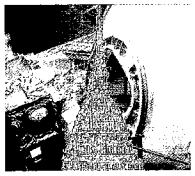

Session 2

Verification and Test Philosophies/Test Effectiveness

Title

Jet Propulsion Laboratory

Environmental Verification Processes and Test Effectiveness

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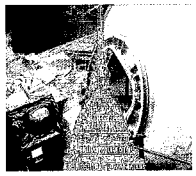
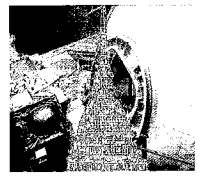


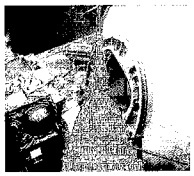
Topics

- Processes
  - -JPL Design Principles
  - -JPL Flight Project Practices
- Environmental Verification
- Test Effectiveness Assessment: Inflight Anomaly Trends
- Summary



JPL Institutional Processes

- **Design Principles**
  - Capture institutional standards for designing, verifying, validating, and operating flight systems
- **Flight Project Practices**
  - Establish standards of uniformity, where standardization is judged to have significant benefit
  - Capture approaches and methods important to sponsors
  - Incorporate lessons learned that were key to past successes, and where deviations created significant problems
  - Require management review and approval to waive



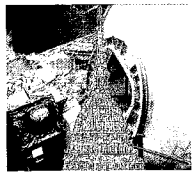
Design and Verification for Environmental Compatibility

Overall

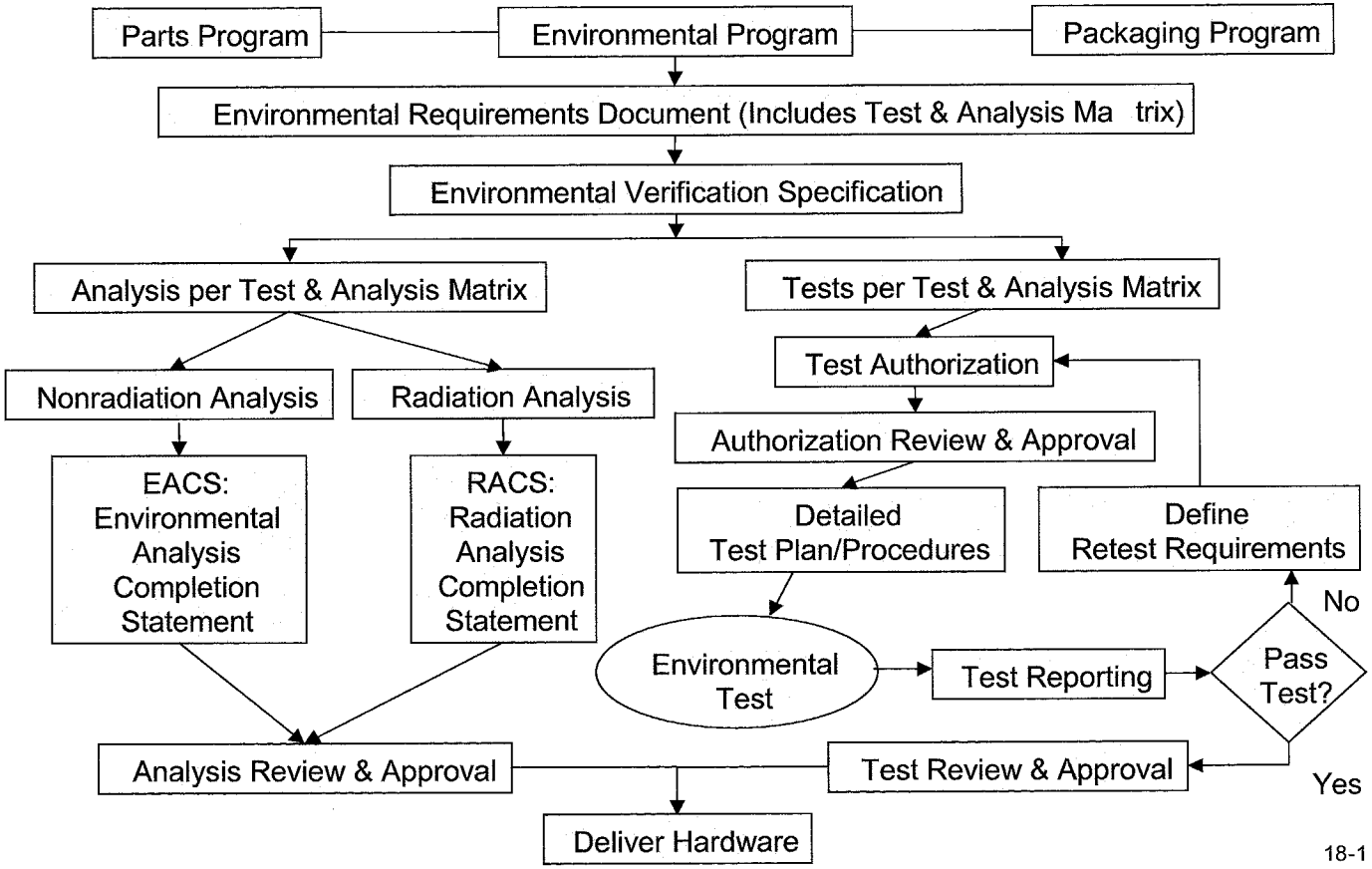
- Flight Project designs and verifies all flight hardware to be fully compatible with all anticipated environments

