8 SUMMARY OF POTENTIAL DS2 FAILURE MODES

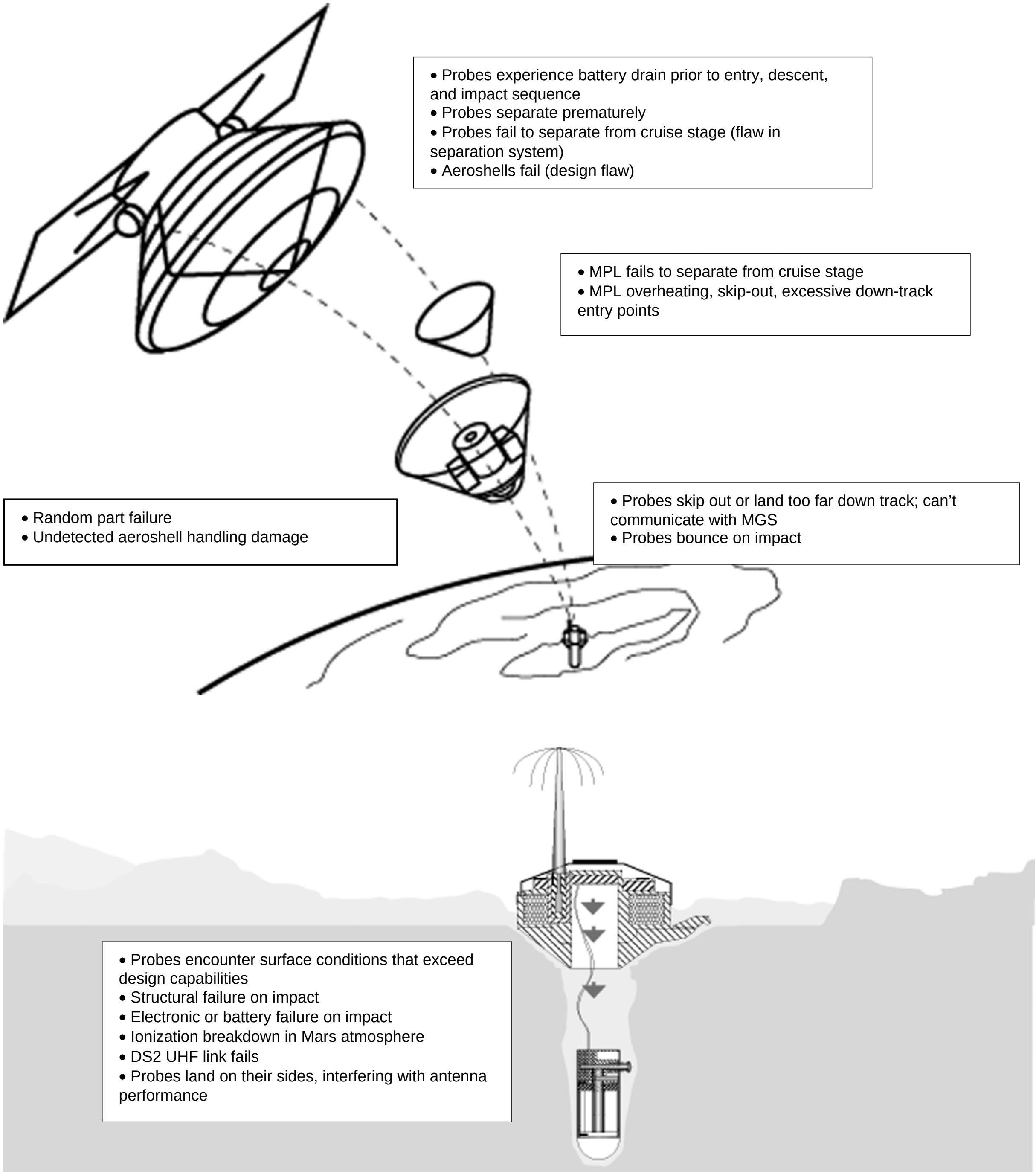
This section provides a summary description of the DS2 potential failure modes considered by the Board. It also provides a high-level assessment of the plausibility of each of the failure modes based on the Board's review of the relevant design, implementation, and test history, and what may be inferred from data obtained throughout the mission operations. References are made to Sections 9, which contains detailed descriptions of the failure modes summarized in this section, along with findings and Lessons Learned.

Failure modes are divided into two groups:

- Failure Modes Affecting Both Probes
- Failure Modes Affecting a Single Probe

The four DS2 potential failure modes identified by the Board as plausible are highlighted as *FLAG 1*, *FLAG 2*, *FLAG 3*, and *FLAG 4*.

Figure 8-1 illustrates the DS2 entry, descent, and impact (EDI) sequence and shows potential failure modes.



- Probes experience battery drain prior to entry, descent, and impact sequence
- Probes separate prematurely
- Probes fail to separate from cruise stage (flaw in separation system)
- Aeroshells fail (design flaw)

- MPL fails to separate from cruise stage
- MPL overheating, skip-out, excessive down-track entry points

- Random part failure
- Undetected aeroshell handling damage

- Probes skip out or land too far down track; can’t communicate with MGS
- Probes bounce on impact

- Probes encounter surface conditions that exceed design capabilities
- Structural failure on impact
- Electronic or battery failure on impact
- Ionization breakdown in Mars atmosphere
- DS2 UHF link fails
- Probes land on their sides, interfering with antenna performance

Figure 8-1. DS2 Entry, Descent, and Impact Sequence with Potential Failure Modes

8.1 DS2 Failure Mode Assessments

8.1.1 Failure Modes Affecting Both Probes

Failure Mode	Assessment
Both probes separate prematurely.	IMPLAUSIBLE. This failure mode is implausible during the launch environment prior to spacecraft separation from the launch vehicle because the probes would have impacted and damaged the cruise stage solar panels. There is no evidence of this in flight. Additionally, no plausible failure mode for premature separation of the probes after spacecraft separation has been identified. See Section 9.2.1.
Both probes experience battery drain prior to EDL due to: —Sneak path electrical transient, e.g., at launch vehicle separation —EMI effect, e.g., from Range or launch vehicle emitted radiation —Plasma discharge, e.g., from pyro firings	PLAUSIBLE BUT UNSUPPORTED. There are several design deficiencies associated with the probe power switch circuit. The most critical of these could result in inadvertent turn-on of the probe and premature battery depletion. Inadvertent probe activation did occur during the final hardware assembly activity but was discovered before significant battery depletion. Several mitigation steps were subsequently implemented to minimize the chance for reoccurrence during processing or after integration with the MPL cruise stage. Although it is believed that these mitigation steps were successful, the actual circuit deficiency could not be corrected. See Section 9.3.
Both probes fail to separate from cruise stage due to systematic flaw in the probe separation system.	IMPLAUSIBLE. Judged not plausible based on a review of the design and test program. See Section 9.2.3.
Aeroshells fail on both probes due to systematic flaw in the aeroshell design.	IMPLAUSIBLE. Judged not plausible based on a review of the design and test program. See Section 9.2.4.
Both probes skip out or land too far down track to be able to communicate with MGS due to atmospheric model errors, e.g., density lower than design range.	IMPLAUSIBLE. The penetrator shape (the critical aerodynamic design factor) was selected to be identical to the Viking and Pathfinder designs to take advantage of these well-established databases. Some updates to the Mars atmosphere database were made based on MGS data, and the modeling approach has been independently verified by LaRC.
FLAG 1 Both probes bounce on impact due to unanticipated surface effects, e.g., lubrication effects of upper layer.	PLAUSIBLE. Probe impact on an ice surface was not a design requirement and not tested during development because this possibility was believed unlikely. This condition still seems unlikely, but cannot be ruled out. As another example, the MGS site survey suggests at least a few centimeters of soft material on top of whatever the underlying material may be. Since this soft material would support only a minimal shear force, it could act as a lubricant that would make penetration of any smooth hard underlying material less likely. See Section 9.1.2.
Both probes suffer structural failure at impact.	PLAUSIBLE BUT UNSUPPORTED. The probe aft-body, without the aeroshell, was empirically designed to withstand the impact tests. Due to lack of a suitable air gun, an impact test of the probe integrated with the aeroshell was never successfully conducted, preventing full characterization of the dynamic interaction between the aeroshell and the aft-body. The probe did survive the impact tests to which it was subjected. See Section 9.2.5.

