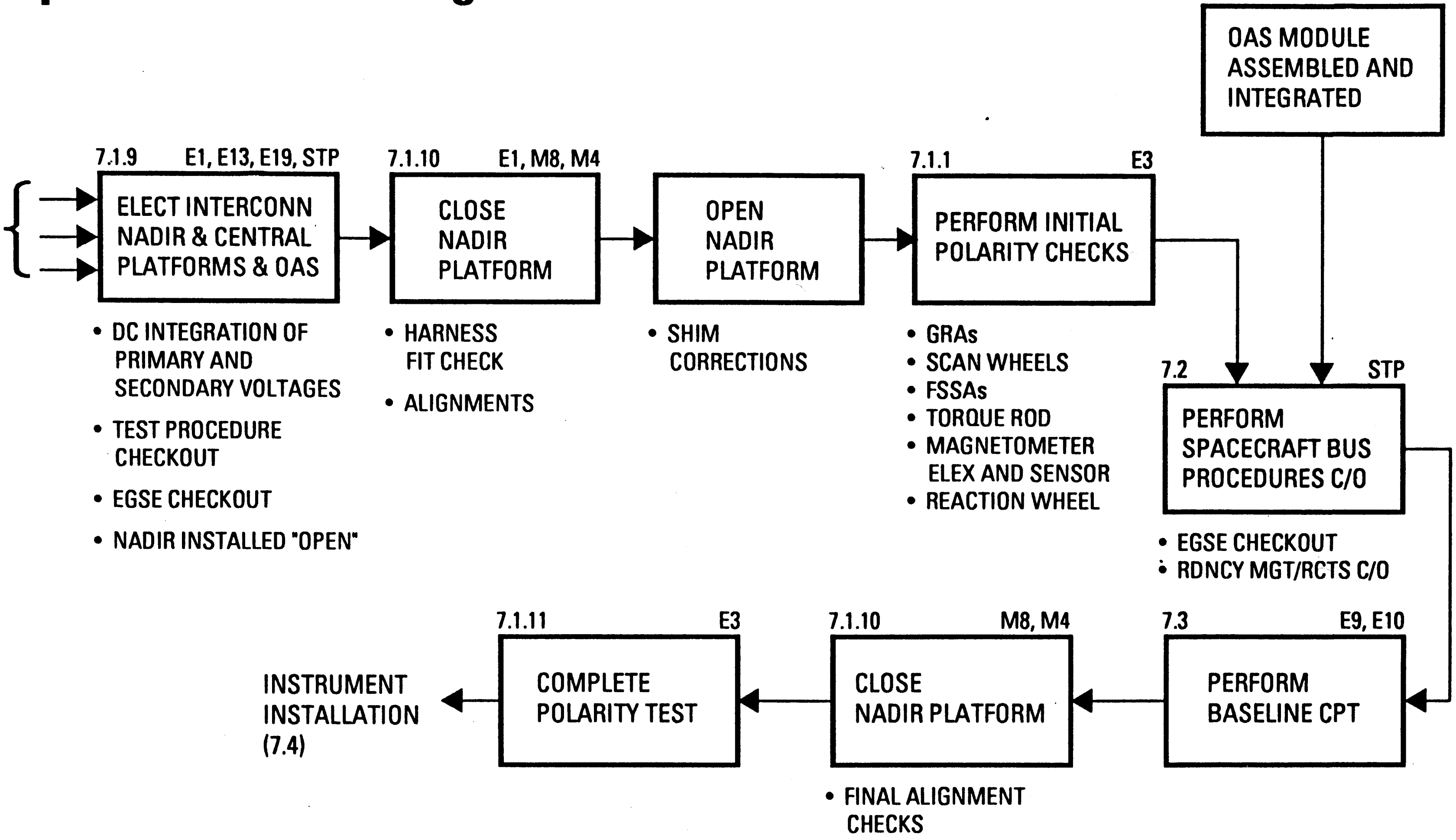
7.1.7 M1
INSTALL UNITS AND CABLES ON +Z SIDE OF CENTRAL PLTFRM

- THERMOSTATS (5)
- DATA PROCESSOR
- S/C PROCESSOR (2)
- PCU
- CEA

1) THERMOSTAT AND HEATER WIRING TESTED AS PART OF INSTALLATION PROCEDURE

2) UNIT BONDING TESTED AS PART OF BOX INSTALLATION PROCEDURE

Spacecraft Bus Integration and Test



7.1.9 E1, E13, E19, STP

ELECT INTERCONN NADIR & CENTRAL PLATFORMS & OAS

- DC INTEGRATION OF PRIMARY AND SECONDARY VOLTAGES
- TEST PROCEDURE CHECKOUT
- EGSE CHECKOUT
- NADIR INSTALLED "OPEN"

7.1.10 E1, M8, M4

CLOSE NADIR PLATFORM

- HARNESS FIT CHECK
- ALIGNMENTS

OPEN NADIR PLATFORM

- SHIM CORRECTIONS

7.1.1 E3

PERFORM INITIAL POLARITY CHECKS

- GRAs
- SCAN WHEELS
- FSSAs
- TORQUE ROD
- MAGNETOMETER ELEX AND SENSOR
- REACTION WHEEL

OAS MODULE ASSEMBLED AND INTEGRATED

7.2 STP

PERFORM SPACECRAFT BUS PROCEDURES C/O

- EGSE CHECKOUT
- RDNCY MGT/RCTS C/O

7.3 E9, E10

PERFORM BASELINE CPT

7.1.10 M8, M4

CLOSE NADIR PLATFORM

- FINAL ALIGNMENT CHECKS

7.1.11 E3

COMPLETE POLARITY TEST

INSTRUMENT INSTALLATION (7.4)

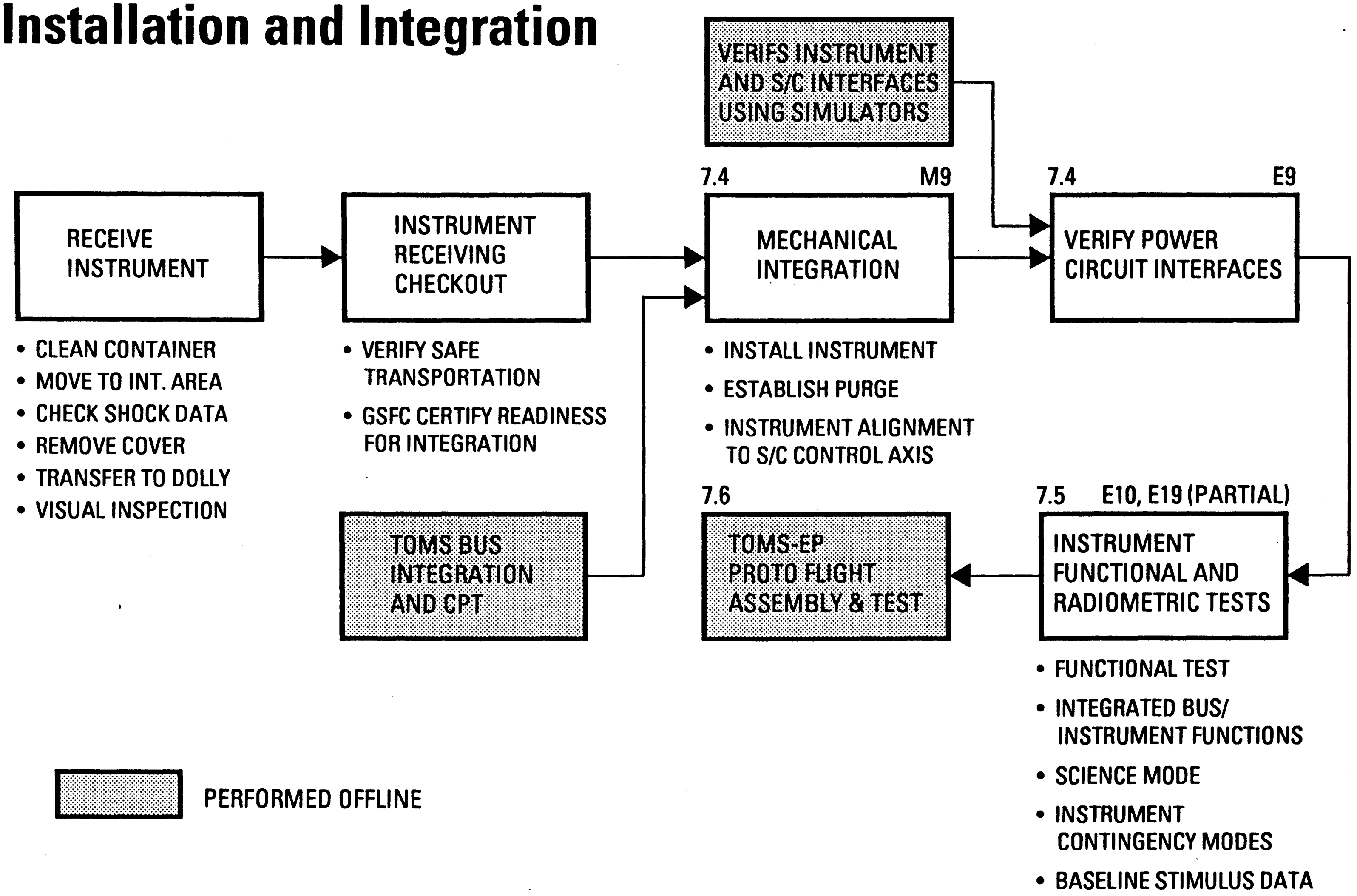
Comprehensive Performance Test (CPT) Contents

- Performed to demonstrate satisfactory operation of spacecraft hardware
- Performed as close as practical to flight configuration
  - No solar arrays
  - Hardline power connection
  - Sensor stimulation (light sources, earth rotation, earth magnetic field)
- Tests performed in prime, redundant, and cross strapped configurations
- Communication transponder
  - Receiver thresholds
  - U/L and D/L modulation indexs
  - RF output power and spurs
  - D/L frequency stability
- C&DH digital
  - Command reception, execution and verification
  - On board memory loads
  - Telemetry data rates, modulation and format reprogramming
  - Data record and playback
  - Post separation stored command sequences

CPT Contents (Continued)

- EPDS
  - SAR functional
  - Converter outputs
  - PCU load switching
  - Solar array release driver functions
- ACDS
  - Earth sensor, sun sensor and Gyro (earth rate) stimulation
  - Magnetometer stimulation (earth magnetic field) and torque rod response
  - Reaction wheel, scan wheels, and gyro run up/down
  - Thruster pulsing
- Special tests
  - Launch sequence
  - Instrument SOH and performance (instrument contracts) tests
  - Operation of spacecraft at high and low bus voltage
  - Hardware driven redundancy switchovers

TOMS Instrument to Bus Installation and Integration



RECEIVE INSTRUMENT

- CLEAN CONTAINER
- MOVE TO INT. AREA
- CHECK SHOCK DATA
- REMOVE COVER
- TRANSFER TO DOLLY
- VISUAL INSPECTION

INSTRUMENT RECEIVING CHECKOUT

- VERIFY SAFE TRANSPORTATION
- GSFC CERTIFY READINESS FOR INTEGRATION

TOMS BUS INTEGRATION AND CPT

VERIFS INSTRUMENT AND S/C INTERFACES USING SIMULATORS

7.4 M9

MECHANICAL INTEGRATION

- INSTALL INSTRUMENT
- ESTABLISH PURGE
- INSTRUMENT ALIGNMENT TO S/C CONTROL AXIS

7.4 E9

VERIFY POWER CIRCUIT INTERFACES

7.5 E10, E19 (PARTIAL)

INSTRUMENT FUNCTIONAL AND RADIOMETRIC TESTS

- FUNCTIONAL TEST
- INTEGRATED BUS/ INSTRUMENT FUNCTIONS
- SCIENCE MODE
- INSTRUMENT CONTINGENCY MODES
- BASELINE STIMULUS DATA

7.6

TOMS-EP PROTO FLIGHT ASSEMBLY & TEST

▨ PERFORMED OFFLINE

Instrument Integration Highlights

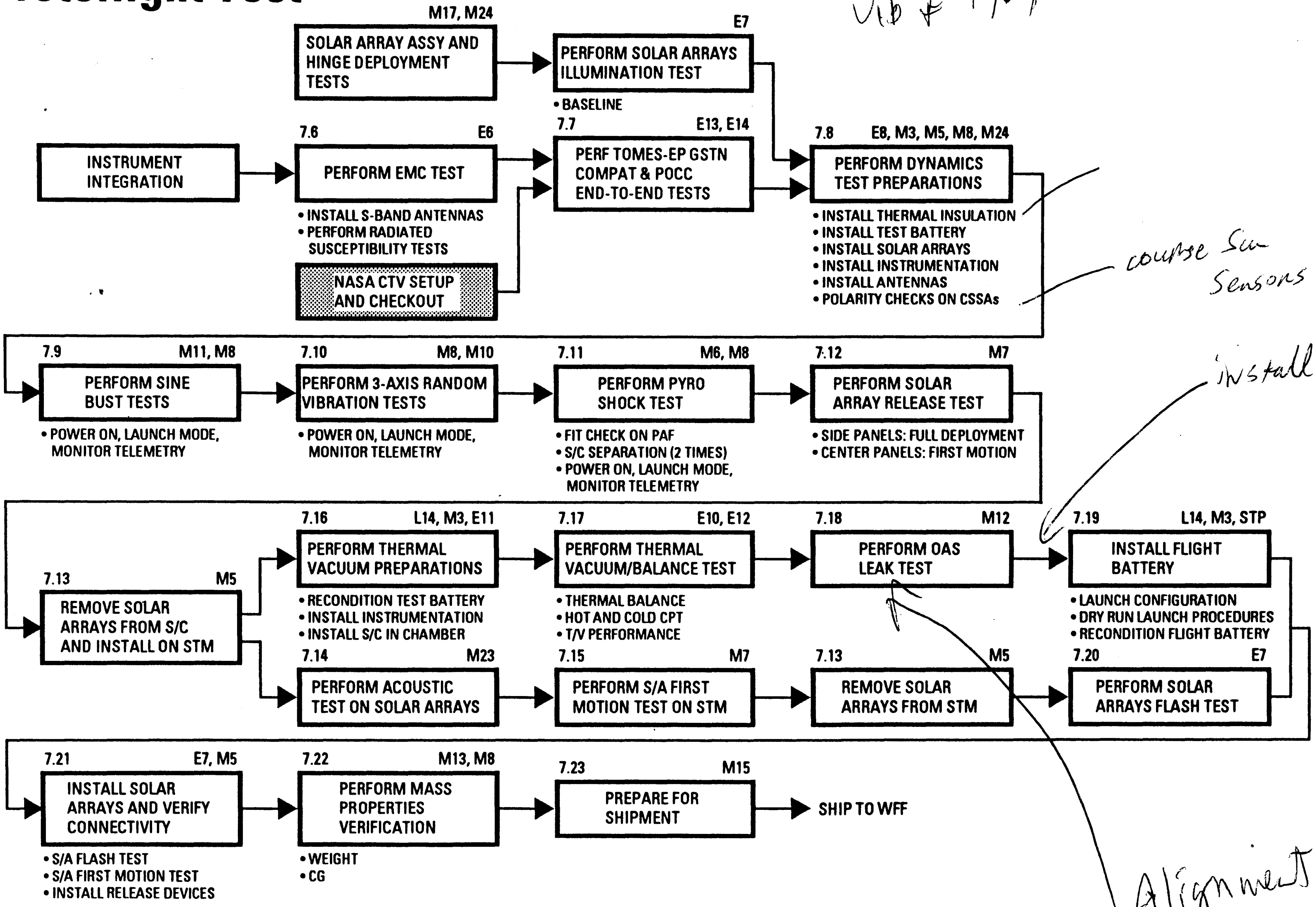
- Post shipment inspection and preparations for installation are performed in class 100 bench as required
- Instrument and spacecraft interfaces previously checked using appropriate spacecraft and instrument simulators
- The instrument is mechanically mated and power interface checks made through breakout boxes (BOB)
- After initial I/F check, flight connections are made
- Instrument alignment reference is measured relative to the gyros alignment reference within 0.01 degree
- Functional and radiometric tests are performed using the IGSE, instrument stimulus light source, and spacecraft GTS
- The TOMS-EP spacecraft is now completely integrated and ready to start environmental testing

TOMS-EP

TRW

Protoflight Test

Need to Add testing between Vib & T/V, T/B



M17, M24
SOLAR ARRAY ASSY AND HINGE DEPLOYMENT TESTS

E7
PERFORM SOLAR ARRAYS ILLUMINATION TEST
- BASELINE

INSTRUMENT INTEGRATION

7.6 E6
PERFORM EMC TEST
- INSTALL S-BAND ANTENNAS
- PERFORM RADIATED SUSCEPTIBILITY TESTS

NASA CTV SETUP AND CHECKOUT

7.7 E13, E14
PERF TOMES-EP GSTN COMPAT & POCC END-TO-END TESTS

7.8 E8, M3, M5, M8, M24
PERFORM DYNAMICS TEST PREPARATIONS
- INSTALL THERMAL INSULATION
- INSTALL TEST BATTERY
- INSTALL SOLAR ARRAYS
- INSTALL INSTRUMENTATION
- INSTALL ANTENNAS
- POLARITY CHECKS ON CSSAs

course Sun Sensors

7.9 M11, M8
PERFORM SINE BUST TESTS
- POWER ON, LAUNCH MODE, MONITOR TELEMETRY

7.10 M8, M10
PERFORM 3-AXIS RANDOM VIBRATION TESTS
- POWER ON, LAUNCH MODE, MONITOR TELEMETRY

7.11 M6, M8
PERFORM PYRO SHOCK TEST
- FIT CHECK ON PAF
- S/C SEPARATION (2 TIMES)
- POWER ON, LAUNCH MODE, MONITOR TELEMETRY

7.12 M7
PERFORM SOLAR ARRAY RELEASE TEST
- SIDE PANELS: FULL DEPLOYMENT
- CENTER PANELS: FIRST MOTION

Fit Install Diffuser

7.13 M5
REMOVE SOLAR ARRAYS FROM S/C AND INSTALL ON STM

7.16 L14, M3, E11
PERFORM THERMAL VACUUM PREPARATIONS
- RECONDITION TEST BATTERY
- INSTALL INSTRUMENTATION
- INSTALL S/C IN CHAMBER

7.17 E10, E12
PERFORM THERMAL VACUUM/BALANCE TEST
- THERMAL BALANCE
- HOT AND COLD CPT
- T/V PERFORMANCE

7.18 M12
PERFORM OAS LEAK TEST

7.19 L14, M3, STP
INSTALL FLIGHT BATTERY
- LAUNCH CONFIGURATION
- DRY RUN LAUNCH PROCEDURES
- RECONDITION FLIGHT BATTERY

7.14 M23
PERFORM ACOUSTIC TEST ON SOLAR ARRAYS

7.15 M7
PERFORM S/A FIRST MOTION TEST ON STM

7.13 M5
REMOVE SOLAR ARRAYS FROM STM

7.20 E7
PERFORM SOLAR ARRAYS FLASH TEST

7.21 E7, M5
INSTALL SOLAR ARRAYS AND VERIFY CONNECTIVITY
- S/A FLASH TEST
- S/A FIRST MOTION TEST
- INSTALL RELEASE DEVICES

7.22 M13, M8
PERFORM MASS PROPERTIES VERIFICATION
- WEIGHT
- CG

7.23 M15
PREPARE FOR SHIPMENT

SHIP TO WFF

Alignment double check done Here

TOMS-EP Protoflight Test Highlights

- Initial GSTN compatibility and POCC end-to-end test provides early check of ground operations interface and POCC software
  - Final checks performed at launch site to verify POCC fixes
- Dynamic Tests
  - Spacecraft power-on, launch configuration (electrical and mechanical) with EGSE T–0 umbilical connected
  - Interleave random vibration and sine burst on each axis to minimize test set-ups
  - Flight PAF fit check perfomed during T/V test preparations
  - Test PAF used for shock test
  - Solar array acoustic test performed offline on STM structure after spacecraft shock test

TOMS-EP Protoflight Test Highlights
(Continued)

- Thermal vacuum/balance test summary
  - Test consists of six thermal cycles (one for thermal balance)
  - Solar arrays will be removed before T/V
  - Test heaters are installed on the spacecraft side panels to simulate orbital heat inputs
  - Test heaters are adjusted to drive as many boxes as practical to their minimum and maximum protoflight temperature limits on each cycle
  - Data from the thermal balance test is used to validate the analytical thermal model
  - Spacecraft and instrument comprehensive performance tests will be performed at hot and at cold conditions
  - Spacecraft and instrument powered on in a baseline configuration with monitoring of SOH telemetry during all cycles

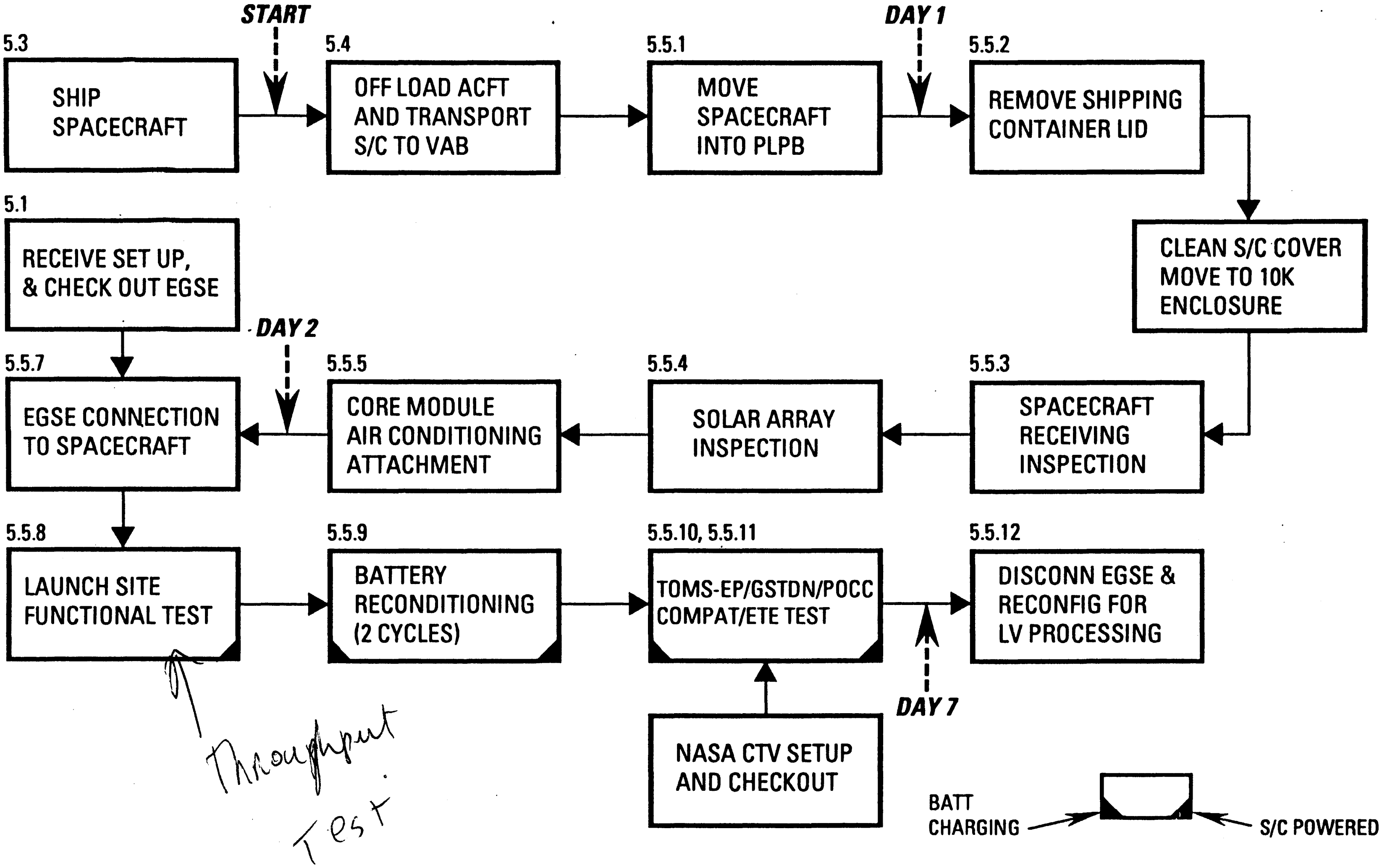
Spacecraft Alignments

- The nadir platform mounted alignment cube is the reference for component alignments
- All critical alignment components are attached to the same platform providing a stable base and eliminating the need for post dynamic test flight alignment measurements
- Shimming required to meet installation tolerances for the following components:
  - Gyro reference assemblies (3)
  - Scanning wheels (2)
  - Fine sun sensors (2)
  - Instrument
  - Reaction wheel assembly
- STM Confirms the overall spacecraft structural stability after dynamic environment exposure and validates the "one-G" nadir platform "droop" error analysis