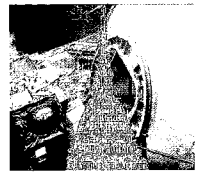
Specifics

- Define relevant mission environments
- Specify environmental design and verification requirements with appropriate margins
- Define and document environmental verification plan
- Implement plan
- Identify Track and manage risk
- Track progress and report status



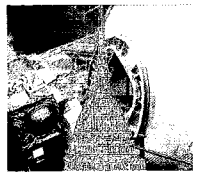
Process: Environmental Verification





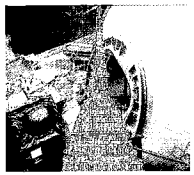
Environmental Verification Summary

Method	Environment	Assembly	Spacecraft
Test (T)	Dynamics	T	T
	Thermal	T	T
	Electromagnetic Compatibility	T	T
	Magnetics	T	A
Analysis (A)	Electrostatic Discharge	A	—
	Radiation	A	—
	Solid Particles	A	A
	Atomic Oxygen	A	—



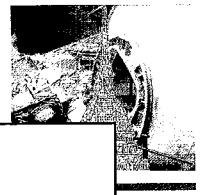
Test Effectiveness Assessment
Inflight Anomaly Trends

- Analyze post launch anomalies for planetary missions
- Look for trends to assist design and verification planning for future missions
  - How many anomalies?
  - When do they occur?
  - Where are they coming from?
  - What kinds of responses?
- Baseline for current technology



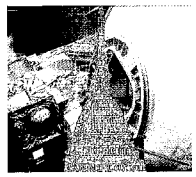
NASA Missions to Mars since 1990

Name	Launch Date	Mars Arrival	Spacecraft Type	Results
Mars Observer	25 September 1992	22 August 1993 (Loss of Signal)	Orbiter	Lost contact with spacecraft prior to orbiting Mars
Mars Global Surveyor	7 November 1996	12 September 1997	Orbiter	Successfully entered Mars orbit. Still in operation as of January 2006.
Mars Pathfinder	4 December 1996	4 July 1997	Lander/Rover	Successful landing and rover operations
Mars Climate Orbiter	11 December 1998	23 September 1999	Orbiter	Lost upon Mars arrival
Mars Polar Lander	3 January 1999	3 December 1999	Lander	Lost during decent to Mars surface
Mars Odyssey	7 April 2001	24 October 2001	Orbiter	Successfully entered Mars orbit. Still in operation as of January 2006
Mars Exploration Rover	Spirit: 10 June 2003 Opportunity: 7 July 2003	Spirit: 3 January 2004 Opportunity: 24 January 2004	Rover	Both spacecraft successfully descended to the surface of Mars. Both are still in operation as of February 2006.