Failure Mode	Assessment
FLAG 2 Both probes suffer electronic or battery failure at impact.	PLAUSIBLE. The DS2 project implemented a qualification program whose goal was to mitigate the potentially destructive effect of probe impact with the Mars surface. This program concentrated on qualification of the design approach, associated processes, and critical devices using engineering or otherwise representative hardware. Testing was performed on the hardware in an unpowered state with inspection and functional testing (where possible) performed pre- and post-test. Survival of a particular process method or hardware element constituted acceptable qualification. More than 50 impact tests were performed per the above described incremental build–test strategy. It was fundamentally successful as a method for qualifying the design and assembly approaches, but was incomplete with respect to qualifying several of the key subsystems and components. In particular, qualification of the battery and RF system is not considered adequate. There was no system-level impact test of a flight-like RF subsystem. It was qualified, mechanically and structurally, with brassboard and breadboard components in most cases. Many of these components were not electrically functional and, therefore, only limited pre-test and post-test DC continuity checks could be performed. The battery test program was reasonably thorough but also inadequate to assure qualification. During the program, an evolutionary series of failures were experienced as part of the design and development effort. However, it does appear that the incremental build–test effort led to an acceptable final design. The flight battery cell lot was delivered very late and could not be impact tested. Instead, the flight units were qualified by similarity to a preceding lot of identical cells. During qualification of the preceding lot, one of eight cells experienced physical damage but did not fail catastrophically. The small sample size and observed damage lead to a concern that the flight cell lot was not fully qualified. At a higher level, impact qualification of a complete flight-like probe was not attempted due to cost and schedule constraints, and due to the fact that it is technically challenging. Therefore, the impact qualification program is judged successful at verifying the general technology approach but not with respect to the integrated probe design. See Sections 9.2.6 and 9.3.
FLAG 3 Probes fail due to ionization breakdown in Mars atmosphere.	PLAUSIBLE. The DS2 antenna uses umbrella-like whiskers on its end to increase the effective electrical length it to 1/4 wavelength. This type of antenna has a relatively high electric field potential at the end of the sharp antenna tips. The voltage generated at these tips could potentially exceed the ionization breakdown limit for CO_2 in the 6-torr Mars environment. The probe antenna was not tested for this environment. Therefore, it is possible that the antenna could experience breakdown when operated under such conditions. If breakdown did occur, the antenna performance would be degraded such that the uplink margin could be reduced below the threshold for communication. Until a test is performed, this failure mode is considered plausible. See Section 9.3.

Failure Mode	Assessment
DS2 UHF link fails due to: —Beacon on MGS —DS2 transceiver —Incompatible protocol	PLAUSIBLE BUT UNSUPPORTED. Failure of any of the conditions listed would have precluded UHF communications between DS2 and MGS. The MGS to DS2 interface was simulated in a post-launch test with Stanford University in November 1996. Some of the 16 modes were verified during this test. The performance of the DS2 probes' Telecommunications Subsystem was tested in ATLO prior to delivery to KSC, but the probes could not be powered once installed on MPL until they were separated from the MPL cruise stage. A pre-launch test was performed between the flight spare telecommunications hardware and a CNES breadboard that verified the compatibility of the interface. See Section 9.4.1.

8.1.2 Failure Modes Affecting a Single Probe

Failure Mode	Assessment
Random part failure.	PLAUSIBLE BUT UNSUPPORTED. The probe design used commercial parts in the telecom system and in a number of other locations. Despite the lower inherent reliability of such parts, the extremely short probe operational time makes the chance of a random failure relatively small.
Undetected aeroshell handling damage.	PLAUSIBLE BUT UNSUPPORTED. The aeroshell material is extremely sensitive to fracture and even a very small scratch or other mechanical damage could have resulted in fracturing of the aeroshell during the launch environment. The acoustic acceptance test on the flight systems would have dramatically revealed any critical flaw existing in the aeroshell. This problem was well understood by the operations personnel, and, while plausible, is not considered likely given the extreme care in handling during ATLO.
FLAG 4 Probe lands on its side, interfering with antenna performance (e.g., anomalous surface).	PLAUSIBLE. The probe antenna was not designed, tested, or characterized for the condition where it is lying on its side and potentially in contact with the ground. Under such a condition, the radiation pattern would be affected. Therefore, it is possible that the link margin would drop below the threshold for communication.

9 DS2 DISCIPLINE AREA ASSESSMENTS

This section describes the detailed reviews conducted by the Board in specific technical discipline areas. Each of the technical discipline Review Teams focused on a list of postulated failure modes and attempted to ascertain whether or not the failure was plausible, based on precautions taken during the design phase and tests or verifications conducted during system validation.

Each of the following subsections describes the failure mode investigation results within each pertinent technical discipline area.

9.1 DS2 Environment and Impact Site

9.1.1 DS2 Environment and Delivery Corridor

Refer to Section 7.1, MPL Environment and Landing Site, for a description of environment and delivery issues affecting both MPL and DS2.

9.1.2 DS2 Landing Site Unsurvivable

FAILURE MODE DESCRIPTION

The DS2 probes were designed to withstand impact in a wide variety of soil conditions on Mars. However, identified failure modes included impact into an extremely soft surface thick enough to bury a probe and its antenna, or impact on rock or solid ice. Above a certain hardness, the soil behaves like a rock, and could cause a probe to fail if it bounced off the surface and came to rest in an orientation that prevented the probe antenna from communicating with MGS.

The DS2 probes must impact at no more than 30 degrees off the vertical axis to ensure penetration. It is projected that the impact angle resulting from a nominal entry would have been 20 degrees. Therefore, the probes might not be able to penetrate if the slope at point of impact is greater than 10 degrees.

FINDINGS

The DS2 project completed numerous impact tests in homogeneous dirt models, but seems to have conducted only limited testing in multilayered samples. Apart from this specific concern, the program appears to have been quite thorough.

No in-flight verification data from the probes themselves are available with respect to the failure modes. The remote-sensing data from the MGS orbiter indicate that the large-scale (100-meter footprint) slopes are all less than 10 degrees in the DS2 landing ellipse, although this does not preclude the possible existence of steeper locals slopes on the scale of the probes. Other MGS remote-sensing data also indicate that the surface of the landing site is covered with a material that has a low thermal inertia, typically indicative of a loosely packed material. The thickness of this material cannot be definitively ascertained, although the MGS data suggest that it uniformly covers most of the surface to a depth of at least 1 centimeter.

LESSONS LEARNED

The most common conditions to be encountered should be considered for test prior to any planned reflight.

Bibliography

DS2 Environment Specification and Landing Site Description — Sue Smrekar, January 13, 2000 viewgraph presentation to Environment and Landing Site Review Team at JPL, January 24, 2000.

Recommended Environments and Design ranges for the Mars Microprobe — Sue Smrekar and George Powell, Feb. 19, 1997, revised Aug. 12, 1997, Memorandum.

9.2 DS2 Mechanical Systems

This section summarizes the DS2 failure modes examinations and findings of the Mechanical Systems Review Team. The reviews were conducted with the DS2 project and technical staff at JPL on 26 January 2000. Materials handed out at this meeting, as well as other materials gathered via e-mail, are listed in the Bibliography.

9.2.1 DS2 Premature Separation

FAILURE MODE DESCRIPTION

This failure results in early deployment and loss of a probe. The following sub-failures could lead to this condition:

a) Structural failure of the probe separation joint during launch environment. This failure includes the loss of separation joint pin engagement in flexure due to late modification to pin end without subsequent testing and verification.
b) Longitudinal deflection of cruise stage separation joint and plunger relative to strut mounted separation device of 0.5 inch minimum. The probe separation initiation plunger, which rests against the MPL aeroshell ring, must move 0.5 inch to actuate probe release.

INTRODUCTION

The Mechanical Systems Review Team met with JPL DS2 mechanical systems engineers on 26 January 2000 to review this failure mode. DS2 engineers presented the material. There were no follow-up actions.

FINDINGS

The configuration of the probe structural support system is a straightforward truss assembly. The three-point attachment between the probe and support structure is insensitive to deformations occurring in the truss. The general design is acceptable.

The launch vehicle design loads were conservative and verified by coupled loads analysis. The NASTRAN finite-element model (FEM) was constructed for the aeroshell and support structure to determine member loads and deflections. The aeroshell/support structure system fundamental frequency was 60 Hz. In general, the structural system was well designed and analyzed.

The aeroshell/support structure system was qualification tested with cold temperature –65 degrees C, 43 g's quasi-static load, 15 grms random vibration, acoustic acceptance level plus 7 db, and pyrotechnic shock. This is a full complement of environmental tests and establishes high confidence in the structural integrity of the system.

Modifications to the three separation joint pins would not have compromised the integrity of the separation joint. These modifications were performed in a controlled manner, fully documented, and with full Quality Assurance participation.

Deflections of the cruise stage interface ring in the amount necessary to actuate a premature probe release would not be possible without catastrophic structural failure of the cruise stage.

Premature release of the probes would damage the MPL solar panels, and damage to solar panels would likely result in an electrical power deficiency. There was no evidence of this during cruise.

Flaws in the DS2 aeroshell that could cause premature separation would have been detected during acoustic tests performed on the flight probes. Flaws in the silicon carbide heatshield would produce a catastrophic failure of the aeroshell when subjected to the acoustic environment. After testing, there is high confidence in the integrity of the aeroshell. Specialized handling equipment and procedures were developed and implemented to ensure against handling damage to the probes.

