Tropical Rainfall Measuring Mission

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PMSEP 6

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Agenda

- Introduction
- TRMM Scope
  - Characteristics and Challenges
  - New Technology
- Management Systems and Processes
  - Schedule and Cost Management
  - Risk Management
  - Innovative Approaches
  - Project Communication and Team Activities
  - Responding to Crisis
- Accomplishments and Results
  - Development and Operating Phases
  - Science Results
- Summary and Conclusions

TRMM Characteristics

- TRMM Objective
  - Advance our understanding of global rainfall and its effect on climate change

- TRMM Implementation
  - Cooperative mission between U.S.and Japan
  - Observatory subsystem components built in house or procured
  - GSFC acts as Prime Contractor and System Integrator
  - Science instruments through contracts to industry
  - Science data processing at GSFC

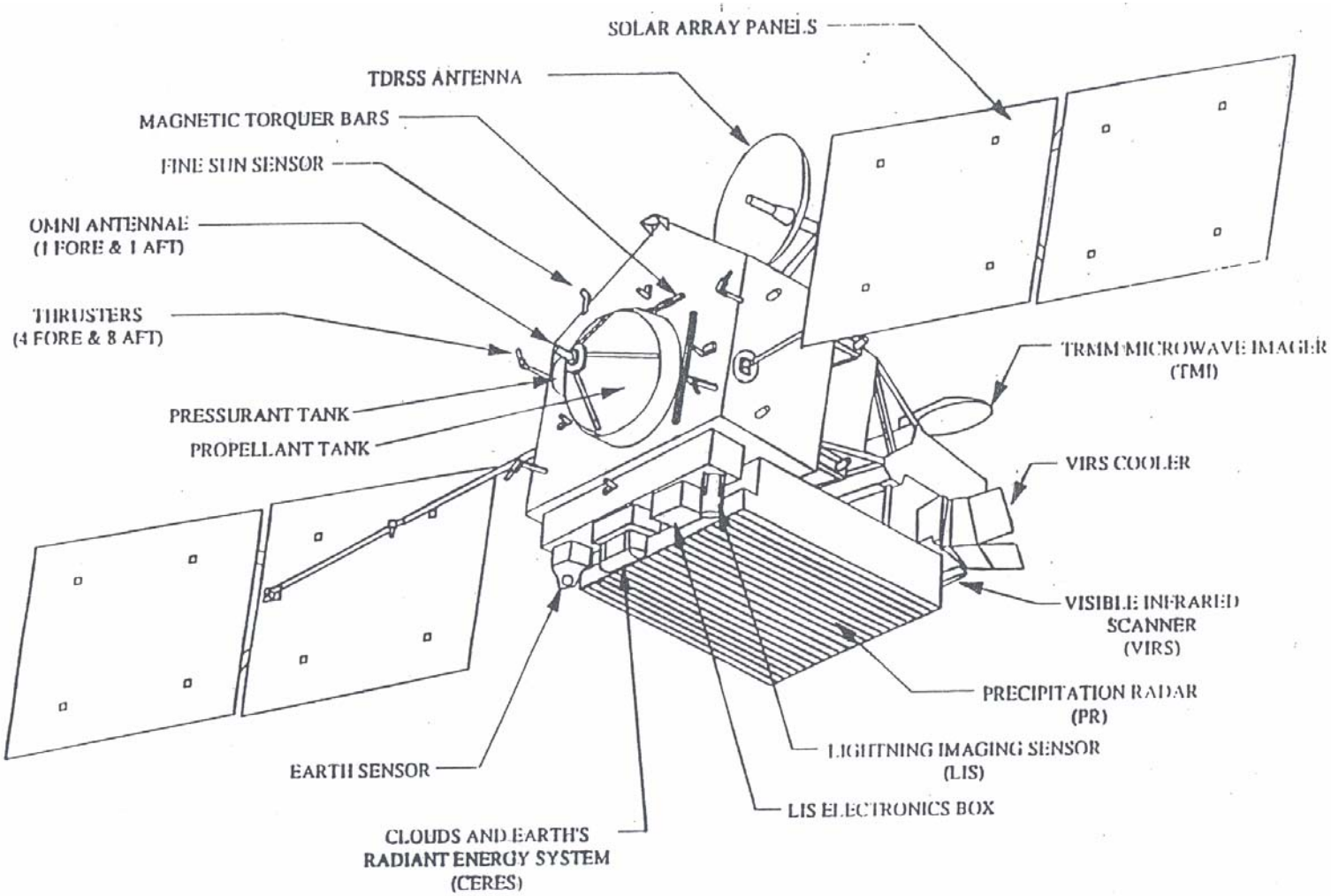
TRMM Program Characteristics

- 3 years of mission operations, 4 years of science data processing
- Joint mission with National Space Development Agency of Japan
  - Precipitation Radar
  - Launch vehicle (H-II) and services
  - Science participation
- November 1997 launch
- Largest observatory (16’ x 17’ x 48’ - orbit configuration) designed, developed, assembled and tested in-house at GSFC
- Science data processing system (TSDIS) designed and built in-house
- Mission operations planning and implementation in-house at GSFC

TRMM Observatory Characteristics

- Mass: 3520 kg
- Power: 1100 watts max continuous
- Stabilization: 3-axis Earth pointing 0.20 degrees
- Data rate: 200 kbps
- Orbital altitude: 350 Km with 35 degree inclination
- Reliability: Class B
- Communications: TDRSS S-Band

