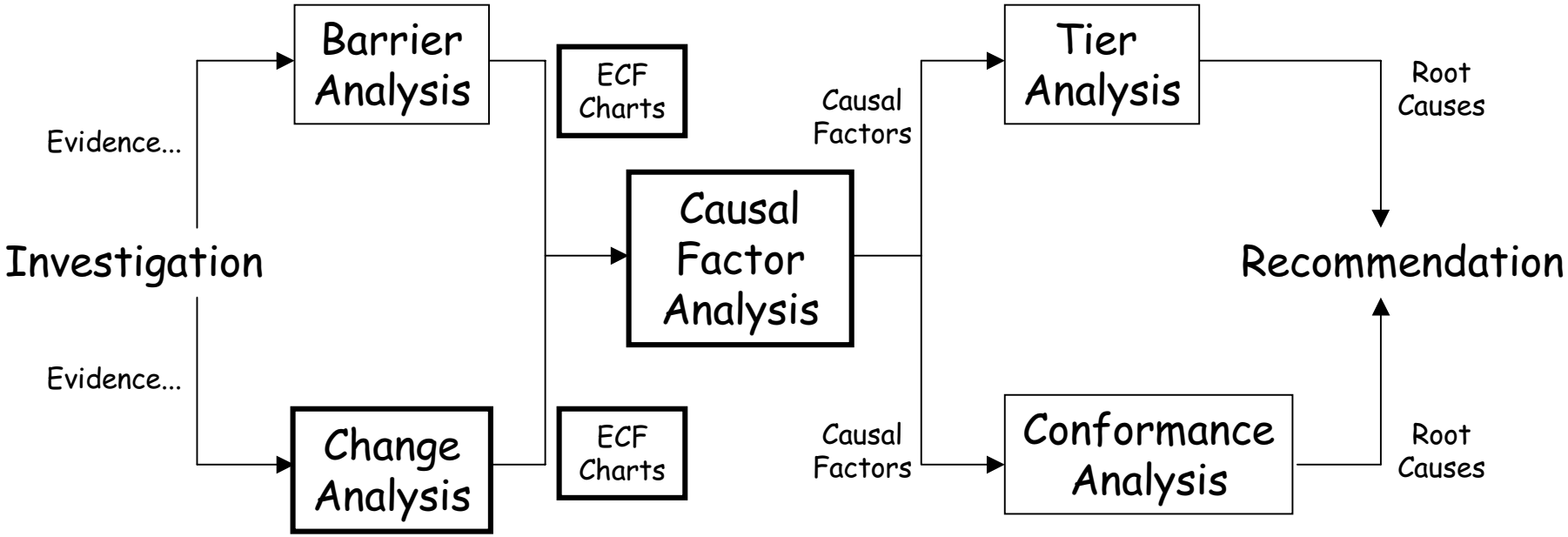
Bruce Willis is Braver than You Think?

Chris Johnson

University of Glasgow, Scotland.
http://www.dcs.gla.ac.uk/~johnson

April 2001.

NPG. 8621.1

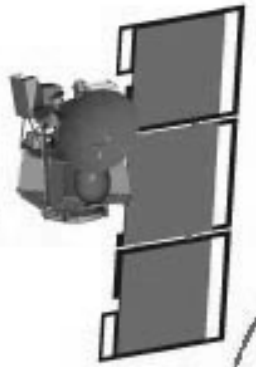

Barrier Analysis
ECF Charts
Evidence...
Causal Factors
Tier Analysis
Root Causes
Causal Factor Analysis
Investigation
Recommendation
Evidence...
Change Analysis
ECF Charts
Causal Factors
Conformance Analysis
Root Causes

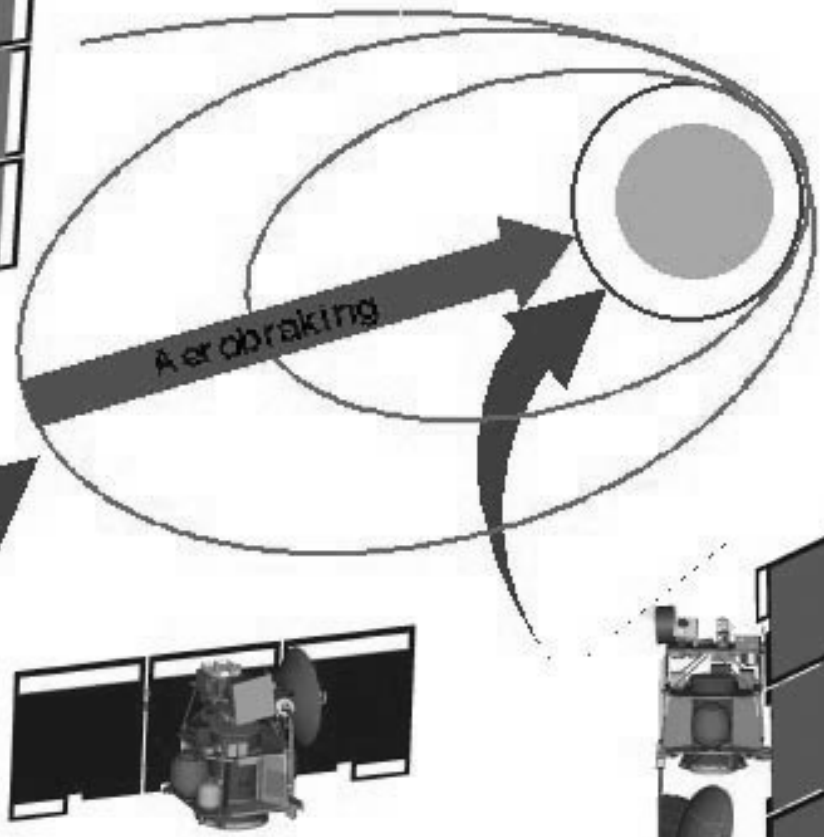

C17 28 PAD SFTY

Orbiter Mission Overview

Cruise

- Reaction Wheel Attitude Control
- 4 TCMs
- 10 Month Cruise





Launch

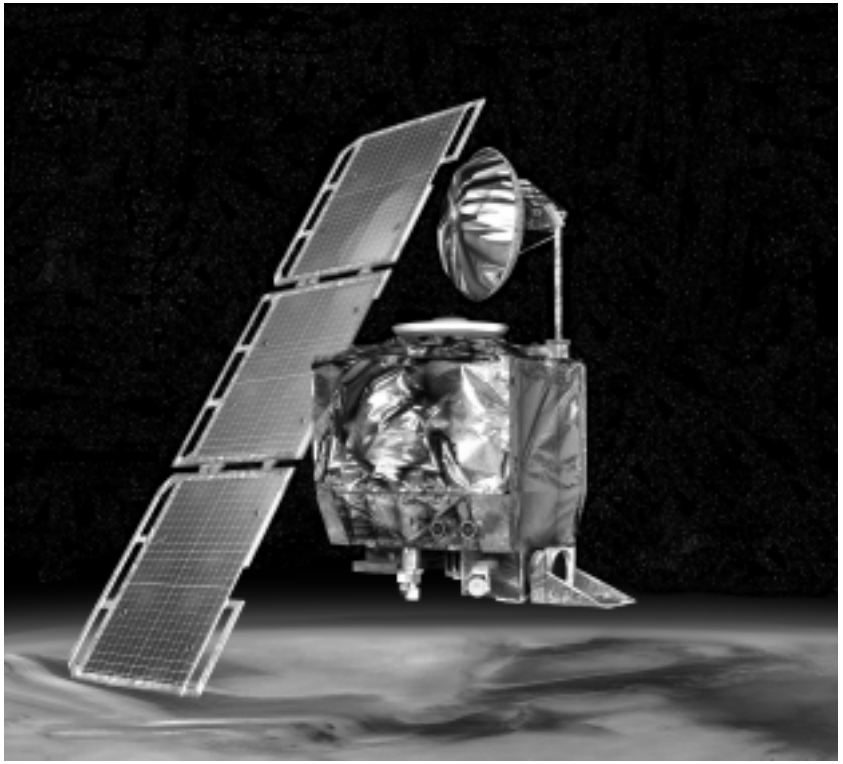
- Delta 7425
- December 10-23 Launch Period
- 643 kg Max Launch Mass