Launch Site Operations

- Launch Site Flow
- Launch Site Requirements
- Open Issues

TOMS-EP Payload Processing Area Activities



START

5.3 SHIP SPACECRAFT

5.4 OFF LOAD ACFT AND TRANSPORT S/C TO VAB

5.5.1 MOVE SPACECRAFT INTO PLPB

DAY 1

5.5.2 REMOVE SHIPPING CONTAINER LID

CLEAN S/C COVER MOVE TO 10K ENCLOSURE

5.5.3 SPACECRAFT RECEIVING INSPECTION

5.5.4 SOLAR ARRAY INSPECTION

5.5.5 CORE MODULE AIR CONDITIONING ATTACHMENT

DAY 2

5.1 RECEIVE SET UP, & CHECK OUT EGSE

5.5.7 EGSE CONNECTION TO SPACECRAFT

5.5.8 LAUNCH SITE FUNCTIONAL TEST

5.5.9 BATTERY RECONDITIONING (2 CYCLES)

5.5.10, 5.5.11 TOMS-EP/GSTDN/POCC COMPAT/ETE TEST

NASA CTV SETUP AND CHECKOUT

DAY 7

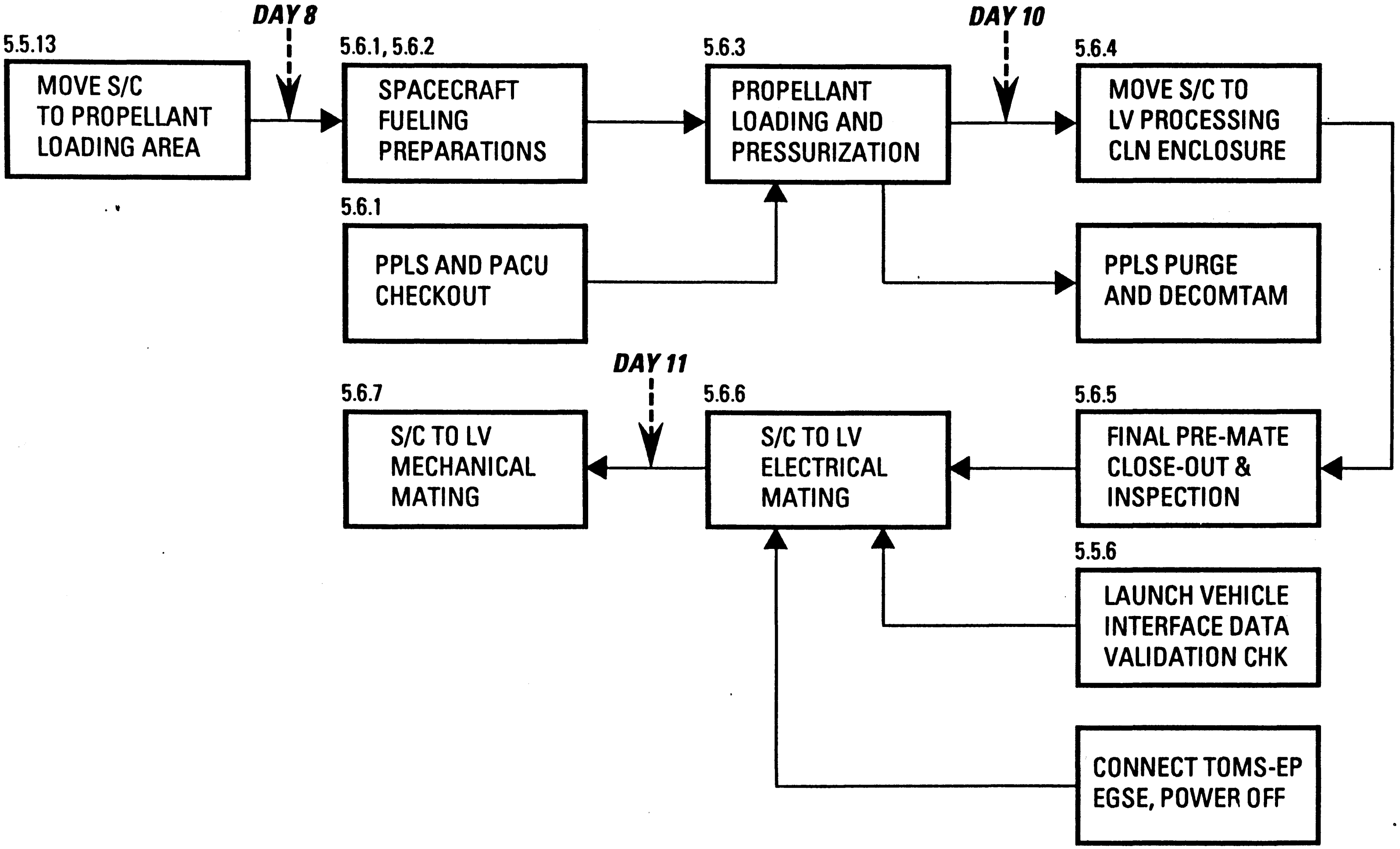
5.5.12 DISCONN EGSE & RECONFIG FOR LV PROCESSING

BATT CHARGING

S/C POWERED

Throughput Test

TOMS-EP Fueling and Launch Vehicle Mating Activities



DAY 8

5.5.13 MOVE S/C TO PROPELLANT LOADING AREA

5.6.1, 5.6.2 SPACECRAFT FUELING PREPARATIONS

5.6.1 PPLS AND PACU CHECKOUT

5.6.3 PROPELLANT LOADING AND PRESSURIZATION

DAY 10

5.6.4 MOVE S/C TO LV PROCESSING CLN ENCLOSURE

PPLS PURGE AND DECOMTAM

5.6.5 FINAL PRE-MATE CLOSE-OUT & INSPECTION

5.5.6 LAUNCH VEHICLE INTERFACE DATA VALIDATION CHK

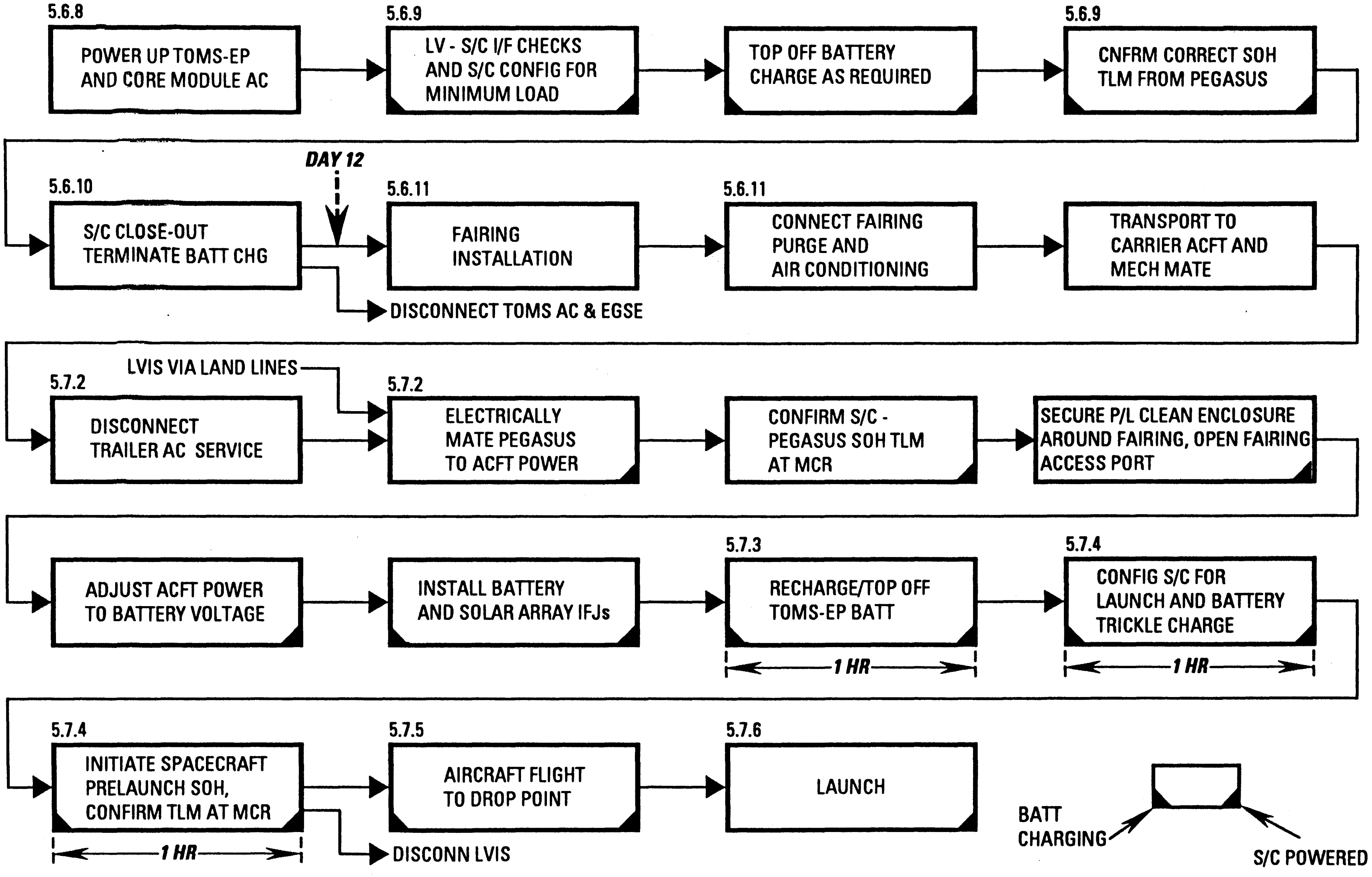
CONNECT TOMS-EP EGSE, POWER OFF

5.6.6 S/C TO LV ELECTRICAL MATING

DAY 11

5.6.7 S/C TO LV MECHANICAL MATING

Post Mate to Launch Activities



5.6.8 POWER UP TOMS-EP AND CORE MODULE AC

5.6.9 LV - S/C I/F CHECKS AND S/C CONFIG FOR MINIMUM LOAD

TOP OFF BATTERY CHARGE AS REQUIRED

5.6.9 CNFRM CORRECT SOH TLM FROM PEGASUS

5.6.10 S/C CLOSE-OUT TERMINATE BATT CHG

DAY 12

DISCONNECT TOMS AC & EGSE

5.6.11 FAIRING INSTALLATION

5.6.11 CONNECT FAIRING PURGE AND AIR CONDITIONING

TRANSPORT TO CARRIER ACFT AND MECH MATE

5.7.2 DISCONNECT TRAILER AC SERVICE

LVIS VIA LAND LINES

5.7.2 ELECTRICALLY MATE PEGASUS TO ACFT POWER

CONFIRM S/C - PEGASUS SOH TLM AT MCR

SECURE P/L CLEAN ENCLOSURE AROUND FAIRING, OPEN FAIRING ACCESS PORT

ADJUST ACFT POWER TO BATTERY VOLTAGE

INSTALL BATTERY AND SOLAR ARRAY IFJs

5.7.3 RECHARGE/TOP OFF TOMS-EP BATT

1 HR

5.7.4 CONFIG S/C FOR LAUNCH AND BATTERY TRICKLE CHARGE

1 HR

5.7.4 INITIATE SPACECRAFT PRELAUNCH SOH, CONFIRM TLM AT MCR

1 HR

DISCONN LVIS

5.7.5 AIRCRAFT FLIGHT TO DROP POINT

5.7.6 LAUNCH

BATT CHARGING

S/C POWERED

TOMS-EP LV Spacecraft Power Requirements

Activity	Function	GSE and Access
Post mate S/C I/F checks	Supply primary S/C bus power for interface tests, battery trickle charging	TOMS-EP PCMTS in VAB at pass thru I/F connector P2 in L/V
Transport to flight line and mate to carrier aircraft	None, TOMS battery charged, open circuit	none
Battery top off charge and configure S/C for launch	Supply primary S/C bus power for launch loads and battery charge	Adjustable regulated GFE power supply in L1011 with access at the LPO panel
Takeoff & captive flight	Same as above	Same as above
Powered flight	None	None

TOMS-EP LV Telemetry Verification Monitor Requirements

Activity	Function	Equipment Required
Post mate S/C I/F checks	Monitor L/V I/F S/C SOH telemetry	Pegasus S3 Mux, TLM EGSE, and P/L display console in MCR
Flight line mate to aircraft power thru final launch configuration	Monitor L/V I/F S/C SOH telemetry	Same as above
Takeoff and captive flight	Same as above	Same as above
Powered flight	Same as above	Same as above

- SOH functions are all functions on the P1 L/V I/F connector being routed to the Pegasus S3 Mux

TOMS-EP LV PCU Command and Status Verification Requirements

Activity	Function	GSE	Access
Post mate S/C configuration checks	Command PCU, check relay status	TOMS-EGSE and LVIS in VAB	Pass thru I/F connector P2 & P3 on L/V
Transport to flight line and mate to carrier aircraft	None	None	None
Configure S/C for launch	Command PCU, check relay status	TOMS-EGSE in VAB, LVIS in carrier aircraft	Pass thru connector on L/V thru PCA LPO panel
Takeoff and captive flight	None	None	None
Powered flight	None	None	None

- LVIS used in carrier aircraft only for preflight operations and removed prior to takeoff

TOMS-EP Ground Support Equipment

- MGSE
- EGSE

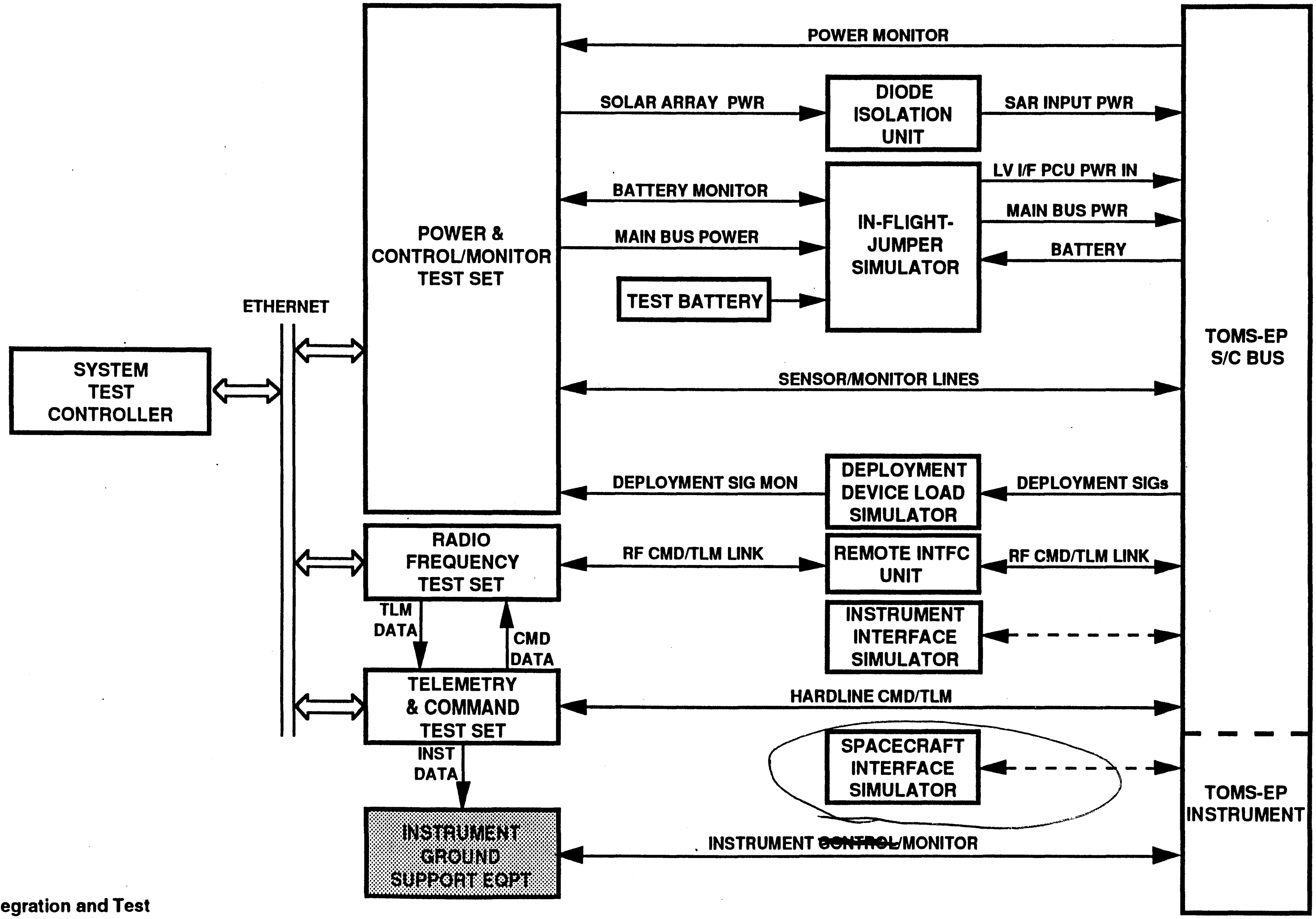
Mechanical Ground Support Equipment

- Spacecraft and solar array dollies
- Spacecraft rotation, rate and vibration fixtures (3)
- Alignment adapter
- Nadir platform pivot strongback
- Spacecraft covers
- Solar Array Protective Covers (6)
- Shipping container
- Shipping container air conditioner
- Core module air conditioner
- Vertical and Horizontal sling
- Propellant and pressurant loading system

TOMS-EP
EGSE Subsystem (Ground Test System)
Major Components

- System Test Controller (STC)
- Automated Test Sets
  - Power and Control/Monitor Test Set (PCMTS)
  - Telemetry and Command Test Set (TCTS)
  - Radio Frequency Test Set (RFTS)
- Ancillary Equipment (supplied with above test sets)
  - Diode Isolation Unit (DIU)
  - In-Flight-Jumper (IFJ) Simulator
  - Deployment Device Load Simulator (DDLS)
  - Remote Interface Unit (RIU)
- Test Battery (Battery Simulator Console)
- Manual Test Sets
  - Spacecraft Interface Simulator (SIS)
  - Instrument Interface Simulator (IIS)
- Instrument Ground Support Equipment (IGSE) [GFE]

TOMS-EP
Integrated Test Configuration



POWER MONITOR

SOLAR ARRAY PWR

DIODE ISOLATION UNIT

SAR INPUT PWR

BATTERY MONITOR

MAIN BUS POWER

IN-FLIGHT-JUMPER SIMULATOR

LV I/F PCU PWR IN

MAIN BUS PWR

BATTERY

TEST BATTERY

POWER & CONTROL/MONITOR TEST SET

ETHERNET

SYSTEM TEST CONTROLLER

SENSOR/MONITOR LINES

TOMS-EP S/C BUS

DEPLOYMENT SIG MON

DEPLOYMENT DEVICE LOAD SIMULATOR

DEPLOYMENT SIGs

RADIO FREQUENCY TEST SET

RF CMD/TLM LINK

REMOTE INTFC UNIT

RF CMD/TLM LINK

TLM DATA

CMD DATA

INSTRUMENT INTERFACE SIMULATOR

TELEMETRY & COMMAND TEST SET

HARDLINE CMD/TLM

SPACECRAFT INTERFACE SIMULATOR

INST DATA

TOMS-EP INSTRUMENT

INSTRUMENT GROUND SUPPORT EQPT

INSTRUMENT ~~CONTROL~~/MONITOR

TOMS-EP
System Test Controller
Functional Capabilities

- Execute automated test sequences (ATSs)
- Keyword library
- Spacecraft commanding (via the TCTS)
  - Command effects
  - Command constraints
- Telemetry processing
  - Limit checking
  - Alarm processing of telemetry parameters
- Windows MMI for test execution
  - Alarm monitoring
  - Page/plot
  - Displays
  - Scrolling history
- Test history data archiving and analysis tools
- Spacecraft memory load and dump
- Data base driven system

TOMS-EP
Power & Control/Monitor Test Set
Functional Capabilities

- Supply external power
  - Diode isolated to SARs
  - Main bus via LV I/F or battery IFJ
- Charge/recondition battery
- Monitor bus voltage & battery volt/current/temp
- Simulate spacecraft IFJs
- Simulate deployment device loads
- Monitor deployment signals to specified thresholds
- Monitor thruster valve drive signals to specified thresholds
- Simulate earth sensor & sun sensor (fine and coarse) signals
- Generate UV/OV detector trigger signal to PCU
- Provide launch vehicle interface functions
- Built-in self-test

TOMS-EP
Telemetry & Command Test Set
Functional Capabilities

- Commanding
  - STDN compatible, hardline or via RFTS
  - Accept command data from STC
  - Command echo checking
- Telemetry
  - STDN compatible, hardline or via RFTS
  - Process clear text telemetry for transmission to STC
  - Telemetry sync status to STC
  - Extract instrument data & output to IGSE
- Convolutional encoding/decoding
- Spacecraft processor hardline enable & standby mode control interfaces
- Archiving & self-test capability

TOMS-EP
Radio Frequency Test Set
Functional Capabilities

- S-band (uplink/downlink) RF links
- Ranging tones
- Receives and demodulates telemetry subcarrier
- RF measurements
  - Power
  - Frequency
  - Spectral purity
  - Modulation index
  - Time delay
- Measure command receiver sensitivity via power and frequency control of RF uplink
- Modulation index adjustment capability

TOMS-EP
Mission Operations

T. Watson

Presentation Outline

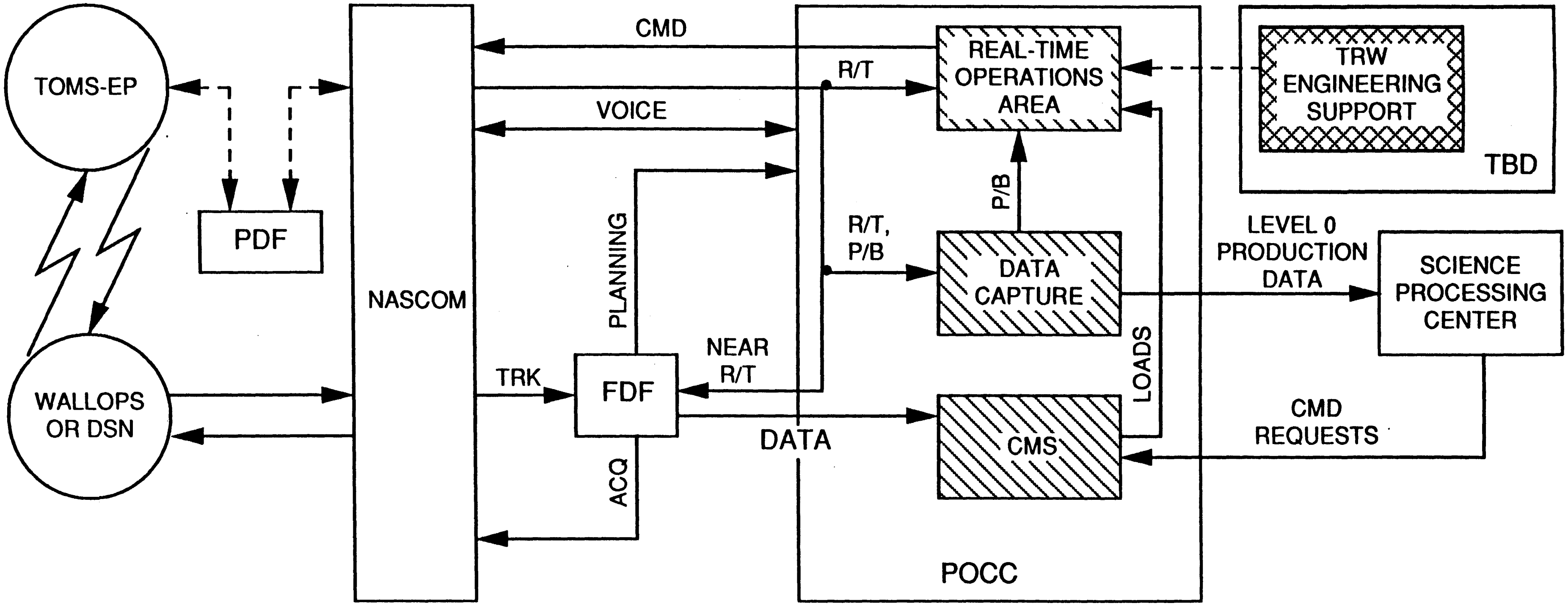
- Flight Operations Concept
- Data Flow Overview
- Uplink Activities/Command Types/Dumps
- Science Capture
- Routine Pass
- Routine 24 Hour Activities
- Contingency Operations

Flight Operations Concept

- Early Mission
  - Maximum ground station coverage, short contacts
  - Twenty-four hour/day support
  - Autonomous deployment
  - Autonomous initial ascent burns
  - Intensive orbit determination activities
  - Subsystem activation and checkout

- Routine Operations
  - Nadir pointed using scan wheels
  - Five to 8 contacts per day, 10-12 minutes each
  - Stored commands to perform most spacecraft and instrument operations
  - Twenty-four hour/day support
  - Science data capture and Level 0 processing
  - No attitude maneuver or orbit adjust requirements

TOMS-EP Command and Telemetry Flow



☐ NASA ▩ TRW ▨ GE

------ TEST & LAUNCH SUPPORT ONLY

Uplink Activities

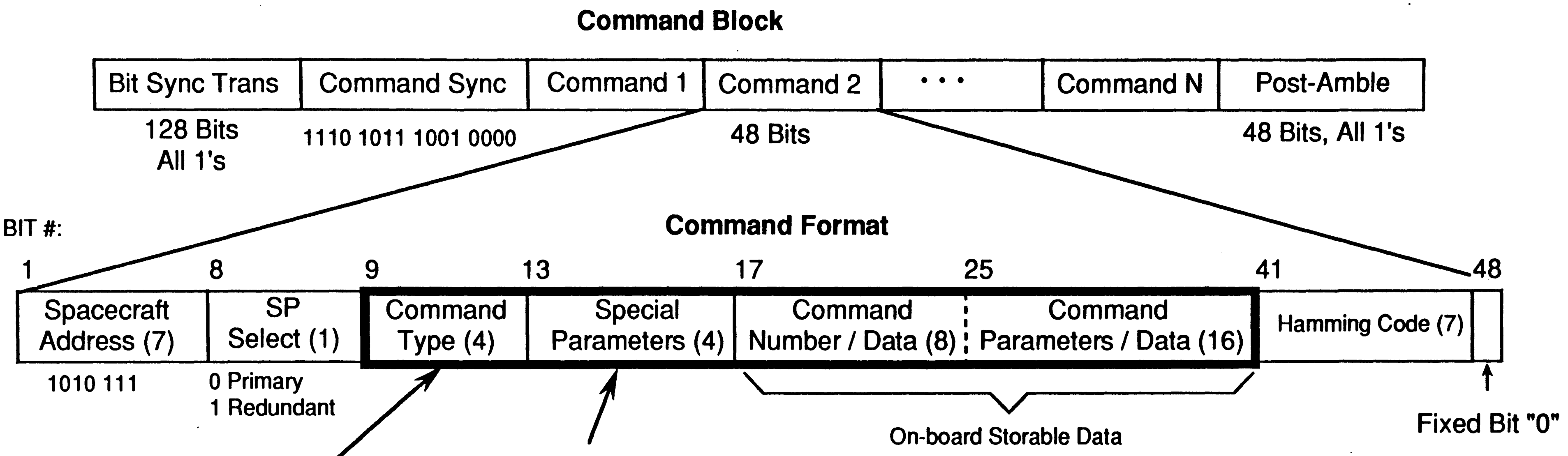
- Real Time Commands
  - Early mission subsystems configuration
  - Link management
  - Mass memory playbacks

- Absolute Time Commands (ATCs)
  - Ascent Δ Vs and maneuver activities
  - Link management
  - Orbital event control - instrument cals, lunar eclipse requirements, etc.
  - RTCS activations
- Relative Time Command Sequences (RTCSs)
  - Deployment
  - Autonomous ascent
  - Safe mode configurations
  - Link management
  - Repetitive operations

Uplink Activities (Continued)

- Memory Loads
  - Attitude initialization
  - Ephemeris
  - Attitude and ΔV maneuver targets
  - Alignments and gains "tweaking" (key parameters data base)
- Details of specific operations will be provided in "Initial Activation and Checkout Procedures," MO-06.