TRMM Observatory Configuration



TRMM Instrument Complement

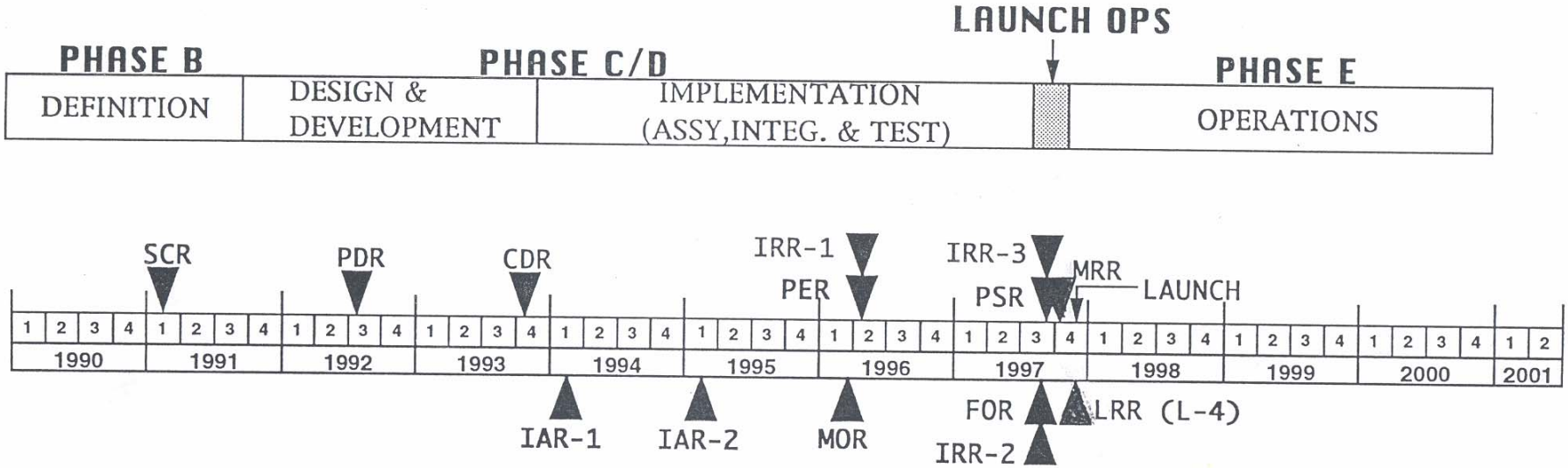
- Rain Package
  - TRMM Microwave Imager (TMI)
    - GSFC - Hughes Space & Communications Company
  - Visible Infrared Scanner (VIRS)
    - GSFC - Hughes Santa Barbara Remote Sensing
  - Precipitation Radar (PR)
    - NASDA -Toshiba

- Additional Instruments
  - Clouds and Earth's Radiant Endiant System(CERES)
    - GSFC/EOS - LaRC - TRW
  - Lightning Imaging Sensor (LIS)
    - GSFC/EOS-MSFC in house

TRMM Significant Challenges

- Limited budget and tight schedule
- Major international participation with Japan
- Development of first space active Precipitation Radar
- Launch on H II from Japan
- Design for high levels of atomic oxygen at 350 Km
- Development of science data processing system to handle large data volumes and support both research and generation of data products

TRMM Timeline – Observatory and Ground Data Systems



Legend

CDR - CRITICAL DESIGN REVIEW
FOR - FLIGHT OPERATIONS REVIEW
IAR - INDEPENDENT ANNUAL REVIEW
IRR - INDEPENDENT READINESS REVIEW
LRR - LAUNCH READINESS REVIEW
MOR - MISSION OPERATIONS REVIEW
MRR - MISSION READINESS REVIEW
PDR - PRELIMINARY DESIGN REVIEW
PER - PRE-ENVIRONMENTAL TEST REVIEW
PSR - PRE-SHIPMENT REVIEW
SCR - SYSTEMS CONCEPT REVIEW

TRMM Observatory New Technology

- Development of a special thermal blanket coating to withstand the high atomic oxygen condition in the 350 Km orbit
- Extensive use of fiber optics especially in data subsystem
- Solid state data recorders in place of mechanical type
- Extensive use of gallium arsenide solar cells in low earth orbit
- Development of a molecular absorber system for contamination control
- Development of a 13.8 GHz Pulsed Beam Precipitation Radar (1st Precipitation Radar ever flown in orbit)

Elements of the TRMM Management System

- Logic networks and schedules for all project activities
- Budget requirements phased to project schedules
- Changes to baselined cost, schedule, and technical areas require CCB approval
- Risk indicators in technical, cost and schedule areas,identified and tracked against baselined levels. Exceeding threshold levels results in action plans to resolve problems before they become major
- Technical Management Board to resolve technical problems in a timely manner
- Work authorization process to approve tasks and their costs
- Monthly project level status meetings to review subsystem, instrument, ground system progress and problems

Cost Management and Control

- Clear definition of requirements and flow down top level to lowest level provides sound basis for budgeting
- Budget allocations from grassroots costing at lowest level
- Budget requirements developed by element managers who are fully responsible for managing to budget
- Close coordination between element managers and project financial staff to develop budget estimates and initiate procurements
- Element managers present top level budget status at monthly reviews
- Element managers present detailed budget status at lowest level semiannually concurrent with project POP submittals
- Contingency accountability system used to record, quantify, and track all cost liens for effective cost management and control

Schedule Management and Control

- Centralized schedule system maintained by project and updated monthly
- PERT networks and slack charts for all elements (subsystems, etc.)
- Work breakdown structure defines tasks for logic networks
- Master schedule provides baseline for all subordinate schedules
- Vertical traceability of all element schedules to master schedule
- Changes to baseline element schedules require project approval
- Schedules and critical path slack reviewed at monthly status meeting