MOI & Aerobraking

- BiProp MOI
- Accelerated Aerobraking
- On Orbit to Support Lander Sol-0

Mapping

- 2 Year Mapping
- PMIRR & MARCI Science
- '98 & '01 Lander Relay

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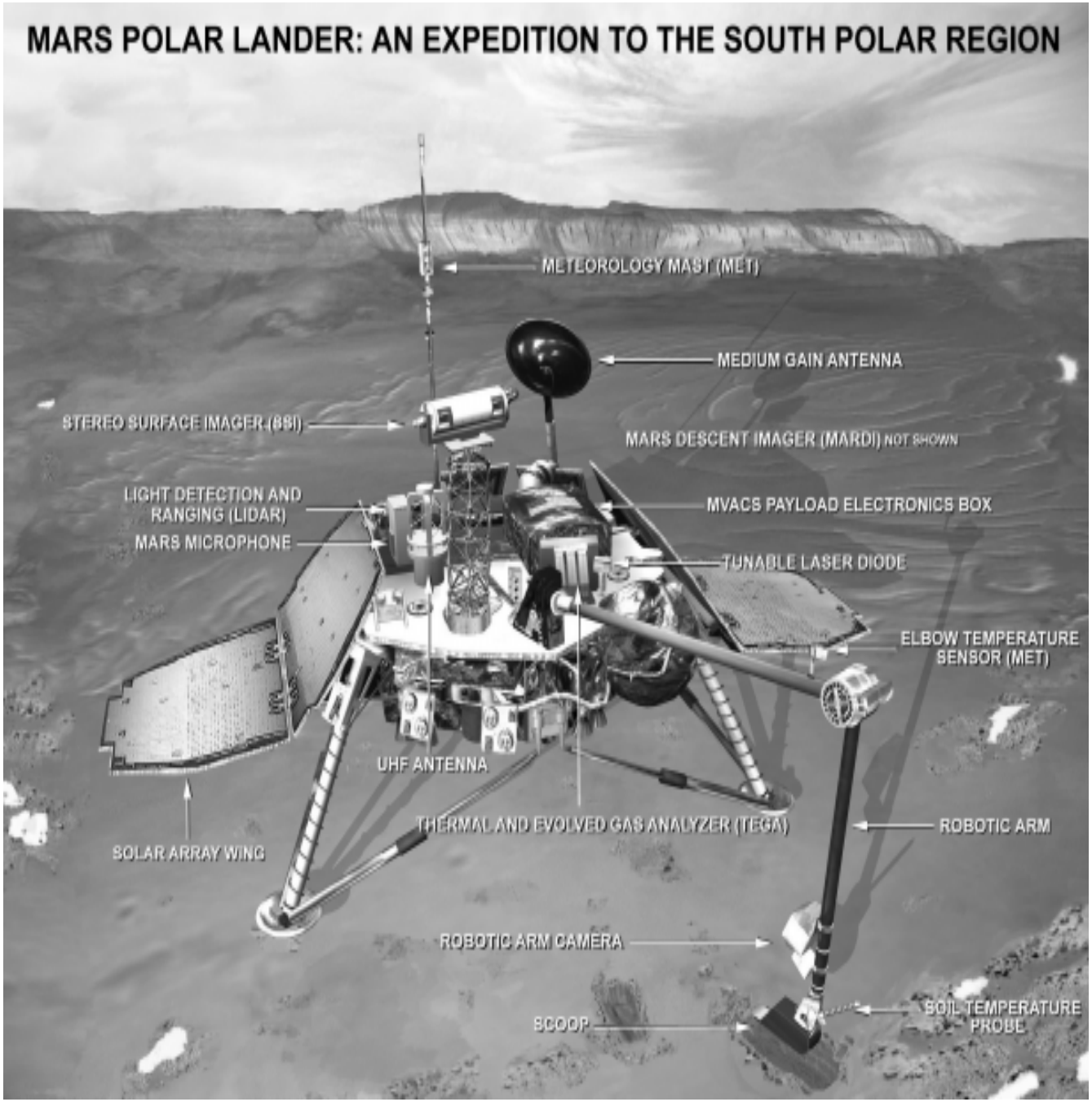
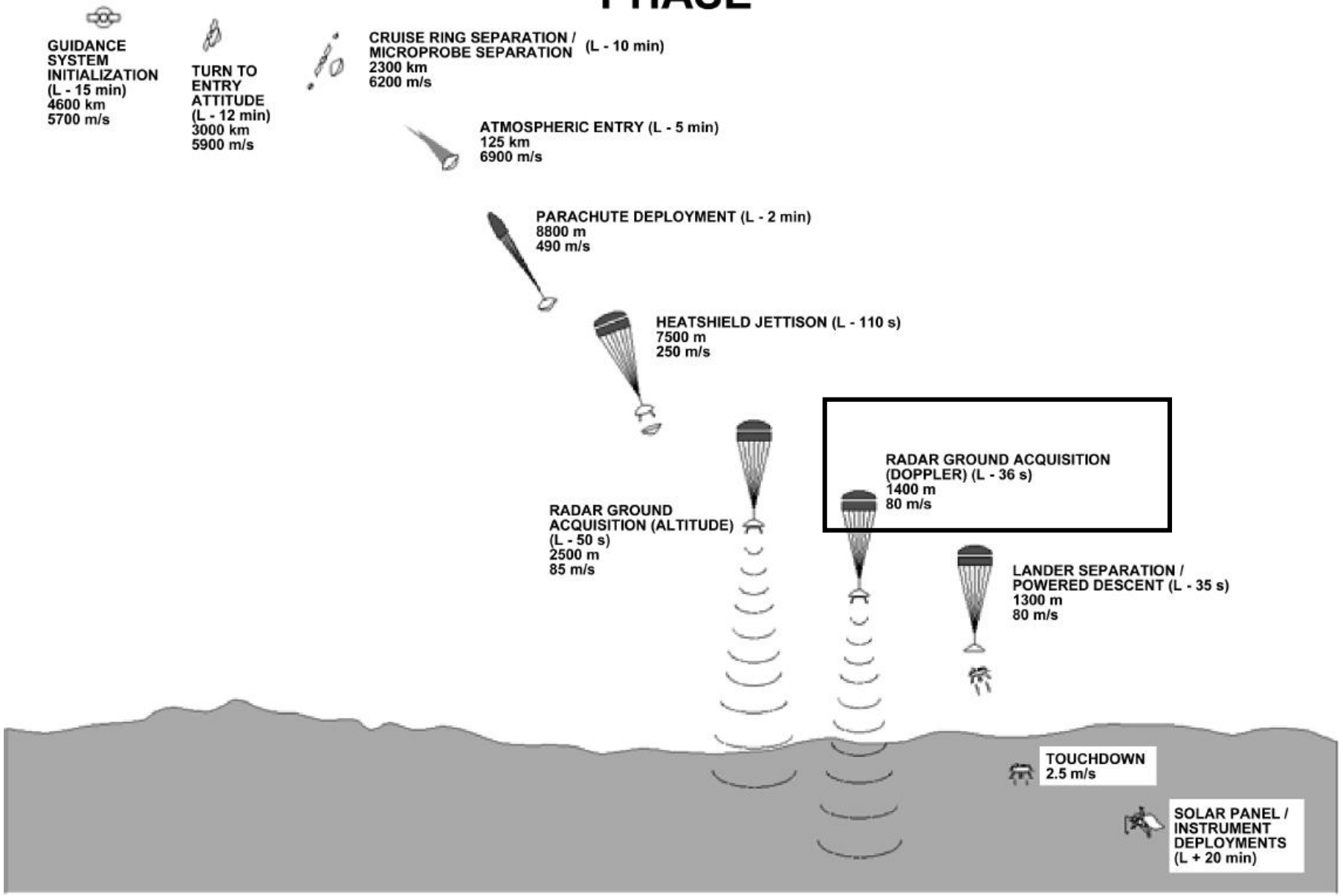

MARS POLAR LANDER: AN EXPEDITION TO THE SOUTH POLAR REGION
METEOROLOGY MAST (MET)
MEDIUM GAIN ANTENNA
STEREO SURFACE IMAGER (SSI)
MARS DESCENT IMAGER (MARDI) NOT SHOWN
LIGHT DETECTION AND RANGING (LIDAR)
MVACS PAYLOAD ELECTRONICS BOX
MARS MICROPHONE
TUNABLE LASER DIODE
ELBOW TEMPERATURE SENSOR (MET)
UHF ANTENNA
THERMAL AND EVOLVED GAS ANALYZER (TEGA)
ROBOTIC ARM
SOLAR ARRAY WING
ROBOTIC ARM CAMERA
SOIL TEMPERATURE PROBE
SCOOP

Mars Surveyor '98

JPL

ENTRY, DESCENT, AND LANDING PHASE



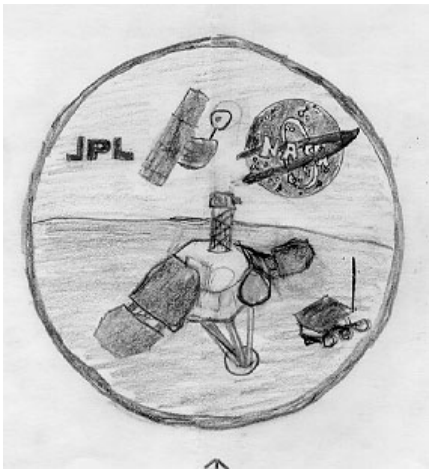
``I told them that in my effort to empower people, I pushed too hard... and in so doing, stretched the system too thin. It wasn't intentional. It wasn't malicious. I believed in the vision... but it may have made failure inevitable. I wanted to demonstrate to the world that we could do things much better than anyone else. And you delivered -- you delivered with Mars Pathfinder... With Mars Global Surveyor... With Deep Space 1. We pushed the boundaries like never before... and had not yet reached what we thought was the limit.

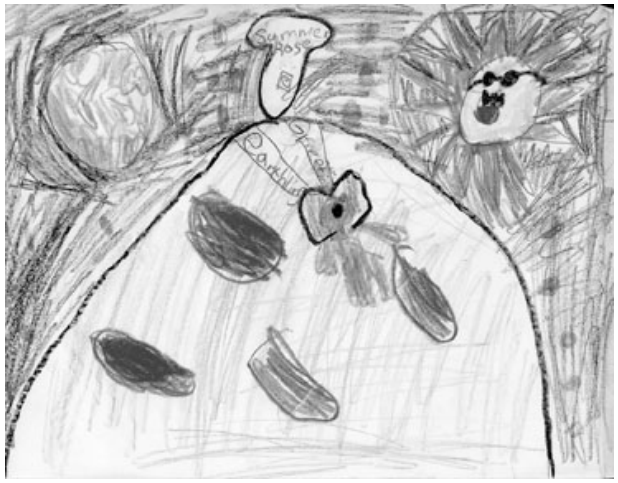
Not until Mars 98.

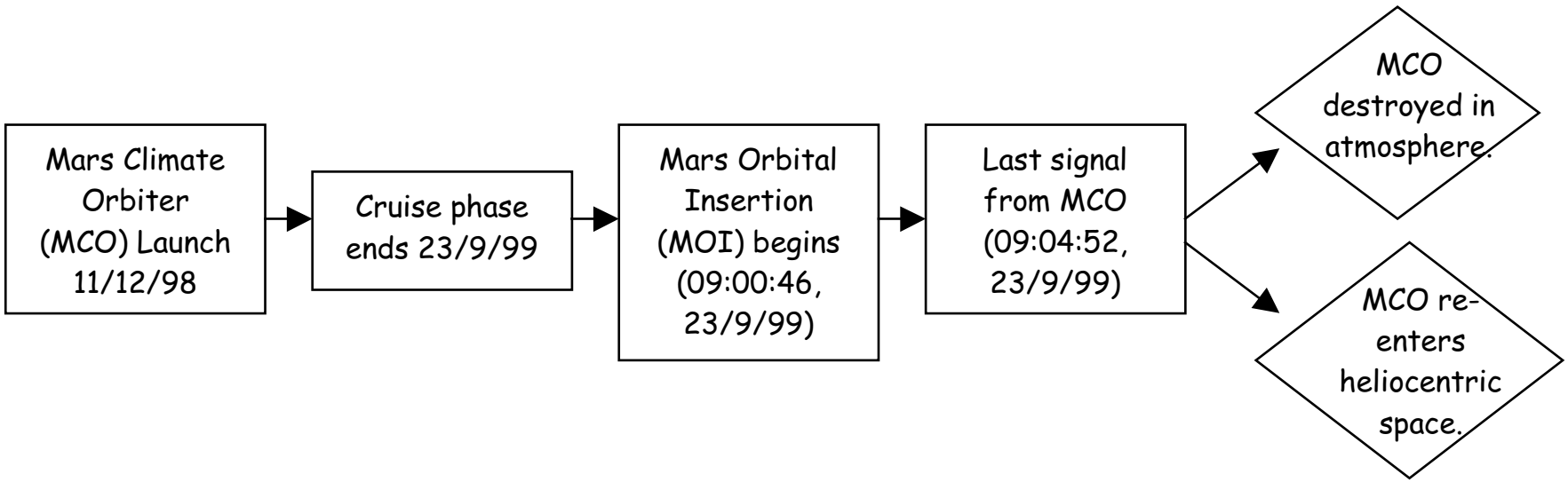
I salute that team's courage and conviction. And make no mistake: they need not apologize to anyone. They did not fail alone. As the head of NASA, I accept the responsibility.