TOMS-EP Command Format



Hex:
- 0 Reserved
- 1 Real-time
- 2 ATC
- 3 Spare
- 4 RTCS
- 5 KPD Load
- 6 SP Data Load
- 7 SP Code Load
- 8 DP Data Load
- 9 DP Code Load
- A Manage CIB
- B-E Spare
- F Special H/W Cmd

Hex:
- 0 Continue Cmd
- 1 End of Cmd, Type = 0 - 4, A - F
- 2 RTCS Reference
- 3 Clear CIB
- 4 Transfer CIB
- 5 Reset CIB Cmd Cntr
- 6 Restart CIB Load
- 7 End of Cmd, 1 Data Byte, Type = 5 - 9
- 8 End of Cmd, 2 Data Bytes, Type = 5 - 9
- 9 End of Cmd, 3 Data Bytes, Type = 5 - 9

Real-Time Commands

Real-time commands consist of only the basic command structure.

Command Type	Special Parameter	Uplink Data		
1	1	Command #	Arg 1	00

Sample 2-Byte Real-Time Command Upload

Command Type	Special Parameter	Command Data		
1	0	Command #	Arg 1	Arg 2
1	1	Arg 3	00	00

Sample 4-Byte Real-Time Command Upload

Absolute Time Command Definition

- COMMANDS WITH UTC TIME TAGS WHICH CAN PERFOM OPERATIONS BASED ON ORBITAL POSITION.
- TIME-TAGGED TO NEAREST SECOND.
- AN ATC CAN BE USED TO CONTROL AN RTCS OR ISSUE A REAL TIME COMMAND.
- ATCs WILL PROVIDE THE MANAGEMENT OF ROUTINE ON-ORBIT OPERATIONS. THE RTCSs WILL PROVIDE THE DETAILED COMMAND SEQUENCES.
- AN ATC CAN BE CREATED, DELETED, AND DUMPED FOR GROUND VERIFICATION.
- CAPABILITY IS PROVIDED FOR 512 ATCs IN THE COMMAND STORAGE AREA (CSA).
- AFTER AN ATC HAS TIMED OUT, THAT COMMAND SLOT BECOMES AVAILABLE FOR ADDITIONAL ATCs TO BE UPLINKED.
- GROUND OPERATIONS IS RESPONSIBLE FOR MAINTAINING SUFFICIENT SPACE IN THE CSA FOR REQUIRED RTCSs.

Absolute Time Commands (ATCs)

ATCs contain a 5-byte time tag with 1-second resolution, followed by a basic command.

Time Tag "day (2): hour (1): minute (1): second (1)" (5 bytes)	Command Number (1 byte)	Command Arguments (5 bytes max)

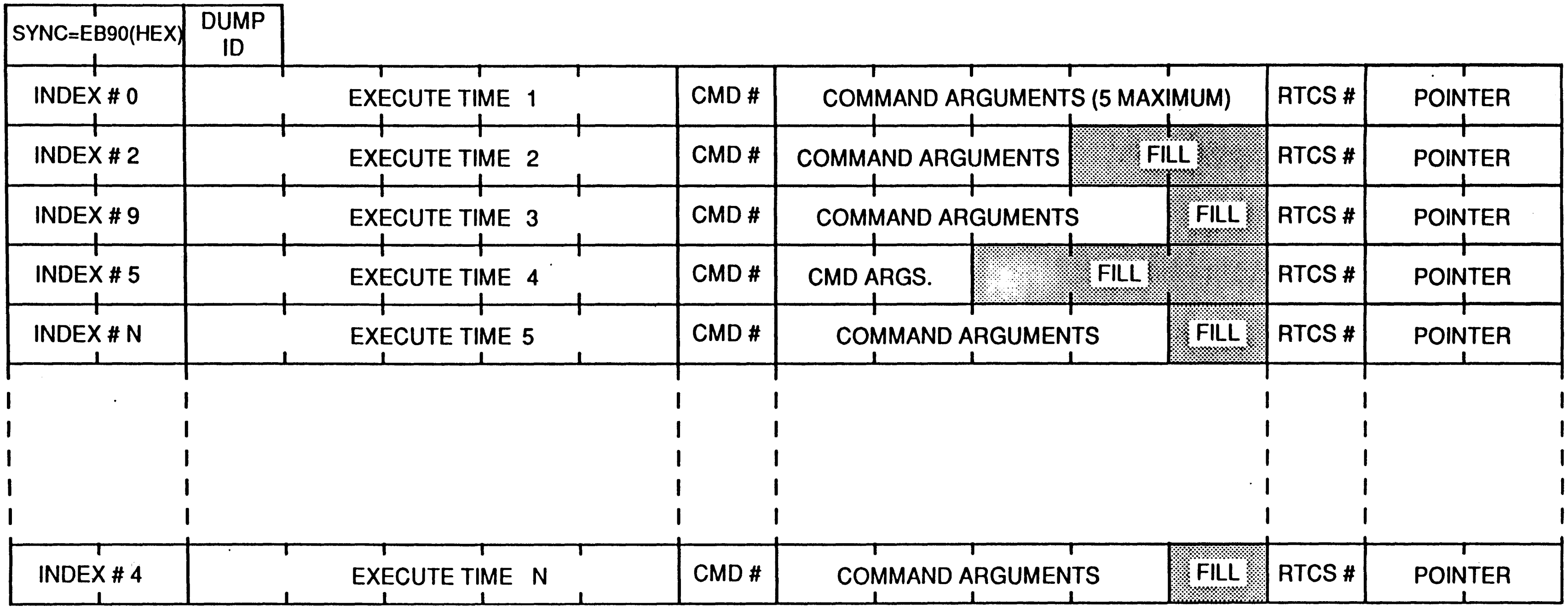
Absolute-Timed Command Structure

The time tag and command number in an ATC load must begin in the first byte of the uplink data area.

<table>
<tr><th>Command Type</th><th>Special Parameter</th><th colspan="3">Command Data</th></tr>
<tr><td>2</td><td>0</td><td colspan="2">Time Tag (Day)</td><td>Time Tag (Hour)</td></tr>
<tr><td>2</td><td>0</td><td>Time Tag (Minute)</td><td>Time Tag (Second)</td><td>00</td></tr>
<tr><td>2</td><td>1</td><td>Command #</td><td>Arg 1</td><td>00</td></tr>
</table>

Sample 2-Byte ATC and Time Tag Upload

Command Storage Area (CSA) Dump



SYNC=EB90(HEX)	DUMP ID					
INDEX # 0	EXECUTE TIME 1	CMD #	COMMAND ARGUMENTS (5 MAXIMUM)		RTCS #	POINTER
INDEX # 2	EXECUTE TIME 2	CMD #	COMMAND ARGUMENTS	FILL	RTCS #	POINTER
INDEX # 9	EXECUTE TIME 3	CMD #	COMMAND ARGUMENTS	FILL	RTCS #	POINTER
INDEX # 5	EXECUTE TIME 4	CMD #	CMD ARGS.	FILL	RTCS #	POINTER
INDEX # N	EXECUTE TIME 5	CMD #	COMMAND ARGUMENTS	FILL	RTCS #	POINTER
INDEX # 4	EXECUTE TIME N	CMD #	COMMAND ARGUMENTS	FILL	RTCS #	POINTER

NOTES:
1) COMMANDS ARE NOT NECESSARILY STORED IN THE ORDER THEY WILL EXECUTE.
2) DUMP ID = 04 (HEX) = CSA DUMP.
3) DUMP WILL REPEAT FROM SYNC UNTIL DUMP HALTED.
4) N = 512 CMDS MAXIMUM, INCLUDING ATC'S AND ANY ACTIVATED RTCS'S.
5) RTCS # = 1 TO 255 IF CMD IS FROM AN RTCS. 0 = ATC.
6) POINTER CONTAINS INDEX NUMBER OF NEXT CMD TO EXECUTE.
7) INDEX 0 IS ALWAYS CONTAINS NEXT PENDING CMD.
8) POINTER = 0 MEANS THIS INDEX NUMBER IS AVAILABLE FOR OVERWRITE.
9) POINTER = -1 MEANS THIS INDEX NUMBER IS LAST CMD IN CSA.

- The complete CSA can be dumped in approximately 6 minutes in the Computer Dump Telemetry Format (assumes 22 bytes/minor frame of dump data).

Relative Time Command Sequence Definition

- LIST OF COMMANDS AND DELTA TIME TAGS TO PROVIDE SEQUENCES OF ACTIVITIES WITH PREDETERMINED TIME SPACINGS.

- TIME TAGS ARE IN WHOLE SECONDS, VALUES FROM 0 TO 65,535.

- MOST COMMAND FUNCTIONS CAN BE CONTROLLED BY AN RTCS. SOME EXCEPTIONS:
  - SPECIAL HARDWARE COMMANDS
  - RTCS LOADS
  - CIB OPERATIONS

EXAMPLE - RTCS 26, ROUTINE TOMS SCAN:

DELTA T (SECONDS)	COMMAND	ELAPSED TIME
0	SELECT NORMAL SCAN MODE	00:00:00
4140	SELCT STANDBY MODE	01:09:00
2100	EXECUTE RTCS 26	01:44:00

RTCS Operational Aspects

- AN RTCS CAN BE EXECUTED BY:
  - REAL TIME COMMANDS
  - ABSOLUTE TIME (STORED) COMMANDS
  - SPACECRAFT PROCESSER WAKE-UP/SAFING LOGIC
  - ANOTHER RTCS
  - BY ITSELF (REPEAT FUNCTION)
  - TOMS-EP FLIGHT SOFTWARE ROUTINES

- AN RTCS CAN BE INHIBITED/ENABLED, EXECUTED/HALTED. RTCSs IN PROGRESS ARE TERMINATED ON SP SWITCH-OVER.

- ACTIVATION OF AN RTCS CREATES ABSOLUTE TIME COMMANDS WHICH ARE MERGED WITH PREVIOUSLY EXISTING ATCs.

- AN RTCS CAN BE CREATED, DELETED, EDITTED, AND DUMPED FOR GROUND VERIFICATION.

- CAPABILITY FOR UP TO 255 RTCSs IS PROVIDED.

- A MAXIMUM OF 512 COMMANDS CAN BE STORED IN AN RTCS (LIMITED BY SIZE OF STORED COMMAND STORAGE AREA (CSA).

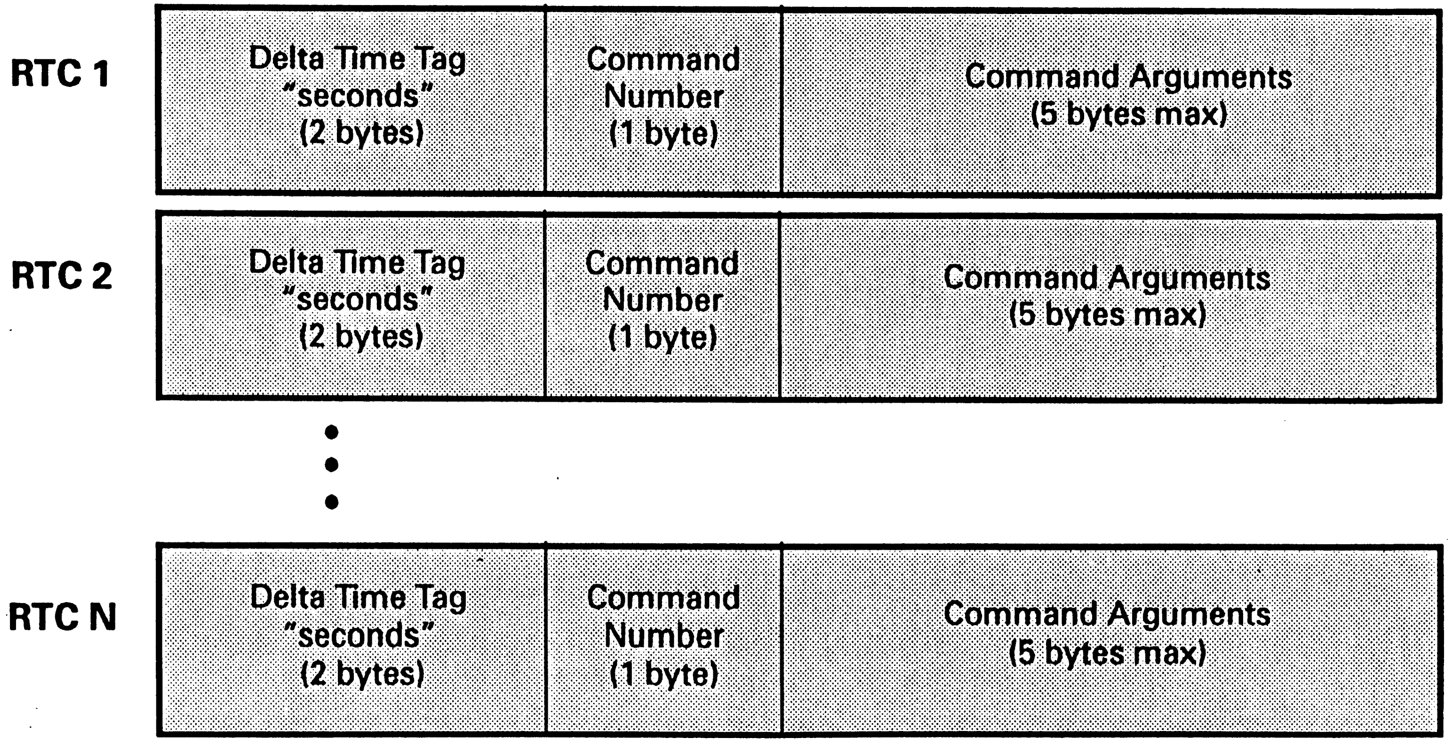
- TOTAL NUMBER OF RELATIVE TIME COMMAND STORAGE IS 1024 COMMANDS.

- A DEFAULT SET OF RTCSs IS PROVIDED AT SP WAKE-UP FOR KEY EVENTS SUCH AS DEPLOYMENT & SAFE MODE SEQUENCES.

Relative Time Command Sequences (RTCSs)

An RTCS is a sequence of basic commands (RTCs) with specified time intervals, in seconds, between their execution times.

Sequence XX



RTC 1	Delta Time Tag "seconds" (2 bytes)	Command Number (1 byte)	Command Arguments (5 bytes max)
RTC 2	Delta Time Tag "seconds" (2 bytes)	Command Number (1 byte)	Command Arguments (5 bytes max)
	• • •		
RTC N	Delta Time Tag "seconds" (2 bytes)	Command Number (1 byte)	Command Arguments (5 bytes max)

Relative-Timed Command Sequence Structure

Relative Time Command Sequences (RTCSs) (Continued)

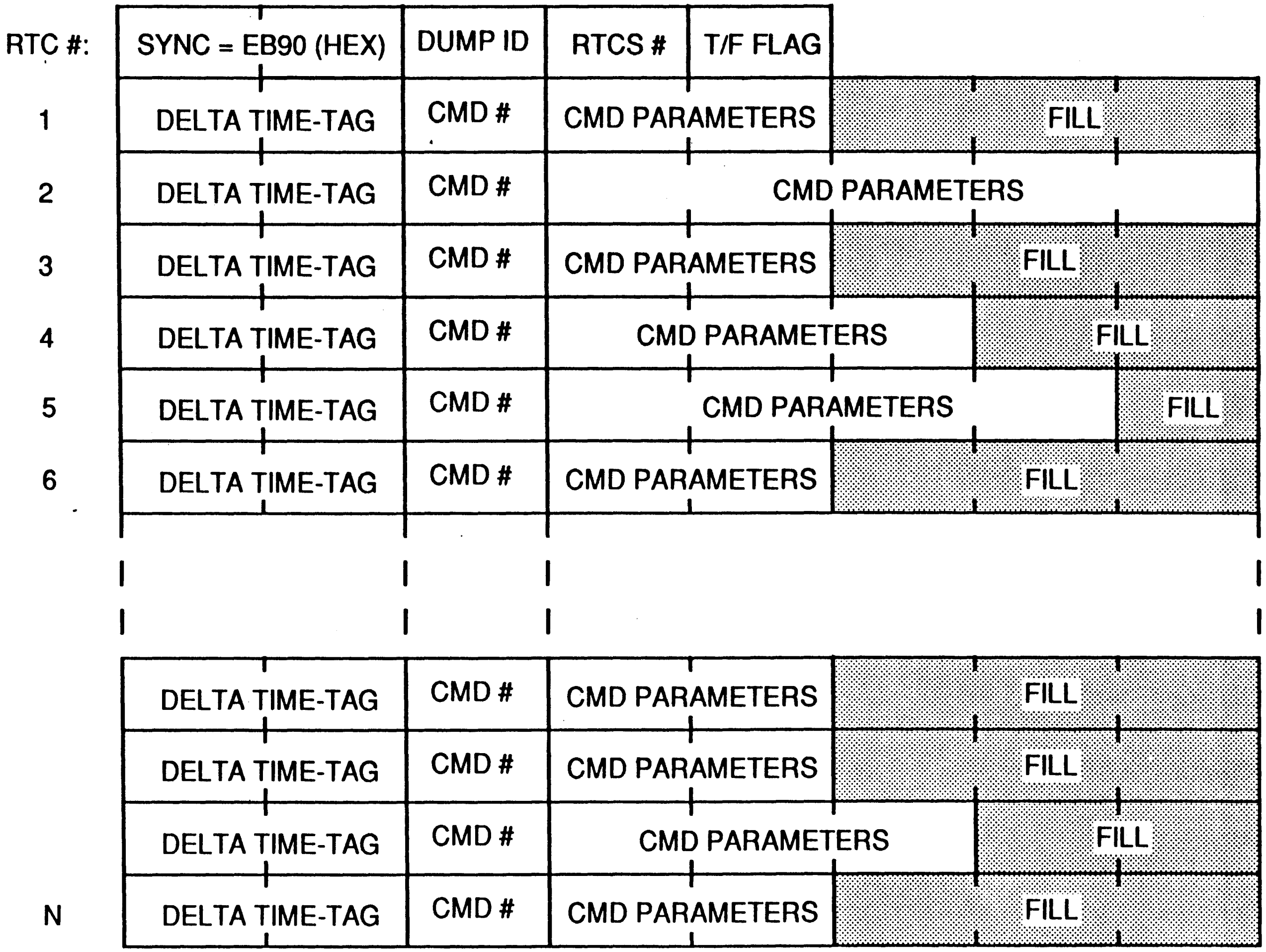
An RTCS reference must precede an RTCS upload.

The time tag and command number in an RTCS load must begin in the first byte of the uplink data area.

Command Type	Special Parameter	Command Data		
3	2	Sequence Number	RTC Number	
3	0	Delta Time Tag (Seconds)		00
3	1	Command #	Arg 1	00
3	0	Delta Time Tag (Seconds)		00
3	0	Command #	Arg 1	Arg 2
3	1	Arg 3	00	00
3	0	Delta Time Tag (Seconds)		00
3	0	Command #	Arg 1	Arg 2
3	1	Arg 3	Arg 4	00

Sample 3-Command RTCS Upload

RTCS Dump



RTC #:	SYNC = EB90 (HEX)	DUMP ID	RTCS #	T/F FLAG	
1	DELTA TIME-TAG	CMD #	CMD PARAMETERS		FILL
2	DELTA TIME-TAG	CMD #	CMD PARAMETERS		
3	DELTA TIME-TAG	CMD #	CMD PARAMETERS		FILL
4	DELTA TIME-TAG	CMD #	CMD PARAMETERS		FILL
5	DELTA TIME-TAG	CMD #	CMD PARAMETERS		FILL
6	DELTA TIME-TAG	CMD #	CMD PARAMETERS		FILL
	DELTA TIME-TAG	CMD #	CMD PARAMETERS		FILL
	DELTA TIME-TAG	CMD #	CMD PARAMETERS		FILL
	DELTA TIME-TAG	CMD #	CMD PARAMETERS		FILL
N	DELTA TIME-TAG	CMD #	CMD PARAMETERS		FILL

NOTES:
1) DUMP ID = 03 (HEX) = RTCS DUMP.
2) DUMP WILL REPEAT FROM SYNC UNTIL DUMP HALTED.
3) TRUE/FALSE FLAG INDICATES ENABLED/INHIBITED, RESPECTIVELY.
4) N = 512 COMMANDS MAXIMUM PER RTCS DUE TO CSA SIZE OF 512.
5) COMMANDS ARE DUMPED IN ORDER OF EXECUTION.

RTCS Directory

RTCS #	# OF CMDS	DESCRIPTION	PHASE LOADED	USED DURING
1	105	PRI SP WAKE-UP, DEPLOY, SUN ACQ	PROM FIXED	DEPLOY
2	104	RDNT SP WAKE-UP, DEPLOY, SUN ACQ	PROM FIXED	DEPLOY
3	5	CSSA CHECK OKAY, ACQ SUN & SET DEPLOY FF	PROM FIXED	DEPLOY
4	28	CONFIG FOR SAFE HOLD, PRIME SP	PROM FIXED	SAFING
5	28	CONFIG FOR SAFE HOLD, RDNT SP	PROM FIXED	SAFING
6	51	CONFIG FOR SAFE PWR/SUN PT RECOVERY, PRIME SP	PROM FIXED	SAFING
7	51	CONFIG FOR SAFE PWR/SUN PT RECOVERY, RDNT SP	PROM FIXED	SAFING
8	0	SPARE		
9	23	CONFIG FOR SAFE PWR/LONG TERM HOLD, PRIME SP	PROM FIXED	SAFING
10	23	CONFIG FOR SAFE PWR/LONG TERM HOLD, RDNT SP	PROM FIXED	SAFING
11	30	ASCENT MASTER SEQUENCE	PROM FIXED	DEPLOY/ASCENT
12	3	CSSA CHECK FAILS - DP CPUs OFF	PROM FIXED	DEPLOY
13	0	CONFIG FOR PREMATURE WAKE-UP	PROM FIXED	BOOST
14	0	CONFIG FOR STANDBY MODE	PROM FIXED	A & T
15	0	SPARE		
16	0	SPARE		
17	0	SPARE		
18	0	SPARE		
19	2	SELECT SP DUMP FORMAT FOR 12 MINUTES	PROM FIXED	ROUTINE OPS
20	4	CONFIG FOR XMTR A ON, RANGING OFF, 10 MINUTES	PROM FIXED	ROUTINE OPS
21	6	CONFIG FOR XMTR A ON, RANGING ON, 10 MINUTES	PROM FIXED	ROUTINE OPS
22	4	CONFIG FOR XMTR B ON, RANGING OFF, 10 MINUTES	PROM FIXED	ROUTINE OPS
23	6	CONFIG FOR XMTR B ON, RANGING ON, 10 MINUTES	PROM FIXED	ROUTINE OPS
24	2	CLOCK ADJUST, 12 HR REPEAT	SCIENCE OPS	ROUTINE OPS
25	5	BATTERY/OAS TANK HEATER CONTROL	PROM FIXED	ROUTINE OPS
26	3	NORMAL SCAN, REPEAT EVERY ORBIT	SCIENCE OPS	SCIENCE OPS
27	2	SOLAR CAL, REPEAT ONCE PER DAY	SCIENCE OPS	SCIENCE OPS
28	2	WAVELENGTH CAL, REPEAT ONCE PER DAY	SCIENCE OPS	SCIENCE OPS
29	2	ELECTRONICS CAL, REPEAT ONCE PER DAY	SCIENCE OPS	SCIENCE OPS
30	2	REFLECTANCE CAL, REPEAT ONCE PER DAY	SCIENCE OPS	SCIENCE OPS
31	4	SAFE INSTRUMENT (ALL OFF)	PROM FIXED	ALL
32	1	SELECT STANDBY MODE (STOW OPTICS)	PROM FIXED	ALL
TOTAL:	496			

Memory Loads

Memory loads consist of a memory address location, and the data to be placed in memory starting at the specified address.