GODDARD SPACE FLIGHT CENTER

APPROVAL RESP: V. WEYERS

ACCOMP RESP: T. LaVIGNA

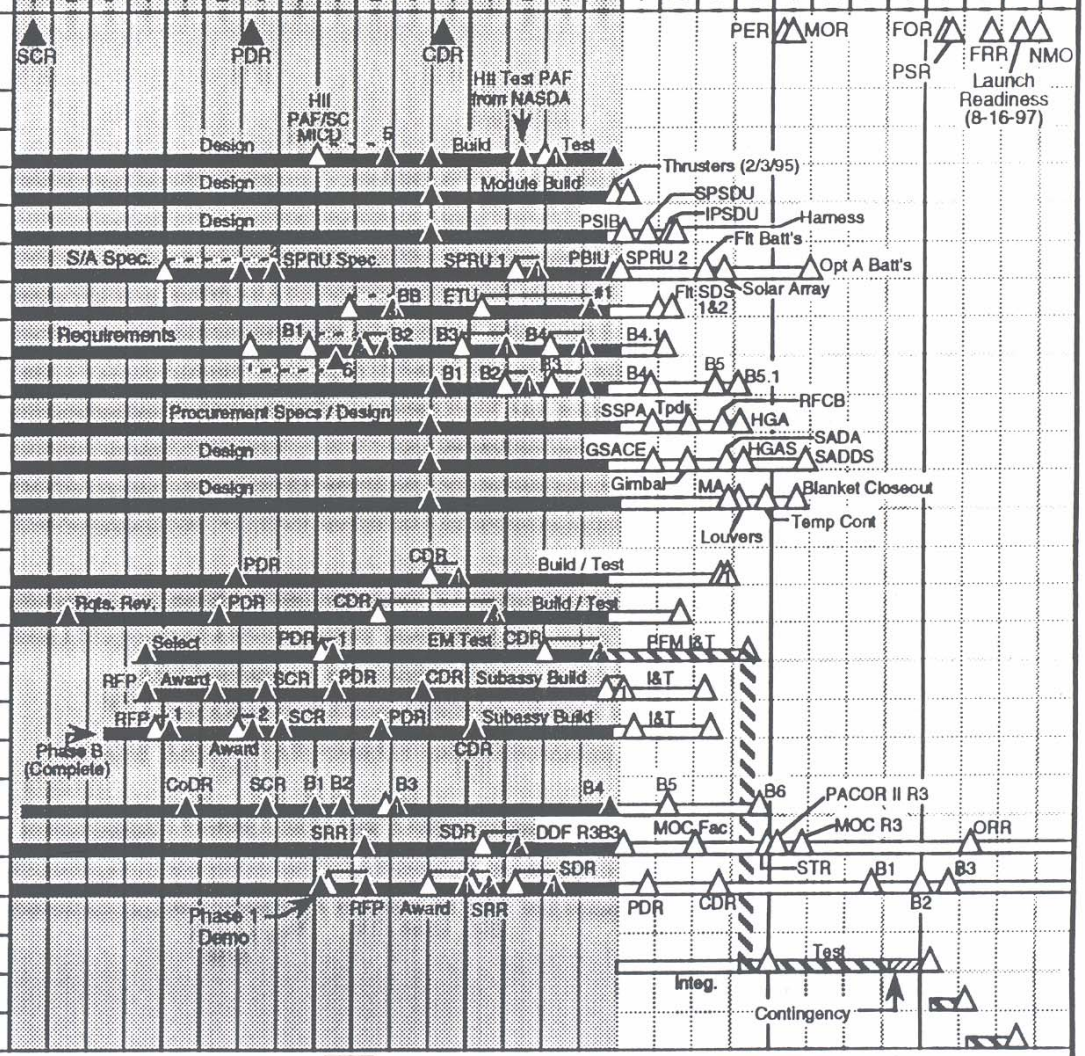
TRMM PROJECT MASTER SCHEDULE

ORIG SCHED APPVL: 05/22/90

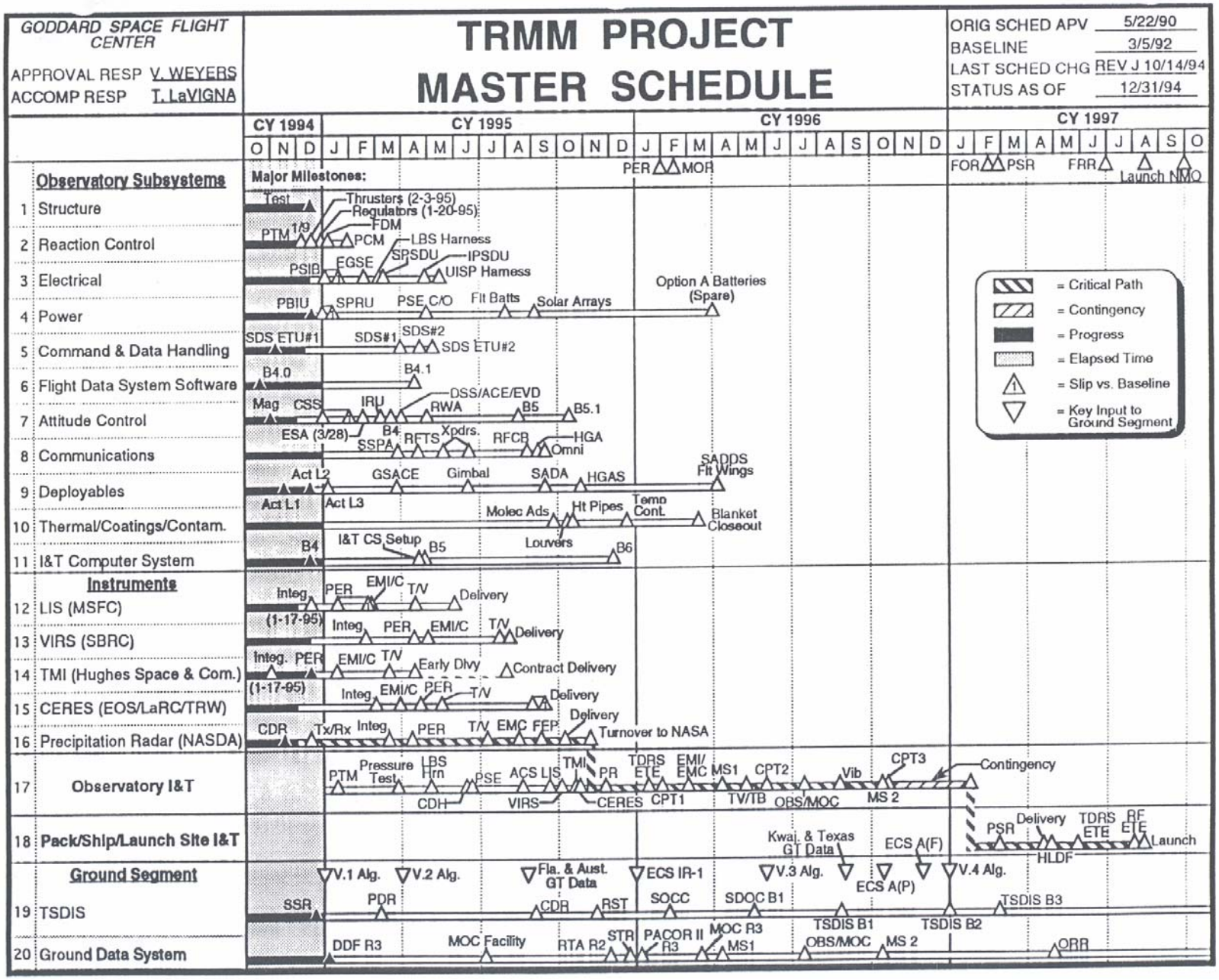
BASELINE: 3/25/92

LAST SCHED CHG: REV J 10/14/94

STATUS AS OF: 12/31/94



NOTE: = 3 Months Schedule Contingency; = Critical Path


GODDARD SPACE FLIGHT CENTER
APPROVAL RESP V. WEYERS
ACCOMP RESP T. LaVIGNA
TRMM PROJECT
MASTER SCHEDULE
ORIG SCHED APV 5/22/90
BASELINE 3/5/92
LAST SCHED CHG REV J 10/14/94
STATUS AS OF 12/31/94
CY 1994
CY 1995
CY 1996
CY 1997
O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O
Major Milestones:
PER MOR
FOR PSR FRR Launch NMO
Observatory Subsystems
1 Structure
Test
Thrusters (2-3-95)
Regulators (1-20-95)
FDM
2 Reaction Control
PTM 1/9
PCM
LBS Harness
3 Electrical
PSIB
EGSE
SPSDU
IPSDU
UISP Harness
4 Power
PBIU
SPRU
PSE C/O
Flt Batts
Solar Arrays
Option A Batteries (Spare)
5 Command & Data Handling
SDS ETU#1
SDS#1
SDS#2
SDS ETU#2
6 Flight Data System Software
B4.0
B4.1
7 Attitude Control
Mag
CSS
IRU
DSS/ACE/EVD
RWA
B5
B5.1
8 Communications
ESA (3/28)
B4
SSPA
RFTS
Xpdrs.
RFCB
HGA
Omni