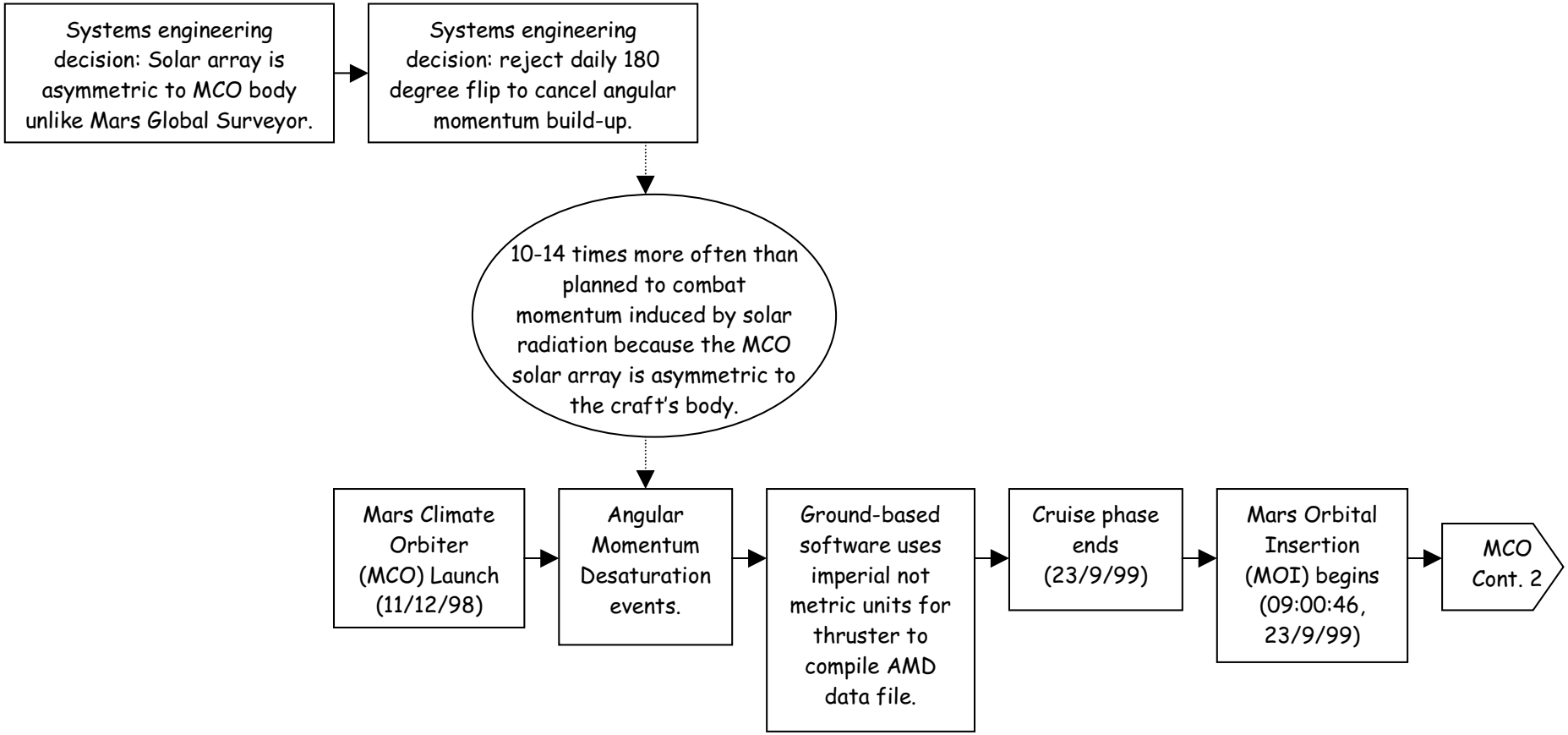
If anything, the system failed them.''

The Mars Climate Orbiter



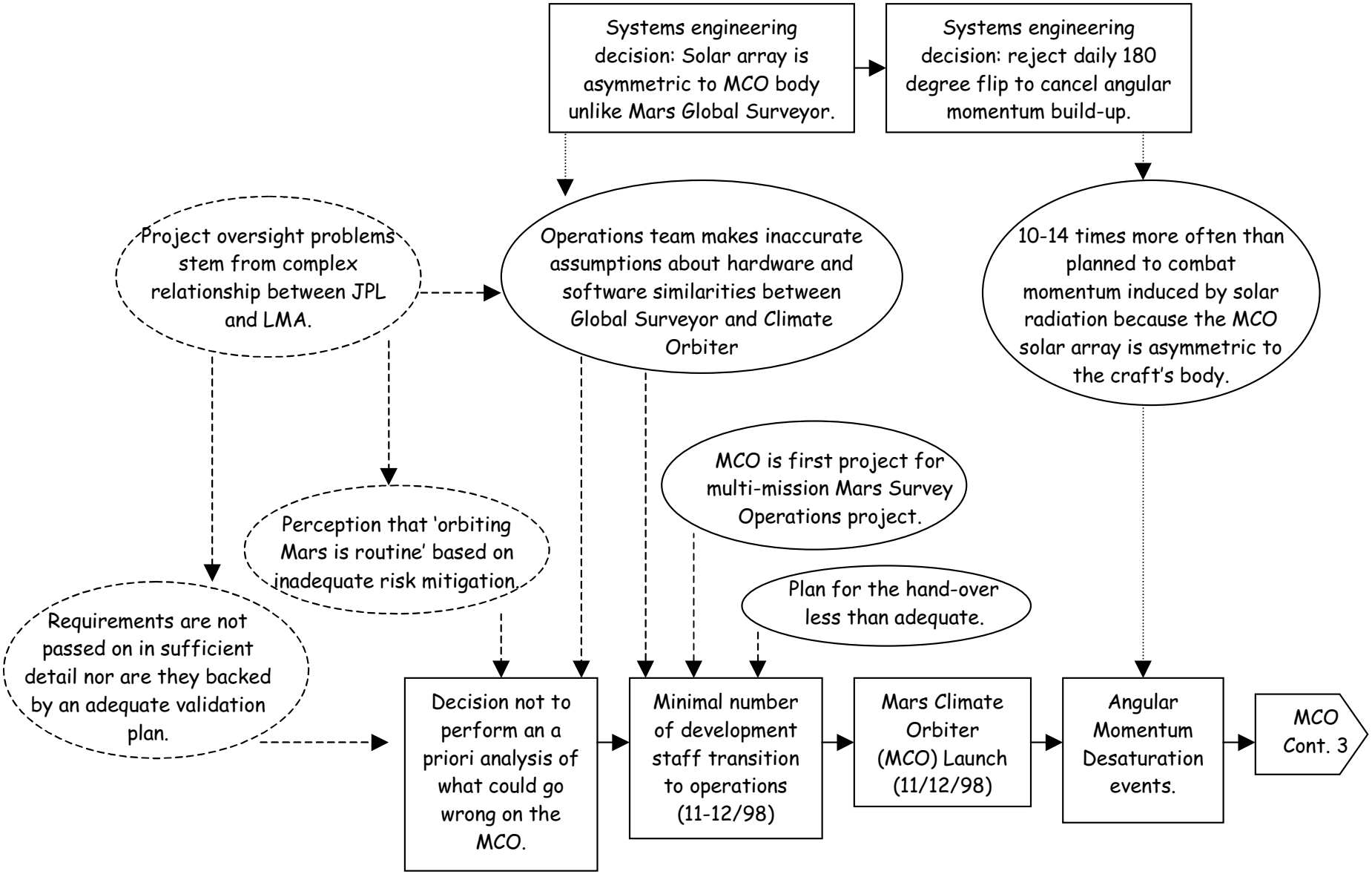



Mars Climate Orbiter (MCO) Launch 11/12/98
Cruise phase ends 23/9/99
Mars Orbital Insertion (MOI) begins (09:00:46, 23/9/99)
Last signal from MCO (09:04:52, 23/9/99)
MCO destroyed in atmosphere.
MCO re-enters heliocentric space.


Systems engineering decision: Solar array is asymmetric to MCO body unlike Mars Global Surveyor.
Systems engineering decision: reject daily 180 degree flip to cancel angular momentum build-up.
10-14 times more often than planned to combat momentum induced by solar radiation because the MCO solar array is asymmetric to the craft's body.
Mars Climate Orbiter (MCO) Launch (11/12/98)
Angular Momentum Desaturation events.
Ground-based software uses imperial not metric units for thruster to compile AMD data file.
Cruise phase ends (23/9/99)
Mars Orbital Insertion (MOI) begins (09:00:46, 23/9/99)
MCO Cont. 2