Several other possible failure modes were presented and reviewed. They included ejection pin failure, slippage of ejection pin assembly, insufficient slack in the cable cutter lanyard, and buckling of the internal elements of the plunger mechanism. The design features and test verification program for these elements were satisfactory.

PROCESS ASSESSMENT

The design of the structural and separation system, margins, and test qualification program were excellent.

9.2.2 DS2 Fails to Separate from Cruise Stage Due to Failure of Cruise Stage Separation from Aeroshell/Lander

FAILURE MODE DESCRIPTION

For this failure to occur, the cruise stage to aeroshell separation distance would have to be less than the 0.5 inch required to initiate probe release. The failure modes for MPL cruise stage separation that are applicable to DS2 failure to separate are:

a) Separation nut fails to release bolt.
b) Separation connector/ESD cover and/or other drag forces/energy exceeds separation spring forces/energy.
c) Cold welding of aluminum-to-aluminum surfaces.
d) Mechanical hang-up between separating hardware.

INTRODUCTION

The Mechanical Systems Review Team examined the failure of cruise stage separation from the aeroshell/lander with LMA on 19 January 2000. The report on that examination can be found under Section 7.2.1, Lander/Aeroshell Fails to Separate from Cruise Stage. Cruise stage separation failure mode descriptions and findings that are applicable to DS2 failure to separate can be found in the same section. Excerpts from that examination as they relate to the DS2 failure to separate failure mode are shown below.

FINDINGS

See Section 7.2.1 for complete text.

A failure of one separation spring would not prevent the required 0.5-inch separation and therefore is not applicable. MPL ATLO system-level separation tests and analyses verified cruise stage separation.

A failure of one of the six cruise stage separation nuts to release is unlikely. Release nut qualification tests and MPL ATLO system-level separation tests verified release nut function. Given that one of the release nuts failed to release its bolt, there is enough structural compliance to allow push-off springs to open the separating rings by the amount necessary to release at least one probe.

ITT Canon connector pull forces have been test qualified. The separation joint energy margin = 1.4. MPL ATLO cruise stage separation tests verified that the connectors pulled properly.

There is no credible failure of the cruise stage to separate due to cold welding of interface materials, and there is no credible mechanical hang-up scenario that would prevent cruise stage separation.

A full system, quasi-static separation test verification, with flight hardware, was performed during MPL ATLO testing. The actuation of the DS2 separation plungers was verified in the test.

PROCESS ASSESSMENT

The design, analysis, and test verification process for the cruise stage separation joint was adequate.

9.2.3 DS2 Fails to Separate After Cruise Stage/Aeroshell Separation

FAILURE MODE DESCRIPTION

This failure mode can be caused by the following sub-failures:

a) Separation initiation plunger does not stroke (stuck plunger).
b) Guillotine does not actuate, or fails to sever restraint ligament.
c) Separation pins do not retract from probe flexures. This item includes failure modes introduced by late modification to the engagement end of pin without subsequent testing and verification.

INTRODUCTION

The Mechanical Systems Review Team met with JPL DS2 mechanical systems engineers on 26 January 2000 to review this failure mode. There were no follow-up actions.

FINDINGS

It was procedurally and physically verified that the “remove before flight” safety pins used to prevent accidental actuation of the separation initiation plunger were removed.

Modifications to the three separation joint pins would not have compromised the integrity of the separation joint or prevented probe separation. These modifications were performed in a controlled manner, fully documented, and with Quality Assurance participation.

The designs of the separation initiation plunger, guillotine, separation pins and associated retraction and push-off springs, were examined and found to be acceptable. Functional margins and qualification tests were adequate. Aeroshell/support structure environmental qualification tests verified system-level structural and separation mechanisms integrity. System-level qualification ambient and cold separation tests verified separation function.

PROCESS ASSESSMENT

The separation joint design, margins, and test verifications were very satisfactory.

9.2.4 DS2 Aeroshell Failure/Fracture at Entry Max-G

FAILURE MODE DESCRIPTION

This failure during entry could cause a probe not to survive entry/impact. This item includes failure of the adhesive bond holding the parts together and fracture of SiC at the probe attachment lugs.

INTRODUCTION

The Mechanical Systems Review Team met with JPL DS2 mechanical systems engineers on 26 January 2000 to review this failure mode. There were no follow-up actions.

FINDINGS

The DS2 aeroshell components are the SiC heatshield structure and thermal protection system (TPS), SiC backshell structure and TPS, and interface and penetrator bushings. The thin-wall SiC shells have high stiffness, high temperature capability, and extreme resistance to thermal stress and shock. They are brittle and fracture completely upon impact. Three titanium (kinematic) mounts transmit the load from penetrator to aeroshell.

A JPL FEM analysis of the SiC structure, using a conservative 39 g's launch acceleration, produced 5600 psi maximum stress. The same analysis, using the entry decelerations of 12 g's, produced 1700 psi maximum stress. The launch environment is the loads and stress defining case. The aeroshell has been designed for 60 g's. The strength margins of the aeroshell are large.

The aeroshells were analyzed by NASA Lewis Research Center using Ceramics Analysis and Reliability Evaluation of Structures (CARES). Coupon tests provided data for analysis. X&Y&Z load cases at 60 g's indicated that the probability of aeroshell failure is less than 0.5 percent.

Launch venting analysis was performed at JPL.

The aeroshell was structurally qualified by two-axis quasi-static, acoustics, pyro shock, and thermal cycle tests. The qualification aeroshell went through system-level acoustics test at LMA, and system-level thermal–vacuum and separation testing at JPL. Acceptance test of flight aeroshells was system-level acoustics.

Coefficient of thermal expansion (CTE) mismatch analysis was done for all bond joints between SiC and Ti, SiC and Epoxy 9394. Data for thermal analysis were provided by NASA LaRC. The bond line between heatshield and backshell is 2.5 millimeters wide around the entire perimeter of the shell. Maximum bond line stress at heatshield/backshell interface is 1 ksi at launch and negligible at entry. Bond lines get hot *after* peak deceleration pulse. Bond line margins at max g and at high temperature are very high.

Flaws in the aeroshell that could cause failure of the aeroshell during entry would have been detected during flight acoustics test. Critical flaws in the SiC heatshield and backshell would have produced catastrophic failure of the aeroshell during the test. Specialized handling equipment and procedures were developed and implemented to insure against subsequent handling damage to the probes.

PROCESS ASSESSMENT

The design of the aeroshell and its structural margins, including bond lines, was acceptable. The analyses and test program used to verify the design was also acceptable.

9.2.5 DS2 Structural Failure at Impact

FAILURE MODE DESCRIPTION

These failure modes result in the probes' inability to communicate:

a) Aeroshell causes damage to probe structure at impact.
b) Antenna mast bending propagates to structure/electronics failure at impact.

INTRODUCTION

The Mechanical Systems Review Team met with JPL DS2 mechanical systems engineers on 26 January 2000 to review this failure mode. There were no follow-up actions.

FINDINGS

It is commonly understood that impact analyses at very high g levels are not reliable. Therefore, the design process is empirical and impact testing is the only reliable verification method.

The kinetic energy of the backshell, dissipated on the probe aft-body cover and antenna at impact, was assumed to be the worst-case scenario for this failure mode. Development impact tests of the aft-body cover against a flat plate aeroshell simulator produced significant structural damage to an early prototype design. Material and design changes to the cover were implemented and shown to survive the impact tests. These tests only approximated the actual dynamic interaction between the aeroshell and the aft-body. Due to a test apparatus limitation, no impact tests of a flight-configuration aeroshell with probe attached were performed. The probe aft-body design was qualified by a series of impact tests. It was not established how conservatively the tests represented the flight impact dynamics.

No detailed analysis was done of the aft-body to antenna interaction. Both FEM analysis and hand calculations were used for the antenna structure, but neither provided confident results because the loads were not well understood. Several antenna masts were slightly bent during impact testing, but no analytic models could be made to match the empirical damage. Damage to the antenna was limited to bending of the mast above the base. There has been no evidence of antenna base/aft-body deformations. The base fixity stiffness of the aft-body is high. The antenna structure design was proven empirically by several impact tests.

Analysis shows that impact between the aeroshell and the antenna tip occurs at greatly reduced relative speed due to the short distance between them. A special impact drop test was performed on the antenna to qualify aeroshell/antenna interaction. The test demonstrated that the aeroshell would not damage the antenna or whiskers.

PROCESS ASSESSMENT

The probe structure and antenna have been empirically designed to withstand the impact tests to which they were subjected. The structure and antenna integrity has been verified by these same tests. Within the limits of the impact tests, the probe structure and antenna demonstrated their survivability. However, the verification process is less than complete, due to the absence of a combined aeroshell–probe impact test. The flight configuration was not impact tested.

LESSONS LEARNED

For future missions, perform impact tests with the probe integrated with the aeroshell to demonstrate acceptable dynamic interaction between them.

9.2.6 DS2 Telecom Subsystem Fails at Impact

FAILURE MODE DESCRIPTION

In this potential failure mode, the RF subsystem does not survive impact with the surface within the limits of the design.