9 Deployables
Act L2
GSACE
Gimbal
SADA
HGAS
SADDS Flt Wings
10 Thermal/Coatings/Contam.
Act L1
Act L3
Molec Ads
Ht Pipes
Temp Cont.
Blanket Closeout
11 I&T Computer System
B4
I&T CS Setup
B5
Louvers
B6
Instruments
12 LIS (MSFC)
Integ
PER
EMI/C
T/V
Delivery
13 VIRS (SBRC)
(1-17-95)
Integ
PER
EMI/C
T/V
Delivery
14 TMI (Hughes Space & Com.)
Integ. PER
EMI/C
T/V
Early Dlvy
Contract Delivery
15 CERES (EOS/LaRC/TRW)
(1-17-95)
Integ
EMI/C
PER
T/V
Delivery
16 Precipitation Radar (NASDA)
CDR
Tx/Rx
Integ
PER
T/V
EMC
FEP
Delivery
Turnover to NASA
17 Observatory I&T
PTM
Pressure Test
LBS Hrn
PSE
ACS LIS
TMI
PR
TDRS ETE
EMI/ EMC
MS1
CPT2
Vib
CPT3
Contingency
CDH
VIRS
CERES
CPT1
TV/TB
OBS/MOC
MS 2
18 Pack/Ship/Launch Site I&T
Kwaj. & Texas GT Data
ECS A(F)
PSR
Delivery
TDRS ETE
RF ETE
Launch
HLDF
Ground Segment
19 TSDIS
V.1 Alg.
V.2 Alg.
Fla. & Aust. GT Data
ECS IR-1
V.3 Alg.
ECS A(P)
V.4 Alg.
SSR
PDR
CDR
RST
SOCC
SDOC B1
TSDIS B1
TSDIS B2
TSDIS B3
20 Ground Data System
DDF R3
MOC Facility
RTA R2
STR
PACOR II R3
MOC R3
MS1
OBS/MOC
MS 2
ORR
= Critical Path
= Contingency
= Progress
= Elapsed Time
= Slip vs. Baseline
= Key Input to Ground Segment