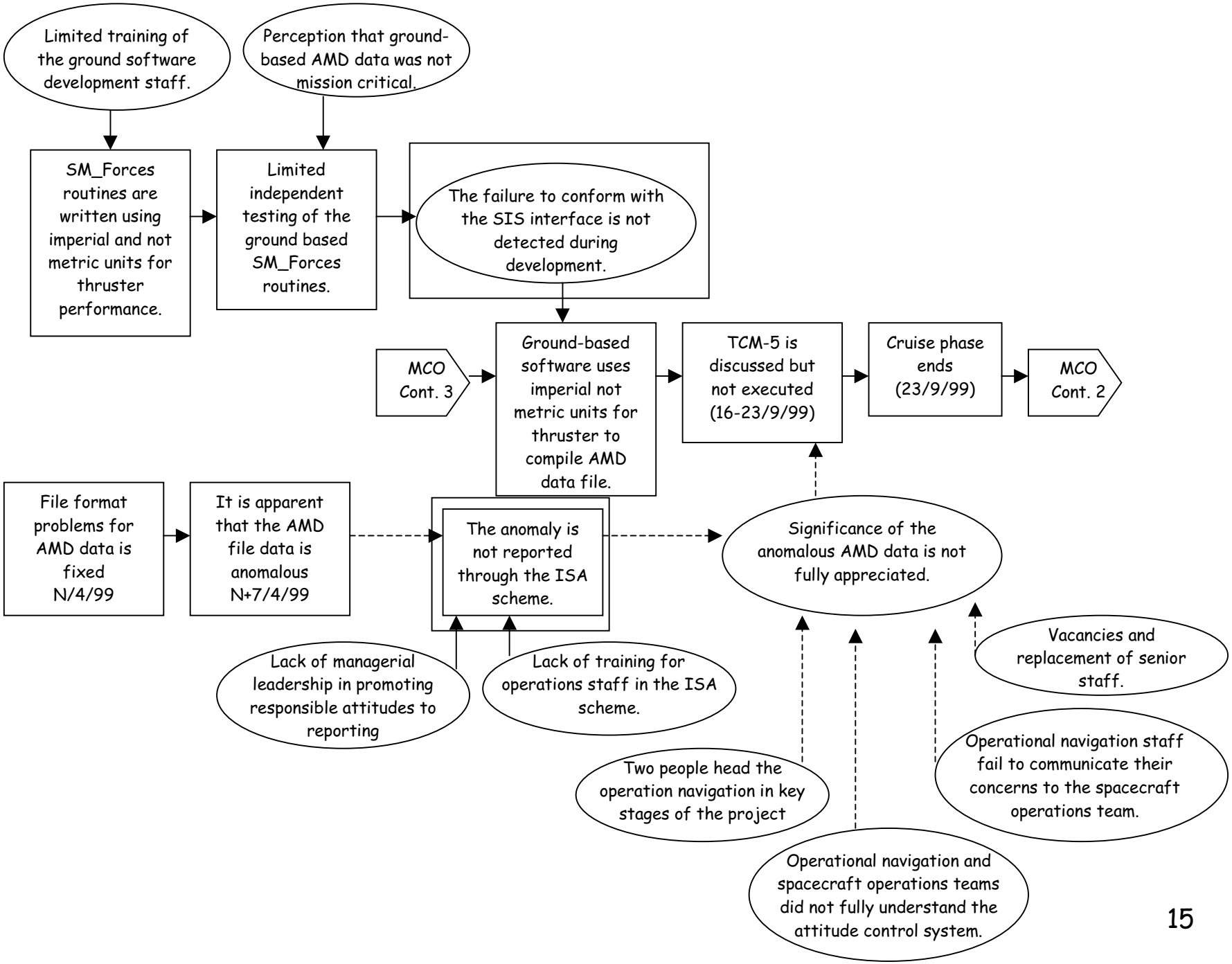
Barrier Analysis

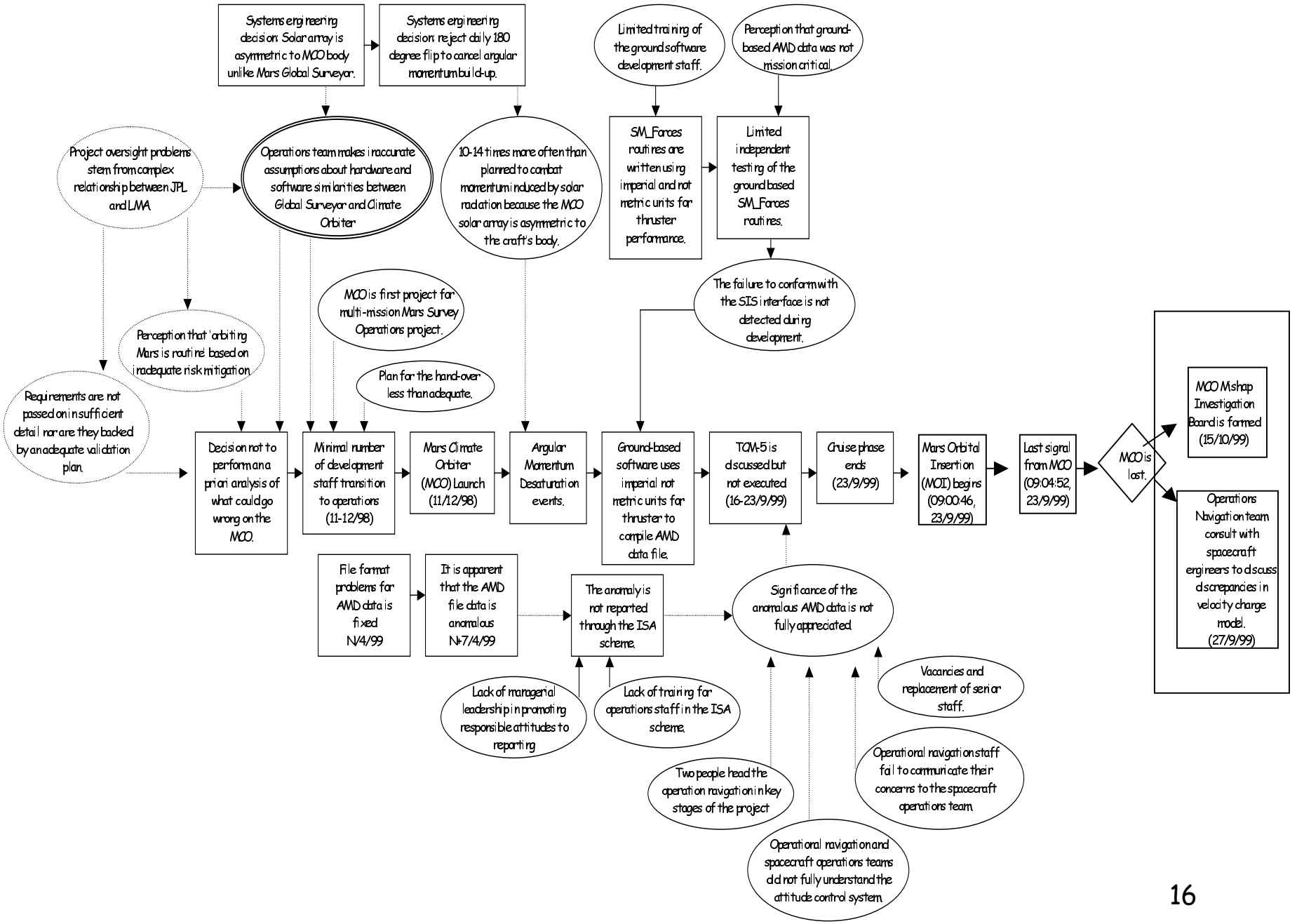
Barrier	Reason for failure?
People	Lack of staff
	Changes in management
	Inadequate training/skills
	Poor communication
Process	Separation of development and operations teams.
	No systematic hazard analysis.
	Inadequate testing.
	Lack of oversight.
Technology	Incorrect trajectory modelling.
	Tracking problems.
	Rejection of barbecue mode.
	Rejection of TCM-5.


Systems engineering decision: Solar array is asymmetric to MCO body unlike Mars Global Surveyor.
Systems engineering decision: reject daily 180 degree flip to cancel angular momentum build-up.
Project oversight problems stem from complex relationship between JPL and LMA.
Operations team makes inaccurate assumptions about hardware and software similarities between Global Surveyor and Climate Orbiter
10-14 times more often than planned to combat momentum induced by solar radiation because the MCO solar array is asymmetric to the craft's body.
MCO is first project for multi-mission Mars Survey Operations project.
Perception that 'orbiting Mars is routine' based on inadequate risk mitigation.
Plan for the hand-over less than adequate.
Requirements are not passed on in sufficient detail nor are they backed by an adequate validation plan.
Decision not to perform an a priori analysis of what could go wrong on the MCO.
Minimal number of development staff transition to operations (11-12/98)
Mars Climate Orbiter (MCO) Launch (11/12/98)
Angular Momentum Desaturation events.
MCO Cont. 3

Barrier Analysis

Barrier	Reason for failure?
Software Interface Specification	No software audit to ensure SIS conformance.
	Poor navigation-spacecraft communication.
	Inadequate training on the importance of SIS
Software testing and validation	Unclear if independent tests were conducted.
	Failure to recognise mission critical software.
	Poor understanding of interface issues.
Incident reporting systems	Team members did not use ISA scheme.
	Leaders failed to encourage reporting.
	Discipline experts not consulted.


Limited training of the ground software development staff.
Perception that ground-based AMD data was not mission critical.
SM_Forces routines are written using imperial and not metric units for thruster performance.
Limited independent testing of the ground based SM_Forces routines.
The failure to conform with the SIS interface is not detected during development.
MCO Cont. 3
Ground-based software uses imperial not metric units for thruster to compile AMD data file.
TCM-5 is discussed but not executed (16-23/9/99)
Cruise phase ends (23/9/99)
MCO Cont. 2
File format problems for AMD data is fixed N/4/99
It is apparent that the AMD file data is anomalous N+7/4/99
The anomaly is not reported through the ISA scheme.
Significance of the anomalous AMD data is not fully appreciated.
Lack of managerial leadership in promoting responsible attitudes to reporting
Lack of training for operations staff in the ISA scheme.
Vacancies and replacement of senior staff.
Operational navigation staff fail to communicate their concerns to the spacecraft operations team.
Two people head the operation navigation in key stages of the project
Operational navigation and spacecraft operations teams did not fully understand the attitude control system.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Mars Climate Orbiter (MCO) Launch (11/12/98)
Angular Momentum Desaturation events.
Ground-based software uses imperial not metric units for thruster to compile AMD data file.
TCM-5 is discussed but not executed (16-23/9/99)
Cruise phase ends (23/9/99)
Mars Orbital Insertion (MOI) begins (09:00:46, 23/9/99)
Last signal from MCO (09:04:52, 23/9/99)
MCO is lost.
MCO Mishap Investigation Board is formed (15/10/99)
Operations Navigation team consult with spacecraft engineers to discuss discrepancies in velocity change model. (27/9/99)
File format problems for AMD data is fixed N/4/99
It is apparent that the AMD file data is anomalous N+7/4/99
The anomaly is not reported through the ISA scheme.
Significance of the anomalous AMD data is not fully appreciated.
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Vacancies and replacement of senior staff.
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Operational navigation and spacecraft operations teams did not fully understand the attitude control system.