INTRODUCTION

The Mechanical Systems Review Team met with the JPL DS2 engineering staff to examine this failure mode on 26 January 2000. There were no follow-up actions.

FINDINGS

1. The probe design did not allow for post-environmental system functional testing without destructive disassembly of the aeroshell and probe; therefore, there was no verification of flight readiness after acoustic test.
2. All system-level impact testing was conducted at the probe level without the aeroshell. There were no impact tests of the combined aeroshell and probe. Tests were conducted with soil requirement conditions #3 through #5, representing the harder surface class of properties.
3. The interaction of the aeroshell and probe aft-body at impact was tested by firing the aft-body into a flat plate of aeroshell material. This test was only an approximation of the actual dynamic interaction. These development tests resulted in an empirical approach to the aft-body design.
4. RF system development impact tests were limited to brassboard and breadboard components and subassemblies. Post-test visual inspections of component mounting integrity and electrical connections were conducted. These development tests provided the component mounting and configuration requirements that were implemented in the flight RF design. Since many of the RF components were not electrically functional, only limited DC pre-test and post-test checks were possible. These development tests did not represent complete qualification of the RF subsystem; they qualified the subsystem structurally, but not functionally.
5. No system-level impact tests were conducted with a flight-equivalent RF subsystem. Design changes emerging late in the program resulted in its unavailability for system testing. The DS2 project's position is that the RF Subsystem was qualified by similarity to other electrical components that satisfactorily survived system impact tests, and were verified as functionally acceptable. Subsystems that were tested at the system level include tunable diode laser (TDL) assembly, power switch, aft sensor board, and pressure sensor electronics. Other electrical parts were tested for performance before and after impact, with special attention paid to components known to be affected by high g loads. Nonetheless, the absence of a flight-equivalent RF Subsystem impact test precluded verification of its functional design and survivability.
6. 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 (Reference: DS2 Comments to Casani Report Version 3b, Sarah Gavit, 2/15/00; also Deep Space 2 Mission: Status — letter from Ed Stone, JPL Director, to Edward Weiler, January 4, 1999 (describes state of readiness for launch on January 3, 1999).
7. The flight spare RF Subsystem, which was planned to be available for post-Mars impact diagnostics, could now be used for impact testing.

PROCESS ASSESSMENT

The absence of functional test access to the probes after integration with their aeroshells precluded verification of the flight RF Subsystem readiness following completion of system acoustic environmental tests. Since there was no system-level qualification impact test of a flight-like RF subsystem, verification of the RF Subsystem is incomplete.

LESSONS LEARNED

1. Conduct an RF flight spare system impact test to demonstrate survivability. Describe criteria for a successful test.
2. Include the aeroshell with the probe for future qualification impact tests. The impact tests performed on this program only approximate the interaction between these two elements (refer to Section 9.2.5, DS2 Structural Failure at Impact).
3. For future probes, include electrical test access features that will allow verification of flight readiness at the fully integrated system level.

SUMMARY

The mechanical systems designs and design process was excellent. With the exception of the incompleteness of system-level impact testing, the test verification process for the mechanical systems was fully satisfactory and well executed. The design review process was effectively implemented. The technical leadership and ownership of this activity was evident.

Bibliography

Deep Space 2 Mission: Status — letter from Ed Stone, JPL Director, to Edward Weiler, January 4, 1999 (describes state of readiness for launch on January 3, 1999).

DS2 Comments to Casani Report Version 3b, by Sarah Gavit, 2/15/00.

DS2 Failure Review handout package, Umbilical/Electronics Packaging Design and Verification, by Saverio D’Agostino, 13 January 2000, 20 pages.

DS2 Mechanical Systems Failure Modes handout package, by Tom Rivellini, January 26, 2000, 189 pages.

New Millennium DS2 Failure Review handout package, by Tom Rivellini, January 13, 2000, 86 pages.

9.3 DS2 Avionics

INTRODUCTION

Meetings were held with the DS2 team on 26 January 2000 to review the DS2 system avionics and potential failure modes. The Avionics Review Team addressed the key avionics system elements from a design and test perspective, although there was insufficient time to cover all items in great depth.

SYSTEM DESIGN

The DS2 system is divided between aft-body and penetrator elements with a flexible polyimide tether electrically linking them together. All power and signal communication between the two bodies is performed via this tether. The penetrator is a round-nose penetrator containing the science instrumentation together with a small three-sided prism structure holding the science-related power and control electronics. The aft-body contains the batteries, power switch, and telecom hardware, together with a sensor ASIC.

With respect to the inability of the DS2 probes to communicate, the aft-body contains all of the hardware associated with the critical power and communication functions. With the exception of a power bus short in the umbilical, there is no evident single failure or common mode in the penetrator that would preclude proper operation of the telecom system. Therefore, efforts have focused on the power and telecom functional elements, together with the tether. The aeroshell configuration with respect to EMI and ESD sensitivity was also examined.

PROCESS ASSESSMENT

a) Batteries. The cell development effort was well done in most respects, especially given the difficulty in packaging and testing the devices to meet the extreme impact requirements. The team worked closely with the battery vendor, Yardney, and appears to have done all the right things from a design and quality perspective to get a good product. As would be expected, there were many test failures of diverse nature during the development process. That process went through two major design modifications and seven impact validation tests leading to the final flight design. For the most part, it appears that the final design is adequate to meet the environmental and energy requirements associated with the DS2 mission. However, no impact testing was performed on the flight cell lots. Therefore, the flight batteries are currently qualified only by similarity to a lot that experienced one performance degradation (non-catastrophic internal damage) out of eight devices.

Assembly of the cells into an aft-body battery pack appears to be a robust process that should survive impact. Each cell is epoxied into a cylindrical Torlon sleeve and has the wire terminations fully encapsulated with low-temperature Solithane polyurethane. The completed cell is then epoxied into a bored-out hole in the magnesium aft-body (four cells per battery; two complete batteries) and the motherboard is mounted on top of it. This is a very nice scheme, since the wire leads are kept short and can be fully staked at the point where they emerge through the motherboard. From a power perspective, the flight lot of cells was well characterized through a series of realistic storage and operational scenarios. The available energy is strongly dependent on cell temperature but testing has shown that a flight battery pair could be expected to have at least 2.4 amp-hours of energy (under very worst-case conditions) when operated through the planned mission profile. Assuming the batteries survived, the energy available meets the mission requirement with substantial margin.

b) Power Switch. The power switch design was originally developed by Boeing and uses a p-channel and n-channel MOSFET in combination with a bias network to produce a regenerative latch effect.

The design by its nature is optimized to assure turn-on and does not effectively guard against inadvertent activation. It is also dependent on having a load connected that will draw enough current to assure that the p-channel switch leakage will not reach the turn-on threshold for the n-channel latch (the circuit could actually self-activate if there is no external load). The design also does not account for the worst-case specification leakage for the p-channel switch, which can be as high as 250 microamps. Testing of prototype hardware and other sample devices shows that the device leakage is extremely low and not an issue.

A second design weakness for the power switch is that wires for the switch arm function are isolated with 100-kohm resistors. By virtue of this relatively high impedance, the wires can appear to be floating from an EMI perspective and could act as a pickup antenna for EMI. However, the RC time constant of the filter circuit on the gate of the power switch is 10 milliseconds. Therefore, the circuit should be immune to all but the strongest RF signals.

c) Aft-body to Penetrator Tether. The tether design is well thought out and looks as though it will function as intended. The test program also appears adequate, with the exception that most of the failed test specimens were only qualitatively analyzed. When failures occurred, the samples were looked at visually and measured with a standard ohmmeter. The failed specimen was not evaluated with more powerful material analysis tools, nor were tests performed at higher, more representative test voltages (standard ohmmeters only apply 0.2 volt to the circuit). However, the tether appears tough enough and the test program was thorough enough that a tether failure is considered extremely unlikely for both probes.

d) Telecom System. The original telecom system was abandoned late in the probe development flow due to technical problems. As an obvious risk area, the replacement telecom system design was reviewed in fair detail as part of this assessment to determine both its suitability for the planned mission and state of readiness at the time of delivery. In particular, the antenna design, uplink and downlink margins, and the development/test program were evaluated. Some effort has also been spent on the detailed electrical design.

Based on discussions with the engineers, it was clear that the telecom effort was in skilled hands and was (eventually) well supported by Laboratory resources. The design, which is based on cellular telephone technology, appears to be sound. The majority of the active parts were plastic commercial types with no radiation pedigree, although it was pointed out that the project accepted plastic parts for all the DS2 subsystems. There was also no consideration given to the radiation hardness of the specific parts. Again, this approach was based on a radiation effects review (IOM 507-B-DBI-97, D, Bergens, Results of DS2 Microprobe Radiation Effects Review) showing that rad-hard parts were not necessary. A subsequent review initiated by the Board (SSM-514-C-001-00, S. McClure, 24 February 2000) concurs with the original assessment.