TRMM Total Slack Summary

(less 3 months contingency)

Element	Baseline Master Schedule - REV J[2] Delivery	Baseline Master Schedule - REV J[2] Total Slack	Nov 1994 Total Slack	Dec 1994 Total Slack	Forecast Delivery	Current Month Driver
Spacecraft Structure	12-15-94	+22 Days	+31 Days	N/A	N/A	COMPLETE
Reaction Control	**12-13-94**	**+52 Days**	**+20 Days**	**+8 Days**	**1-9-95**	**Propellant Tank Module**
Electrical	**1-5-95**	**+25 Days**	**+19 Days**	**+9 Days**	**1-18-95**	**PSIB**
Power	**4-27-95**	**+16 Days**	**+12 Days**	**+9 Days**	**5-26-95**	**PSE Checkout**
C & DH	**4-24-95**	**+31 Days**	**+20 Days**	**+7 Days**	**5-30-95**	**Flight SDS Box #2**
FDS Software	4-14-95	+37 Days	+36 Days	+36 Days	4-17-95	FDS Build 4.1
Attitude Control	8-17-95	+39 Days	+36 Days	+36 Days	8-22-95	ACS S/W Build 5.0
Communications	9-11-95	+12 Days	+12 Days	+29 Days ↑	11-14-95	Omni Antenna
Deployables	**6-14-95**	**+23 Days**	**+24 Days**	**+8 Days**	**7-6-95**	**Gimbal Assembly**
Thermal / Contam.	12-22-95	+51 Days	+32 Days	+34 Days	1-19-96	Temperature Controller
LIS	6-1-95	+63 Days	+63 Days	+63 Days	√	Electronics Assembly
CERES	**9-1-95**	**+34 Days**	**+34 Days**	**+24 Days**	**9-15-95**	**Sensor Scanner**
Precipitation Radar	11-7-95	+4 Days	+4 Days	+4 Days	√	PFM Fabrication
TMI	8-1-95	+37 Days	+37 Days	+37 Days	√	SPU Rework
VIRS	8-4-95[3]	+24 Days	+12 Days	+22 Days ↑	8-8-95	Radiative Cooler
TSDIS	8-21-96	+33 Days	+33 Days	+33 Days	√	TSDIS Build 1
Ground Data System	1-3-96	+20 Days	+20 Days	+20 Days	√	PACOR II R3
I&T Computer System	4-27-95	+56 Days	+56 Days	+56 Days	√	I&TCS Build #5
Observatory I&T	1-23-97	+4 Days	+4 Days	+4 Days	√	Precipitation Radar

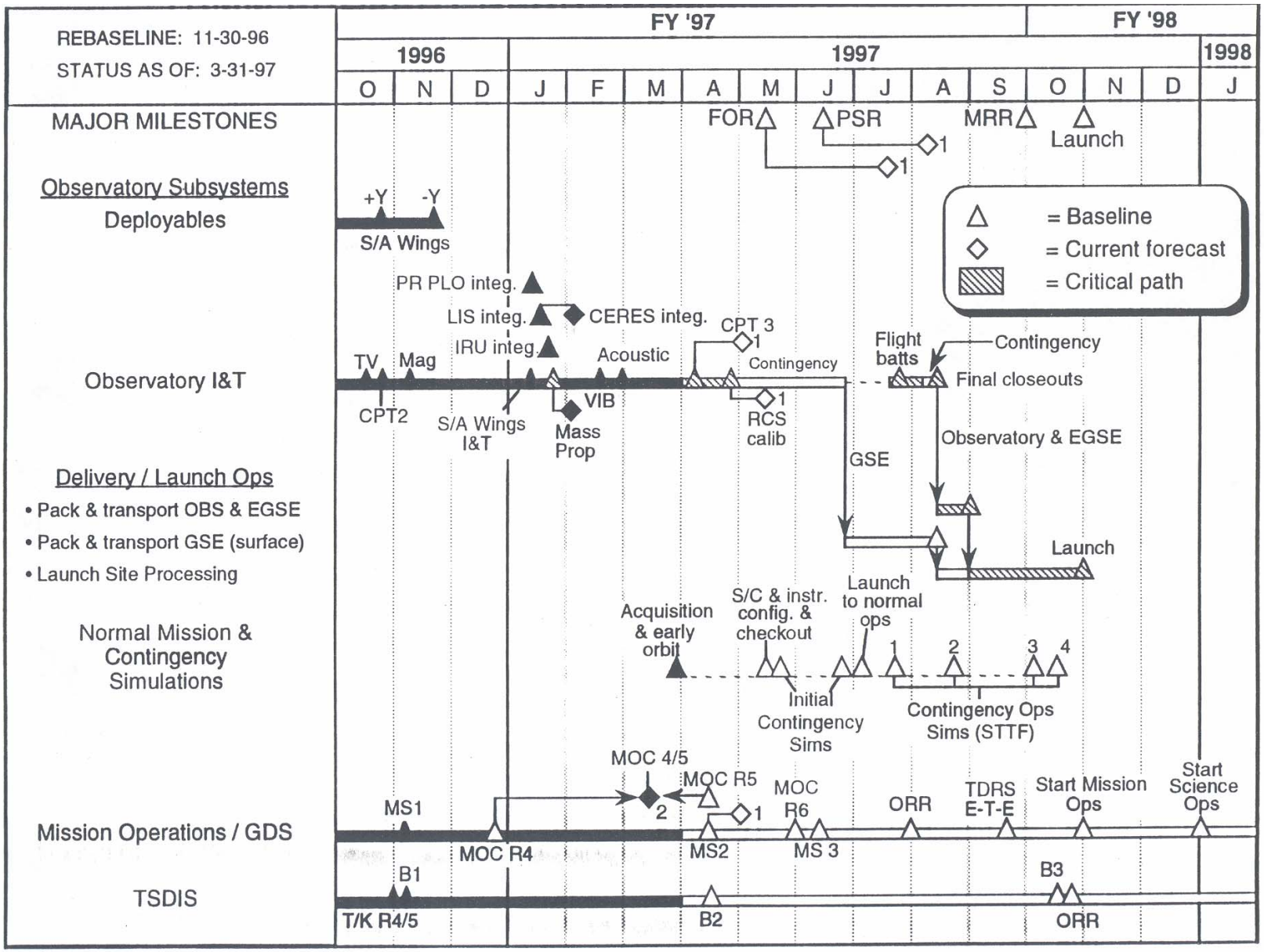
NOTE:
1) Total slack calculated in working days
2) TRMM schedule was rebaselined effective 10/14/94
3) VIRS contract delivery is 7/1/95