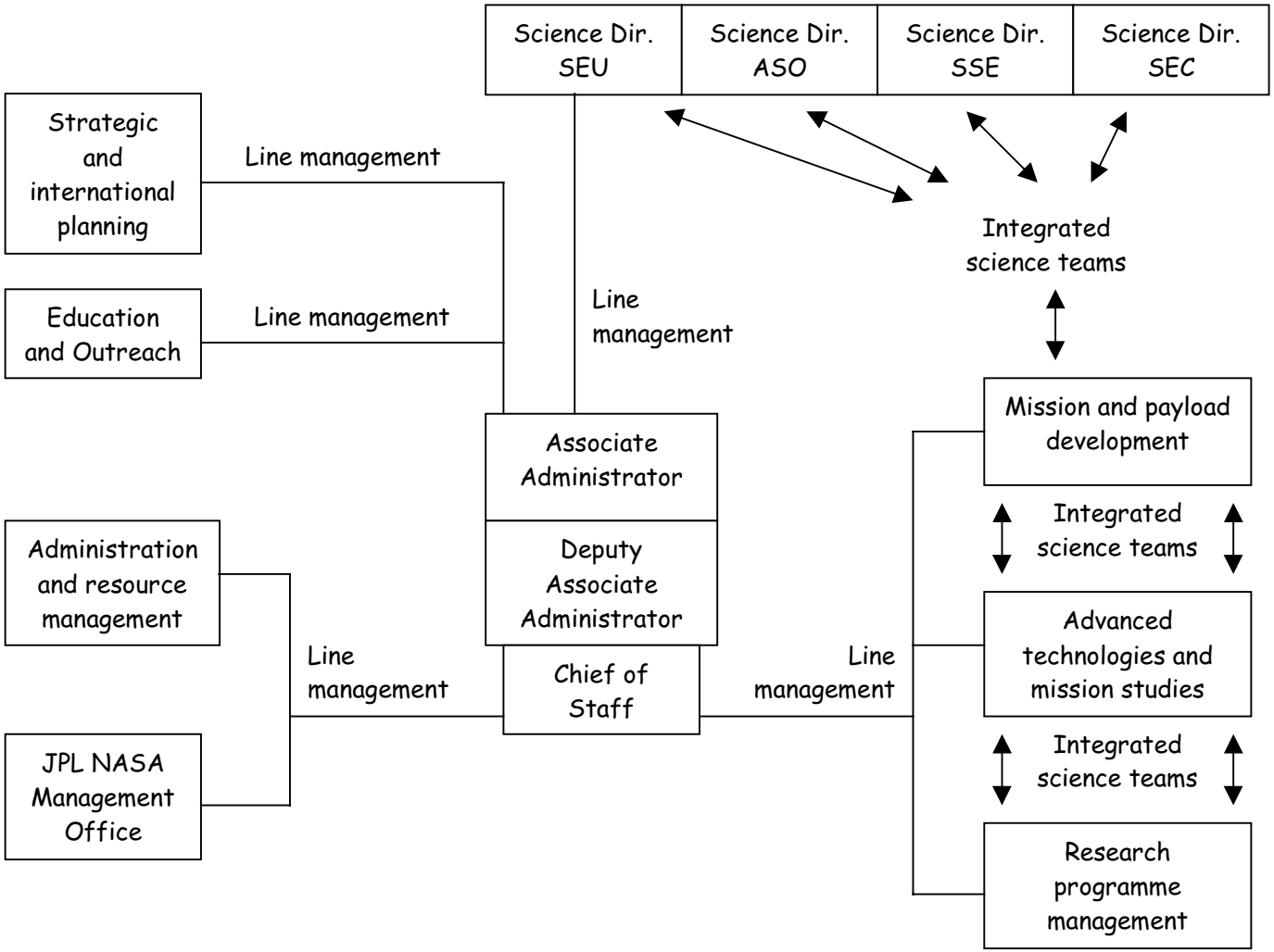
Cause-Context Summary

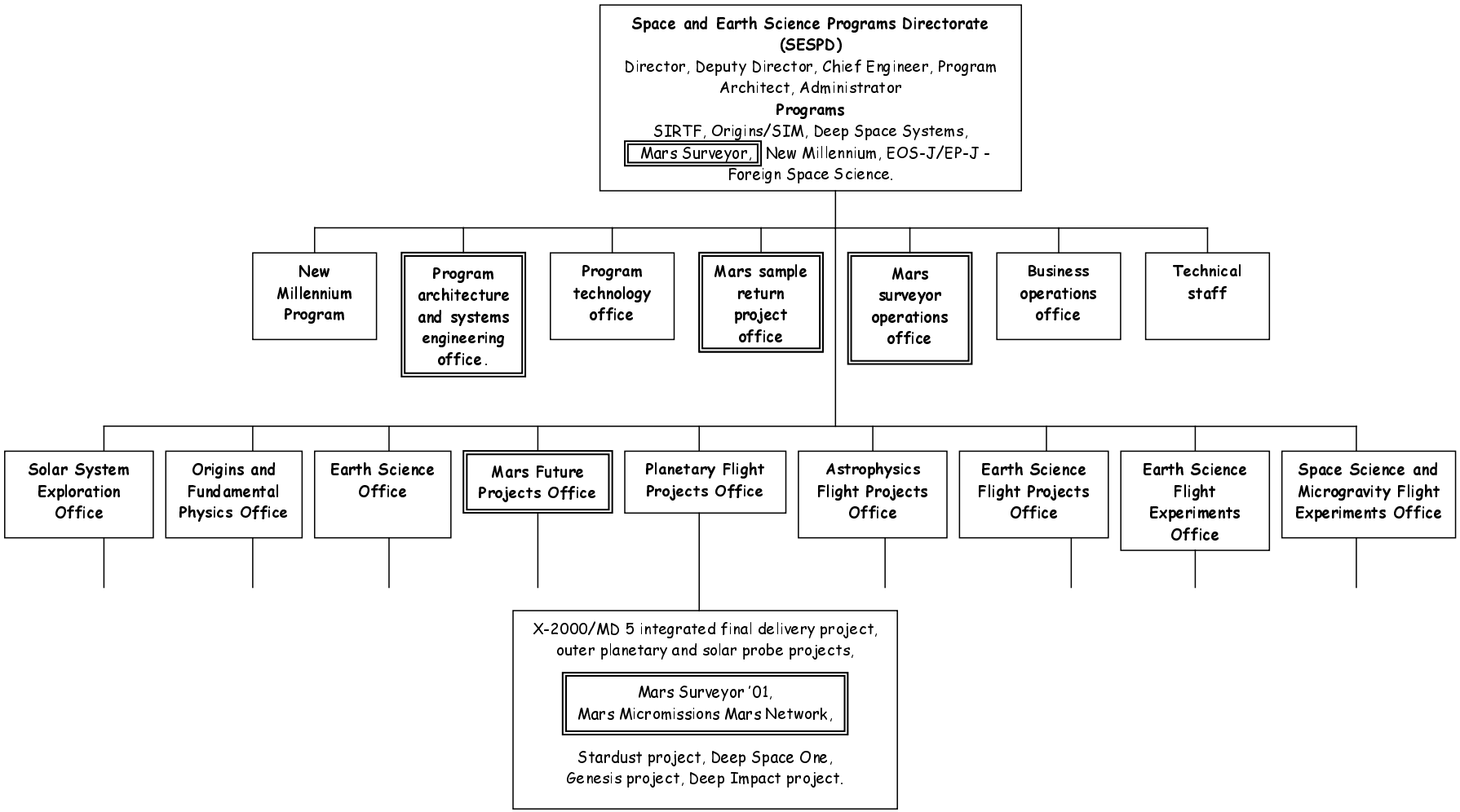
Event	Contextual/ Causal	Justification
MCO Mishap Investigation Board is formed.	Contextual	Post-incident event
Ops Nav. Consult craft engineers to discuss discrepency in velocity change model.	Contextual	Post-incident event
Last signal from MCO	Contextual	The incident would not have happened if this had been avoided.
Mars Orbital Insertion begins	Contextual	Normal or intended behaviour.
Cruise phase ends	Contextual	Normal or intended behaviour.
TCM-5 discussed but not executed	Causal (Barrier)	Subjunctive arguments created by failure of a barrier – would TCM-5 have been executed correctly?
File format anomaly not reported through ISA	Contextual (Barrier)	Would ISA have prevented incident if it had been used? Considered incident would still occur even with report.
AMD data is seen to be anomalous.	Contextual	Non-causal, opportunity to avoid mishap.
AMD file format problem is corrected.	Contextual	Non-causal, opportunity to avoid mishap.

Event	Contextual/ Causal	Justification
Ground software uses Imperial not Metric units for AMD file.	Causal	The incident would not have happened if this had been avoided.
Limited independent test of SM_forces routine.	Causal (Barrier)	Testing likely to have avoided the incident.
SM_forces written using Imperial not Metric units	Causal	The incident would not have happened if this had been avoided.
AMD events	Contextual	Normal or intended behaviour given asymmetrical array.
Decision to reject barbecue mode.	Causal	Incident might not have happened with the barbecue mode but there is a slight doubt about the navigation systems even with this.
Decision to use asymmetrical solar array.	Causal	Global surveyor's symmetrical design avoided some navigation problems.
MCO launch	Contextual	Normal or intended behaviour.
Minimal number of staff transition from development to operations.	Causal (Barrier)	The incident would not have happened if more staff transitioned.
Decision not to perform a priori analysis of MCO failure modes.	Causal (Barrier)	The incident would not have happened if this had been avoided (debatable).

Tier Analysis

Tier	Causal Factors	Cause
5: Senior Management		
4: Middle Management		
3: Lower Management		
2: Supervision		
1: Workers Actions		
0: Direct Cause		


Science Dir. SEU
Science Dir. ASO
Science Dir. SSE
Science Dir. SEC
Strategic and international planning
Line management
Education and Outreach
Line management
Line management
Integrated science teams
Associate Administrator
Deputy Associate Administrator
Chief of Staff
Administration and resource management
JPL NASA Management Office
Line management
Line management
Mission and payload development
Integrated science teams
Advanced technologies and mission studies
Integrated science teams
Research programme management


Space and Earth Science Programs Directorate (SESPD)
Director, Deputy Director, Chief Engineer, Program Architect, Administrator
Programs
SIRTF, Origins/SIM, Deep Space Systems, Mars Surveyor, New Millennium, EOS-J/EP-J - Foreign Space Science.
New Millennium Program
Program architecture and systems engineering office.
Program technology office
Mars sample return project office
Mars surveyor operations office
Business operations office
Technical staff
Solar System Exploration Office
Origins and Fundamental Physics Office
Earth Science Office
Mars Future Projects Office
Planetary Flight Projects Office
Astrophysics Flight Projects Office
Earth Science Flight Projects Office
Earth Science Flight Experiments Office
Space Science and Microgravity Flight Experiments Office
X-2000/MD 5 integrated final delivery project, outer planetary and solar probe projects,
Mars Surveyor '01, Mars Micromissions Mars Network,
Stardust project, Deep Space One, Genesis project, Deep Impact project.

Organisation: LMA (Contractor)

Tier	Causal Factors	Cause
5: Senior Management	Requirements are not passed on in sufficient detail nor are they backed by an adequate validation plan. Decision not to perform an a prior analysis of what could go wrong on the MCO. Limited independent testing of the ground-based SM_Forces routine.	No documented guidance on the implementation of the Faster, Better, Cheaper strategy prevented managers from resisting pressures to cut costs/schedules that might compromise mission success.
4: Middle Management	Minimal number of development staff transition to operations. SM_Forces routines are written using Imperial and not metric units for thruster performance.	Lack of resources for the Mars Surveyor Program limited the number of staff available and may also have prevented staff from receiving adequate training on critical aspects of the mission.
3: Lower Management	TCM-5 is discussed but not executed.	
2: Supervision		
1: Workers Actions	Decision to reject barbecue manoeuvre. Decision to use asymmetrical solar array.	
0: Direct Cause	Ground-based software uses Imperial and not Metric units for thruster performance in compiling AMD data file.	

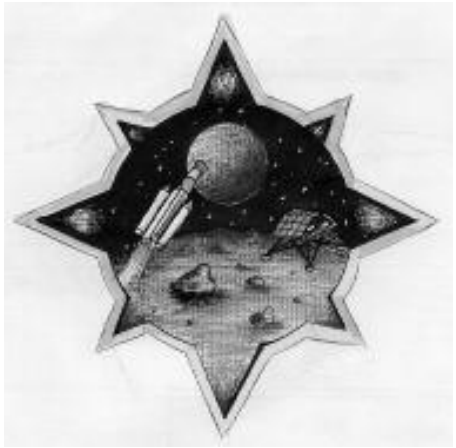
Organisation: JPL

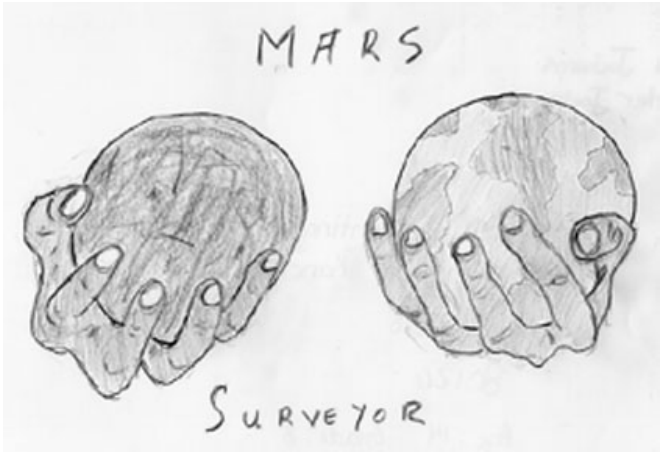
Tier	Causal Factors	Cause
5: Senior Management (JPL Laboratory Director and Mars Program Office Director)	Minimal number of development staff transition to operations. Decision not to perform an a prior analysis of what could go wrong on the MCO. Limited independent testing of the ground-based SM_Forces routine.	Feeling that orbiting Mars is routine. Insular relationship with LMA prevented adequate risk assessment and mitigated against independent reviews.
4: Middle Management (Climate Orbiter Project Manager)	TCM-5 is discussed but not executed.	
3: Lower Management (Flight Operations Manager/Flight Development Manager)	SM_Forces routines are written using Imperial and not metric units for thruster performance. Decision to reject barbecue mode. Decision to use asymmetrical solar array.	