The flight telecom units were tested as an integrated system with some environmental testing exceptions. Specifically, the telecom system was not tested at Mars pressure, nor was it impact tested as a complete system. Flight unit subassemblies (e.g., the daughter boards, digital boards) were all tested and characterized individually over the thermal qualification range prior to integration as a system into the flight probes. While the flight units were not environmentally tested as an integrated system, the telecom flight spare unit was fully tested and characterized over the thermal qualification range (also not at Mars pressure).

e) Aeroshell. The design was reviewed and an assembled aeroshell used for EMI testing was inspected, as was a cracked reject that was not assembled. The Review Team also checked the resistance of the SiC material and the glue joints. Altogether, the design appears quite good from a mechanical perspective, although there was no attention paid to EMC, ESD, and grounding with respect to making the complete shell an effective electrostatic shield. Only one out of the three sample glue joints associated with the probe mounting pads was conductive. Therefore, it is possible that the probe was electrically floating when attached to the inside of the aeroshell body.

Based on the sample hardware, it appears that the circumferential joint between the two hemispheres is uneven enough to assure a partially conductive connection between the mating halves. However, depending on the quality of the epoxy joint, it is likely that the shielding effectiveness would be compromised. This is borne out by preliminary measurements performed in the EMC lab showing a measured attenuation of approximately 12 dB. This is not an unreasonable result for a poorly bonded shield. A well-bonded shield would be expected to provide 40 to 60 dB of attenuation.

f) <u>Test Program</u>. The test program was limited by time and budget plus the fact that a flight-ready probe, as designed, could not be fully tested once integrated. Therefore, the elements of each probe were tested fairly completely on an individual basis, but the complete probes did not get an end-to-end series of environmental tests under fully simulated flight conditions. Beyond the lack of a complete system test, there are four principal concerns: 1) The flight battery lot was impact qualified by similarity to another lot that was not flown (other qualifications tests were performed); 2) Impact testing of electronic modules was done in a power-off condition rather than under a powered condition; 3) The probe RF system was not tested for proper operation as a complete system in the 6-torr Mars environment.

g) <u>Documentation and Data Review</u>. The project records are in relatively good shape and the project team should be commended for their efforts to maintain configuration control despite extreme schedule and cost pressure.

FINDINGS

1. The battery cell design is considered fundamentally rugged enough to survive impact. However, the test program was incomplete since there was no impact testing of the flight cell lot. As well, the sample size of the impact test lot was too small to statistically assure qualification of the design. Therefore, a catastrophic battery failure at probe impact is considered plausible but unsupported.
2. The power switch design is marginal and the switch can inadvertently turn on due to a handling error, an ESD event, or EMI. Great care was taken during the ground processing of the probes to mitigate this deficiency and there is no direct evidence suggesting that the probes experienced a premature turn-on. Due to the extreme sensitivity of the circuit, however, early inadvertent turn-on is considered a plausible but unsupported failure mode.
3. The worst-case leakage current specification for the power switch MOSFETs is high enough that, in principle, it is possible for the batteries to be discharged during the long storage and cruise interval. Testing of a prototype circuit and some representative parts demonstrated leakages low enough to make this scenario unlikely.
4. The probe mounting and associated aeroshell assembly methods were not designed or controlled to achieve good probe grounding and effective EMI shielding. Though probably not catastrophic, the resulting shield performance is not predictable and cannot be counted on to remain consistent through the series of probe test and operational environments. One possible result would be ESD or EMI sensitivity sufficient to inadvertently activate the power switch as discussed above. This is considered unlikely, however.
5. The power lines in the aft-body–to–penetrator tether were not fused or current limited. The design of the tether also did not specifically preclude the possibility of an electrical power short. Test

program results indicate that a short is unlikely, but testing was insufficient to guarantee that a short could not occur and/or would not be catastrophic in the event of occurrence. It is unlikely that a failure of both probes can be explained by this finding.

6. The flight telecom subsystem was not qualified as part of the flight probe system test. However, sufficient testing at lower levels in combination with testing of the spare hardware makes a problem unlikely.
7. While an analysis was performed, the associated high E-Field at the antenna tips could result in breakdown of the CO_2 at the 6-torr Mars atmospheric pressure. This is considered a plausible failure mode until a test is performed to preclude its possibility.
8. The antenna test activity did not quantify pattern and gain performance for the off-nominal condition where the probe is lying on its side (the probes did not have a requirement to function under this condition). Therefore, inadequate link margin is plausible for this case. The link calculations themselves appear correct, so a probe that did not skip or bounce would not be affected by this finding.
9. The parts selected for the telecom system (and the rest of the probe system) are mostly commercial types since there was no requirement to do otherwise. A part failure is plausible, but the short lifetime of the probe makes a malfunction of both probes highly unlikely.
10. The overall probe test program did not perform any impact testing of a fully integrated and powered system. Therefore, the probes were flown (with JPL management's knowledge) without being fully qualified for the expected environments. A failure due to inadequate qualification is considered plausible.

9.4 DS2 Communications

9.4.1 UHF Link Fails

FAILURE MODE DESCRIPTION

In this potential failure mode, the DS2 probes are unable to communicate with MGS. This could be caused by a failure of the MGS or DS2 telecommunications hardware or an incompatible interface between MGS and DS2.

Thermal tests of the telecommunications system were limited to the following:

- Engineering units — All subassemblies were tested over the temperature range.
- Flight spare — Tested as a system over the temperature range (post-launch).
- Flight units — Only the digital board and aftsensor assemblies were tested over the temperature range.

During thermal tests of the telecommunications system after launch, a software error was detected for which the oscillator frequency was not compensated as a function of temperature. Further tests revealed that this error had a minimal impact on link performance (<1 db).

There were no tests of the telecommunications system at Mars pressures.

There were no airlink tests of the flight units to verify link performance. Tests were performed on the flight units using uncalibrated antennas to verify the presence of a signal only. Link-performance tests were performed on engineering units only.

A pre-launch compatibility test of the CNES MGS MR flight spare and the DS2 telecommunications flight spare was performed as an end-to-end telecommunications qualification test. (*Note*: At project start, it was acknowledged that a system end-to-end test with MGS was not possible because MGS was to be launched before the DS2 telecom system was fabricated).

An in-flight test was conducted between Stanford University and MGS to verify the Mars Relay (MR) operational modes in November 1996. During this test, it was determined that there was a wiring error that resulted in the wrong operational modes being selected. This required a software change to make the operational mode commands consistent with the hardware configuration. A follow up in-flight test with MGS was not performed to verify the MR responses to the new commands. The MR receiver was verified as part of the November 1996 Stanford University test but it was not verified after that time.

The MGS MR downlink modes for MGS-to-DS2 communications were verified after the Mars anomaly in December 1999 using the Stanford University 46-meter antenna (several unsuccessful attempts had been made earlier in cruise).

There was no capability to power the DS2 probes from the time they were attached to the MPL cruise stage at KSC, until after separation from the MPL cruise stage.

PROCESS ASSESSMENT

An end-to-end link compatibility test was never performed with the MGS spacecraft and the DS2 probes. This was an accepted risk at DS2 project start, as it was known that the MGS spacecraft would be launched before the DS2 telecom system would be built. While in-flight MGS tests verified the MR for commanding the DS2 probes, these tests were unable to verify MR receive functions for DS2. End-to-end tests performed between the MR flight spare at CNES and the DS2 flight spare were performed with a hardline connection, thus link margins were not verified.

LESSONS LEARNED

Perform pre-launch link compatibility tests.

Bibliography

DS2 Electronic Subsystem Review — Handout, DS2 Briefing 01/13/00.

DS2 Impact Shock and Random Vibration Qualification, IOM 5053-99-001, dated January 15, 1999.

DS2 Impact Testing of Telecom hardware — via Saverio D’Agostino e-mail 01/14/00.

DS2 Integration and Test System Test Program Overview — Handout, DS2 Briefing 01/13/00.

DS2 Software (Flight, Test and Operations) — Handout, DS2 Briefing 01/13/00.

DS2 Telecom POR Circuit — via Eric Archer e-mail 01/28/00.

DS2 Telecom Questions on AMC Failure Modes — via Robert Nowicki e-mail 01/27/00.

DS2 Telecom Questions on Response to MGS — via Christopher Morse e-mail 01/27/00.

Environmental Specifications and Landing Site Description — Handout, DS2 Briefing 01/13/00.

Mars Microprobe Project (DS2) Mission Assurance Plan and Specification, D-14323, dated March 1997.

Mission Assurance — Handout, DS2 Briefing 01/13/00.

Possible Failure Modes — Handout, DS2 Briefing 01/13/00.

Operational Process & Validation — Handout, DS2 Briefing 01/13/00.

Structural Test Program Overview — Handout, DS2 Briefing 01/13/00.

System and Mission Design Overview — Handout, DS2 Briefing 01/13/00.

Telecommunications Subsystem — Handout, DS2 Briefing 01/13/00.

Umbilical/Electronics Packaging Design and Verification — Handout, DS2 Briefing 01/13/00.