□ = Loss in slack from last month 10 days or greater

↑ = Growth in slack from last month 10 days or greater

√ = Forecast delivery on track to baseline schedule

TRMM Near Term Master Schedule



Risk Assessment and Management

- Proactive management to identify and manage problems before adverse programmatic or technical impacts occur
- Graphical method used to track key technical, cost, and schedule parameters and compare them to established thresholds
- Charts also show trends toward exceeding limits thus providing advance warning of problems
- Risk reduction plan with corrective actions defined when parameters exceed established thresholds to avert major impacts and get violating parameters under control

TRMM Risk Assessment Summary

For Month Ending April 1995

Critical Design Parameters

- Data Storage - Memory Usage
- OBC - EEPROM Memory Usage
- OBC - ACS EEPROM Memory Usage
- Power Margin
- Weight Margin
- Mission Life

Project Management

- Civil Service Workforce
- Schedule Contingency
- Financial Contingency
- Procurement
- Configuration Changes
- Control Milestone Performance

Observatory Subsystems

	M	T P	C	S
Structure	Complete			
RCS	Complete			
Electrical	■			▨
Power				▨
C&DH			■	▨
Flight Software				▨
ACS				▨
Communications			▨	
Deployables SADDS HGAS				▨
Thermal				▨
Thermal Coatings				
Test & Verification/I&T				▨
Contamination				▨
I&T Computer System				

Instruments

	M	T P	D	C	M/P	S
LIS						▨
TMI						
VIRS			▨			▨
CERES	▨		▨			
PR	▨		▨			▨

Ground Segment

	T	S
TSDIS		▨
GDS		
ECS *		

Legend

Status:
- ☐ = No Impact
- ▨ = Potential Impact
- ■ = Major Impact

Category:
- T = Technical
  - M = Mass
  - P = Power
  - D = Data Rate
- C = Cost
- M/P = Manpower
- S = Schedule

* Assumes IR-1 will be upgraded to support Mission Sim. #2.

TRMM Risk Assessment Plan

- Identify and define critical areas of risk
- Define and establish objective criteria to measure degree of risk in terms of three levels or alert zones:

  - ☐ No Impact
  - ▨ Potential Impact
  - ■ Major Impact

- On a monthly basis, determine status of risk indicators.
- Prepare a Risk Reduction Plan for each area exceeding risk thresholds
- Maintain log of Risk Reduction Plans and track their disposition

Criteria are defined as:

☐ **No Impact:** performance reflects that Project cost, schedule, and technical requirements are being met with no current major concerns

▨ **Potential Impact:** performance reflects the existence of problems or concerns or a potential major impact upon accomplishments unless timely and effective corrective action is taken

■ **Major Impact:** performance reflects the existence of or eminent threat of major problems, concerns, high risks, or similar severe impact upon accomplishment of project requirements