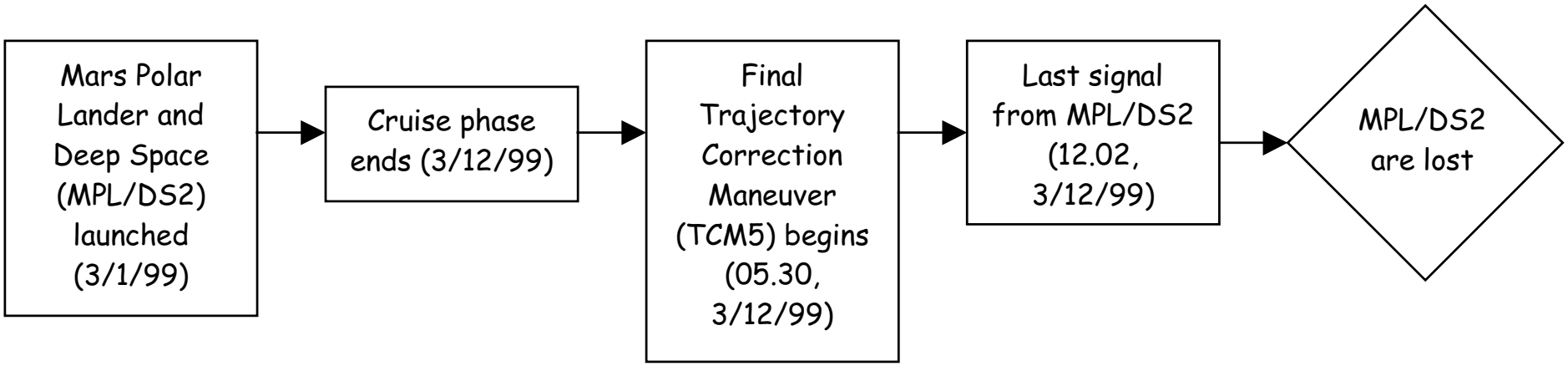
Organisation: NASA Headquarters

Tier	Causal Factors	Cause
5: Senior Management (Science Board of Directors)	Project oversight problems stem from complex relationship between JPL and LMA (and NASA HQ).	Failure to communicate the mission implications of the Faster, Better, Cheaper strategy.
4c: Middle Management (Associate Administrator, Office of Science)		
4b: Middle Management (Science Chief of Staff)	Lack of managerial leadership in promoting responsible attitudes to Incidents, Surprises and Anomaly reporting.	Failure to communicate the importance of expressing concerns both about specific implementation issues as well as resource and management problems.
4a: Middle Management (Advanced Studies Division, Mission Development Division, Research and Program Management Division…)	Requirements are not passed on in sufficient detail nor are they backed by an adequate validation plan.	

The Mars Polar Lander

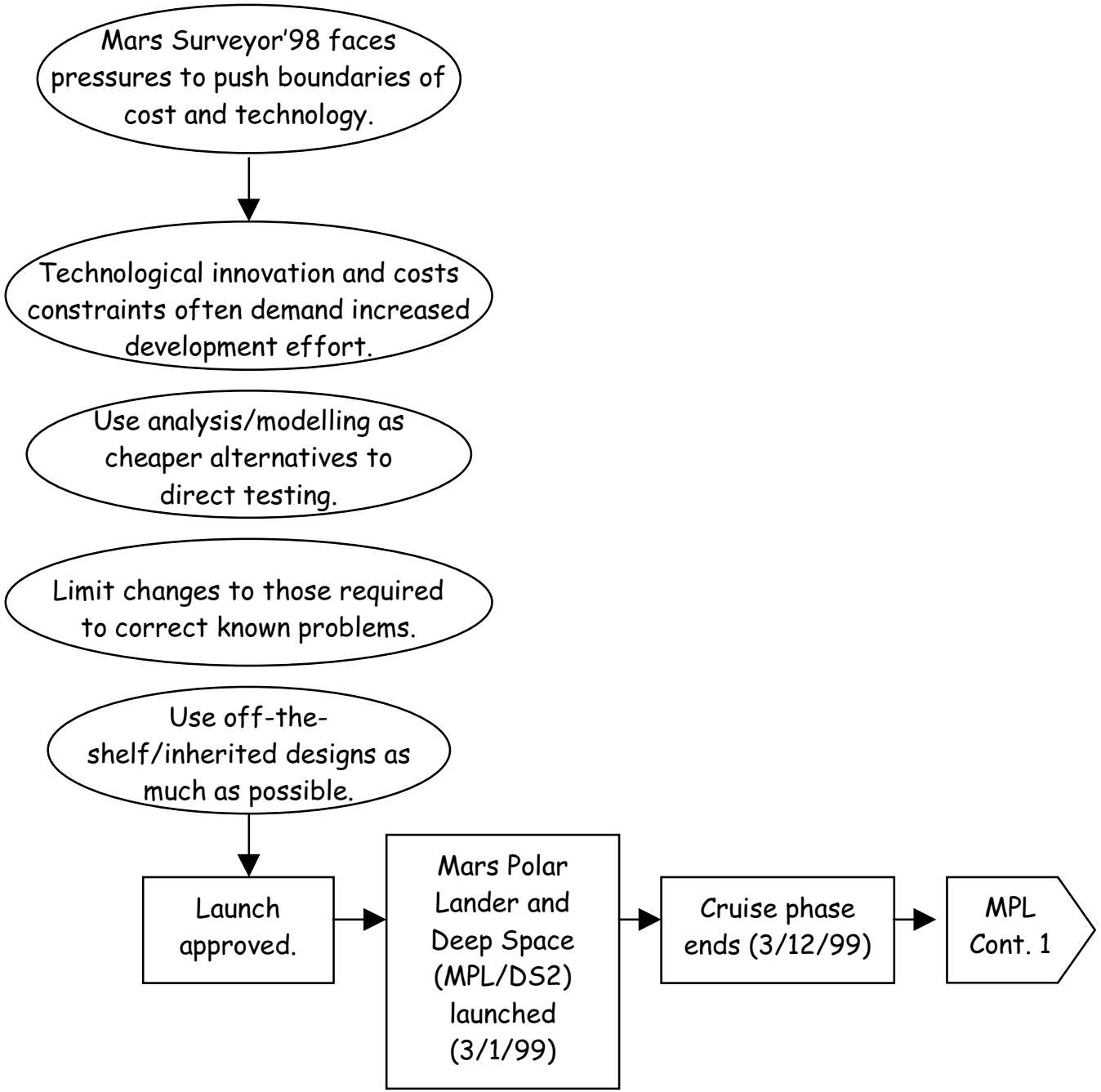





Mars Polar Lander and Deep Space (MPL/DS2) launched (3/1/99)
Cruise phase ends (3/12/99)
Final Trajectory Correction Maneuver (TCM5) begins (05.30, 3/12/99)
Last signal from MPL/DS2 (12.02, 3/12/99)
MPL/DS2 are lost

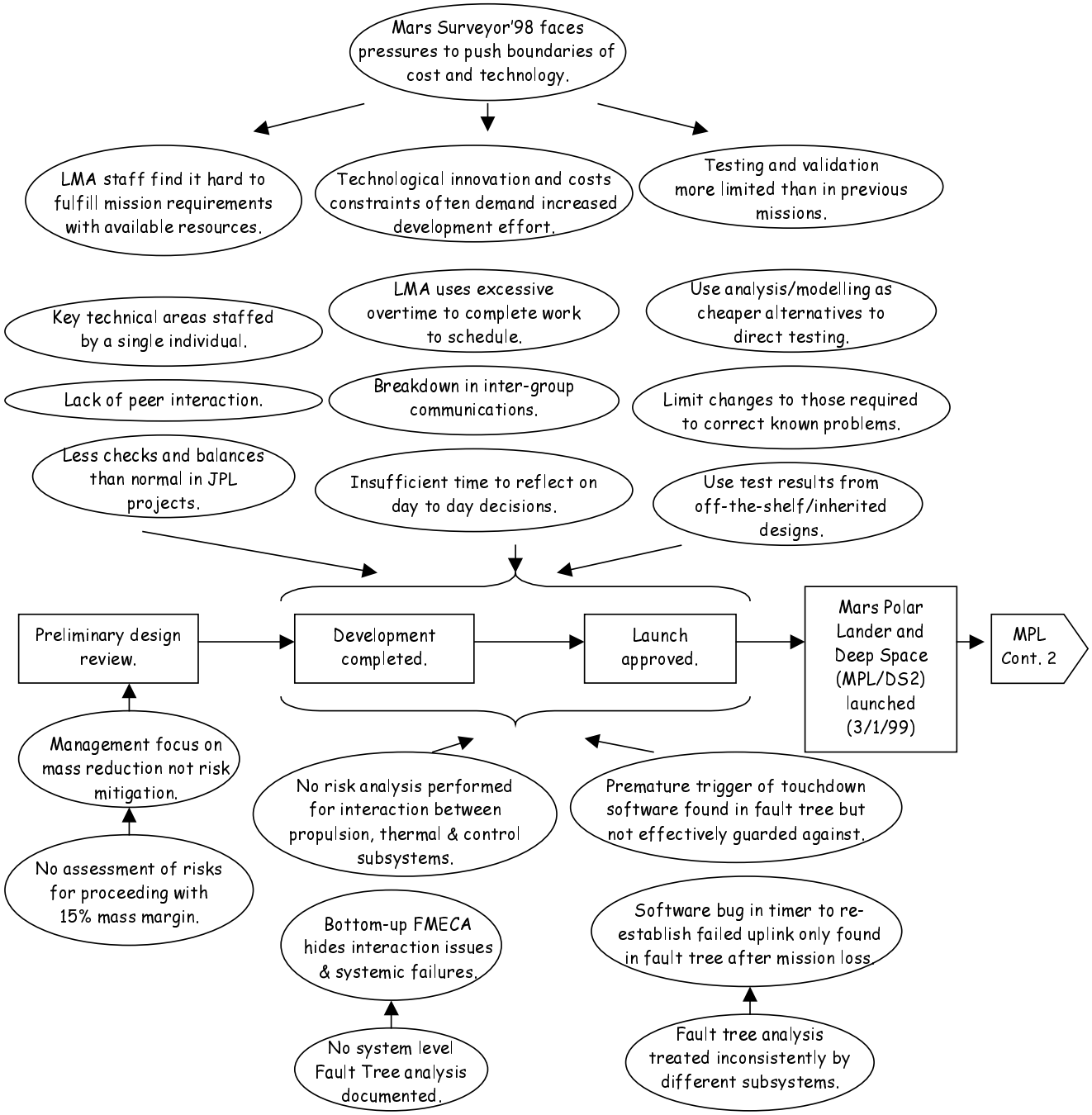
Change Analysis

Prior/Ideal Condition	Present Condition	Effect of change
Faster, better, cheaper strategy required sufficient investment to validate high-risk technologies before launch.	Mars Surveyor'98 faces pressures to push the boundaries of technology and cost.	Greater development effort
		Use of off-the-shelf hardware and inherited designs as much as possible.
		Use analysis and modelling as cheaper alternatives to system test and validation.
		Limit changes to those required to correct known problems; resist changes that do not contribute to mission success.