Appendix 1

Bibliography

AACS Algorithm: Entry Navigation Kalman Filter, Report Rev. 2, dated 3/11/98, presented on 01/26/00 at LMA.

AACS Algorithm: GyroCompass — Handout, LMA Meeting 01/31/00.

AACS Algorithm: Radar Commanding, Report Rev. 4, dated 5/25/99, presented on 01/26/00 at LMA.

AAIA-98-3665, Test and Modeling of the Mars ’98 Descent Propulsion System Waterhammer — T. Martin, L. Rockwell, C. Parish, LMA, 7/13-15/98, Joint Propulsion Conference & Exhibit at Cleveland, Ohio.

AAS Algorithm: Radar Processing, Report Rev. 4, dated 06/23/99, presented on 01/26/00 at LMA.

Additional Information of MPL Prop Peer Review Process — via Lad Curtis, 2/24/00, e-mail from Greg McAllister on 2/22/00 regarding Propellant Isolation AI from Prop CDE, electronic format.

Additional Information on MPL Tank Outlet Temperature — via Lad Curtis, 2/21/00, e-mail from Kevin Miller on 2/18/00 regarding MSP ’98, Memorandum to Greg McAllister, Tim Martin on 9/16/99, MSP ’98 MPL Fuel Tank Status.

Additional Information on MPL CM Offset Calculations From Flight TCM Data — Lad Curtis, 3/7/00, e-mail responding to Questions on MPL CM Offset Calculations from Flight TCM Data, H. Curtis, J. Wynn.

Additional Information on Propulsion: Zero-G Fuel Transfer Considerations — Lad Curtis, 2/17/00, e-mail of report from Tim Martin regarding Consideration of MPL Zero-G Fuel Transfer During Design and Development.

Ambiguity on MPL System FMECA Status — via Lad Curtis, 03/14/00, e-mail from Robert Menke.

Analysis of MGS/MOC Observations of the Mars Polar Lander (MPL) Landing Zone, Michael Malin, February 24, 2000, HTML Publication.

Analysis of MGS/MOC Observations of the Mars Polar Lander (MPL) Landing Zone — Supplementary Data, Michael Malin, March 7, 2000, HTML Publication.

ATLO Leg Deployment — via Lad Curtis e-mail of 02/15/00; memo from Thomas McCaa to Shane Roskie of 02/14/00 re Touchdown Sensor Miswire on MPL in June 1998.

B3. ACS Lander Hardware Description — Kent Hoilman, 01/25/00, viewgraph presentation at LMA.

Battery power capability — via Kyle Martin e-mail 02/07/00.

Brace Concerns — Handout, LMA Meeting 01/31/00.

C&DH CDR Peer Review, D-14523, dated 12 November 1996.

C&DH Failure (Reply to Postulated C&DH Failure) — via Lad Curtis e-mail of 02/15/00; information re potential failure modes in Avionics section of Board report; topics: processor resets during EDL, CMIC errors after landing (add EDAC to CMIC), EEPROM errors after landing; info from Jerry Henderson.

CFD Analysis of Mars ’01 Lander Near-Ground Environments — Joe Bomba, Pete Huseman, 2/24/00.

CG Offset Effect on Landed Location — Bill Willcockson and Jason Wynn, 01/25/00, viewgraph presentation at LMA.

CG Offset Effect on Landed Location — Willcockson and Wynn, January 26, 2000, viewgraph presentation to Environment and Landing Site Review Team at LMA, February 1, 2000.

CMIC_map — Handout, LMA Meeting 01/31/00.

Collection of Action Item Responses from the Dynamics and Control Review Team meeting on 01/25–26/00 at LMA.

Comm/C&DH/FSW/Seq MPL FRB Action Item List — Kyle Martin to Richard Brace e-mail of 02/04/00; cover message includes Scott Toro-Allen e-mail to Kyle Martin of 02/04/00, response to Comm FRB Action Item #5.

Comments on Entry and Descent Separation Analyses and Test Report — forwarded from Frank Locatell via e-mail of 01/17/00; memo from Jeff Bene dated 01/11/00 re document VR022 of 12/10/98.

Corona Analyses for MPL UHF Antenna — via Lad Curtis e-mail of 02/18/00; Scott Toro-Allen e-mail to Lad Curtis of 02/18/00 incorporating message from Mike Pearce to Bill Wallace of 03/26/97.

Cruise Stage Separation Analysis — via Lad Curtis e-mail of 02/15/00; info from Jeff Bene.

Deep Space 2 Mission: Status — letter from Ed Stone, JPL Director, to Edward Weiler, January 4, 1999 (describes state of readiness for launch on January 3, 1999).

Detection of a Candidate Signal from the Mars Polar Lander — via Richard L. Horttor, 02/17/00, original memo from George Resch to Richard Cook, Mars UHF Signal and Analysis.

Diplexer and bandpass filter plating — via Kyle Martin e-mail 02/04/00.

DS2 Comments to Casani Report Version 3b, by Sarah Gavit, 2/15/00.

DS2 Electronic Subsystem Review — Handout, DS2 Briefing 01/13/00.

DS2 Environment Specification and Landing Site Description — Sue Smrekar, January 13, 2000 viewgraph presentation to Environment and Landing Site Review Team at JPL, January 24, 2000.

DS2 Failure Review handout package, Umbilical/Electronics Packaging Design and Verification, by Saverio D’Agostino, 13 January 2000, 20 pages.

DS2 Impact Shock and Random Vibration Qualification, IOM 5053-99-001, dated January 15, 1999.

DS2 Impact Testing of Telecom hardware — via Saverio D’Agostino e-mail 01/14/00.

DS2 Integration and Test System Test Program Overview — Handout, DS2 Briefing 01/13/00.

DS2 Mechanical Systems Failure Modes handout package, by Tom Rivellini, January 26, 2000, 189 pages.

DS2 Software (Flight, Test and Operations) — Handout, DS2 Briefing 01/13/00.

DS2 Telecom POR Circuit — via Eric Archer e-mail 01/28/00.

DS2 Telecom Questions on AMC Failure Modes — via Robert Nowicki e-mail 01/27/00.

DS2 Telecom Questions on Response to MGS — via Christopher Morse e-mail 01/27/00.

DST Environmental Comparison MSP98 vs. Cassini — Handout, LMA Meeting 02/01/00.

DST Fault Protection — Lad Curtis e-mail 02/08/00.

DST Fault Protection — Lad Curtis e-mail of 02/14/00; and Rev. 1, Lad Curtis e-mail of 2/14/00.

EDL Backup Timers (Justification for No EDL Backup Timers) — via Lad Curtis e-mail of 02/16/00; re fault-tolerance section of Board report; info from Bill Willcockson.

EDL Critical Events Review — Steve Jolly, 01/05/00 viewgraph presentation to Board at LMA.

EDL Electrical States — Handout, LMA Meeting 02/01/00.

EDL Fault Tree — Lad Curtis, 01/05/00 viewgraph presentation to Board at LMA.

EDL Propellant Tank Modeling and Analysis, LMA IOM FSMO-00-007, J. Wynn to Jim Chapel, Bill Willcockson, Tim Martin, 3/8/00.

Effect of Recent CG Shift Estimates on Touchdown Location — via Lad Curtis e-mail of 01/26/00, memo from Bill Willcockson to Milt Hetrick of 01/26/00; cover e-mail message from Curtis discusses center-of-mass displacement at entry as result of center-of-mass shift during cruise due to fuel migration along axis of prop tanks.

Entry and Descent Separation Analyses and Tests, LMA document VR022, Lowell Cogburn, 10 December 1998.

Entry Systems — Bill Willcockson, 01/25/00, viewgraph presentation at LMA.

Entry, Descent and Landing (EDL) Overview — John Cuseo, 01/25/00, viewgraph presentation at LMA.

Environmental Specifications and Landing Site Description — Handout, DS2 Briefing 01/13/00.

Fault Protection enable/disable states — via Kyle Martin e-mail 02/07/00 with the following attachments: EDL FP State Changes; MSP_11.pdf Section 11 Component-Level Fault Protection; MSP_12.pdf Section 12 Performance-Level Fault Protection; MSP_13.pdf Section 13 System-Level Fault Protection

Fault-tree Analyses — Lad Curtis e-mail of 02/08/00 to Pete Burr re FTA, Failure Mode Effects and Criticality Analyses (FMECAs), Redundancy Verification Analyses (RVAs), and Worst-Case Analyses (WCAs) for MSP ’98.

FBC#2 — via Philip Garrison e-mail, 1/13/00, from John McNamee e-mail on 12/23/99.

Feed System Transient Pressure Effects on Operational Thruster Performance For a Pulse Modulated Controlled Multiple Thruster Planetary Lander, Report #D99-41717 — 12/23/99, Timothy Martin, William J. Bailey, Kelly R. Scheimbert, LMA.

Flight Software Changes and Problem Reports — via Lad Curtis, e-mail of 01/28/00, file name = FSW Changes Accounting Prelim 011700 from Greg Bollendonk.