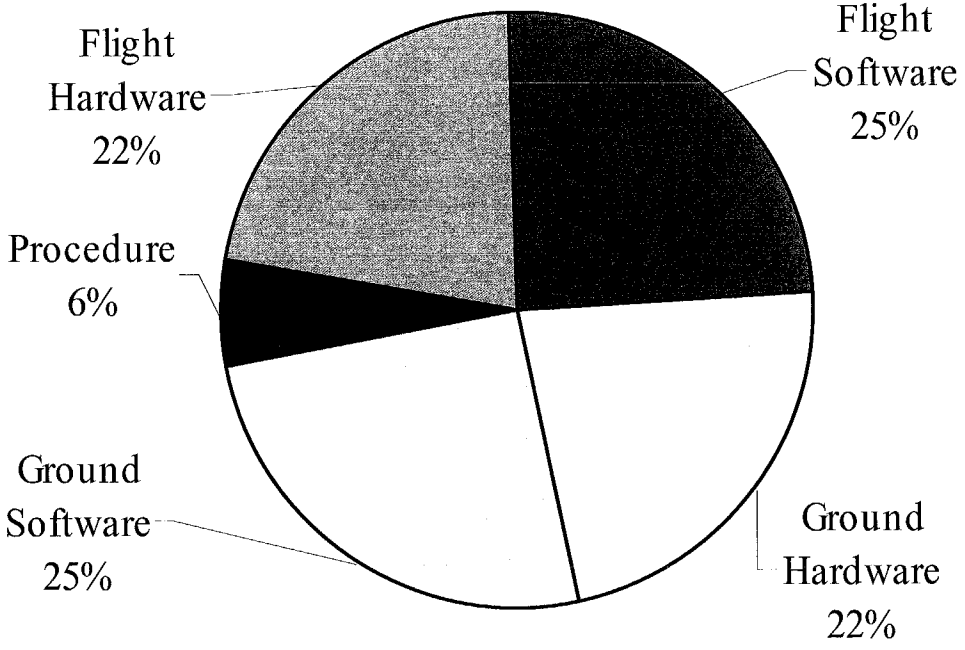
Anomaly Sources

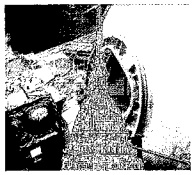
- Flight Hardware
  - Spacecraft component anomaly or failure
- Ground Hardware
  - Mission Control or Deep Space Network facilities
- Flight Software
  - Software event on board spacecraft
- Ground Software
  - Software event at Mission Control
- Procedure
  - Improper procedure
  - Lack of prior knowledge



Anomaly Sources

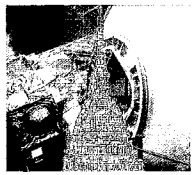
- Average of Mars mission anomaly sources during Earth to Mars phase
- Types
  - Software – 50%
  - Hardware – 44%
  - Procedure – 6%
- Location
  - Flight 47%
  - Ground – 53%





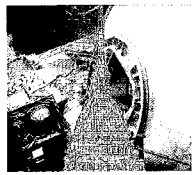
Corrective Actions

- "Use As Is"
  - Essentially taking no action
    - Flight hardware problems
    - Single incident
- Flight software
  - Radiated to spacecraft
  - Fix hardware and software issues on board spacecraft
- Ground software
  - Earth based computers