Mars Surveyor'98 faces pressures to push boundaries of cost and technology.
Technological innovation and costs constraints often demand increased development effort.
Use analysis/modelling as cheaper alternatives to direct testing.
Limit changes to those required to correct known problems.
Use off-the-shelf/inherited designs as much as possible.
Launch approved.
Mars Polar Lander and Deep Space (MPL/DS2) launched (3/1/99)
Cruise phase ends (3/12/99)
MPL Cont. 1

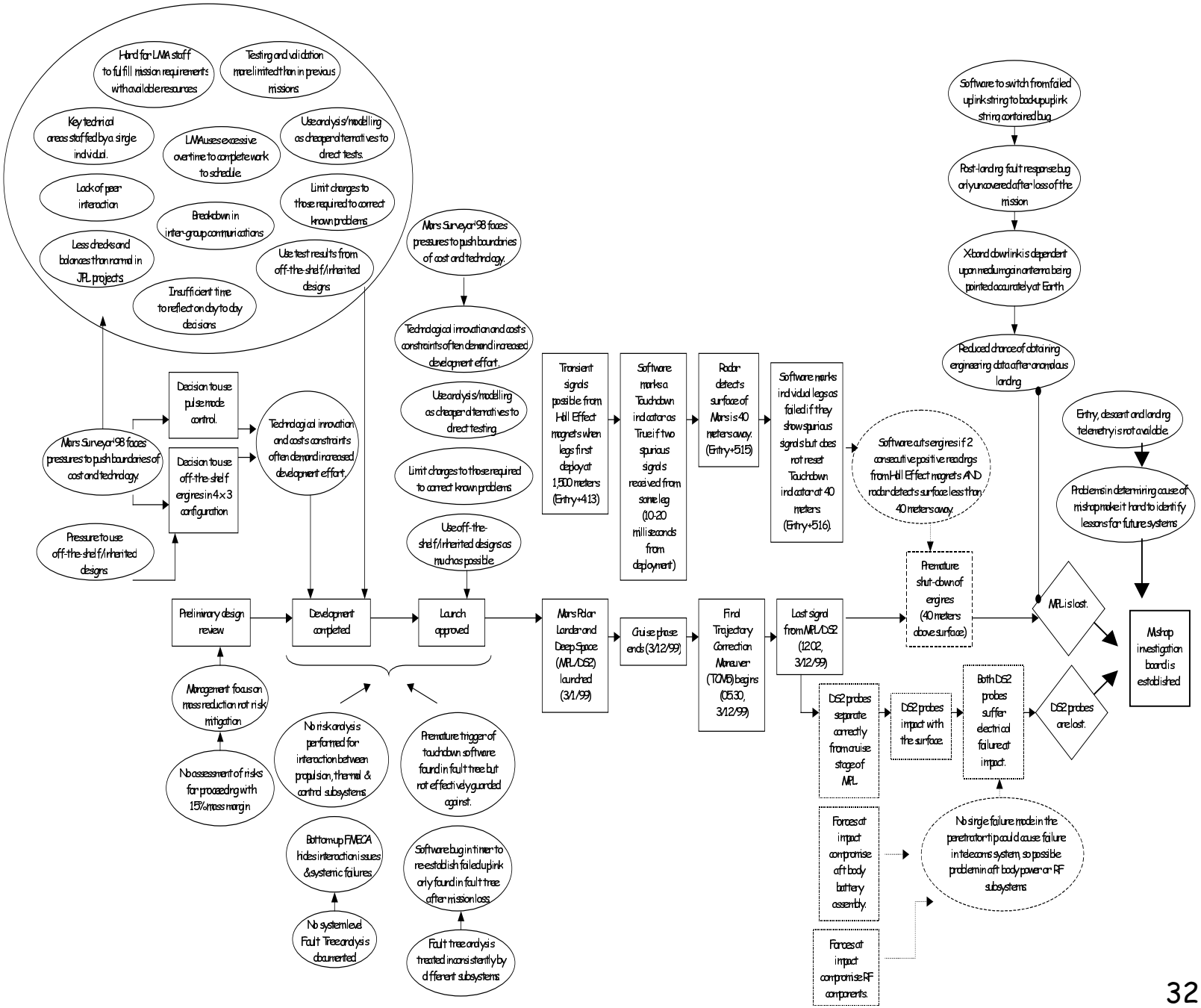
Change Analysis

Prior/Ideal Condition	Present Condition	Effect of change
Adequate risk assessment at system level.	No system level fault tree analysis was formally conducted or documented.	Bottom-up FMECA hides systemic issues and interactions.
		No risk analysis of propulsion, thermal and control system interaction.
Adequate risk assessment at subsystems level	Fault tree analysis treated inconsistently for different subsystems.	Bug in time up-link loss routines not found until after the failure.
		Premature trigger of touchdown sensor found in FT before EDL but not guarded against!!
Project management maintains explicit risk signature for the project.	No risk assessment for going beyond Prelim. Design review with 15% mass threshold.	Management focus on mass reduction not on risk reduction.


Mars Surveyor'98 faces pressures to push boundaries of cost and technology.
LMA staff find it hard to fulfill mission requirements with available resources.
Technological innovation and costs constraints often demand increased development effort.
Testing and validation more limited than in previous missions.
Key technical areas staffed by a single individual.
LMA uses excessive overtime to complete work to schedule.
Use analysis/modelling as cheaper alternatives to direct testing.
Lack of peer interaction.
Breakdown in inter-group communications.
Limit changes to those required to correct known problems.
Less checks and balances than normal in JPL projects.
Insufficient time to reflect on day to day decisions.
Use test results from off-the-shelf/inherited designs.
Preliminary design review.
Development completed.
Launch approved.
Mars Polar Lander and Deep Space (MPL/DS2) launched (3/1/99)
MPL Cont. 2
Management focus on mass reduction not risk mitigation.
No assessment of risks for proceeding with 15% mass margin.
No risk analysis performed for interaction between propulsion, thermal & control subsystems.
Premature trigger of touchdown software found in fault tree but not effectively guarded against.
Bottom-up FMECA hides interaction issues & systemic failures.
No system level Fault Tree analysis documented.
Software bug in timer to re-establish failed uplink only found in fault tree after mission loss.
Fault tree analysis treated inconsistently by different subsystems.

Change Analysis

Prior/Ideal Condition	Present Condition	Effect of change
Sufficient resources to validate and verify software in landed configuration.	Flight software not subjected to `system level' tests.	Post-landing fault response bugs only uncovered after mission loss.
		Touchdown sensor software untested with lander in flight configuration.
Subsystem preliminary and critical design reviews provide independent evaluation of key decisions.	Contractors lacked necessary input from external sources.	Flight system manager chaired all subsystem reviews.
		LMA staff approve closures on actions without independent technical support.
		Some actions did not adequately address concerns raised by reviews.


Hard for LMA staff to fulfill mission requirements with available resources
Testing and validation more limited than in previous missions
Key technical areas staffed by a single individual.
LMA uses excessive overtime to complete work to schedule.
Use analysis/modelling as cheaper alternatives to direct tests.
Lack of peer interaction
Limit changes to those required to correct known problems
Breakdown in inter-group communications
Less checks and balances than normal in JPL projects.
Use test results from off-the-shelf/inherited designs
Insufficient time to reflect on day to day decisions
Mars Surveyor'98 faces pressures to push boundaries of cost and technology.
Technological innovation and cost constraints often demand increased development effort.
Use analysis/modelling as cheaper alternatives to direct testing
Limit changes to those required to correct known problems
Use off-the-shelf/inherited designs as much as possible
Mars Surveyor'98 faces pressures to push boundaries of cost and technology.
Decision to use pulse mode control.
Decision to use off-the-shelf engines in 4 x 3 configuration
Technological innovation and cost constraints often demand increased development effort.
Pressure to use off-the-shelf/inherited designs
Preliminary design review
Development completed
Launch approved
Management focus on mass reduction not risk mitigation
No assessment of risks for proceeding with 15% mass margin
No risk analysis performed for interaction between propulsion, thermal & control subsystems.
Premature trigger of touchdown software found in fault tree but not effectively guarded against.
Bottom-up FMECA hides interaction issues & systemic failures.
Software bug in timer to re-establish failed uplink only found in fault tree after mission loss.
No system-level Fault Tree analysis documented
Fault tree analysis treated inconsistently by different subsystems
Transient signals possible from Hall Effect magnets when legs first deployed at 1,500 meters (Entry+413)
Software marks a Touchdown indicator as True if two spurious signals received from same leg (10-20 milliseconds from deployment)
Radar detects surface of Mars is 40 meters away. (Entry+515)
Software marks individual legs as failed if they show spurious signals but does not reset Touchdown indicator at 40 meters (Entry+516).
Software cuts engines if 2 consecutive positive readings from Hall Effect magnets AND radar detects surface less than 40 meters away.
Mars Polar Lander and Deep Space (MPL/DS2) launched (3/1/99)
Cruise phase ends (3/12/99)
Final Trajectory Correction Maneuver (TCM5) begins (05:30, 3/12/99)
Last signal from MPL/DS2 (12:02, 3/12/99)
Premature shut-down of engines (40 meters above surface)
DS2 probes separate correctly from cruise stage of MPL
DS2 probes impact with the surface.
Both DS2 probes suffer electrical failure at impact.
DS2 probes are lost.
MPL is lost.
Forces at impact compromise aft body battery assembly.
Forces at impact compromise RF components.
No single failure mode in the penetrator tip could cause failure in telecoms system, so possible problem in aft body power or RF subsystems
Software to switch from failed uplink string to backup uplink string contained bug.
Post-landing fault response bug only uncovered after loss of the mission
X-band downlink is dependent upon medium gain antenna being pointed accurately at Earth
Reduced chance of obtaining engineering data after anomalous landing
Entry, descent and landing telemetry is not available.
Problems in determining cause of mishap make it hard to identify lessons for future systems
Mishap investigation board is established

Cause-Context Summary

Event	Contextual/Causal	Justification
Mishap investigation board is established.	Contextual	Post-incident event
Premature shut-down of engines.	Causal	The incident would not have happened if this had been avoided.
Software marks individual legs as failed if they show spurious signals but does not reset touchdown indicator.	Causal (Barrier)	The incident would not have happened if this had been avoided. This represents a failed barrier because the software does check for spurious signals in individual legs but does not reset the Touchdown indicator.
Radar detects surface of Mars is 40 meters away.	Contextual	Normal or intended behaviour.
Software marks a touchdown indicator as true if two spurious signals received from the same leg.	Contextual	The incident would not have happened if this had been avoided. The software could have disregarded sensor values until some time after leg deployment.
Transient signals possible from Hall Effect magnets when legs first deploy at 1,500 meters.	Causal	The incident would not have happened if this had been avoided.

Cause-Context Summary

Event	Contextual/ Causal	Justification
Last signal from MPL/DS2	Contextual	Normal or intended behaviour.
TCM5 begins	Contextual	Normal or intended behaviour.
Cruise phase ends.	Contextual	Normal or intended behaviour.
MPL/DS2 launch	Contextual	Normal or intended behaviour.
Launch approved	Causal	The incident would not have happened if this had been avoided. Could be intended behaviour but launch should not have been approved without more analysis.
Development completed	Contextual	Normal or intended behaviour.
Preliminary design review is passed.	Causal	Could be normal behaviour but passing PDR without further risk management was causal
Decision to use pulse-mode control,	Contextual	Added complexity to development process.
Decision to use off-the-shelf engines in a 4x3 configuration.	Contextual	Added complexity to development process.