FSW Action Item Closure — Kyle Martin e-mail of 02/07/00 to Richard Brace re fault protection enable/disable states. Attachments: Lander EDL Fault Protection State Changes; Section 11–Component-Level Fault Protection; Section 12–Performance-Level Fault Protection; Section 13–System-Level Fault Protection.

FSW Overview — Handout, LMA Meeting 01/01/00.

Fuel Tank Outlet — via Lad Curtis e-mail of 02/28/00; Kevin Miller e-mail to Frank Locatell of 02/28/00; presentation to Jeff Leising et al. of 02/24/00, MPL Fuel Tank Outlet Discussion by K. Miller and G. McAllister.

Fuel Tank Outlet — via Marilyn Morgan, 2/29/00, e-mail from Lad Curtis on 2/28/00, and Kevin Miller on 2/28/00, attachment: MPL Fuel Tank Outlet Discussion, 2/24/00.

Heatshield Review — Ron Turner, February 1, 2000, viewgraph presentation to Environment and Landing Site Review Team at LMA, February 1, 2000.

Heatshield Structure Pinhole Arc Jet Testing — Jan Thornton, February 1st, 2000, viewgraph presentation to Environment and Landing Site Review Team at LMA, February 1, 2000.

Hot Descent Engine Valve Issue — via Lad Curtis, e-mail of 02/09/00, viewgraph presentation documenting testing performed at LMA.

How Long Will the Lander Live? — via Lad Curtis e-mail of 02/08/00; Adrian Adamson response to Comm Review Team query pertaining to possible UHF signal from MPL.

IMU Descent Vibration Environment — Kent Hoilman and Jim Chapel, 01/25/00, graph presented at LMA.

In-Flight Verification of Telecom, C&DH and Flight Software — Handout 6, LMA Meeting 01/31/00.

Integrated Propulsion and GN&C System Modeling and Results; Flowtran Propulsion Modeling — Tim Martin, 01/26/00, model presented at LMA.

JPL FRB Question: Entry Center-of-Mass Requirement — Lad Curtis, 1/13/00, e-mail reporting on center-of-mass requirement for entry on 1/12/00.

Justification for Non-Standard Disk-Gap-Band (DGB) Parachute on Mars Pathfinder Project, document ME-2589-Rpt Rev. A.

Lander Configuration After EDL — Handout, LMA Meeting 01/31/00.

Lander EDL Fault Protection State Changes — Gregory Bollendonk, via Lad Curtis e-mail, 02/04/00; e-mail response to action item from Comm Review Team.

Lander Entry State File (LESF) — Tom Kelecy, 01/25/00, viewgraph presentation at LMA.

Lander Propulsion Loading Data — via Lad Curtis, e-mail of 01/14/00: Tank Center of Gravity Calculations; MPL Lander Flight Propellant Load (memo VR-192 from J. Greg McAllister to Lad Curtis of 01/16/00); MSP Lander Verification Report VR006, paragraphs 3.3.7.7 and 3.3.7.11 (no date).

Lander/Backshell Recontact Analysis, MPL/DS2 Mishap Investigation — Spencer (JPL), Desai, and Queen (LaRC), February 1, 2000, viewgraph presentation to Environment and Landing Site Review Team at LMA, February 1, 2000

Latest Revision of MPL FRB Section 7.5 on Propulsion and Thermal — Carl S. Guernsey, 2/28/00, e-mail

Leg Test Status — forwarded from Frank Locatell on 02/08/00; e-mail from Jeff Bene of 02/08/00. Also note re Framotome lanyard testing.

Legs Sensor — Lad Curtis e-mail of 02/24/00 to John Casani et al., message discusses TD sensor transient and how observation was documented.

Lessons Learned Report from Mars Polar Lander Descent Engine Cold Catalyst Bed/Cold Inlet Manifold Issues — Milt Hetrick, Kevin Miller, LMA, 11/24/99, memo to Bill Meersman, Larry Talafuse, Lad Curtis, Al Herzl.

L-GN&C Subsystem Test/Verification — Tom Kelecy, 01/25/00, viewgraph presentation at LMA.

LMA Comments on Board Report, draft #3b — via Lad Curtis e-mail of 02/15/00.

LMA Comments on Board Report, draft #3b, propulsion section only — via Lad Curtis e-mail of 02/15/00.

LMA Comments on Board Report, draft #6 — via Lad Curtis e-mail of 02/23/00.

LMA Comments on Board Report, draft #7a — via Lad Curtis e-mail of 03/03/00.

LMA memorandum: from Thomas C. McCay to Shane Koskie, regarding Touchdown Sensor Miswire on the MPL in June 1998, February 14, 2000.

LMA MPL Investigations Since Landing Day — Lad Curtis, 01/05/00 viewgraph presentation to Board at LMA.

LMA report: LMSS-DO Investigation of Process Contributors to Mars Polar Lander Premature Thrust Termination Due to Touchdown Indication, March 5, 2000.

LMA viewgraph presentation: Functional Flow Chart, HHC-1.

LMA viewgraph presentation: Mars Polar Lander Premature Descent Engine Termination Due to Touchdown (TD) Indication Conclusions, February 25, 2000, H.H. Curtis, R. Gehling, J.Bene, and G. Bollendonk.

LMA viewgraph presentation: Mars Polar Lander Touchdown Sensor Code Issue, January 28, 2000, H. H. Curtis — Lander Systems Engineering, with an Appendix: Touchdown Monitor FSW Description, G. Bollendonk, MPL Flight Software.

LMA viewgraph presentation: Mars Polar Lander Touchdown Sensor Code Issue, February 11, 2000, H.H. Curtis – Lander Systems Engineering.

LMA viewgraph presentation: System Requirement Mapping to FSW, HHC31.

LMA viewgraph presentation: Timeline, HHC-3.

Mars ’01 Heritage Changes, Lesson Learned, and Enhancements from MSP ’98 — via Lad Curtis, e-mail of 01/12/00, viewgraph presentation at JPL on 12/15/99.

Mars Climate Orbiter and Mars Polar Lander: Spacecraft Development and Operations Summary — Ed Euler, 01/05/00 viewgraph presentation to Board at LMA.

Mars Global Surveyor Mars Relay Flight Test Final Report, D-14423, John L. Callas, dated 1997 March 14.

Mars Microprobe Project (DS2) Mission Assurance Plan and Specification, D-14323, dated March 1997.

Mars Polar Lander Angle of Attack with Maximum Propellant Shift — Bill Willcockson, 01/10/00 memo to Ed Euler (via Lad Curtis e-mail of 01/13/00).

Mars Polar Lander Descent Thruster MR-107N Thermal Analysis Verification Test Report (MSOP-00-0003) — Kevin Miller e-mail message of 02/16/00 (hard copies sent); report by Jon R. White, February 2000. (File name = final-desc-eng3.doc).

Mars Polar Lander Descent Engine Plume Issues Summary — via Lad Curtis, e-mail of 03/14/00, presentation by H.H. Curtis, 03/14/00.

Mars Polar Lander EDL Attitude Determination — Tom Kelecy, 01/25/00, viewgraph presentation at LMA.

Mars Polar Lander EDL Inertial Navigator — Tom Kelecy, 01/25/00, viewgraph presentation at LMA.

Mars Polar Lander EDL Success Rates with Large CG Offsets — via Lad Curtis e-mail of 02/17/00; Bill Willcockson memo to Duncan MacPherson and Charles Whetsel.

Mars Polar Lander Entry Design States vs. Reconstruction, Pre-Entry Lateral Miss — via Lad Curtis e-mail of 02/17/00; memo from Bill Willcockson to Richard Cook et al. of 02/14/00.

Mars Polar Lander Large Aero Effects on EDL — Bill Willcockson, 01/10/00 memo to Ed Euler (via Lad Curtis e-mail of 01/13/00).

Mars Polar Lander Possible Premature Descent Engine Thrust Termination Process Investigation Report — Joseph Vellinga, MSP-00-5001, 02/10/00; via e-mail from J. Vellinga, 02/11/00.

Mars Polar Lander Premature Descent Engine Termination Due to Touchdown (TD) Indication Conclusions, LMA charts, H. H. Curtis, R. Gehling, J. Bene, G. Bollendonk, February 25, 2000.

Mars Polar Lander Premature Descent Engine Thrust Termination: Quantitative Definition of Likelihood — H.H. Curtis, J. Bene, R. Gehling, presentation, March 10, 2000; via e-mail from Lad Curtis, 03/13/00.

Mars Polar Lander Propulsion System Schematic — John Cuseo, 01/25/00, viewgraph presentation at LMA.

Mars Polar Lander Spacecraft Overview — Lad Curtis, 01/05/00 viewgraph presentation to Board at LMA.

Mars Polar Lander Surface Power Constraints — Handout, LMA Meeting 01/31/00.

Mars Polar Lander Touchdown Sensor Code Issue — Handout, LMA Meeting 01/31/00.