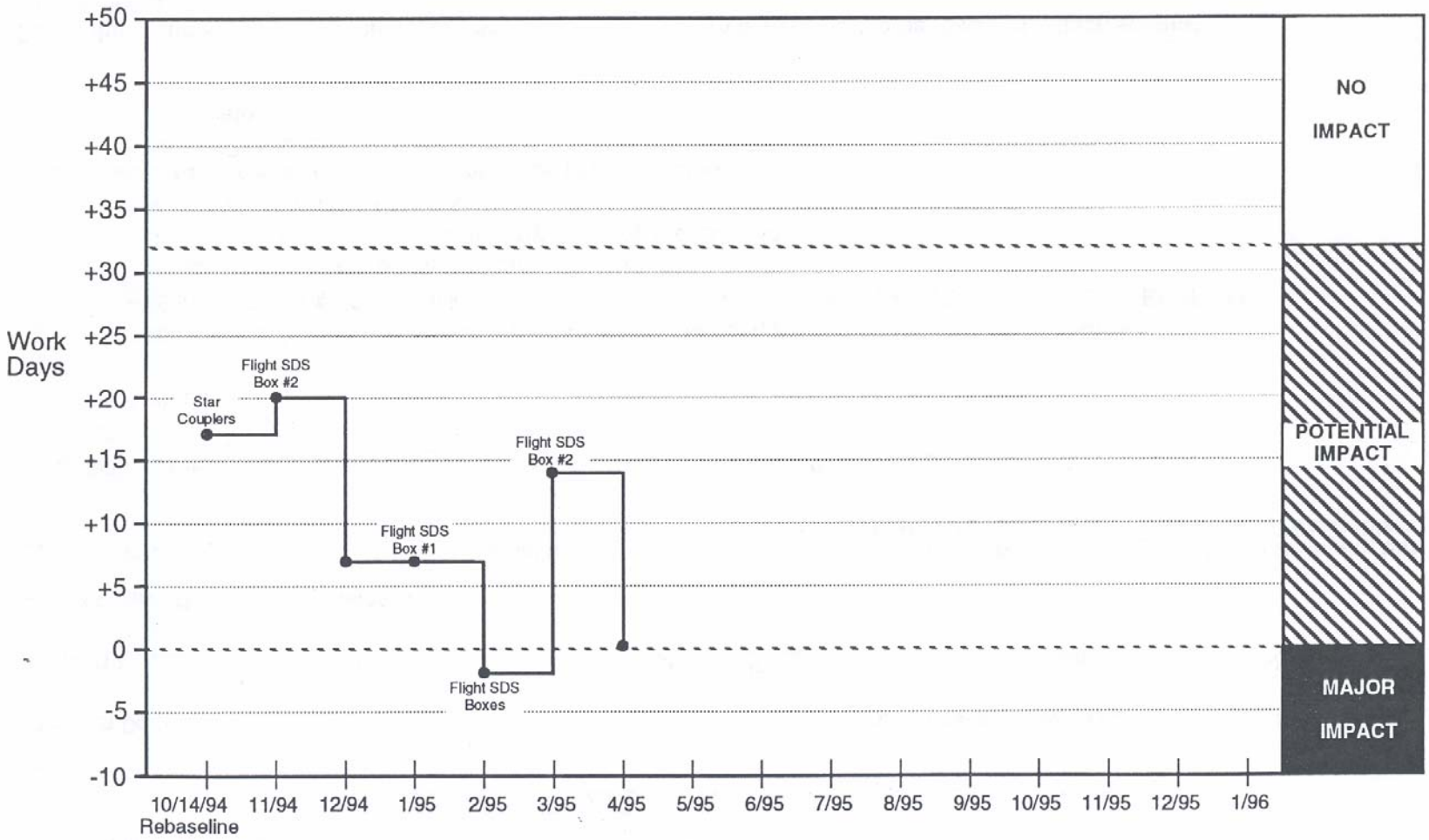
TRMM Indicator Summary

Observatory Subsystems – Schedule

- **Purpose:** To assess overall schedule margin of each Observatory Subsystem against baseline plan
- **Data Ground Rules:** Determine Subsystem Total Slack
- **Alert Zones:**

☐	No Impact:	Tracking to baseline plan; Total Slack within tolerance
	or	
▨	Potential Impact:	Total Slack ≥ +1day and < +32 days
	or	
■	Major Impact:	Total Slack ≤ 0 days

TRMM C&DH Subsystem Total Slack



FILE: C&DH.RISK.3

Log Number 76

TRMM PROJECT RISK REDUCTION PLAN

Problem Description C&DH - Schedule **Name of Indicator** Observatory Subsystems - Schedule

Originator Walt Majerowicz/ Harry Culver **Date** 4/30/95 **Phone Number** x5622/ x5874

Check the Alert Zone that applies:

____ ■ **Major Impact** X ▨ **Potential Impact** ____ ☐ **No Problem, but has unfavorable trend** ____ ☐ **No Problem, but RRP desirable**

Potential Impact: ____ **Cost** X **Schedule** ____ **Technical Performance**

Describe Problem

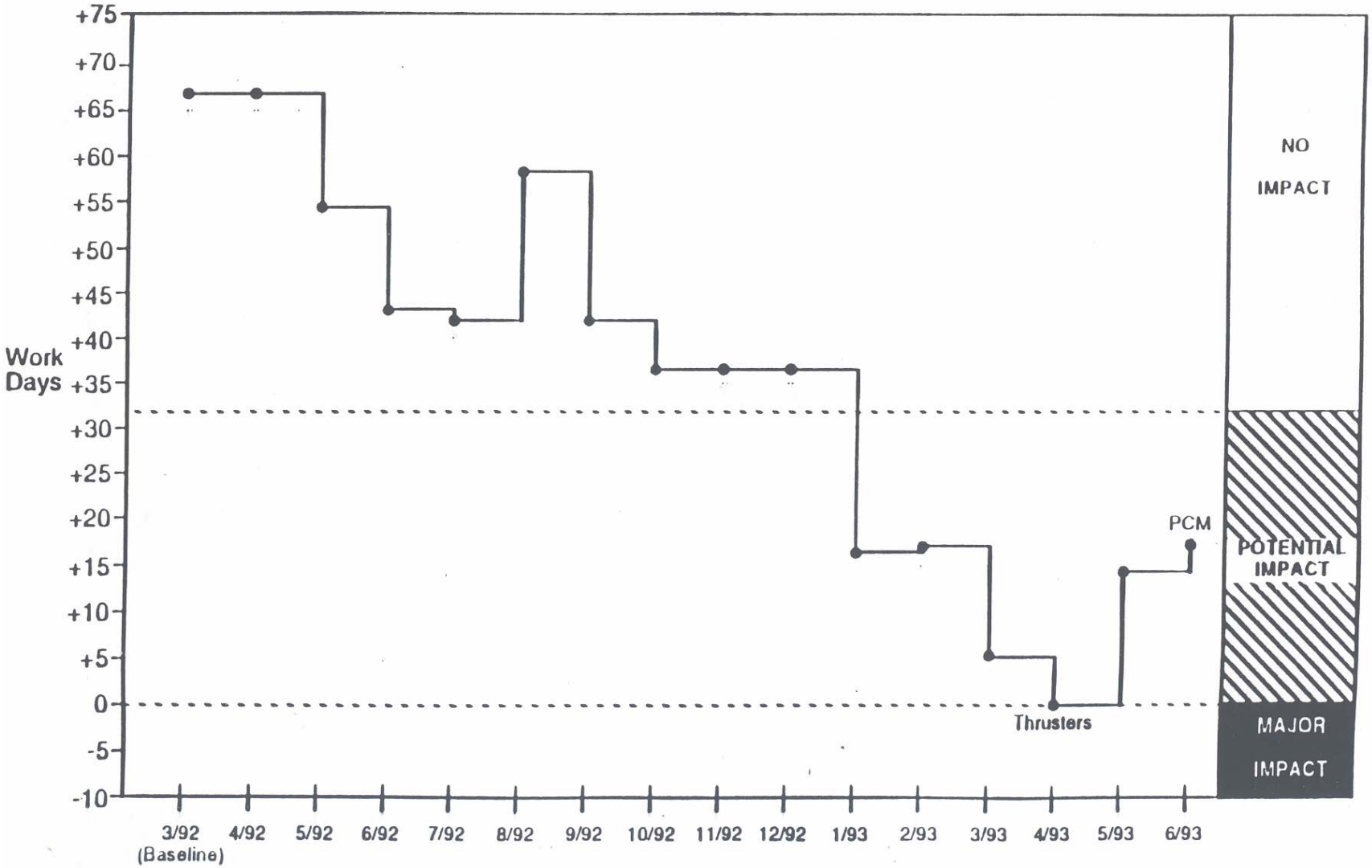
1. **Summarize problem, identify cause, quantify impact to cost, schedule technical performance.**
   - Flight SDS Box #1 & #2 slacks at +1 & 0 days respectively are within Alert Zone 1 due to the EEPROM re-procurement for the processor card assemblies
   - Current HDI memory module delivery is driving the SDS Box #2
   - No impact as yet to TRMM I&T
2. **List hardware and/or software configured items affected.**
   - Flight SDS Boxes
   - Observatory