Non-Compliance Analysis

Don't Know	
Never knew	Poor training or a failure to disseminate regulations to the appropriate recipients.
Forgot	Individual factors, inadequate reminders or unrealistic assumptions on the part of an organisation about what can be recalled, especially under stress.
Didn't understand	Lack of experience or of guidance in how to apply information that has already been provided.

Can't comply	
Scarce resources	Often used to excuse non-compliance. Investigators must be certain that adequate resources were requested.
Impossible	Organisations may impose contradictory constraints so that it is impossible to satisfy one regulation without breaking another.

Won't comply	
No penalty/no reward	There may be no incentive to comply with a requirement and hence there may be a tendency to ignore it.
Disagree	Individuals and groups may not recognise the importance of a requirement and so may refuse to satisfy it. Local knowledge may suggest that a regulation threatens safety.

1. Both DS2 probes suffer electrical failure at impact

2. Forces at impact compromise aft body battery.

3. Forces at impact compromise RF components

4. Premature Engine Shut-Down 40 m. from surface.

5. Software marks individual legs as failed if they show spurious signals but does not reset touchdown indicator at 40 meters (entry +5:16)

6. Transient signals possible from Hall Effect magnets when legs first deploy at 1,500 meters (Entry +4:13).

7. Launch approved.

8. Preliminary Design Review passed

"Analyses are performed early in the design of radio frequency (RF) hardware to determine hardware imposed limitations which affect radio performance. These limitations include distortion, bandwidth constraints, transfer function non-linearity, non-zero rise and fall transition time, and signal-to-noise ratio (SNR) degradation. The effects of these hardware performance impediments are measured and recorded. Performance evaluation is a reliability concern because RF hardware performance is sensitive to thermal and other environmental conditions, and reliability testing is constrained by RF temperature limitations."

- Preferred Reliability Practice PT-TE-1435 governed the verification of RF hardware within JPL from February 1996.

Non-Compliance Analysis

Causal Factors	Procedures or Regulations	Compliance Failure?
Forces at impact compromise RF components.	Preferred reliability practice PT-TE-1435. Early validation of RF reliability under thermal and other environmental conditions.	Can't comply. RF assembly unavailable for impact testing as design changes delay development.

"The DS2 project thought there was no alternative to accepting the absence of a flight-like RF Subsystem impact test, short of missing the MPL launch opportunity. The rationale for proceeding to launch was presented and accepted at two peer reviews and presented at three project-level reviews: Risk Assessment, Mission Readiness, and Delta Mission Readiness. The project had proceed to launch concurrence from JPL and NASA upper management.''

``NASA currently has a significant infrastructure of processes and requirements in place to enable robust program and project management, beginning with the capstone document: NASA Procedures and Guidelines 7120.5. To illustrate the sheer volume of these processes and requirements, a partial listing is provided in Appendix D. Many of these clearly have a direct bearing on mission success. This Boards review of recent project failures and successes raises questions concerning the implementation and adequacy of existing processes and requirements. If NASAs programs and projects had implemented these processes in a disciplined manner, we might not have had the number of mission failures that have occurred in the recent past.

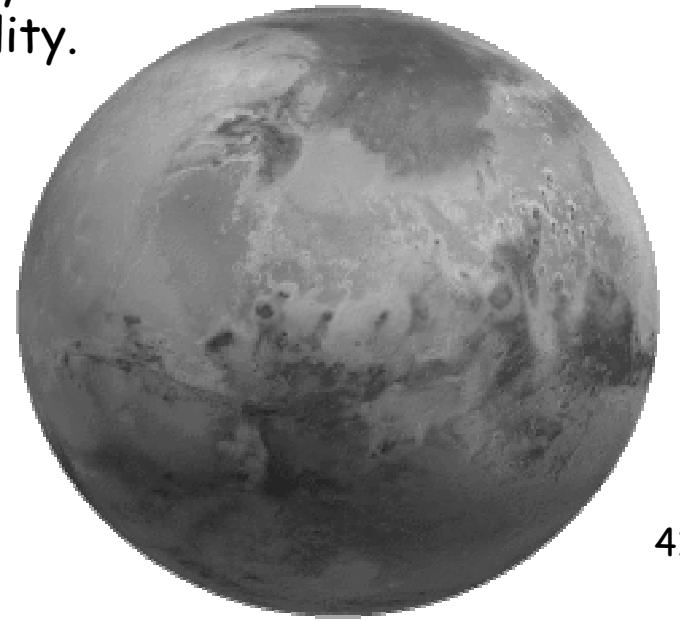
Causal Factors	Procedures or Regulations	Compliance Failure?
Forces at impact compromise RF components.	Preferred reliability practice PT-TE-1435. Early validation of RF reliability under thermal and other environmental conditions.	Can't comply. 1. RF assembly unavailable for impact testing as design changes delay development. 2. Mathematical modelling of high G impacts yields unreliable results. Won't comply. 1. JPL and NASA upper management approve launch without RF impact in order for DS2 to meet launch schedule. 2. RF subsystem components had been structurally tested and were similar to other components used in previous missions.

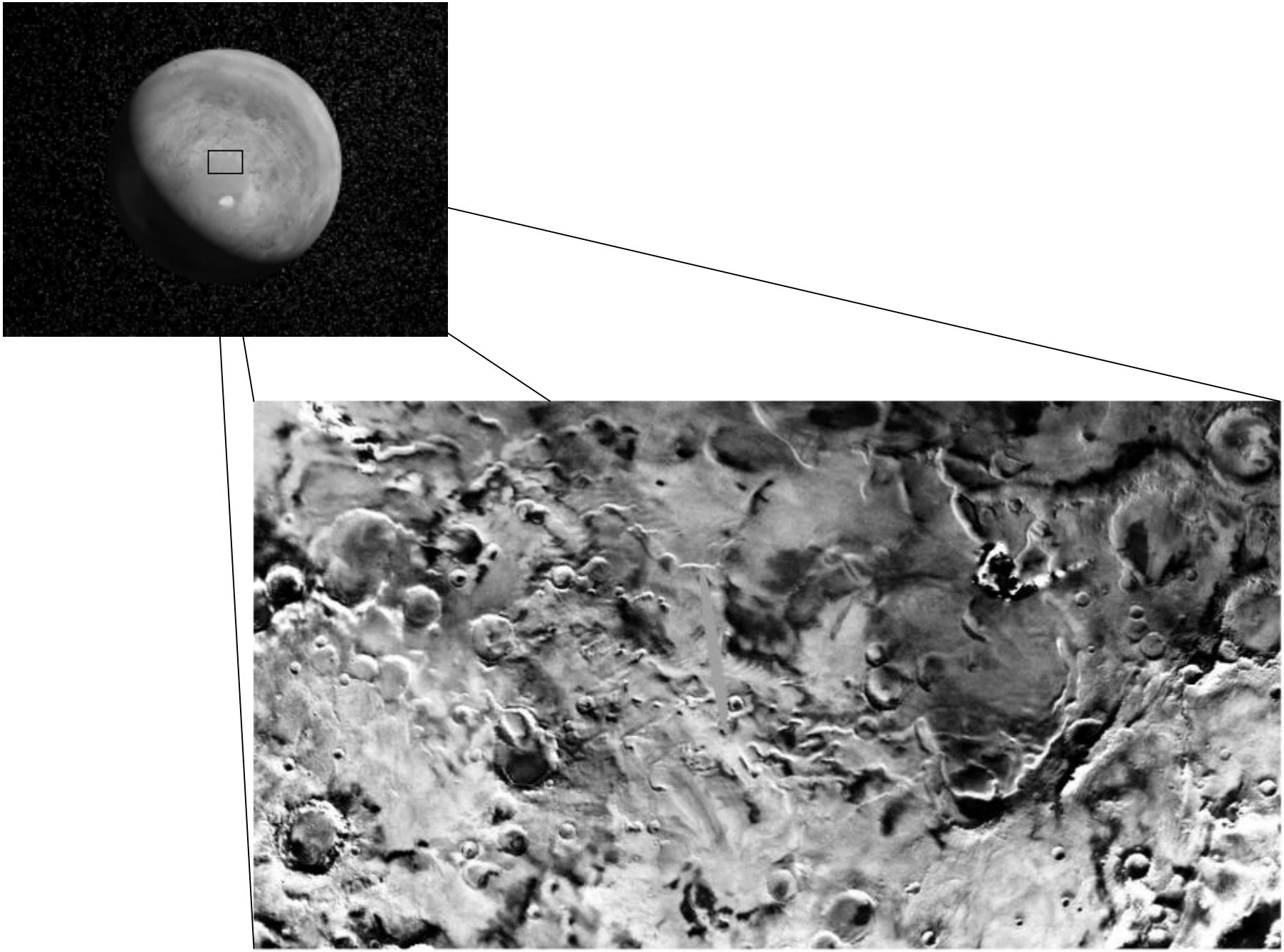
``I told them that in my effort to empower people, I pushed too hard... and in so doing, stretched the system too thin. It wasn't intentional. It wasn't malicious. I believed in the vision... but it may have made failure inevitable. I wanted to demonstrate to the world that we could do things much better than anyone else. And you delivered -- you delivered with Mars Pathfinder... With Mars Global Surveyor... With Deep Space 1. We pushed the boundaries like never before... and had not yet reached what we thought was the limit.

Not until Mars 98.

I salute that team's courage and conviction. And make no mistake: they need not apologize to anyone. They did not fail alone. As the head of NASA, I accept the responsibility.

If anything, the system failed them.''





EXCLUSIVE 19 March 2001 :

Spy Agency May Have Located Mars Polar Lander

According to a source close to the National Imagery and Mapping Agency (NIMA) effort, photographic specialists think they've spotted something...

"If found intact, it would mean that we would have to reexamine our most probable cause of failure...It would also tell me that the 2001 lander that we built and have at the company is perfectly good. We think that anyway…so why not use that asset?"
Noel Hinners, Lockheed Martin Astronautics in Denver, Colorado.

http://www.space.com/news/mpl_found_010319.html

NASA and the National Imagery and Mapping Agency (NIMA) today said researchers from the two agencies will continue a joint review of the initial results of NIMA's search for the missing Mars Polar Lander. This analysis is extremely challenging, and has thus far produced no definitive conclusions.

One of the principal challenges in locating the missing lander using images from the orbiter is that the Mars Polar Lander is only somewhat larger -- about six and a half feet across -- than the smallest objects the orbiter's camera can see on the surface of Mars.

In an initial analysis, NIMA researchers reviewed and assessed features seen in several images that they believe could be indicative of the lander and its protective aeroshell. An alternative view presented by NASA is that these features could be noise introduced by the camera system, so further work between NASA and NIMA will be conducted to address differences of interpretation.

Donald Savage, Headquarters, Washington, DC, March 26, 2001

Jennifer Lafley, National Imagery and Mapping Agency, Bethesda, MD