- The length of the data is limited only by the size of the CIB.
- Memory loads to multiple locations within one processor may coexist in the CIB.

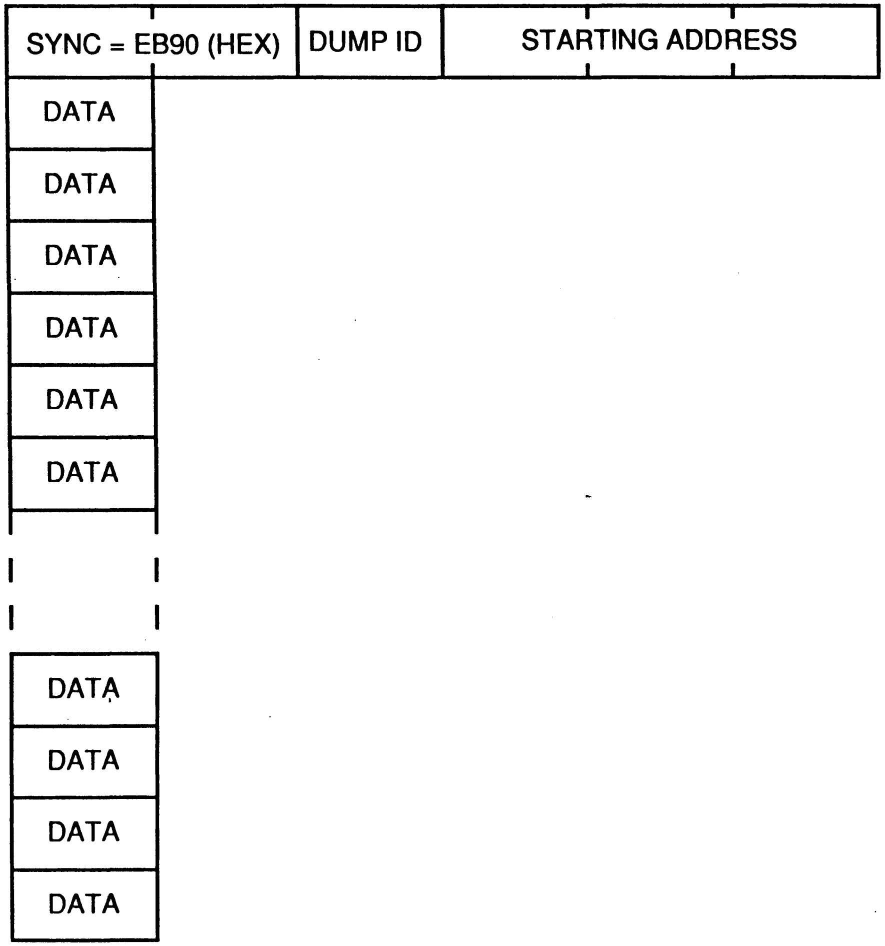
Memory Address (3 bytes)	Memory Load Data (n bytes)

Memory Load Structure

Command Type	Special Parameter	Command Data	
5	0	Address	
5	0	Data	
5	8	Data	00

Sample 5-Byte SP RAM Data Upload

General Memory Dump



SYNC = EB90 (HEX)

DUMP ID

STARTING ADDRESS

DATA

DATA

DATA

DATA

DATA

DATA

DATA

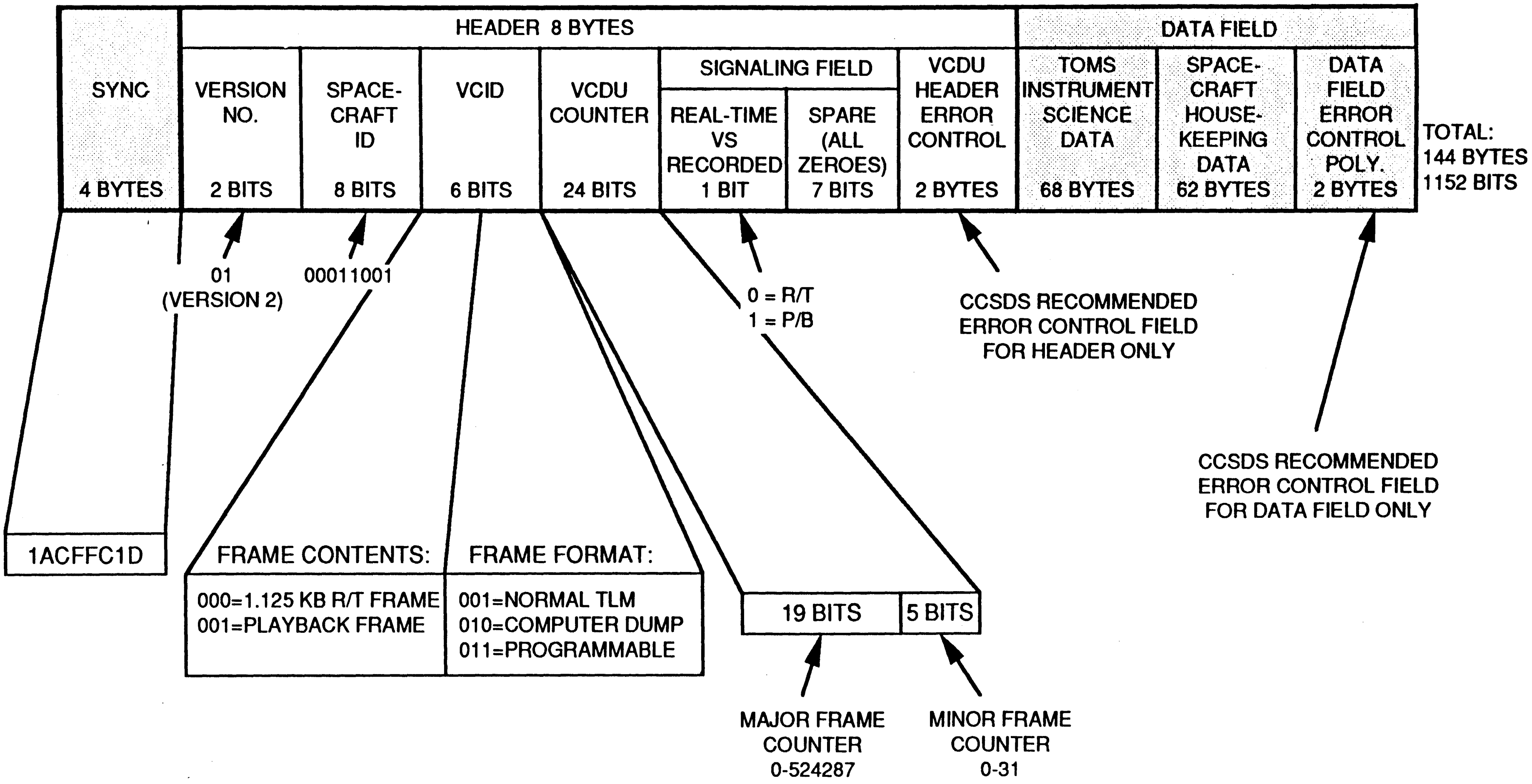
DATA

DATA

DATA

NOTES:
1) DUMP ID = O3 (HEX) = SP MEMORY DUMP, 08 (HEX) = DP MEMORY DUMP.
2) DUMP WILL REPEAT FROM SYNC UNTIL DUMP HALTED.
3) DUMP CAN BE ANY SPECIFIED LENGTH, UP TO 64K BYTES MAXIMUM.

Minor Frame and Header Overview



	HEADER 8 BYTES							DATA FIELD		
					SIGNALING FIELD					
SYNC	VERSION NO.	SPACE-CRAFT ID	VCID	VCDU COUNTER	REAL-TIME VS RECORDED	SPARE (ALL ZEROES)	VCDU HEADER ERROR CONTROL	TOMS INSTRUMENT SCIENCE DATA	SPACE-CRAFT HOUSE-KEEPING DATA	DATA FIELD ERROR CONTROL POLY.
4 BYTES	2 BITS	8 BITS	6 BITS	24 BITS	1 BIT	7 BITS	2 BYTES	68 BYTES	62 BYTES	2 BYTES

TOTAL:
144 BYTES
1152 BITS

1ACFFC1D

01
(VERSION 2)

00011001

FRAME CONTENTS:
000=1.125 KB R/T FRAME
001=PLAYBACK FRAME

FRAME FORMAT:
001=NORMAL TLM
010=COMPUTER DUMP
011=PROGRAMMABLE

0 = R/T
1 = P/B

19 BITS	5 BITS

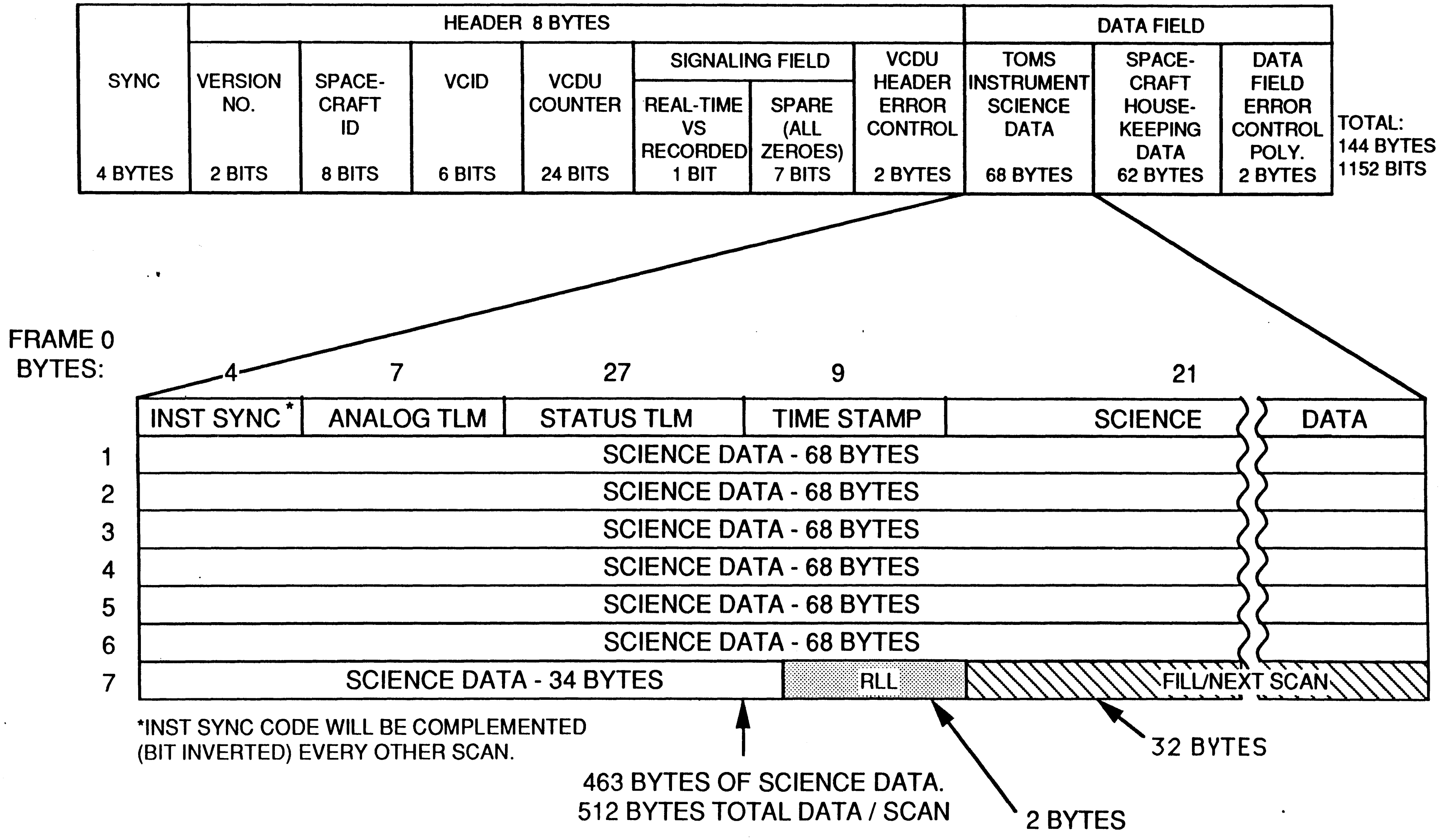
MAJOR FRAME
COUNTER
0-524287

MINOR FRAME
COUNTER
0-31

CCSDS RECOMMENDED
ERROR CONTROL FIELD
FOR HEADER ONLY

CCSDS RECOMMENDED
ERROR CONTROL FIELD
FOR DATA FIELD ONLY

Instrument/Spacecraft Telemetry Allocations



SYNC	HEADER 8 BYTES							DATA FIELD		
	VERSION NO.	SPACE-CRAFT ID	VCID	VCDU COUNTER	SIGNALING FIELD		VCDU HEADER ERROR CONTROL	TOMS INSTRUMENT SCIENCE DATA	SPACE-CRAFT HOUSE-KEEPING DATA	DATA FIELD ERROR CONTROL POLY.
					REAL-TIME VS RECORDED	SPARE (ALL ZEROES)				
4 BYTES	2 BITS	8 BITS	6 BITS	24 BITS	1 BIT	7 BITS	2 BYTES	68 BYTES	62 BYTES	2 BYTES

TOTAL:
144 BYTES
1152 BITS

FRAME 0 BYTES:	4	7	27	9	21
	INST SYNC*	ANALOG TLM	STATUS TLM	TIME STAMP	SCIENCE DATA
1	SCIENCE DATA - 68 BYTES				
2	SCIENCE DATA - 68 BYTES				
3	SCIENCE DATA - 68 BYTES				
4	SCIENCE DATA - 68 BYTES				
5	SCIENCE DATA - 68 BYTES				
6	SCIENCE DATA - 68 BYTES				
7	SCIENCE DATA - 34 BYTES	RLL	FILL/NEXT SCAN		

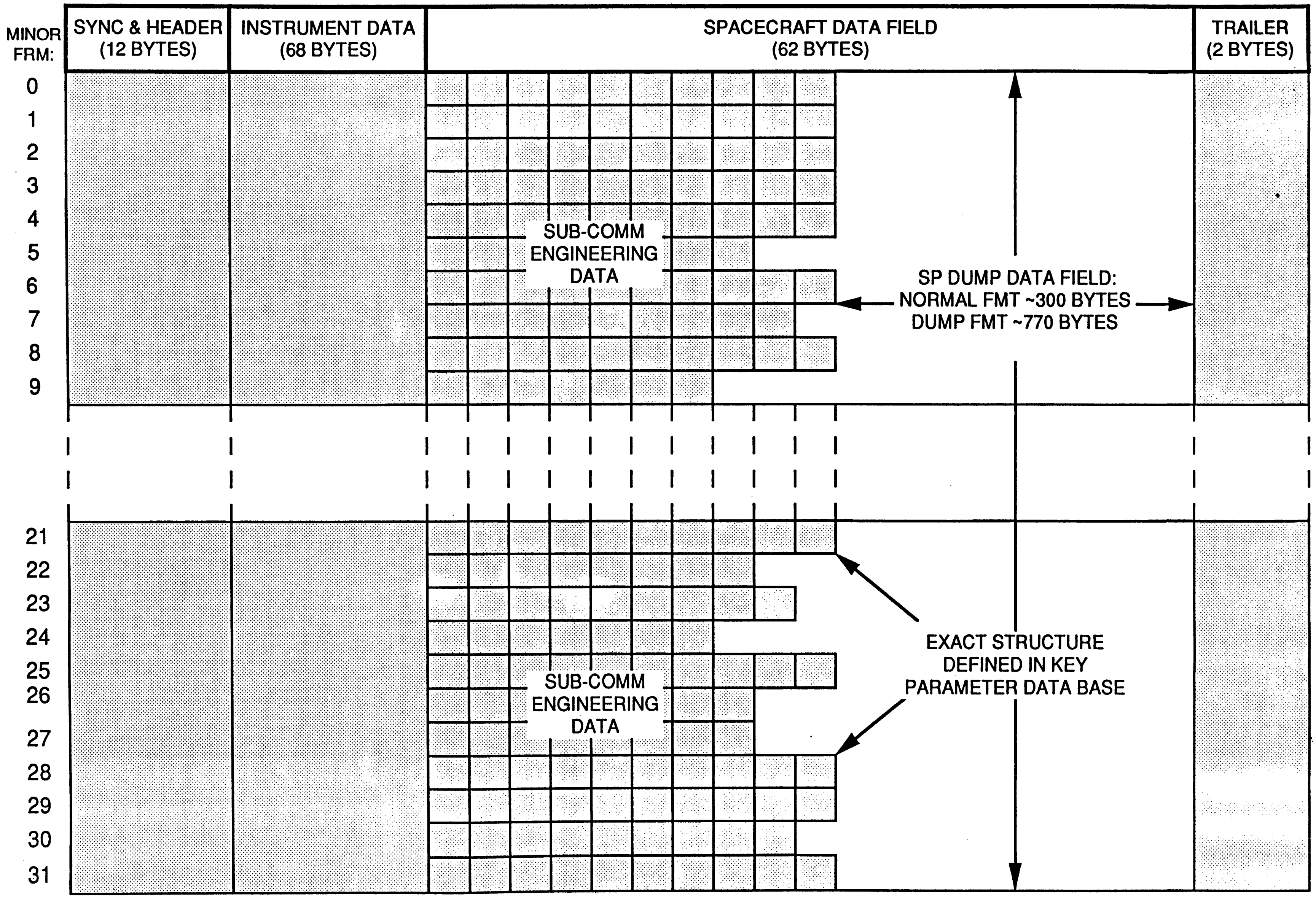
*INST SYNC CODE WILL BE COMPLEMENTED (BIT INVERTED) EVERY OTHER SCAN.

463 BYTES OF SCIENCE DATA.
512 BYTES TOTAL DATA / SCAN

2 BYTES

32 BYTES

Computer Dump Field Allocation

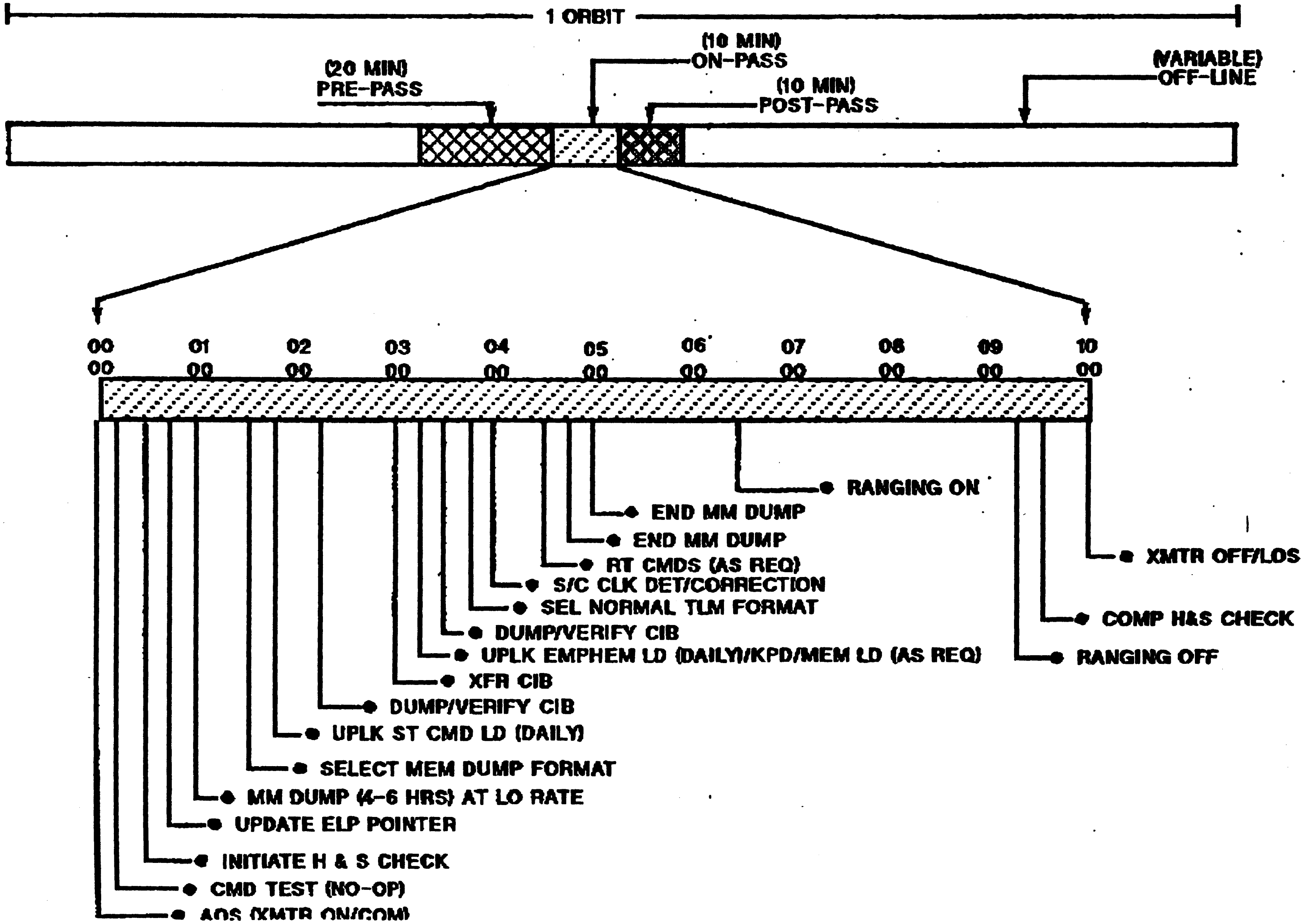


Science Data Capture

- Instrument gathers data every daylight pass as controlled by repeating RTCSs
- Capability to record 24 hours of science on-board
- Madrid and Canberra have 56 KBPS NASCOM lines and can route 50.625 KBPS playback stream to POCC, or can strip and ship real time data from 202.5 KBPS playback and do low rate playbacks post-pass
- Wallops and Goldstone have ≥224 KBPS NASCOM lines
- Playback times for 24 hours of data are 8.04 minutes at 202.5 KBPS, or 32.7 minutes at 50.625 KBPS
- Typically, 50 to 90 minutes of ground coverage will be scheduled daily. Good margins exist even under worst case configurations

Routine Pass Timeline

TRW



1 ORBIT

(20 MIN)
PRE-PASS

(10 MIN)
ON-PASS

(10 MIN)
POST-PASS

(VARIABLE)
OFF-LINE

00 00 | 01 00 | 02 00 | 03 00 | 04 00 | 05 00 | 06 00 | 07 00 | 08 00 | 09 00 | 10 00

- AOS (XMTR ON/COM)
- CMD TEST (NO-OP)
- INITIATE H & S CHECK
- UPDATE ELP POINTER
- MM DUMP (4-6 HRS) AT LO RATE
- SELECT MEM DUMP FORMAT
- UPLK ST CMD LD (DAILY)
- DUMP/VERIFY CIB
- XFR CIB
- UPLK EMPHEM LD (DAILY)/KPD/MEM LD (AS REQ)
- DUMP/VERIFY CIB
- SEL NORMAL TLM FORMAT
- S/C CLK DET/CORRECTION
- RT CMDS (AS REQ)
- END MM DUMP
- END MM DUMP
- RANGING ON
- RANGING OFF
- COMP H&S CHECK
- XMTR OFF/LOS

Twenty-Four Hour Timeline

TIME	ACTIVITY	COMMANDS	DURATION (h:mm:ss)
0:00	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:09:00
0:50	**AOS CANBERRA**		:10:00
	MASS MEMORY PLAYBACK @ 202.5KBPS		:02:00
	ROUTINE STATE OF HEALTH CHECKS		
	UPDATE S/C EPHEMERIS		:01:00
	TRACKING		:07:30
1:00	**LOS CANBERRA**		
1:09	ECLIPSE/TOMS TO STANDBY		
1:44	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:09:00
2:53	ECLIPSE/TOMS TO STANDBY		
2:58	ELECTRONICS CAL		
		RTCS 29, 24 HR REPEAT	:06:00
3:06	WAVELENGTH CAL		
		RTCS 28, 24 HR REPEAT	:06:00
3:28	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:09:00
4:37	ECLIPSE/TOMS TO STANDBY		
5:05	**AOS WALLOPS**		:10:00
	MASS MEMORY PLAYBACK @ 202.5KBPS		:02:00
	ROUTINE STATE OF HEALTH CHECKS		
	UPLINK NEXT DAY'S STORED COMMAND LOAD		:03:00
	TRACKING		:07:30
5:12	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:09:00
5:15	**LOS WALLOPS**		:10:00
	CLOCK ERROR DETERMINATION		:05:00
6:21	ECLIPSE/TOMS TO STANDBY		
6:56	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:09:00
8:05	ECLIPSE/TOMS TO STANDBY		
8:40	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:09:00
9:49	ECLIPSE/TOMS TO STANDBY		

Twenty-Four Hour Timeline (Continued)