Corrective Action Plan (Be specific, include dates when problem is expected to be resolved, attach separate schedule if necessary.)

- EE PROMs issues resolved
- Expediting one flight box to support TRMM integration; second box to be integrated with the observatory when available without impact to current schedule
- ETU backups remain available for integration if neccessary and would be swapped out when the flight units are complete

FILE: C&DH.RRP

TRMM Reaction Control Subsystem Total Slack



Project Communication and Team Activities

- Weekly 1 hour project meetings
- Monthly status review meetings
- Quarterly “All-Hands” meetings
- Quarterly TRMM-LINE newsletter
- Quarterly awards for individual and group achievements presented at “All-Hands” meetings
- Occasional TGIF end of week socials
- Semi-annual social and dinner for NASA/NASDA partnership meetings at GSFC
- Socials on occasion of major accomplishment such as, observatory thermal vacuum test completion

Innovative Approaches

- Special graphical tool to track key parameters to reduce project risk
- Contingency accountability process to provide a structured method to catalog and track potential cost items and identify actions to prevent growth
- International cooperation of US and Japan's science teams to use data and release findings
- Development of novel thermal coating to prevent erosion of materials due to atomic oxygen

Responding to Crisis

- Precipitation Radar (PR) delivery delay will impact launch
  - NASDA estimates 6 to 9 months delay due to part failure
  - Workarounds recommended by TRMM Project reduces delay to 3 months
  - Use of PR Eng. Model for observatory I&T reduces risk and time
  - NASDA culture was to stop work and focus on problems; use of parallel path workarounds new for NASDA

- NASDA wants to delay TRMM launch 6 months
  - Only 2 launch windows a year (February and August)
  - NASDA COMETS satellite cannot launch in February ‘97; slip to August would move TRMM to February ‘98
  - Strong TRMM Project opposition forces NASDA to negotiate with fisherman’s union for November ‘97 launch

Responding to Crisis (Continued)

- TRMM earth sensor could fail from lens fogging
  - Problem discovered on TIROS
  - Star tracker proposed very expensive at $2M and delays schedule
  - Further study required by project manager led to solution using existing sensors and modified software at cost of $400K and slightly lower pointing accuracy
  - Evaluation by science team led to acceptance
  - Cost avoidance of $1.6M and “in orbit” test showed pointing accuracy within spec

Accomplishments and Results

- Development Phase
  - Completed on schedule and within budget in spite of 10% contingency
  - Met all technical requirements
  - Provided “hands on” experience and career development for civil servants
  - Developed major science data processing system within $25M allocation

- Operational Phase
  - Observatory continues to operate very well over 4 3/4 years exceeding the 3 year requirement
  - Observatory boosted to 400 Km orbit to extend lifetime in presence of higher than expected solar flux levels
  - Science date processing system operating extremely well and has added a new feature of providing real time data
  - Science results exceed all expectations

Science Results

- TRMM data have provided an improved and more detailed four year map of precipitation climatology
- Unique, fine-scale hurricane/typhoon rainfall structure including observations of giant towers associated with rapid intensification of storm
- Monitoring of tropical rainfall variation related to El Nino and La Nina over oceans and land for understanding climate change
- Significantly improved modeling of climate processes through use of TRMM rainfall data

Summary and Conclusions

- Project manager should pay close attention to details
  - "The devil is in the details"
- Baseline requirements early in project, flowdown to lowest level, and allow changes only through CCB approval
- Incorporate project tracking and control tools for risk management and cost and schedule control
- Conduct monthly project meetings for status reporting and career development of element managers
- Allocate responsibility and accountability to element managers
- Maintain project communication through quarterly "All Hands" meetings, periodic news letters, and short weekly project meetings
- Recognize individual and group achievements through a periodic awards process; suggest presentation at "All Hands" meetings