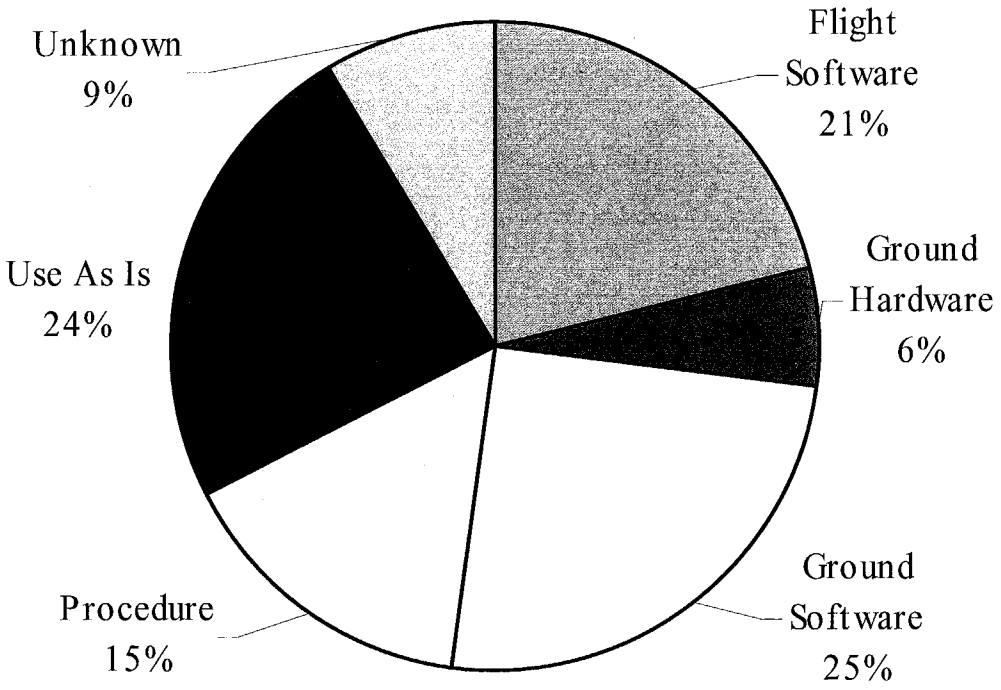
Corrective Actions

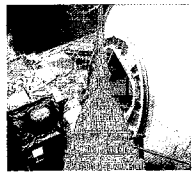
- Ground Hardware
  - Changing Earth based hardware
    - Mission Control
    - Deep Space Network
- Procedure
  - Spacecraft operations
  - Mission team operations
- Unknown
  - Information not available in electronic ISA database



Corrective Actions

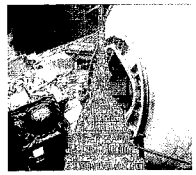
- Average of Mars missions corrective actions
- Types
  - Software – 46%
  - Use As Is – 24%
  - Ground Hardware – 6%
  - Procedure – 15%





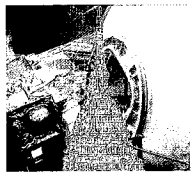
Inflight Anomaly Trends- Observations

- Anomaly events peak at beginning of mission and as spacecraft encounters planet
  - Learning curves
  - Activation of instruments
- Equal spread of anomalies between Ground and Flight suggest need for care in designing both systems



Summary

- Processes for flight systems have been evolving at JPL and other NASA centers for the last 40 years.
  - JPL processes documented in institutional standards such as Flight Project Practices
  - System level environmental test program: modal, static, vibration, pyroshock, acoustic, thermal, and EMI/EMC
  - Assembly/subsystem level environmental test program: random vibration, acoustic, thermal pyroshock, EMI/EMC



Summary (Continued)

- Inflight Anomaly Trends
  - Sources of Anomalies
    - Spread evenly
      - Software and Hardware
      - Ground and Flight
    - Least common are anomalies due to procedure
  - Corrective actions
    - Software fix most common
      - Almost equally spread between Flight and Ground
    - "Use As Is" used for ~25% of anomalies
      - Often for flight hardware
    - Procedure change less common
    - Ground hardware change relatively rare