TIME	ACTIVITY	COMMANDS	DURATION (h:mm:ss)
9:51	**AOS MADRID**		:10:00
	MASS MEMORY PLAYBACK @ 202.5KBPS		:02:00
	ROUTINE STATE OF HEALTH CHECKS		
	BACKUP SITE FOR STORED CMD UPLINK		:03:00
	TRACKING		:07:30
10:01	**LOS MADRID**		
10:24	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:02:00
11:26	SOLAR IRRADIANCE CAL		
		RTCS 22, 24 HR REPEAT	:06:00
11:33	ECLIPSE/TOMS TO STANDBY		
12:08	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:09:00
12:28	**AOS CANBERRA**		:10:00
	MASS MEMORY PLAYBACK @ 202.5KBPS		:02:00
	ROUTINE STATE OF HEALTH CHECKS		
	BACKUP SITE FOR STORED CMD UPLINK		:03:00
	TRACKING		:07:30
12:38	**LOS CANBERRA**		
13:17	ECLIPSE/TOMS TO STANDBY		
13:52	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:09:00
15:01	ECLIPSE/TOMS TO STANDBY		
15:36	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:09:00
16:45	ECLIPSE/TOMS TO STANDBY		
16:49	**AOS WALLOPS**		:10:00
	COMPLETE MASS MEMORY PLAYBACK @ 202.5KBPS		:08:30
	ROUTINE STATE OF HEALTH CHECKS		
	BACKUP SITE FOR STORED CMD UPLINK		:03:00
	TRACKING		:01:00
16:59	**LOS WALLOPS**		
	CLOCK ERROR DETERMINATION		:05:00
17:20	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:09:00
18:29	ECLIPSE/TOMS TO STANDBY		

Twenty-Four Hour Timeline (Continued)

TIME	ACTIVITY	COMMANDS	DURATION (h:mm:ss)
19:04	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:09:00
20:13	ECLIPSE/TOMS TO STANDBY		
20:20	REFLECTANCE CAL		
		RTCS 25, 24 HR REPEAT	:15:00
20:48	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:09:00
21:57	ECLIPSE/TOMS TO STANDBY		
22:32	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:09:00
22:33	**AOS MADRID**		:10:00
	MASS MEMORY PLAYBACK @ 202.5KBPS		:02:00
	UPDATE S/C CLOCK		:01:00
	ROUTINE STATE OF HEALTH CHECKS		
	LAST OPPORTUNITY FOR STORED CMD UPLINK		:03:00
	TRACKING		:07:30
23:41	ECLIPSE/TOMS TO STANDBY		
23:43	**LOS MADRID**		
0:16	SUNRISE/TOMS NORMAL SCAN		
		RTCS 26, 104 MIN REPEAT	1:09:00

Contingency Operations

- Contingency planning to be provided in "Flight Operations Handbook," D19828
- Currently planning to provide information as follows:
  - Recovery from loss of communication/fail to acquire
  - Recovery from Safe Hold Mode
  - Recovery from Safe Power Mode
  - Recovery from UV/OV trip
  - Reconfigurations following subsystem fault isolations (selected cases)

    Examples: Configure for Normal Science Mode with alternate gyro
    Configure Normal Backup Mode 1 (scan wheel 2 failed)

TOMS-EP
Performance Assurance

Performance Assurance Agenda

System Performance Verification	J. Giglio
EMI/EMC Verification	R. Bal
Spacecraft Test	J. Durschinger
Reliability/FMEA	B. Woerner
System Safety	D. McGraw
Contamination Control	K. Henderson
Materials and Processes	M. Hirsch
EEE Parts	G. Penney
Hardware Quality Assurance	L. Irwin
Software Quality Assurance	G. Walsh

Reliability

Reliability Agenda

- Summary
- System Predictions
- FMEA - Critical Items List
- Limited Life Items List
- Trend Analysis Parameters

TOMS-EP Reliability Summary

- Reliability program implemented in accordance with TOMS-EP Reliability Implementation Plan (PA-03)

- Reliability requirements defined in TOMS-EP System Specification (SY1-0012)
  - 0.90 for 2 years (spacecraft bus reliability)
  - Minimize single point failures
  - Critical item list and controls plans for severity categories 1, 1R, 1S or 2 (mission or safety critical or nonredundant equipment)

- Reliability predictions and FMEAs updated to CDR design
  - Subcontractor analyses reviewed, approved, and integrated into system analyses
  - System analyses coordinated across all program elements (safety, EDI, redundancy management, I&T, etc.)

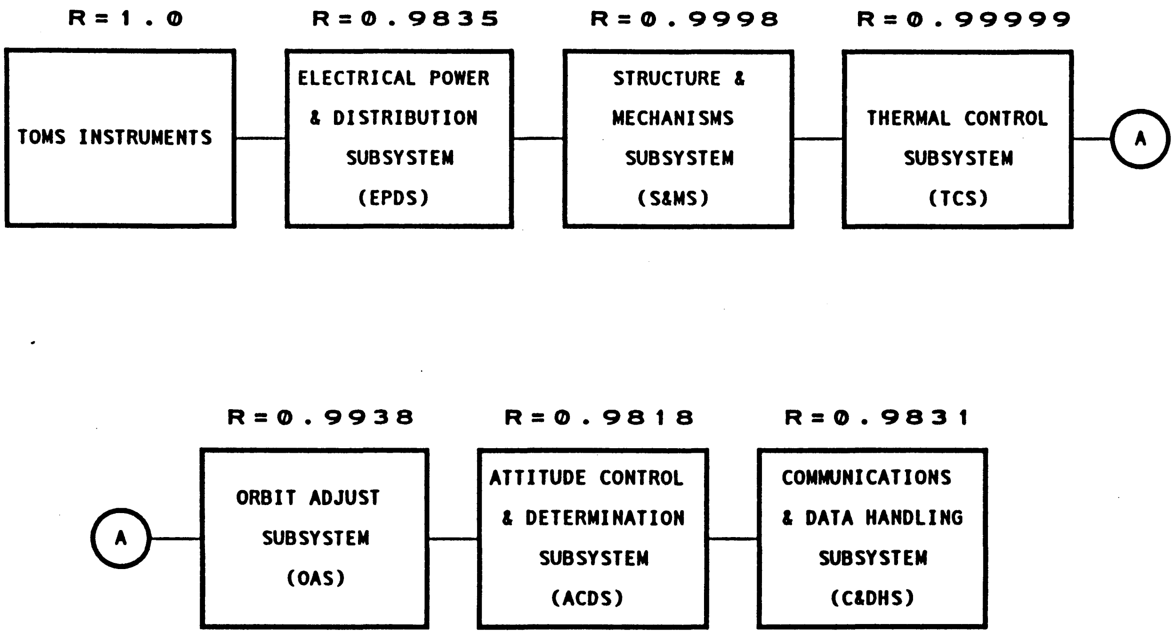
TOMS-EP Reliability Summary (Continued)

- 0.95 predicted reliability exceeds 2-year 0.90 requirement
  - Parts count method implemented. Yields conservative estimate
- FMEAs identified a very limited number of critical failure modes
  - Critical item control plans are being developed
- Limited life items identified
  - Life test plans in place
- Trend parameters identified
  - Trend parameters are being integrated into integration and test planning

TOMS-EP System Predictions

SUBSYSTEM	ALLOCATIONS	2 YEAR PREDICTIONS	3 YEAR PREDICTIONS
Electrical Power & Distribution Subsystem (EPDS)	0.975	0.9835	0.9743
Structure and Mechanisms Subsystem (S&MS)	0.999	0.9998	0.9998
Thermal Control Subsystem (TCS)	0.995	0.99999	0.99997
Orbital Adjust Subsystem (OAS)	0.993	0.9938	0.9908
Attitude Control & Determination Subsystem (ACDS)	0.970	0.9918	0.9823
Communications and Data Handling Subsystem (C&DH)	0.965	0.9831	0.9638
TOMS Instruments	1.000	1.0000	1.0000
TOMS-EP System	0.900	0.9528	0.9136

TOMS-EP System Reliability Block Diagram



$R_{(2\ YR)} = 0.9527$

TOMS-EP Critical Items List

ITEM	FAILURE MODE	SEVERITY LEVEL	JUSTIFICATION FOR RETENTION
PROPELLANT TANK/DIAPHRAGM	EXTERNAL LEAKAGE, TANK RUPTURE OR DIAPHRAGM FAILURE	1,2	- STRESS/FRACTURE ANALYSES VERIFY DESIGN MARGINS - QUAL SINE VIBRATION, PROOF PRESSURE, EXTERNAL LEAKAGE, AND DIAPHRAGM PHYSICAL PROPERTIES TESTS - RADIOGRAPHIC AND PENETRANT WELD INSPECTIONS
PRIMARY (SOLAR ARRAY WING) HINGE	HINGE BINDS DURING SOLAR ARRAY DEPLOYMENT	2	- TITANIUM WASHERS BETWEEN HINGE HALVES PROVIDE REDUNDANT ROTATING SURFACES - ROTATING SURFACES BURNISHED WITH MOLYBDENUM-DISULFIDE TO REDUCE FRICTION - TORQUE VERSUS ANGLE TEST TO VERIFY SPECIFIED TORQUE MARGIN OVER ENTIRE DEPLOYMENT RANGE
NITINOL DEVICE	ENVIRONMENTALLY HEATED (AUTO ACTIVIATION)	2	- DEVELOPMENT AND QUALIFICATION TESTS VERIFY MARGIN BETWEEN DEPLOYMENT AND AUTO ACTIVATION TEMPERATURES - LOT SAMPLE TESTS VERIFY TEMPERATURE CHARACTERISTICS - ALL DEVELOPMENT, QUALIFICATION AND FLIGHT DEVICES WILL BE FROM THE SAME LOT
NITINOL FRANGIBOLT	INCORRECT GAP	2	- BOLT PRELOADED TO 63% OF RATED TENSILE STRENGTH - LOCKING NUT WILL BE USED TO PREVENT LOOSING OF BOLT - LOT SAMPLE TESTS WILL VERIFY BOLT BREAK CHARACTERISTICS - ALL DEVELOPMENT, QUALIFICATION AND FLIGHT DEVICES WILL BE FROM THE SAME LOT
NITINOL WASHER	INCORRECT SIZE	2	- LOT SAMPLE TESTS WILL VERIFY WASHER SIZING AND MATERIAL - ALL DEVELOPMENT, QUALIFICATION AND FLIGHT WASHERS WILL BE FROM THE SAME LOT
SOLAR ARRAY REGULATOR	INPUT WIRING OPEN OR SHORT TO GROUND, OR OPEN RELAY WIPER	2	- ADDITIONAL INSULATION INSTALLED ON BASE OF SAR CHASSIS TO PROVIDE A SECOND INSULATION BARRIER FOR CRITICAL WIRES - SPECIAL CONTROLS FOR STORAGE AND HANDLING OF RELAYS - ADDITIONAL QA INSPECTION CALLOUTS FOR WIRE ROUTING, SHARP EDGES, SOLDER WICKING AND FOR RECORDING THE NUMBER OF RELAY CYCLES

TOMS-EP Critical Items List (Continued)

ITEM	FAILURE MODE	SEVERITY LEVEL	JUSTIFICATION FOR RETENTION
POWER CONTROL UNIT	MAIN POWER BUS SHORT-TO-GROUND	2	- INSULATORS INSTALLED BETWEEN BUS BARS AND PCU CHASSIS - ADDITIONAL INSULATION INSTALLED ON PCU CHASSIS TO PROVIDE A SECOND INSULATION BARRIER FOR CRITICAL WIRES - ADDITIONAL QA INSPECTION CALLOUTS FOR WIRE ROUTING, SHARP EDGES AND SOLDER WICKING
	OPEN WIPER OF THE DC/DC CONVERTER OUTPUT POWER SELECT RELAY, OR A WIRING SHORT-TO-GROUND ON DC BUS	2	- SPECIAL CONTROLS FOR STORAGE AND HANDLING OF RELAYS - ADDITIONAL QA INSPECTION CALLOUTS FOR WIRE ROUTING, SHARP EDGES, WICKING AND FOR RECORDING THE NUMBER OF RELAY CYCLES - ADDITIONAL INSTALLATION INSTALLED ON PCU CHASSIS TO PROVIDE A SECOND INSULATION BARRIER FOR CRITICAL WIRES
	OPEN WIPER OF PRIMARY/REDUNDANT SPACECRAFT PROCESSOR SELECT RELAYS (+5V RELAY OR +/-15V RELAY)	2	- SPECIAL CONTROLS FOR STORAGE AND HANDLING OF RELAYS - ADDITIONAL QA INSPECTION CALLOUTS AND FOR RECORDING THE NUMBER OF RELAY CYCLES
SPACECRAFT HARNESS ASSEMBLIES	BATTERY TO PCU HARNESS SHORT-TO-GROUND	2	- CRITICAL WIRE BUNDLES WILL BE BETA WRAPPED - 1,000V HIGH VOLTAGE INSULATION TEST TO VERIFY THAT THE INSULATION RESISTANCE EXCEEDS 100 MEG OHMS - INSPECTION FOR DAMAGE OF INSTALLED HARNESS ASSEMBLY
	SOLAR ARRAY WING HARNESS TO SOLAR ARRAY REGULATOR SHORT-TO-GROUND	2	- CRITICAL WIRE BUNDLES WILL BE BETA WRAPPED - 1,000V HIGH VOLTAGE INSULATION TEST TO VERIFY THAT THE INSULATION RESISTANCE EXCEEDS 100 MEG. OHMS - INSPECTION FOR DAMAGE OF INSTALLED HARNESS ASSEMBLIES
BATTERY ASSEMBLY	BATTERY CELL SHORT-TO-GROUND	2	- DUAL CERAMIC-TO-METAL SEALS ISOLATING BOTH CELL TERMINALS - EACH CELL IS WRAPPED WITH MYLAR INSULATION MATERIAL
NADIR (S-BAND) ANTENNA	MECHANICAL DAMAGE DUE TO HANDLING AND/OR DURING INSTALLATION	2	- DETAILED MECHANICAL INSTALLATION PROCEDURES TO PREVENT HANDLING/INSTALLATION DAMAGE - INSPECTION FOR DAMAGE PRIOR TO AND AFTER INSTALLATION - ANTENNA RF TESTS PERFORMED PRIOR TO LAUNCH AT WALLOPS FLIGHT FACILITY
NADIR RF CABLE ASSEMBLY	OPEN OR SHORT-TO-GROUND OF EITHER THE ANTENNA CONNECTOR OR THE RF ASSEMBLY CONNECTOR	2	- ALL RF CABLE CONNECTORS ARE X-RAYED AFTER CABLE INSTALLATION AND MATING - INSPECTION FOR DAMAGE AFTER INSTALLATION AND REVIEW OF X-RAY RESULTS

TOMS-EP Limited Life Item List

SUBSYSTEM	ITEM	SENSITIVE PARAMETERS	IMPACT ON MISSION PARAMETERS	EXPECTED LIFE (RATING)	REQUIRED LIFE (APPLICATION)	DUTY CYCLE	COMMENTS
ACDS	Scanwheels	Bearing, Lubricant	Switch to redundant reaction wheel	5 years	2 years	100%	Life tests will be performed. Lubricant loss analysis.
ACDS	Reaction Wheel	Bearing, Lubricant	Second failure	5 years	2 years	100%	Life tests will be performed. Lubricant loss analysis.
ACDS	Gyro	Bearing, Lubricant	Switch to redundant system	5 years	2 years	100%	Life test will be performed.
EPDS	Battery	Temperature, Overcharge bus voltage	Loss of mission	17000 cycles	10100 cycles	100%	Life tests will be performed. Five cells to be tested.

TOMS-EP Trend Analysis Parameters

SUBSYSTEM	COMPONENT	TEST PARAMETER
C&DHS	TRANSPONDER	- RECEIVER INPUT SENSITIVITY - RECEIVER COMMAND THRESHOLD - TRANSMITTER MODULATION INDEX - TRANSMITTER DOWNLINK FREQUENCY STABILITY - TRANSMITTER OUTPUT POWER LEVEL
ACDS	GYRO	- MOTOR CURRENT - RUN-UP-TIME
	RWA AND SCAN WHEELS	- MOTOR VOLTAGE - RUN-UP-TIME AND RUN-DOWN-TIME

System Safety

System Safety Requirements

- Contractual policy documents
  - GMI 1771.1, "Range Safety Policies and criteria for GSFC/Wallops Flight Facility"
  - MIL-STD-1574A, "System Safety Program for Space and Missile Systems"
- Contractual technical requirements documents
  - WSMCR 127-1, "Western Space and Missile Center Range Safety Requirements"
  - MIL-STD-1522A, "Safety Requirements for Pressurized System"
  - Contract NAS5-31488, Modification Number 18, "Propellant Lines shall be one fault tolerance against overheating to temperatures greater than 160°F"
- Pending safety requirements
  - Wallops safety document currently in work. Will address WFF ground safety and Orbital Sciences Corporation (SC) flight safety requirements
  - OSC Pegasus requirements issued to industry are man-rated safety requirements for carrier aircraft

Safety Program

- Systems design safety approach implemented for TOMS-EP
  - Implemented contractual safety requirements (ground safety)
  - Where practical, implemented flight safety design features anticipating man-rated requirements, e.g. two fault electrical and mechanical tolerance for OAS to catastrophic hazards

- Safety analysis activity
  - Preliminary Accident Risk Assessment report (ARAR) prepared and submitted at PDR
  - Hazard analysis completed to WSMCR and MIL-STD-1522A requirements
  - Updated ARAR not planned until flight safety requirements are defined for TOMS-EP

- Preliminary assessment of OSC safety document SSD-TD-005 conducted for OAS System
  - Assessment results reviewed by NASA WFF at interface working group meeting held at WWF

TOMS-EP Design Safety Features

- Propulsion System (OAS)
  - 2 fault tolerant mechanically and electrically to catastrophic hazards
  - 3 seals on fill and drain module
  - All-welded design
  - Hydrazine fully pressurized to thrusters to eliminate adiabatic detonation and pressure transients
  - Propellant tank safety factor of 1.5:1
  - Tank burst factor of 2 to 1
  - Complies with MIL-STD-1522A
  - 2 of 3 electrical inhibits are monitorable
  - Tank temperature and pressure are telemetered for ground monitoring. Other safety parameters are available for telemetry

- Structures
  - Meets 1.5 S.F. during captive carry

TOMS-EP Design Safety Features (Continued)

- Materials
  - Use of flammable materials minimized
- Solar Array
  - 2 fault tolerant against premature deployment/operation

- Batteries
  - Over-charge protection
  - Battery telemetry data available

- Premature computer (spacecraft processor) operation
  - Computer locked-out by breakwire inhibits and cannot issue commands until after separation

Wallops Ground Safety

- Propellant Loading
  - Hydrazine loading tasks are being defined with Wallops
  - Propellant loading will consist of Wallops and TRW personnel

- MGSE
  - Industry-standard safety factors
  - 5 to 1 on lifting equipment
  - Annual proof and nondestructive inspection (NDI) tests

Safety Certification Process

- Open issues
  - Ground rules need to be established for TOMS-EP safety approval process for Pegasus man-rated program
  - To date, no formal safety certification meetings held with Wallops and OSC
  - Wallops safety document not released

TRW

TOMS-EP
Contamination Control

Kelly

K. Henderson

TOMS-EP Contamination Control Plan

Scope

- The plan for contamination control is end-to-end: from design and component fabrication through launch

- The plan includes protective measures for the instrument from the time it is received by TRW until the entire spacecraft is launched

- Contamination Working Group Meetings are being held at regular intervals, including GSFC, TRW, P-E and OSC, to discuss interface issues

TOMS-EP Program
Contamination Control Requirements

- Provide Contamination Control Plan
  - Polymeric materials meeting 0.1% VCM, 1.0% TML (PAR)
  - Bake-out of thermal blankets, solar arrays, and wire harnesses (PAR)
  - I&T in Class 10,000 clean area (System Specification, SY1-0012)
  - Minimize instrument contamination through spacecraft design, Class 100 flow bench (System Specification, SY1-0012)
  - Visibly clean components (derived)
  - Prelaunch cleanliness goal of 750A (derived)

- Provide Source and Effects Analysis
  - Results used to validate design for venting directions/locations and protective covers

Contamination Control Plan

- Requirements
  - Design/Material Requirements
  - Cleanliness Requirements
  - Vendor-Supplied Hardware
  - Facility/Operational Requirements
  - Launch/Mission Requirements

- Implementation
  - Materials and Processes (including thermal vacuum bake-outs)
  - Fabrication, Assembly, Test, Shipment, including critical operations
  - Monitoring
  - Covering/Purging
  - Cleaning/Inspection
  - Clean Area Practices
  - Launch Site Operations

TRW Cleanliness Goals (MIL-STD-1246B)

- Spacecraft Bus (derived)
  - End of assembly/close-out all surfaces: 500A goal
  - End of I&T all surfaces: 600A goal
  - Prelaunch all surfaces: 750A goal
  - Using inspection method that verifies surfaces below 750A

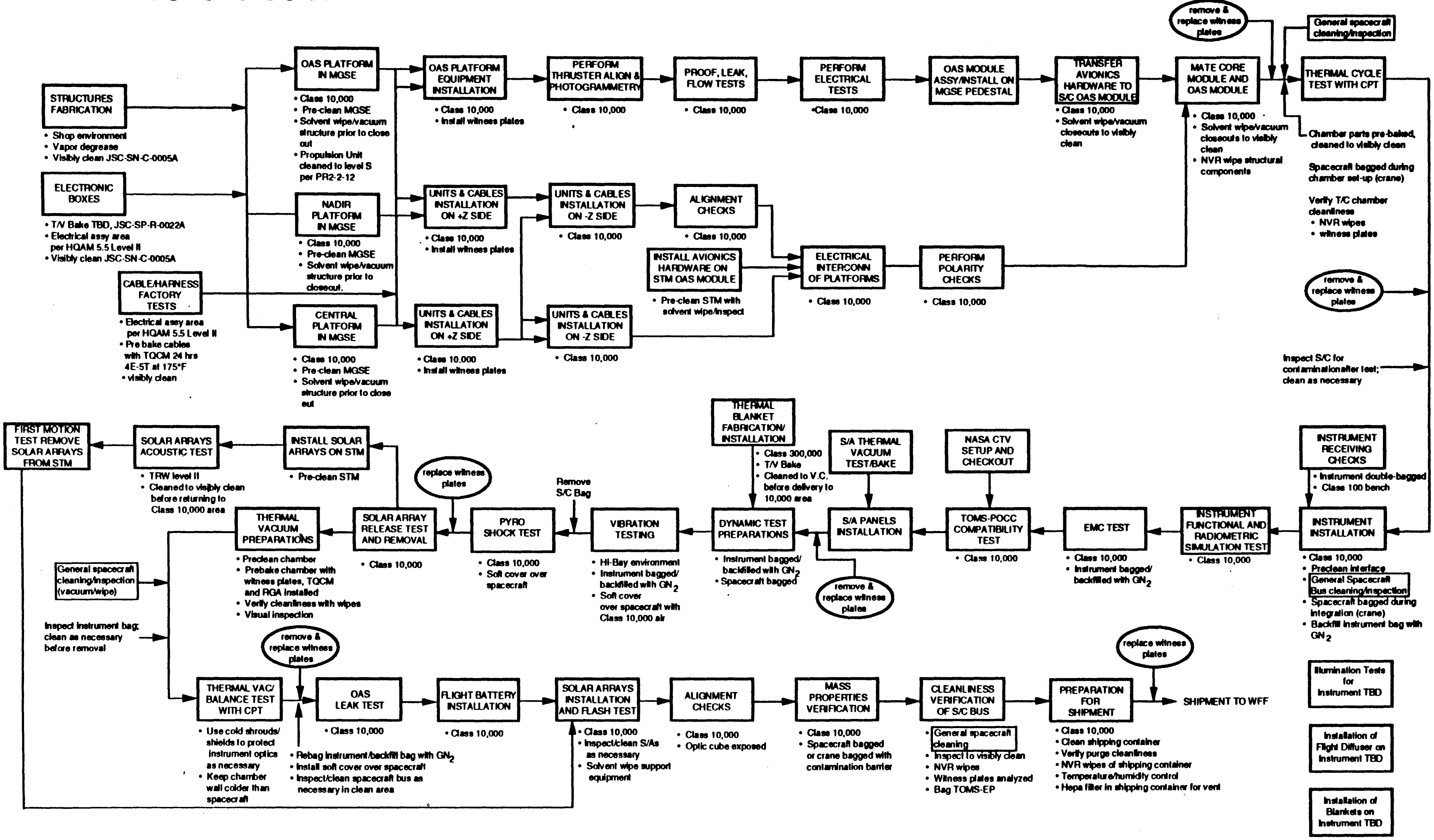
Facility/Operational Requirements

- Facility Air Cleanliness per FED-STD-209D

Hardware Types	Air Cleanliness Requirement per FED-STD-209D	
	Instrument Covered	**Instrument Uncovered**
Structural Details Parts/Assembly	Normal shop environment*	
Electronic Manufacturing and Solar Arrays	TRW document HQAM 5.5	
Propulsion Subsystem	Class 10,000	
Thermal Control Insulation	Class 300,000	
Spacecraft Bus Assembly and Test	Class 10,000	
Thermal Vacuum Facility (TRW)	Per Contamination Control Plan, D19082	Per Contamination Control Plan, D19082
Instrument Integration to Spacecraft	Class 10,000	
Instrument Contingency Operation Area (TRW)		Class 100 (Portable Clean Area)
"Satellite" Test and Integration (TRW)	Class 10,000	
Launch Site Operation	Class 10,000	Class 100

*Parts and assemblies cleaned and/or inspected to visibly clean before transport into the Class 10,000 I&T area.

Contamination Control Implementation – I&T Flow



STRUCTURES FABRICATION
- Shop environment
- Vapor degrease
- Visibly clean JSC-SN-C-0005A

ELECTRONIC BOXES
- T/V Bake TBD, JSC-SP-R-0022A
- Electrical assy area per HQAM 5.5 Level II
- Visibly clean JSC-SN-C-0005A

CABLE/HARNESS FACTORY TESTS
- Electrical assy area per HQAM 5.5 Level II
- Pre bake cables with TQCM 24 hrs 4E-5T at 175°F
- visibly clean

OAS PLATFORM IN MGSE
- Class 10,000
- Pre-clean MGSE
- Solvent wipe/vacuum structure prior to close out
- Propulsion Unit cleaned to level S per PR2-2-12

NADIR PLATFORM IN MGSE
- Class 10,000
- Pre-clean MGSE
- Solvent wipe/vacuum structure prior to closeout.

CENTRAL PLATFORM IN MGSE
- Class 10,000
- Pre-clean MGSE
- Solvent wipe/vacuum structure prior to close out

OAS PLATFORM EQUIPMENT INSTALLATION
- Class 10,000
- Install witness plates

UNITS & CABLES INSTALLATION ON +Z SIDE
- Class 10,000
- Install witness plates

UNITS & CABLES INSTALLATION ON +Z SIDE
- Class 10,000
- Install witness plates

PERFORM THRUSTER ALIGN & PHOTOGRAMMETRY
- Class 10,000

UNITS & CABLES INSTALLATION ON -Z SIDE
- Class 10,000

UNITS & CABLES INSTALLATION ON -Z SIDE
- Class 10,000

PROOF, LEAK, FLOW TESTS
- Class 10,000

ALIGNMENT CHECKS
- Class 10,000

INSTALL AVIONICS HARDWARE ON STM OAS MODULE
- Pre-clean STM with solvent wipe/inspect

PERFORM ELECTRICAL TESTS
- Class 10,000

ELECTRICAL INTERCONN OF PLATFORMS
- Class 10,000

PERFORM POLARITY CHECKS
- Class 10,000

OAS MODULE ASSY/INSTALL ON MGSE PEDESTAL

TRANSFER AVIONICS HARDWARE TO S/C OAS MODULE
- Class 10,000
- Solvent wipe/vacuum closeouts to visibly clean

remove & replace witness plates

MATE CORE MODULE AND OAS MODULE
- Class 10,000
- Solvent wipe/vacuum closeouts to visibly clean
- NVR wipe structural components

General spacecraft cleaning/inspection

THERMAL CYCLE TEST WITH CPT

Chamber parts pre-baked, cleaned to visibly clean

Spacecraft bagged during chamber set-up (crane)

Verify T/C chamber cleanliness
- NVR wipes
- witness plates

remove & replace witness plates

Inspect S/C for contaminationafter test; clean as necessary

INSTRUMENT RECEIVING CHECKS
- Instrument double-bagged
- Class 100 bench

INSTRUMENT INSTALLATION
- Class 10,000
- Preclean interface
- General Spacecraft Bus cleaning/inspection
- Spacecraft bagged during integration (crane)
- Backfill instrument bag with GN$_2$

INSTRUMENT FUNCTIONAL AND RADIOMETRIC SIMULATION TEST
- Class 10,000

EMC TEST
- Class 10,000
- Instrument bagged/ backfilled with GN$_2$

NASA CTV SETUP AND CHECKOUT

TOMS-POCC COMPATIBILITY TEST
- Class 10,000

S/A THERMAL VACUUM TEST/BAKE

S/A PANELS INSTALLATION

remove & replace witness plates

THERMAL BLANKET FABRICATION/ INSTALLATION
- Class 300,000
- T/V Bake
- Cleaned to V.C. before delivery to 10,000 area

DYNAMIC TEST PREPARATIONS
- Instrument bagged/ backfilled with GN$_2$
- Spacecraft bagged

VIBRATION TESTING
- Hi-Bay environment
- Instrument bagged/ backfilled with GN$_2$
- Soft cover over spacecraft with Class 10,000 air

Remove S/C Bag

PYRO SHOCK TEST
- Class 10,000
- Soft cover over spacecraft

replace witness plates

SOLAR ARRAY RELEASE TEST AND REMOVAL
- Class 10,000

INSTALL SOLAR ARRAYS ON STM
- Pre-clean STM

SOLAR ARRAYS ACOUSTIC TEST
- TRW level II
- Cleaned to visibly clean before returning to Class 10,000 area

FIRST MOTION TEST REMOVE SOLAR ARRAYS FROM STM

THERMAL VACUUM PREPARATIONS
- Preclean chamber
- Prebake chamber with witness plates, TQCM and RGA installed
- Verify cleanliness with wipes
- Visual inspection

General spacecraft cleaning/inspection (vacuum/wipe)

Inspect instrument bag; clean as necessary before removal

THERMAL VAC/ BALANCE TEST WITH CPT
- Use cold shrouds/ shields to protect instrument optics as necessary
- Keep chamber wall colder than spacecraft

remove & replace witness plates

- Rebag instrument/backfill bag with GN$_2$
- Install soft cover over spacecraft
- Inspect/clean spacecraft bus as necessary in clean area

OAS LEAK TEST
- Class 10,000

FLIGHT BATTERY INSTALLATION
- Class 10,000

SOLAR ARRAYS INSTALLATION AND FLASH TEST
- Class 10,000
- Inspect/clean S/As as necessary
- Solvent wipe support equipment

ALIGNMENT CHECKS
- Class 10,000
- Optic cube exposed

MASS PROPERTIES VERIFICATION
- Class 10,000
- Spacecraft bagged or crane bagged with contamination barrier

CLEANLINESS VERIFICATION OF S/C BUS
- General spacecraft cleaning
- Inspect to visibly clean
- NVR wipes
- Witness plates analyzed
- Bag TOMS-EP

PREPARATION FOR SHIPMENT
- Class 10,000
- Clean shipping container
- Verify purge cleanliness
- NVR wipes of shipping container
- Temperature/humidity control
- Hepa filter in shipping container for vent

replace witness plates

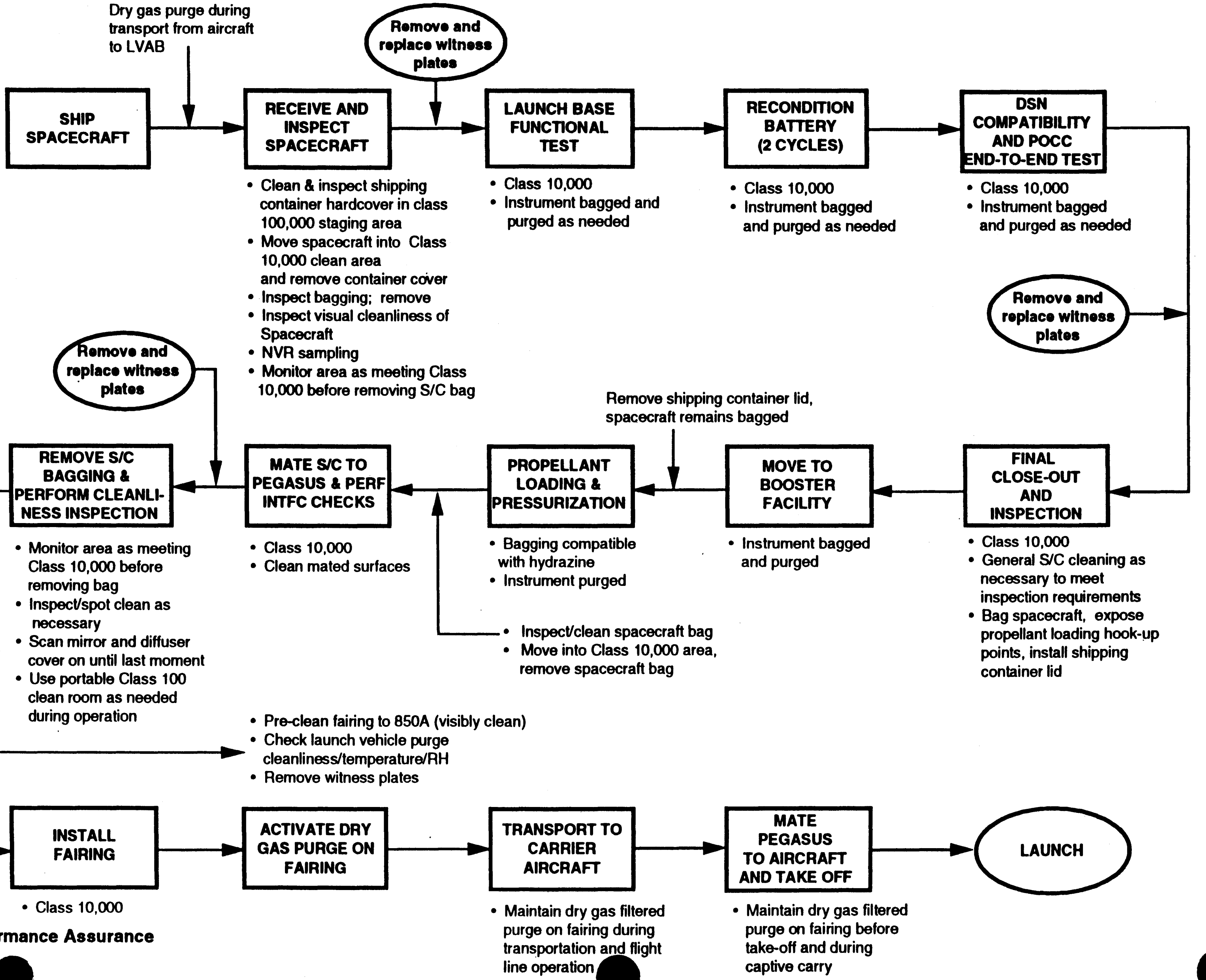
SHIPMENT TO WFF

Illumination Tests for Instrument TBD

Installation of Flight Diffuser on Instrument TBD

Installation of Blankets on Instrument TBD

Contamination Control Implementation – Launch Site Flow



SHIP SPACECRAFT

Dry gas purge during transport from aircraft to LVAB

RECEIVE AND INSPECT SPACECRAFT

- Clean & inspect shipping container hardcover in class 100,000 staging area
- Move spacecraft into Class 10,000 clean area and remove container cover
- Inspect bagging; remove
- Inspect visual cleanliness of Spacecraft
- NVR sampling
- Monitor area as meeting Class 10,000 before removing S/C bag

Remove and replace witness plates

LAUNCH BASE FUNCTIONAL TEST

- Class 10,000
- Instrument bagged and purged as needed

RECONDITION BATTERY (2 CYCLES)

- Class 10,000
- Instrument bagged and purged as needed

DSN COMPATIBILITY AND POCC END-TO-END TEST

- Class 10,000
- Instrument bagged and purged as needed

Remove and replace witness plates

FINAL CLOSE-OUT AND INSPECTION

- Class 10,000
- General S/C cleaning as necessary to meet inspection requirements
- Bag spacecraft, expose propellant loading hook-up points, install shipping container lid

MOVE TO BOOSTER FACILITY

- Instrument bagged and purged

Remove shipping container lid, spacecraft remains bagged

PROPELLANT LOADING & PRESSURIZATION

- Bagging compatible with hydrazine
- Instrument purged

- Inspect/clean spacecraft bag
- Move into Class 10,000 area, remove spacecraft bag

MATE S/C TO PEGASUS & PERF INTFC CHECKS

- Class 10,000
- Clean mated surfaces

Remove and replace witness plates

REMOVE S/C BAGGING & PERFORM CLEANLINESS INSPECTION

- Monitor area as meeting Class 10,000 before removing bag
- Inspect/spot clean as necessary
- Scan mirror and diffuser cover on until last moment
- Use portable Class 100 clean room as needed during operation

- Pre-clean fairing to 850A (visibly clean)
- Check launch vehicle purge cleanliness/temperature/RH
- Remove witness plates

INSTALL FAIRING

- Class 10,000

ACTIVATE DRY GAS PURGE ON FAIRING

TRANSPORT TO CARRIER AIRCRAFT

- Maintain dry gas filtered purge on fairing during transportation and flight line operation

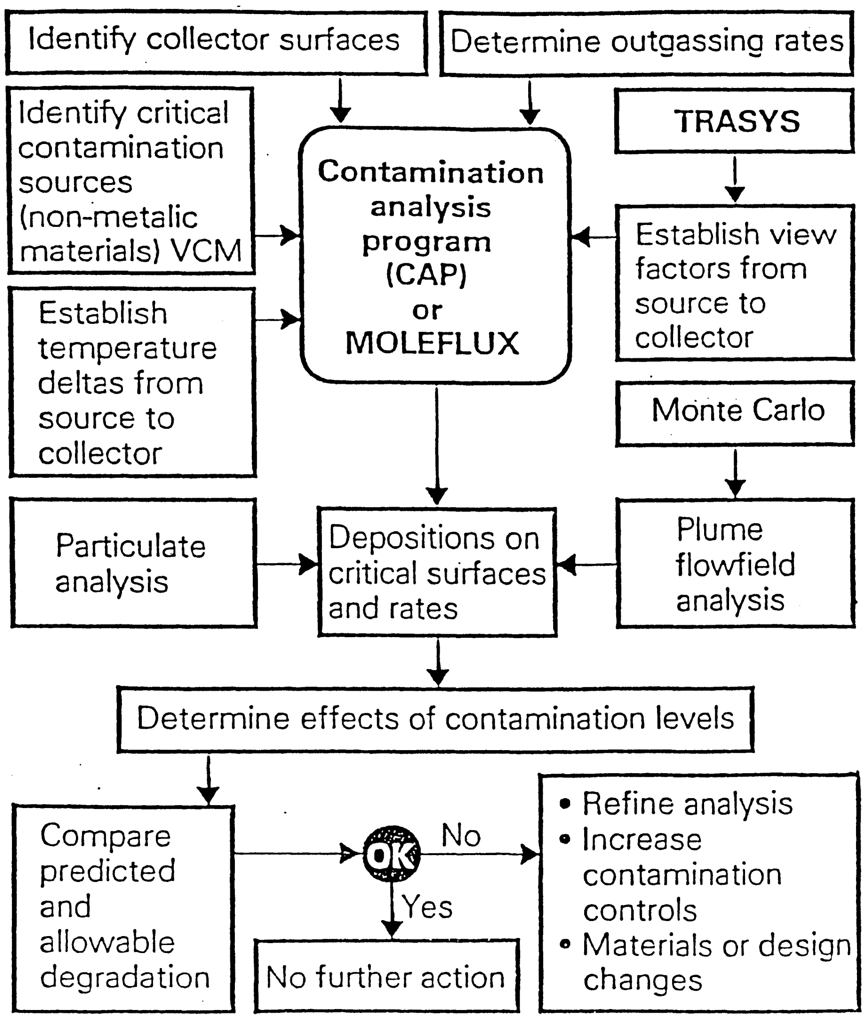
MATE PEGASUS TO AIRCRAFT AND TAKE OFF

- Maintain dry gas filtered purge on fairing before take-off and during captive carry

LAUNCH

Contamination Sources and Effects

Approach



Identify collector surfaces

Determine outgassing rates

Identify critical contamination sources (non-metalic materials) VCM

Contamination analysis program (CAP) or MOLEFLUX

TRASYS

Establish view factors from source to collector

Establish temperature deltas from source to collector

Monte Carlo

Particulate analysis

Depositions on critical surfaces and rates

Plume flowfield analysis

Determine effects of contamination levels

Compare predicted and allowable degradation

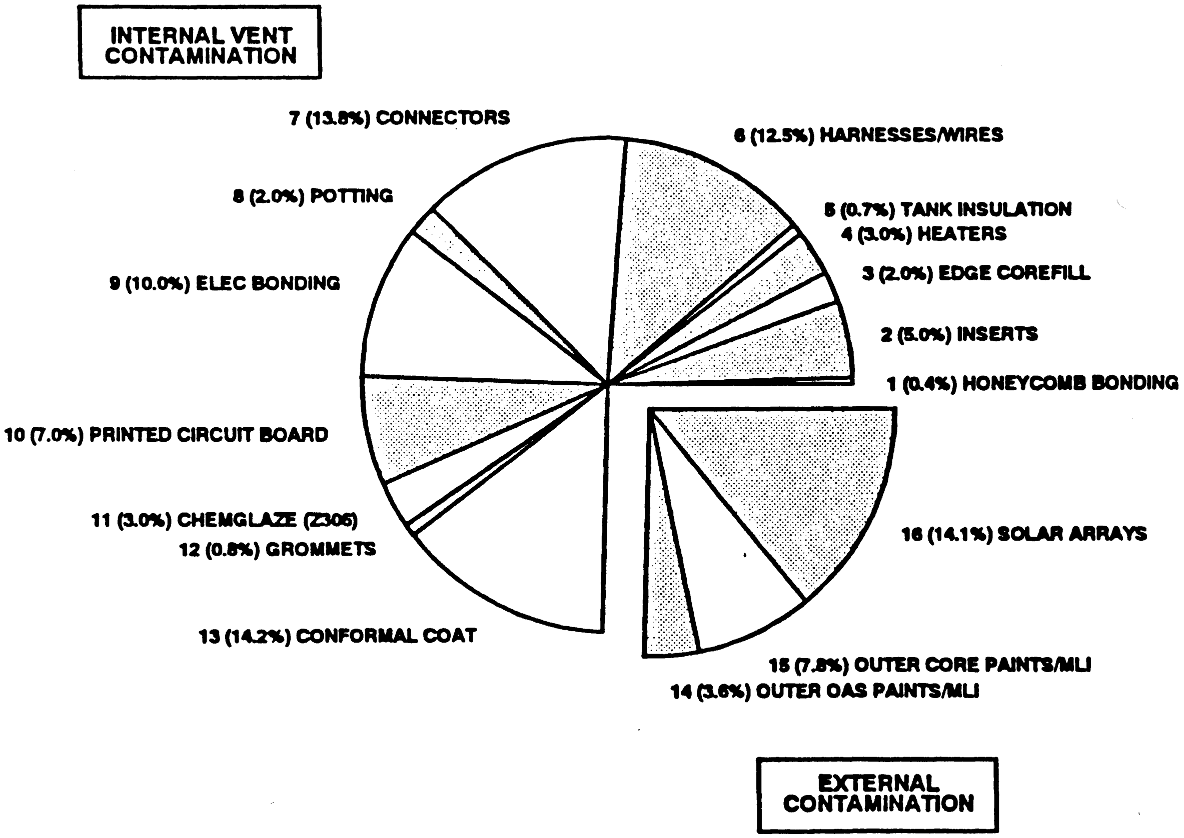
No further action

- Refine analysis
- Increase contamination controls
- Materials or design changes

- Identify contamination sources
- Identify sensitive potential "collector" surfaces
- Perform Molecular Diffusion Analysis
- Perform Particulate Distribution Analysis (launch, on-orbit)
- Perform Plume Flowfield Analysis
- Conservative Assumptions
  - Materials were not pre-conditioned for analysis (i.e., no bake-outs, no thermal vacuum test exposure)
  - Analysis results were not reduced to consider that some materials are overcoated with others

Contamination Sources – Molecular

- Ground operations – 100 Angstroms NVR (non-volatile residue)
- On orbit – Outgassing sources (Penzane lubricant not included here because the amount is insignificant compared to other sources)
- Thruster exhaust gases



Molecular Diffusion Analysis – Computer Model and Inputs

- Contamination Analysis Program (CAP)
  - Developed by J. M. Millard of JPL for GSFC
  - Analysis of mass transport in the free molecular flow environment

- Temperatures Sources and Collectors
  - Outgassing temperature for most sources 70°F
  - Solar arrays: model run twice, at 120°F (as a source) and 0°F (as a collector)
    - Included in the model: with solar arrays at 120°F, contamination outgassing from the spacecraft could "bounce" off the arrays onto the instrument or spacecraft body panels
  - OAS panels: modeled at 70°F as a source, 50°F as a collector
  - Core panels: modeled at 70°F as a source, 0°F as a collector
  - Scan wheel: 0°F (mirror), 20°F (lens) as collectors
  - Instrument radiator: modeled at 20°F as a collector
  - Instrument diffuser: modeled at 20°F as a collector

Molecular Diffusion Analysis (Continued)

- Volatile Condensible Material Source - Electronics

Location	Material	Weight (g)	% VCM	VCM (g)
Interior Surfaces of Platforms				
Electronic boxes	Conformal coat, Solithane 113/300			
	(Nadir/central)	2949.70	0.04(1)	1.18
	(OAS)	194.86	0.04(1)	0.27
	Wire insulation (Tefzel or Kapton)			
	(Nadir/central)	842.77	0.03(1)	0.25
	(OAS)	97.43	0.03(1)	0.06
	Magnetics, potting Hysol C15-015			
	(ES0092) (Nadir/central)	421.38	0.04(2)	0.17
	(OAS)	97.43	0.04(2)	0.04
	Bonding - EC2216 (Nadir/central)	1685.54	0.05(1,2)	0.84
	(OAS)	389.72	0.05(1,2)	0.19
	Printed circuit board (Nadir/central)	6236.50	0.01(1,2)	0.62
	(OAS)	1441.98	0.01(1,2)	0.14
	Connectors (Nadir/central)	589.94	0.10	0.58
	(OAS)	136.40	0.10	0.14
	Exterior Paint - Chemglaze			
	Z306 (Nadir/central)	193.00	0.10(1)	0.19
	(OAS)	58.81	0.10(1)	0.06
Electronics box grommets	Silicone gasket (Nadir/central)	99.9	0.07(1)	0.07
	(OAS)	19.49		0.01
Scan wheel, reaction wheel (gyros hermetically sealed)	Penzane X-2000 plus 5% lead napthenate	2 (est)	0.21(4)	0.004
	Total without bake-out (OAS)			**1.83**
	(Nadir/Center)			**5.75**
	Total with electronics and harness bake-out (OAS)			**1.15**
	(Nadir/Center)			**3.21**

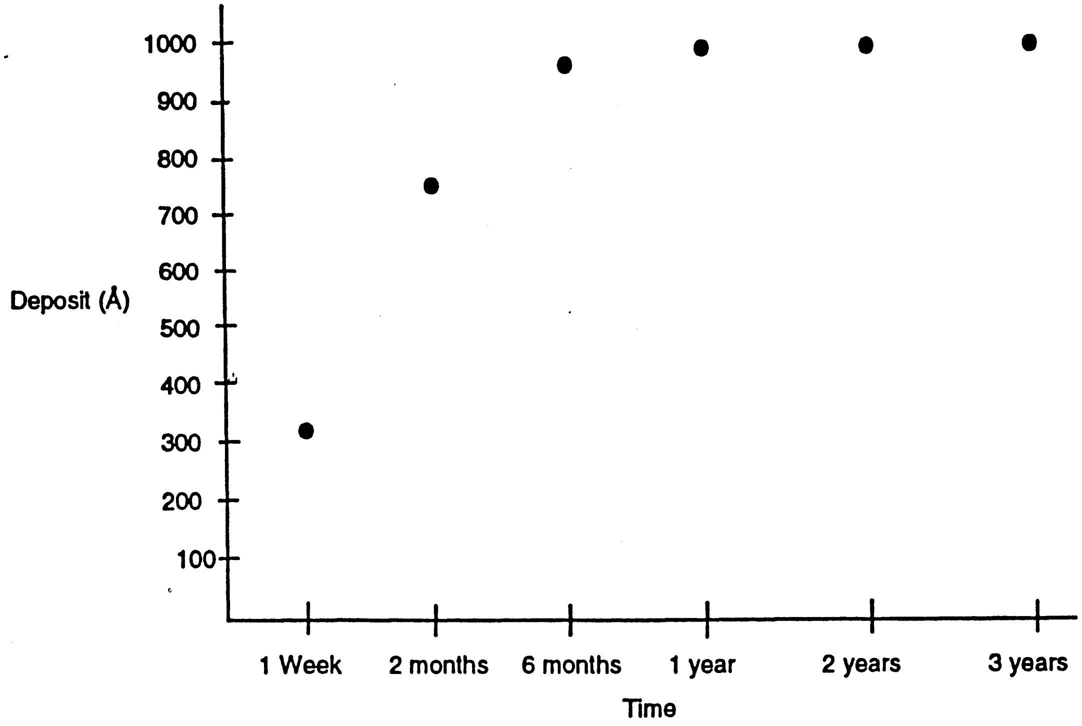
Notes: (1) NASA JSC 08962; (2) TRW tested per ASTM 595; (3) NASA 1124; and (4) GSFC tested.

Generic Electronic Boxes	
Material	**% by weight of box**
Aluminum	40
Printed Circuit Board	14.8
Components	23
Conformal Coating	7
Adhesive	4
Wiring	2
Connectors	2.8
Potting Material	1
Misc. Metallic Materials	5
Exterior Paint	0.4
Harnesses	
Material	**% by weight of harness**
Wire	48
Insulation	32
Connector Potting	8
Connector and Pins	12

- VCM data for electronics based on "generic box" configuration
- Box weight percentages assigned for each type of material generally found in an electronics box
- Assumption has been validated by latest available data from subcontractors supplying electronics
- All surfaces modeled as having 100Å initial surface contamination

Molecular Diffusion Analysis (Continued)

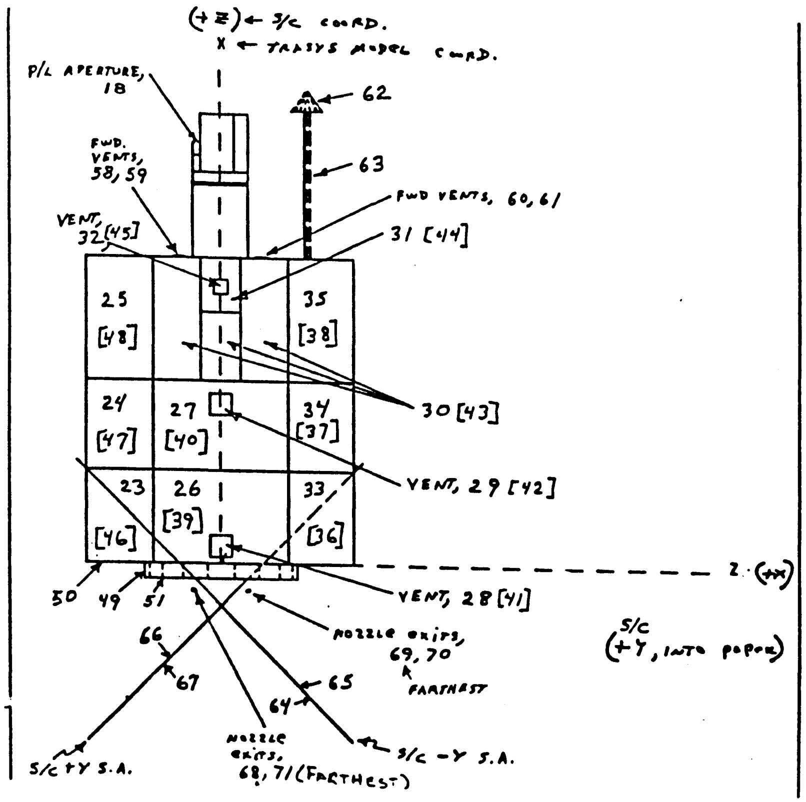
- View factors – calculated by thermal engineer using TRASYS II
- Outgassing rate constants - a multiplier CAP uses for remaining source outgassing VCM
  - Used outgassing data from two different sources:
    - "Characterization of Contamination Generation Characteristics of Satellite Materials", by P. Glassford
    - Used data from a paper on the"Wide Field Planetary Camera", by J. Barnegoltz and D. Taylor
  - Used outgassing data for the same materials or materials similar (i.e. same base polymer) to those used on spacecraft

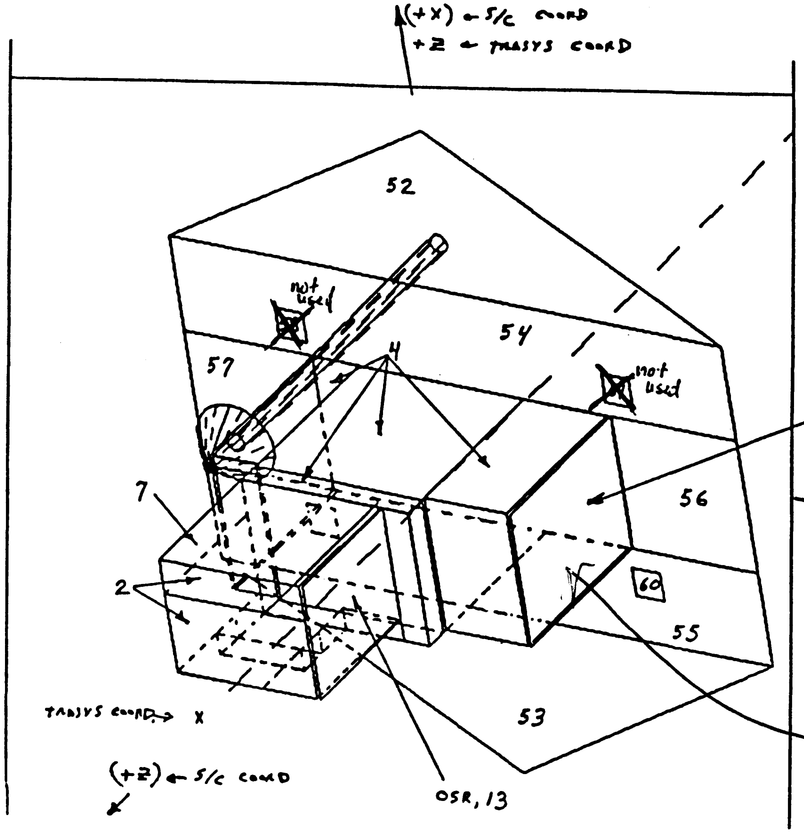


Instrument Radiator Molecular Build-Up (No. 11)

Molecular Diffusion Analysis (Continued)

- Vent Paths





900 Å from 3" hole for interface cables

- Central platform electronics vented out 5 openings:
  - 5% out nadir electrical feed-through (node 60)
  - 23.75% out each of the scan wheel holes (nodes 32,45)
  - 23.75% out each of the central platform electrical feed-throughs (nodes 29,42)
- OAS platform vented out 5 openings
  - 15% out each of the OAS electrical feed-throughs (nodes 28,41 and 29,42)
  - 40% out the 10-inch hole in the bottom of the OAS module

Molecular Diffusion Analysis (Continued)

Summary of Results

what is impact??

Surface	Deposition	Effect	Allowable Change Due to Contamination
Instrument Radiator (1 of 3)	976Å	$\Delta\alpha_S$ 0.10	TBD
Instrument MLI	331Å	$\Delta\alpha_S$ 0.033	TBD
Spacecraft Earth Sensor Mirror Lens	 2701Å 6146Å	Decrease in transmission by 10%	<20% (TBR)
Spacecraft Solar Arrays Molecular outgassing Plume contamination	 1112Å 100Å	1% transmission and power loss	Included in performance uncertainty design factor
+X+Y OAS body panels	109Å	$\Delta\alpha_S$ 0.01	$\Delta\alpha_S$ 0.04 (aluminum tape) $\Delta\alpha_S$ 0.05 (ZOT)
-Y,+Y OAS body panels	360Å	$\Delta\alpha_S$ 0.036	$\Delta\alpha_S$ 0.06 (leafing aluminum paint)
-X-Y OAS body panels	119Å	$\Delta\alpha_S$ 0.012	$\Delta\alpha_S$ 0.04 (aluminum tape) $\Delta\alpha_S$ 0.05 (ZOT)
-Y,+Y core body panels	339Å	$\Delta\alpha_S$ 0.034	$\Delta\alpha_S$ 0.04 (aluminum tape) $\Delta\alpha_S$ 0.05 (ZOT)
-X-Y and +X+Y core body panels	128Å	$\Delta\alpha_S$ 0.013	$\Delta\alpha_S$ 0.05 (ZOT)
Scan Wheel MLI	262Å	$\Delta\alpha_S$ 0.026	N/A

Note: For surfaces with less than 100Å deposition, numbers were not reported
Δ 0.01 α_s for every 100Å

A.I.

976Å is not correct - TRW to redirect vent hole - TRW to give new number to be for $\Delta\alpha_s$.

Particulate Distribution and Plume Flowfield Analysis

Particulate Distribution

- Performed to analyze transfer of particulates to instrument
- Initial surface cleanliness levels of 850, 750, and 500 for the fairing, spacecraft, and instrument respectively
- Results indicate that nadir platform surface of the spacecraft is level 900, the vertical surfaces of the spacecraft are level 750, and the instrument is level 550 following the venting process
- This analysis does not include particulate contamination caused during fairing release
- Atomic oxygen effect is insignificant at the TOMS-EP orbital altitude

Plume Flowfield Analysis

- Direct simulation Monte Carlo model used to compute plume flowfield during delta-V maneuvers
- Results indicate:
  - 10 Angstroms of aniline nitrate deposits onto the instrument and the front face (nadir) of spacecraft due to ambient scattering of plume molecules
  - Peak deposition of 2000Å, average of less than 100Å on one side and 50Å on the other due to direct impingement of plume on solar arrays

Source and Effects Analysis Conclusions/ Recommendations

- Spacecraft self-contamination will not be significant enough to have detrimental effects on spacecraft performance

100 Å @ launch for entire Insm

- Largest depositions identified over three years:
  - Instrument radiator = 976Å (because instrument is near nadir vent)
    - If the thermal vacuum test is considered in the analysis this is reduced to 650Å
  - Spacecraft scan wheel (earth sensor) = 8950Å (because assembly is at large vent for central platform electronics)

- Venting from interior spacecraft electronics is largest source of contamination

- Recommendations
  - Hermetically sealed "plug" in 3-inch hole venting toward instrument or use MLI to redirect any outgassing that leaks past "plug" (reducing the contamination on the instrument radiator to almost nothing)
  - MLI should be used to selectively vent outgassing through scan wheel hole away from scan wheel optics
  - Bake-out all electronics

TOMS-EP Contamination Control

Open Issues	**Approach to Resolution**
1) Pegasus fairing release contamination (particulates)	Fairing separation test conducted in June failed. Meet with GSFC for any useful contamination data. Fairing being re-designed to solve contamination and separation problems.
2) Pegasus fairing outgassing contamination created during aerodynamic warming	Collect material and temperature data for fairing during ascent for quick analysis - pending resolution of item 1.
3) Contamination contributed by frangibolt	Conduct testing in vacuum at simulated temperatures and configuration. Prebake silicone material or replace with low outgassing alternative.
4) Pegasus fairing cleanliness and nitrogen purge and captive carry purge	Work with GSFC and OSC at Contamination Working Group meetings for resolution.

Materials and Processes

Materials and Processes Overview

- TOMS-EP M&P issues are being worked during weekly PMPCBs and GSFC/TRW telecons

- TOMS-EP Materials and Processes (M&P) program being implemented in accordance with PAIP
  - Inorganic materials compliant with MSFC-SPEC-522B, Table I
  - Organic materials compliant with SP-R-0022A vacuum outgassing requirement. Total mass loss (TML) ≤ 1.0% and maximum collected volatile condensible material (CVCM) ≤ 0.1%. Noncompliant materials addressed by Material Usage Agreements (MUAs) and considered in Contamination Analysis

- All TOMS-EP Materials and Processes, TRW and subcontractors, are documented in Project Approved Materials and Processes List (PAMPL)
  - Updated PAMPL (Revision A) is released

- A total of 48 MUAs have been prepared and submitted for GSFC approval
  - Majority submitted because material does not meet outgassing requirement
  - MUAs not submitted for flammability per GSFC Flight Assurance Manager direction

Materials and Processes Overview (Continued)

- Subcontractors are being reviewed for M&P compliance
  - Acceptability of design via drawings and documentation review
  - Materials compliance to TRW subcontractor PARs
  - Fabrication processes to NHB 5300.4 guidelines. Soldering to MIL-STD-2000A/NHB 5300.4(3A-1)/PR3-46
  - Processes certifications
  - SDRL approval, e.g. manufacturing (fabrication and inspection) plan, Materials and Processes List (MUAs)
  - Onsite audits of processes and flight hardware
  - Printed wire board (PWB) coupons inspection to MIL-P-55110 (GSFC)

- Copies of TRW's and subcontractors' processes documents have been forwarded to GSFC per request
  - Fabrication process procedures/specifications
  - Soldering training manuals
  - Soldering certifications

Materials and Processes Overview (Continued)

- Subtier vendors reviewed and certified to TRW processes as appropriate, e.g. Ricmar Engineering to be certified by TRW for insert and bushing installation qualification of panels and platforms

- TRW drawings reviewed to date for compliance to PAMPL
  - 72 structure drawings, 62 reviewed, 40 approved
  - 39 propulsion drawings, 30 reviewed, 24 approved
  - 12 sun sensor drawings reviewed
  - 5 valve drive electronics drawings reviewed

- Wheel Bearing Lubricant: Pennzane SHF-2000 (formerly X2000) plus 5% Lead Napthenate
  - Very low vapor pressure at room temperature (4 x 10^{-12} Torr)
  - Outgassing tested by NASA/GSFC: TML = 2.51%, VCM = 0.21%
  - Outgassing included in Contamination Sources and Effects Analysis
  - MUA submitted

Materials and Processes Requirements Versus Capabilities

Source: D19086, TOMS-EP PAIP

Paragraph/Requirement	**Capability**	**Verification**
6.2.1, Compliant Materials Conventional Application, meet selection criteria	Meet SP-R-0022A criteria, listed in TOMS-EP PAMPL D19079. All noncompliant materials will be addressed by MUA	Analysis, Drawing Review
6.2.5.1, Flammability and Toxic Offgassing NHB 8060.1. WSMCR 127-1, paragraph 3.10.2	Materials properties identified in TOMS-EP PAMPL D19079	Analysis, Test
6.2.5.2, Vacuum Outgassing SP-R-0022A TML ≤ 1.0%, VCM ≤ 0.1%	Selected materials listed in TOMS-EP PAMPL D19079. Noncompliant materials will be addressed by MUA	Analysis, Test
6.2.5.3, Shelf Life Control of Material	TRW shelf life control document D01443	Inspection, Test
6.2.6, Inorganic Materials MSFC-SPEC-522B, Table 1	Metals selected per 522B, Table 1	Drawing Review

Materials and Processes Requirements Versus Capabilities

Source: D19086, TOMS-EP PAIP

Paragraph/Requirement	**Capability**	**Verification**
6.2.6.1, Fasteners GSFC S-313-100	TRW standard quality assurance requirements for procured items, D04740	Inspection, Test
6.3, Processes Selection. Qualified Processes, Material Integrity	Processes selected from TOMS-EP PAMPL, D19079	Analysis, Drawing Review, Specifications Review
6.3.1, Welding and Brazing Approved Procedures, Qualified Operators	Processes selected from TOMS-EP PAMPL, D19079	Drawing Review, Inspection, Specifications Review

Material Usage Agreements Status

	MUAs (1)	Date		Submittal Status	
Source	**Submitted**	**Submitted**	**Open**	**Rejected**	**Approved**
Ithaco	9	4-17-92	9	0	0
Loral	15	6-12-92	14	0	1
Sage	0				
Gulton	4	6-23-92	4	0	0
Kearfott	17	4-30-92 (6) 6-11-92 (8) 6-23-92 (3)	17	0	0
Pyronetics	1	5-15-92	1	0	0
Statham	1	5-15-92	0	0	0
TRW	1	4-14-92	0	0	1

(1) MUAs submitted to GSFC as CDRL PA-11.

Overview Comparison of NHB 5300.4(3A-1), MIL-STD-2000 and MIL-STD-2000A

TRW

Requirement	**NHB 5300.4**	**MIL-STD-2000**	**MIL-STD-2000A**
Lead/wire Deformation	None	Open	10% maximum
Insulation Deformation	None	None	20% maximum
Broken Strands Permissible	No	Yes (Up to 6)	No
Nicks, Cuts, Scrapes	No	Yes	Yes (<10%)
Parts Mounting	Parallel and in contact	Approx. parallel <0.015 inches spacing	Approx parallel <0.025 inches spacing
Surface Mount	3-5.5 (W or D)/Foot	1W or 2D/Foot	1W or 2D/Foot
Overhang	None permitted	25% side (flat) Toe (25% W or D)	25% side (flat) Toe (within El limits)
Heel Fillet	No mention	Required	Required
Stress Relief	Soft requirement	1D to 0.030"	1D minimum
Solder in Stress Relief	Not permitted	Allowed within limits	Allowed within limits

W = width, D = Diameter

Overview Comparison of NHB 5300.4(3A-1), MIL-STD-2000 and MIL-STD-2000A (Continued)

Requirement	NHB 5300.4	MIL-STD-2000	MIL-STD-2000A
Lead End Base Metal Exposure	Not permitted	Not permitted	Permitted
Chip Devices	Not addressed	Covered	Covered
Visual Appearance	Perfect	5% cosmetic defects	10% cosmetic defects
Turret Terminal	180° to 270° 28 awg 180° to 360°	180° to 270°	180° - no overlap for all except rectangular
Hook Terminal	180° to 270°	180° to 270°	
Pierced Terminal	90° to 270°	180° to 270°	
2-Sided Boards	Wire in all holes	No requirement	No requirement
Plated through Holes	Filled with solder	25% solder Rec.	25% solder Rec.
Hand Soldered Boards' Vias	Filled with solder	No solder required	No solder required
Solder Contamination	Gold and Copper only	All elements permits dumping	All elements permits dumping

All other differences are minor

EEE Parts Program

TOMS-EP EEE Parts Program

- EEE Parts
- Project Material Surveillance Plan
- Field Programmable Gate Array (FPGA) Qualification

EEE Parts Overview

- TOMS-EP EEE parts program implementation
  - GSFC, TRW, and subcontractors team effort
  - In accordance with modified Section 5 of GSFC PAR, GSFC-450-006, (GPAR)
  - Fly quality parts
  - Special attention to GIDEP alerts

- NSPAR and parts procurement issues have been and are being worked during weekly GSFC/TRW telecons, on-going telephone conversations with GSFC parts branch personnel, and TRW-PMPCBs.

- Implementation of modified Section 5 of GPAR reduced total NSPARs from 252 to 157. Modified Section 5 also required nonstandard parts QCI data be submitted to GSFC

- Subcontractors are being reviewed for compliance
  - EEE Parts Control Plan
  - Parts Identification List including NSPARs
  - DPA Procedures
  - TRW Parts Audits

- TOMS-EP PAPL includes all subcontractors and TRW EEE Parts Lists. Updated PAPL released 17 July 1992

EEE Parts
Summary of Requirements Versus Compliance

PAR Requirement	**Compliance**
Original PAR classified a Grade 2, or better, part per PPL-19 as standard. All other parts classified as nonstandard including hybrids. QCI data with NSPAR not specified.	Identified 252 parts as nonstandard, requiring a NSPAR for GSFC approval.
Modified PAR expanded the definition of a standard part to be selected in order of preference: 1. Grade 2 or better per PPL-19 2. All JAN microcircuits, JANTX/TXV semiconductors, and ER passive parts. 3. Microcircuit procedures on a DESC certified QPL line with deliverable lot related QCI data. 4. Same as 3 except acceptable generic QCI data	Identified 95 parts (39%) that were reclassified as standard.
All other parts classified as nonstandard requiring NSPAR and established reliability (ER)	Remaining 157 parts require a NSPAR for GSFC approval
QCI data to be delivered to GSFC with the NSPAR.	QCI data is being supplied with the NSPAR

EEE Parts
Summary of Requirements Versus Compliance (Continued)

PAR Requirement	Compliance
Derating per 5.2.3 using PPL-19	Derating per PPL-19/MIL-STD-975 and/or D02700.
Radiation hardness per 5.2.4 includes	Component internal dose rate 14 krads (Si) for 60 mil aluminum wall with 100 mil base plate for 2-year duration
Screening verification per 5.2.5 for all JANTX/TXV semiconductors	All JANTX/TXV semiconductors will be rescreened. Some Loral parts from stock will require a waiver.
DPA per GSFC S-311-M-70 on a sample of each Lot Date Code for microcircuits, hybrids, semiconductors, nonstandard relays and crystal oscillators	DPA is performed per TRW DPA procedure M273876R
Parts Identification List (PIL) per 5.3	TRW PAPL D19078 includes all requirements specified. All subcontractor parts lists are being incorporated. PAPL will include a sort by subcontractor

NSPAR Status

NSPAR Status

7/27/92

SUBCONTRACTOR/TRW STATUS	LORAL	ITHACO	KEARFOTT	GULTON	TRW	TOTAL
TOTAL NSPARS SUBMITTED BY SUB	58	49	80	37	28	252
- WITHDRAWN	2	4	5	14	0	25
- SUPPLIED BY GSFC OR TRW	0	1	0	0	0	1
TOTAL NSPAR PRIOR TO MODIFIED PAR	56	44	75	23	28	226
- STANDARD PARTS PER MODIFIED PAR	3	23	27	16	0	69
TOTAL MODIFIED PAR NSPARS	53	21	48	7	28	157
APPROVED BY TRW	36	13	16	6	13	84
APPROVAL PENDING RECEIPT OF QCI DATA	0	2	11	0	0	13
INPROCESS AT TRW	7	2	6	1	15	31
RETURNED TO SUB FOR REVISION	10	4	15	0	0	29

GSFC / TRW STATUS	LORAL	ITHACO	KEARFOTT	GULTON	TRW	TOTAL
MODIFIED PAR NSPARS SUBMITTED TO GSFC *	52	15	49	7	20	143
APPROVED BY GSFC*	21	0	10	0	7	38
REJECTED BY GSFC	18	0	28	0	13	59
WAIVERS SUBMITTED	0	0	0	0	0	0
WAIVERS APPROVED	0	0	0	0	0	0
INPROCESS AT GSFC	13	15	11	7	0	46

* Excluding Standard Parts Per the Modifed PAR.

EEE Parts
GSFC Rejected NSPARs Under Review

Basis of Rejection	Loral	Ithaco	Kearfott	Gulton	TRW	Total
Inadequate information (e.g., specification modification, etc.)	5	0	19	0	7	31
Inadequate or no QCI data available	11	0	0	0	6	17
Not space qualified part (e.g., failed PDA, nonhermetic package, etc.)	2	0	9	0	0	11
Total	18	0	28	0	13	59

EEE Parts
TRW Closeout Plan for Rejected NSPARs

- Evaluate basis for each rejection
  - Supply additional information requested, e.g. updated specification, missing document, etc.
  - Where applicable, confirm that missing QCI data will be supplied and the expected due date
  - Where data is not available, assess alternatives
    - (1) Determine that the quality of the part is acceptable without data; request waiver
    - (2) Conduct tests to acquire data
    - (3) Change out part

  - Where data shows lot test data exceeds specified rates
    - (1) Assess degree to which specified rates are exceeded. If acceptable, request waiver.
    - (2) Change out part

- Request waivers

Project Material Surveillance Plan

Objective

To ensure all piece parts required by each vendor and by TRW support manufacturing schedules in a timely manner with approved parts using TRW and GSFC parts resources

Plan

- Review each vendors bill of material and procurement plan
- Follow-up with weekly telecons to review material delivery status
- Publish schedule critical parts reports monthly
- Furnish TRW inventory material when available and applicable
- Review procurement status of schedule critical EEE parts with GSFC during weekly telecons
- Solicit GSFC assistance in procuring schedule critical EEE parts as needed
- Visit or interface with subtier vendors to assist/expedite delivery
- Coordinate consolidated procurements for units being built at TRW

Parts Being Supplied by GSFC

VDE Unit (TRW)

Part Number	Quantity	Expected Delivery (1)	Part Number	Quantity	Expected Delivery
54HCS00	15	9-15-92	54HCS02	5	9-15-92
54HCS32	8	9-15-92	54HCS04	7	9-15-92
54HCS74	15	9-15-92	54HCS08	7	9-15-92
54HCS244	12	9-15-92	54HCS138	7	9-15-92
HS181C55RH8	9	9-15-92	54HCS14	5	9-15-92
HS180C85RH	5	9-15-92	54HCS161	15	9-15-92
HM6617883	5	9-15-92	54HCS374	5	9-15-92

Gulton

Part Number	Quantity	Expected Delivery
HS1-80C86RH-Q	12	8-15-92
HS1-1840RH-8	54	8-15-92
HS1-82C545RH-Q	12	8-15-92
HS1-82C37ARH-Q	12	8-15-92

Ithaco

Part Number	Quantity	Expected Delivery
1R7130 IRC	24	7-20-92

Notes: All parts completely tested/screened and DPA by GSFC
(1) Date change from 8-15-92 to 9-15-92

Field Programmable Gate Array Program

Implementation and Basis of Implementation TOMS-EP Field Programmable Gate Array (FPGA) Program

- TOMS-EP subcontractors use Actel FPGAs to:
  - Reduce design and qualification costs
  - Reduce board space and weight

- TRW Evaluation of Actel FPGA
  - Complete evaluation conducted for TRW Universal Test Bed (UTB) Project
    - 3,700 hour accelerated life test
    - DPAs including cross section and current density calculations
    - Radiation testing
  - Collected data from JPL, Hughes, John Hopkins, and Aerospace Corp. on all versions of FPGAs from Actel
  - Part of a industry team (JPL, Hughes, Aerospace, and TRW) to evaluate Actel 1280 FPGA

NASA/GSFC Evaluation of FPGA for TOMS-EP

- GSFC parts branch personnel visited TRW for
  - Technical discussion of Actel's FPGA and "Antifuse" technology
  - Evaluation of TRW's FPGA design, programming, evaluation equipment and test data
  - Review of TRW's life test capabilities

- GSFC parts branch and TRW visited Actel for
  - Technical discussions of wafer processing, assembly and test
  - Discussions regarding programming reliability and Class B and S testing of unprogrammed FPGAs

- GSFC and TRW have agreed that
  - Actel's "antifuse" technology is a permanent, nonreversible mechanism for creating logic patterns in the FPGA
  - Post programming burn-in is not required. Dynamic burn-in of unprogrammed FPGAs stresses all logic cells and is more through than post programming burn-in
  - Samples programmed at the same time as the flight units with Alpha 91 test circuit will qualify the FPGA lot and the programming station
  - The technology is relatively new and requires continuous monitoring until substantial data is collected

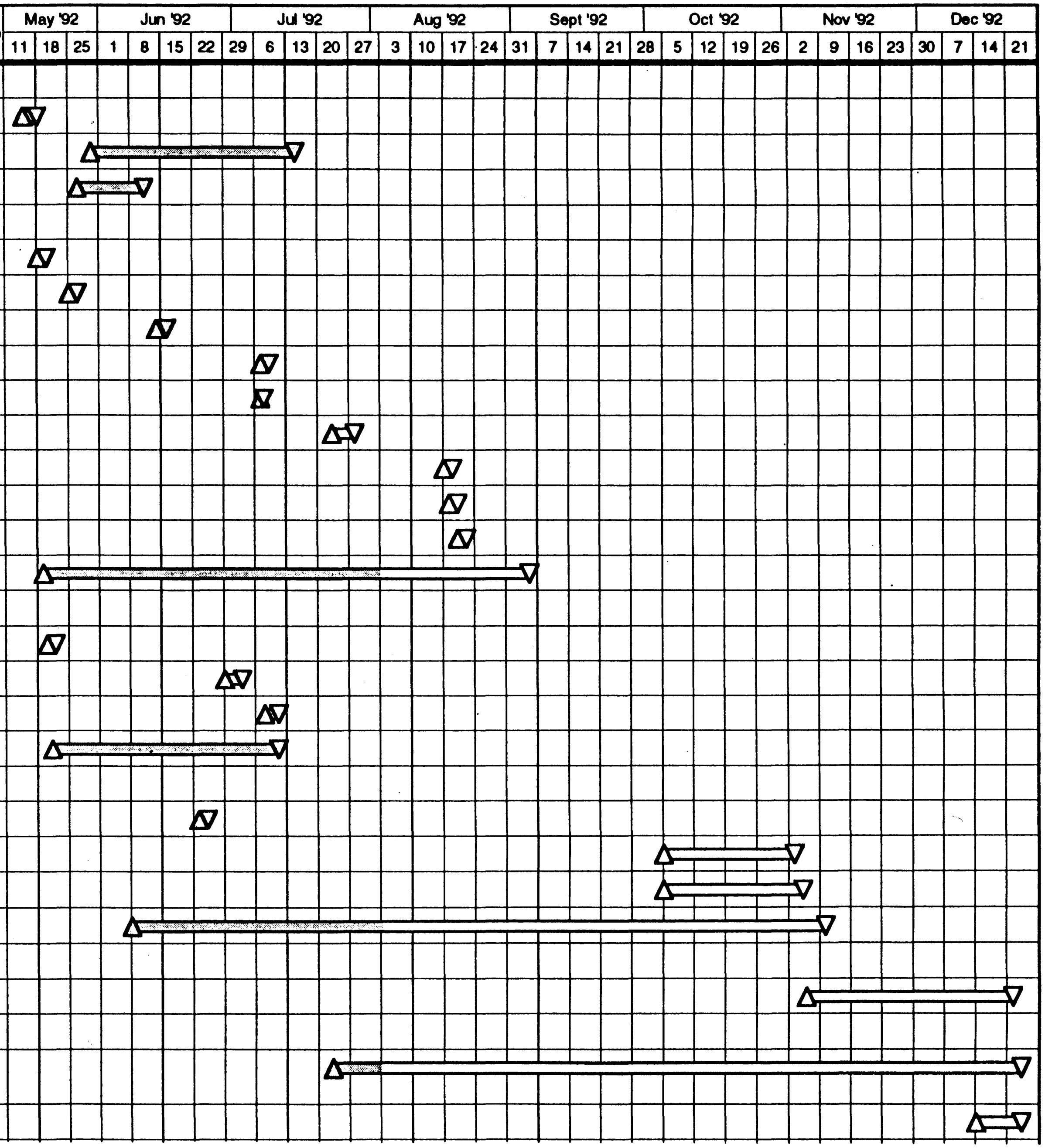
- GSFC has approved TRW/Gulton FPGA NSPARs

TOMS-EP Approach for Purchase and Qualification of FPGAs

- Purchase one lot for use by all subcontractors
  - Lower qualification costs
  - Lower purchase price
- TRW to perform Destructive Physical Analysis (DPA)
- TRW to perform Life Test (1000 hours dynamic burn-in at 125°C)
  - Stage 1: TRW program 22 units followed by burn-in
  - Stage 2: Subcontractors program 22 units before and after flight units followed by burn-in by TRW
- TRW to audit subcontractor's FPGA capabilities and controls (complete)
- Calibrate programming system for flight units programming
- TRW to compile, analyze, and publish lot qualification report
- TRW/Gulton to submit NSPARs for FPGA

FPGA Qualification Schedule for TOMS-EP Project

Task Description	Start Date	Finish Date
Life Test (TRW)		
Program Life Test Units	5/15/92	5/16/92
Perform Life Test	5/30/92	7/14/92
FPGS DPA (Lot Qualification)	5/27/92	6/10/92
Ithaco		
Survey FPGA Station and Procedures	5/18/92	5/19/92
Convert Pinout – PGA to flat pack	5/25/92	5/26/92
Program FPGAs for ETB (first half)	6/14/92	6/15/92
Incorporate New Designs (3 each)	7/7/92	7/8/92
Program Balance of ETB FPGAs	7/7/92	7/7/92
Ship PWBs with FPGAs to Ithaco (ETB)	7/23/92	7/27/92
Program TOMS FPGAs	8/17/92	8/18/92
Test "Ithaco" Life Test Units	8/18/92	8/19/92
Ship PWBs with FPGAs to Ithaco	8/20/92	8/21/92
Coordinate and Resolve FPGA Issues	5/19/92	9/4/92
Kearfott		
Survey FPGA Station and Procedures	5/20/92	5/21/92
Program FPGA (Kearfott)	6/29/92	7/2/92
Test Kearfott Life Test Units	7/8/92	7/10/92
Monitor FPGA Programming and Testing	5/21/92	7/10/92
Gulton		
Survey FPGA Station and Procedures	6/23/92	6/24/92
Program FPGA (27 designs)	10/5/92	11/2/92
Test Gulton Life Test Units	10/5/92	11/4/92
Monitor FPGA Programming and Testing	6/8/92	11/9/92
Life Test (subcontractor)		
Perform Accelerated Life Test	11/6/92	12/21/92
Correlate & Analyze TRW & Subcontractor Life Test Results	7/23/92	12/23/92
Publish FPGA Qualification Report	12/14/92	12/23/92



Quality Assurance

Quality Assurance Implementation

- Hardware quality assurance (QA) requirements and implementation plans contained in PAIP

- TRW QA program being implemented in accordance with TRW company manuals, and TOMS-EP project plans

Manuals

- Hardware Quality Assurance Manual
- Software Quality Assurance Manual
- Quality Directives
- Measurement Assurance Manual
- Configuration Management Manual

TOMS-EP Plans

- ESD Control Plan
- Contamination Control Plan
- Configuration Management Plan
- Manufacturing (Fabrication and Inspection) Plan
- Software Management Plan

- TRW's QA system complies with NHB 5300.4(1B)

- Project specific requirements are flowed down via quality project requirements (QPR) documents to performing organizations within TRW, e.g. procurement document review, receiving inspection requirements,mandatory government inspection points, etc.

- Subcontractor QA requirements are contained in TRW subcontractor PARs and TRW quality (Q) clauses
  - NHB 5300.4(1B) QA program required of subcontractors supplying components containing EEE parts, PAR 700-394
  - NHB 5300.4(1C) QA program required of subcontractors supplying mechanical devices and assemblies, PAR 700-398

Quality Assurance Implementation (Continued)

- Quality assurance provisions are specified in subsystem and equipment (EQ) specifications
- Established interface with resident NASA representative
- TRW source QA for must subcontractors is being implemented through audits versus TRW resident QA. If audits indicate the need, TRW source inspection is implemented as required.
- Dedicated TRW source QA surveillance is being implemented at Luna Defense Systems Inc.

Quality Assurance Requirements Versus Compliance/Implementation

Requirement	Compliance	Implementation
GPAR GSFC-450-006:		
8.1 General	HQAM 0.0	PAIP 1.0
8.2 Organization	HQAM 1.1	PAIP 1.1.3
8.3 Configuration Control and Verification	CMM 1.0, 4.4	Configuration Management Plan, D19084
8.4 Identification and Traceability	CMM 1.0	Configuration Management Plan, D19084
8.5 Procurement Requirements	HQAM 3.0	PAR 700-394, PAR 700-398
8.5.1 Contractor Source Inspection	HQAM 3.0	PAIP 8.5.1
8.5.2 Procurement Review by the Government	HQAM 3.0	PAIP 8.5.2, PAR 700-394 (para 8.5.2), PAR 700-398, (para 8.5.2)
8.6 Contractor Receiving Inspection	QD.P783,0012 AD2-016	Receiving Inspection QPR, QPR 11540
8.8 Contamination Control	HQAM 5.5	Contamination Control Plan, D19082
8.9 Electrostatic Discharge Control	HQAM 5.4	Electrostatic Discharge Control Plan, D19094

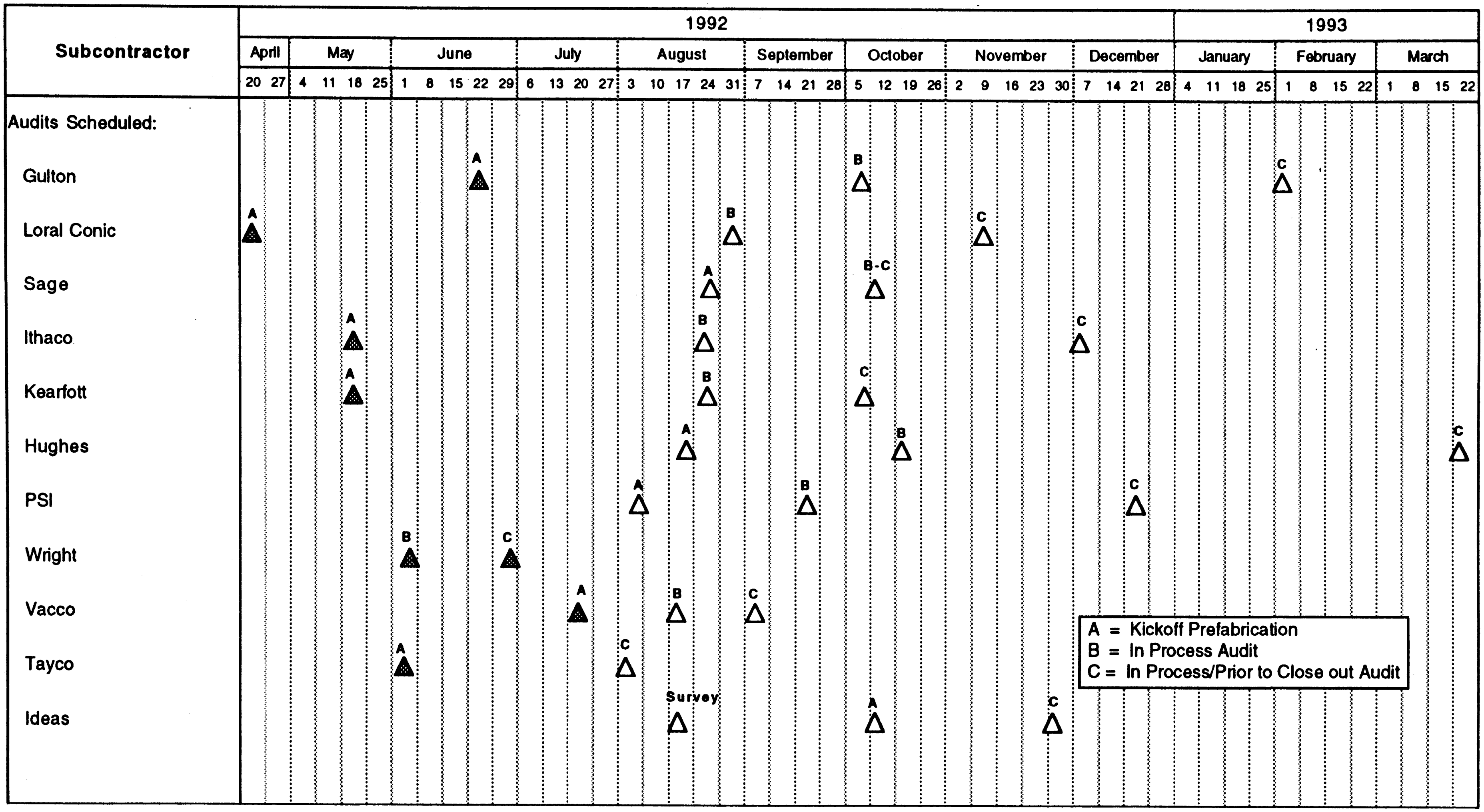
Quality Assurance Requirements Versus Compliance/Implementation (Continued)

Requirement	Compliance	Implementation
GPAR GSFC-450-006:		
8.10 Nonconformance Control	HQAM 9.5	QD.P783.0002
8.10.1 Control, Disposition and Reporting of Discrepancies	HQAM 9.5	QD.P783.0001
8.10.2 Failure Reporting	HQAM 4.8	PAIP, 8.10.2
8.12 Inspection and Tests	HQAM 4.0	QD.P783.0001
8.12.2 Inspection and Test Reports	HQAM 7.1	PAIP 8.12.5
8.12.4 Inspection and Test of Stored Stock Hardware	Property Manual 6.01	PAIP 8.17
8.12.5 QA Activities during the Integration and Test Phase	HQAM 4.0	PAIP 8.12.4
8.12.6 Records of Inspection and Test	HQAM 7.1	PAIP 8.12.5
8.15 Stamp Control	HQAM 8.1	PAIP 8.15
8.16 Handling, Stage, Preservation Marking, Labeling, Packaging, Packing and Shipping	HQAM 12.1	Transportation and Handling Plan, D19088
8.17 Government Property Control	Property Manual	Control of Government Furnished Property Plan, D19090
8.18. Government Acceptance	HQAM 4.9	PAIP 8.18

Quality Assurance Status

- Several QPRs have been generated to flowdown quality requirements within TRW
- MRB authorization issued to six subcontractors
- Subcontractor manufacturing flow plans reviewed. Mandatory inspection points established
- TRW MRB list generated
- Surveys of subcontractors conducted to verify compliance to NHB standards. Subcontractors placed in TRW Quality Assurance Suppliers Directory (QASD) upon satisfactory close out of survey
- A number of subcontractor audits have been conducted and closed to date

Subcontractor Audit Schedule for TOMS-EP Project



TRW Subcontractor Audit Approach

- Three basic audits are planned at most subcontractor's facilities
  - PA requirements flow down (kickoff prefabrication)
  - In process fabrication
  - In process test prior to closeout
- All audits performed to prepared checklists designed to assure subcontractor compliance to PAR document requirements
  - Checklist multidisciplined. Includes QA disciplines, PM&P control, software control, etc.
  - Checklists forwarded to subcontractor at least a week in advance of audit
- Audit team consists of specialists, including quality engineer, parts engineer, M&P engineer, FPGA parts engineer, responsible design engineer, etc.
- Audits are successful in identifying systemic issues
- Currently 30 audits are scheduled at 11 subcontractors, 7 audits completed to date of which 5 closed
- Similarly, software audits are being implemented at Colorado Springs. Two audits completed to date.

Quality Assurance Involvement in Subcontractor Activities (RFP to Delivery)

- **Award Process**
  - Quality assurance requirements generated for subcontractor PAR documents
  - TRW "Q" clauses identified for each subcontract
  - Statements of work reviewed
  - Proposals evaluated during source selection process
  - QA surveys conducted as required to NHB 5300.4(1B) or (1C)
  - Purchase orders reviewed and stamped by quality engineer
- **Manufacturing Process**
  - Subcontractor deliverables reviewed and approved
  - Subcontractor fabrication and inspection flow reviewed and approved for TRW and GSFC mandatory inspection points
  - Issue Type II material review board authorization upon GSFC approval
  - Process Supplier Information Requests (STR) for discrepancies
  - Lead the conduct of TRW audits at subcontractor facilities and source inspection
- **Test and Delivery**
  - Lead the conduct of TRW audits at subcontractor facilities and source inspection
  - Participate in failure reporting
  - Perform final source inspection
  - Review end item data package for acceptance

TRW Quality Engineering at Luna Defense Systems Inc.

- Dedicated TRW source QA surveillance is being implemented at Luna Defense Systems Inc.
  - TRW and LDSI team effort

- Structural Test Model (STM) is the pathfinder for TOMS-EP
  - Developing and validating manufacturing and assembly process with STM
  - Full configuration control being implemented
  - Full TRW inspection of piece parts and assembly being implemented
  - Full documentation, e.g. STM material configurations, process certifications, and traceability

- STM will be to flight quality standards

- TOMS-EP flight structure will have
  - Configuration control to TRW standards
  - Total TRW source inspection of piece parts and assembly
  - Full documentation, e.g. material certifications, process certifications and traceability

Software Quality Assurance
and
Configuration Management

Configuration Management

- Internal design requirements baseline established following PDR: ICDs, system specification, MDI/EDI specifications, and system description document placed under formal CCB control
- 18 CCBs conducted during this phase
- Configuration management requirements flowed to subcontractors via PAR documents; all subcontractor CM plans reviewed and approved
- Allocated baseline will be established following CDR; changes to all specifications and ICDs will be processed through the CCB
- Specification Tree (CDRL SE-05) updated
- Configured Articles Lists (CDRL PA-22) updated

Software Quality Assurance and Configuration Management Requirements Versus Compliance

Requirements	Compliance	Implementation
GPAR		
10.3.1 Software Standards for QA	PAIP 10.3, TRW Software QA Manual (SQAM)	
10.3.2 Assurance Function for for Verifying Standards	SQAM 3.0 SQAM 5.0	Conduct reviews and audits Perform test surveillance
10.4 Establish a Software Configuration Management Process	TRW Configuration Management Manual (CMM) 100.2, 102.2, 102.5, 102.6, 103.2, and 103.5	Apply CM levels of control; perform computer program identification and control
10.5 Software Nonconformance Reporting and Corrective Action Process	SQAM 5.0	Perform software problem reporting, analysis, and support corrective action

Software Assurance Implementation

TRW

- Review and approve the following documents
  - Software Management Plan
  - Software Requirements Specification
  - Software Standards and Procedures Document
  - Flight Software Verification Test Plans, Procedures, and Reports

- Review and audit software development folders

- Attend and participate in Software PDA, PDR, CDA, CDR, PMRS, and design walkthroughs

- Audit software being developed by Colorado Springs Engineering Operations (CSEO)

- Develop a software problem reporting system

- Monitor flight software functional tests

- Witness flight software verification tests

Software Assurance Implementation (Continued)

- Review and approve software problem reports
- Participate in the software CCB process and test review boards
- Implement software quality metrics
  - Requirements stability, initiated at SRS baseline
  - Software problem reports, initiated at software integration test
  - Lines of code change, initiated at flight software verification test

Software Assurance Status/Accomplishments

- Continuous interaction with TRW software developers and GSFC software assurance representative
- Reviewed and approved project software documents
  - Software Management Plan
  - Interim versions of the Software Requirements Specification
  - Flight Software Standards and Procedures document
  - Flight Software Verification Test Plans
- Conducted two software assurance audits at CSEO to date
  - Software assurance requirements flowdown
  - Reviewed/audited software development folders
- DPRO (DCMAO) in Colorado Springs is also auditing software development folders
- Participated in PDA, PDR, PMRS, CDA, CDR, and design walkthroughs
- Developed a software problem reporting system
- Monitoring flight software functional testing
- Performing a traceability analysis of requirements to flight software test cases

CDR Acronym List

A&T	Assembly and Test
AC	Air Conditioning (Launch VEhicle)
ACDS	Attitude Control & Determination Subsystem
ACQ	Acquisition
A/D	Analog-to-Digital
ADE	Attitude Determination Electonics
AHr	Ampere Hour
AOS	Acquisition of Signal
ARAR	Accident Risk Assessment Report
ARE	Array Req. Electronics
ARM	Array Regulator Modules
ASA	Aluminum Substrate Assembly
ASTM	American Society for Testing and Materials
ATC	Absolute Timed Commands
ATS	Absolute Time Sequence
BCCA	Battery Charge Control Algorithm
BSF	Back Surface Field
BSR	Back Surface Reflector
C/O	Check Out
CAL	Calibration
CAP	Contamination Analysis Program
CCB	Configuration Change Board
CDA	Critical Design Audit
CEA	Control Electronics Assembly
CFR	Captive Flight Release
CG	Center of Gravity
CIB	Command Input Buffer
CM	Center of Mass
CMM	Configuration Management Manual
CMS	Command Management System
CONV	Converter
CPT	Comprehensive Performance Test
CPU	Central Processing Unit
CSA	Command Storage Area
CSEO	Colorado Springs Engineering Operations
CSSA	Coarse Sun Sensor Assembly
CTV	Compatibility Test Van
CVCM	Collected Volatile Condensible Material
D/L	Downlink
DDLS	Deployment Device Load Simulator
DIU	Diode Isolation Unit
DMA	Direct Memory ACcess
DP	Data Processor
DPA	Destructive Physical Analysis
DPRO	Defense Plant Representative Office
DSN	Deep Space Network
DTM	Dual Thruster Module
EED	Electro-Explosive Device
EEDC	Electro-Explosive Device Controller
EEE	Electrical, Electronic, and Electromechanical

CDR Acronym List (Continued)

EGSE	Electrical Ground Support Equipment
EM	Engineering Model
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMISM	Electromagnetic Interference Safety Margins
EQ	Equipment
ER	Established Reliability
ESD	Electrosstatic Discharge
ETB	Eagle Test Bed
EV	Environmental
FDM	Flexible Data Mux
FMEA	Failure Mode Effect anmd Criticality Analysis
FOV	Field of View
FPGA	Field Programmable Gate Array
FSA	Fail-SAfe Algorithm
FSSA	Fine Sun Sensor Assembly
GFE	Government-Furnished Equipment
GFP	Government Furnished Property
GN_2	Gaseous Nitrogen
GRA	Gyro Reference Assembly
GSE	Ground Support Equipment
GSTDN	Ground-Space Tracking and Data Network
H/L	Hard Line
H/W	Hardware
HEX	Base 16 (Hexadecimal)
HQAM	Hardware Quality Assurance Manual
I/C	Interface Control
I/F	interface
ICD	Interface Control Document
ICMT	Intercontract Material Transfer
IFJ	In-Flight Jumper
IGSE	Instrument Ground Support Equipment
IIS	Instrument Interface Simulator
IR	Instrument Review
IVT	Interrupt Vector Table
KBPS	Kilo Bits Per Second
KPD	Key Parameter Database
LDSI	Luna Defense Systems Inc.
LOS	Line of Sight
LPO	Launch Project Office
LV	Launch Vehicle
LVAB	Launch Vehicle Assembly Building
LVI	Launch Vehicle Interface
M&P	Materials and Processes
MDE	Motor Drive Electronics
MGSE	Mechanical Ground Support Equipment
MLI	Multilayer Insulation or Machine Language Instruction
MMS	Mass Memory Supervisor
MRB	Material Review Board
MTA	Magnetic Torquer Assembly

CDR Acronym List (Continued)

MUA	Material Usage Agreement
Mux	Multiplexer
NASCOM	NASA Communication
NDI	Nondestructive Inspection
NHB	NASA Handbook
NiCd	Nickel Cadium
NO-OP	No Operation
NSPAR	Nonstandard Parts Approval Request
NVR	Non-Volatile Residue
OAS	Orbital Adjust Subsystem
OSC	Orbital Sciences Corporation
P-E	Perkin Elmer
P/B	Play BAck
PA	Performance Assurance
PAF	Payload Attach Fitting
PAIP	Performance Assurance and Implementation Plan
PAMPL	Project Approved Materials and Processes List
PAPL	Program Approved Parts List
PAR	Performance Assurance Requirement
PCA	Physical Configuration Audit
PCMTS	Power and Control/Monitor Test Set
PCU	Power Control Unit
PDA	Preliminary Design Audit
PDF	Programmable Data Formatter
PF	Powered Flight
PIL	Parts Identification List
PMPCB	Parts, Materials, and Processes Control Board
POCC	Payload Operation Control Center
PPL	Preferred Parts List
PPT	Peak Power Tracking
PRI	Primary
PWB	Printed Wire Board
QA	Quality Assurance
QCI	Quality Conformance Inspection
QD	Quality Directive
QPL	Qualified Parts List
QPR	Quality Project Requirement
R/T	Receive/Transmit
RAM	Random Access Memory
RDNT	Redundant
RF	Radio Frequency
RFTS	Radio Frequency Test Set
RIU	Remote Interface Unit
RPM	Revolutions Per Minute
RSS	Root Sum Squared
RT	Real Time
RTC	Relative Time Command
RTCS	Relative Timed Command Sequence
RWA	Reaction Wheel Assembly
S&MS	Structure and Mechanisms Subsystem

CDR Acronym List (Continued)

S/A	Solar Array
SAR	Solar Array Regulator
S/C	Spacecraft
SC ADDR	Spacecraft Address
SELV	Small Expendable Launch Vehicle
SEMCAP	Specification Electro-Magnetic Compatibility Analysis Program
SEU	Single Event Upset
SIS	Spacecraft Interface Simulator
SOH	State-of-Health
SP	Spacecraft Processor
SQAM	Software Quality Assurance Manual
SRS	Software Requirements Specification
STC	System Test Controller
STM	Structural Test Model
S/W	Software
SWA	Scan Wheel Assembly
SYNC	Synchronous
T-O	Time Zero
T/C	Telemetry/Command
T/V	Thermal Vacuum
TAM	Three-Axis Magnetometer
TBD	To be determined
TBR	To be Reviewed
TCA	Thrust Chamber Assembly
TCTS	Telemetry and Command Test Set
TCVL	Temperature Compensated Voltage Limit
TDE	Torquer Drive Electronics
TFS	TOMS Flight Software
Tlm	Telemetry
TML	Total Mass Los
TRASYS	Computer Program
U/L	Up Link
USART	Universal Synchronous Asynchronous Receiver Transmitter
UTB	Universal Test Bed
UTC	Universal Time, Coordinated
UV/OV	Under Voltage/Over Voltage
VAB	Vehicle Assembly Building
VAX	Mini-computer
VCM	Volatile Condensible Material
VDC	Volt Direct Current
VDE	Valve Drive Electronics
VDEA	Valve Drive Electronics Assembly
Vp-p	Volts Peak to Peak
WDT	Watch Dog Timer
XMTR	Transmitter
Xponder	Transponder