Mars Polar Lander Touchdown Sensor Code Issue — Lad Curtis, 01/27/00, viewgraph presentations to Board Review Teams at LMA (via Lad Curtis e-mail of 01/27/00).

Mars Polar Lander Touchdown Sensor Code Issue, LMA charts, H. Curtis, January 20, 2000.

Mars Polar Lander, Cold Descent Engine Issue Close-out — H.H. Curtis, 11/22/99.

Mars Surveyor Program (MSP) change summary: Lander Descent Velocity Change and Touchdown Sensor Change, UCN XB0114, September 18, 1996.

Mars Surveyor Program ’98 Fault Protection Description Document, D-14512, dated 5 January 1998.

Mars Surveyor Program Landing Radar Overview of Flight Tests and GN&C Interfaces — John Cuseo and Bradley Haack, Report AAS 98-067, presented on 01/25/00 at LMA.

Mechanical Failure Review Splinter — Action Item Review handout package, February 3, 2000.

Mechanical Failure Review Splinter handout package, January 18–19, 2000.

Mechanical Systems Failure Review Team: Action Item Review — Jeff Bene via Frank Locatell, viewgraph presentation of 02/03/00.

Microwave component plating — via Kyle Martin e-mail 02/04/00.

Mission Assurance — Handout, DS2 Briefing 01/13/00.

MOC Photoclinometry — Mike Malin, 1/24/2000, viewgraph presentation to Environment and Landing Site Review Team at JPL, January 24, 2000.

More Info on Flow Split, LMA e-mail, T. Martin to J. Leising, 2/25/00.

More Rebuttal — Timothy Martin, 2/18/00, e-mail regarding section 4.0 of the draft MPL failure review board findings.

MPL 6-DOF EDL Touchdown Scatter, ± 2mm c.g. Dispersion Along Tank Axis — via Lad Curtis e-mail of 02/17/00; attached “flash memo #1,” Bill Willcockson to Sam Thurman et al. of 02/15/00.

MPL ACS Working Group Actions — via Lad Curtis e-mail of 02/03/00: (1) Thomas Kelecy to Jim Chapel e-mail of 02/02/00 re: analysis to address action item #7; (2) Jim Chapel to Garry Burdick e-mail of 01/28/00 re: discussion of action items #1–10.

MPL Area Analysis of Pulse Widths [from MGS MOLA] — Maria Zuber to Casani, Whetsel, Murray, and MacPherson, February 6, 2000, e-mail correspondence.

MPL Avionics, report of the Avionics Review Team, Battel Engineering, document #BE/093/00/020, 02/03/00.

MPL Backshell Recontact Analysis — Bill Willcockson, 01/10/00 memo to Ed Euler (via Lad Curtis e-mail of 01/13/00).

MPL Center-of-Mass Analysis Status — Lad Curtis, 02/01/00 e-mail message reporting on CM analysis.

MPL Center-of-Mass Bound for TCM-4 and TCM-5 — Jason Wynn, 2/15/00, e-mail regarding center-of-mass offset via spacecraft rate of telemetry.

MPL Center-of-Mass Estimation Using TCM Telemetry Data — Jason Wynn, 2/17/00, GN&C PDO Technical Memo MSP AC-00-0381 to MacPherson, Whetsel, Burdick, Macala, Curtis, Euler, Chapel, Willcokson, Cwynar, Spath.

MPL Center-of-Mass Bound for TCM-4 and TCM-5 — via Jason Wynn e-mail of 02/15/00.

MPL Center-of-Mass Estimation Using Flight Dynamics Telemetry Data (file called MPL CG Uncert), and MPL Entry Body and Terminal Descent Mass Properties; Mechanical Coordination vs. ACS Coordinates (file name CG Offset, no cover slide) — via Lad Curtis e-mail of 02/10/00, viewgraphs from Kim Barnstable. (Re-sent via Jeff Bene with more information re: dry center-of-mass analysis in cover e-mail, 02/13/00).

MPL CM Offset Updates and Additions — Lad Curtis e-mail of 03/01/00 to Duane Dipprey et al.; update to Jason Wynn’s memo re reconstruction of CM offset from flight TCM data; attachments: memo Jason Wynn to Duncan MacPherson et al. (MPL Center-of-Mass Estimation Using TCM Telemetry Data, 02/24/00, MSP-AC-00-0381 Rev A); presentation Lad Curtis (CM Offset Summary – Rev B, 02/29/00).

MPL Cruise Stage Separation Interim Report —Ed Euler, 01/03/00, memo SCR01-00 from Shane Roskie and LMA MPL team to Ed Euler.

MPL Descent Engine Termination: Correction — Lad Curtis e-mail of 02/25/00; notes that test date shown as 06-Jun-97 on pp. 8–9 of 02/25/00 presentation should be 16-Jun-97. Page 11 line item correctly identifies test date as 6/16/97.

MPL EDL Propellant Shift Analyses, Rev. A — Timothy Martin, 3/08/00, memo FSMO-00-008 to G. McAllister, M. Hetrick, J. Wynn.

MPL Entry Center-of-Mass Requirement — Lad Curtis, 01/13/00 e-mail message re: CM requirement for entry.

MPL Entry Risk Status Report — MacPherson et alia, November 19, 1999, viewgraph presentation to JPL MPL EDL Red Team.

MPL Flight Reconstruction of Center-of-Mass Offset Using all TCM Data — via e-mail from Lad Curtis of 02/17/00 to Duane Dipprey et al.; memo from Jason Wynn re estimation of center of mass using TCM flight telemetry data (MSP-AC-00-0381).

MPL Framotome Separation Connector Pull Test Results — via Lad Curtis e-mail of 02/24/00; Jeff Bene e-mail of 02/23/00 re tests.

MPL Fuel Tank Outlet Discussion — K. Miller, G. McAllister, 2/24/00.

MPL Lander to Backshell Clearance — Bill Willcockson, February 1, 2000, viewgraph presentation to Environment and Landing Site Review Team at LMA, February 1, 2000.

MPL Landing Estimates — Phil Knocke, January 13, 2000, viewgraph presentation to Environment and Landing Site Review Team at LMA, February 1, 2000.

MPL Maneuver Overview — Phil Knocke, January 13, 2000, viewgraph presentation to Environment and Landing Site Review Team at LMA, February 1, 2000.

MPL Mission Safety and Success Team Final Report — Charles Whetsel, December 1, 1999, IOM 3130-CWW-001.

MPL Premature Descent Engine Termination Conclusions — via Lad Curtis e-mail of 02/25/00; presentation for briefing to JPL MPL FRB on 02/25/00.

MPL Prop Line Temperature — via Lad Curtis e-mail of 02/15/00; info from Kevin Johnson to Milt Hedrick and Lad Curtis.

MPL Propulsion Peer Review Process — via Lad Curtis e-mail of 02/24/00; Greg McAllister e-mail to Lad Curtis of 02/22/00 with attachments: MSP Lander Propellant Differential Draining Analysis (memo from Timothy Martin to D. Doub et al., 01/17/97, MSP-PR-97-0122); MSP Lander Propellant Transfer Analysis Update – Rev. A (memo from Timothy Martin to D. Doub et al., 10/24/97, MSP-PR-97-0214 Rev A); Lander Prop CDR Action Item Summary (no date); Review Board Report: MSP ’98 Propulsion Subsystem CDR Peer Review of 2–3 October 1996 (final report 10/29/96).

MPL Questions — Richard Cowley, 2/16/00, e-mail regarding hydrazine freezing and missing data period.

MPL Radar Lock on Heatshield — Lad Curtis e-mail of 02/17/00 to Garry Burdick et al.

MPL Small Forces Issues — Stu Spath, January 19th, 2000, viewgraph presentation to Environment and Landing Site Review Team at LMA, February 1, 2000.

MPL software changes and problem reports — via Lad Curtis e-mail 01/28/00.

MPL Tank Diaphragm Test ROM — Milt Hetrick e-mail of 02/07/00 to Jeff Leising.

MPL Tank Diaphragm Test ROM — Milt Hetrick, 2/7/00, e-mail regarding a ROM estimate of the test cost to obtain the necessary data on the MPL tank diaphragm.

MPL Tank Outlet Temperature: Additional Information — via Lad Curtis e-mail of 02/21/00; Kevin Miller e-mail of 02/18/00 has info and also refers to attachment to ISA #Z54100, a memo from Jon White re MSP ’98 fuel tank status, 09/16/99.

MPL Telecom Fault Protection Enables/Disables — Handout, LMA Meeting 02/01/00.

MPL Telecom Screen Shots (Telemetry Data) — Handout, LMA Meeting 02/01/00.

MPL Throttle Engine Issue — via Lad Curtis, e-mail of 03/14/00; presentation Mars Polar Lander Pulse Modulated vs. Throttled Descent Engine Issue, Milt Hetrick and H.H. Curtis, 03/14/00.

MPL Uplink Log and Summaries — Kyle Martin, e-mail of 02/02/00: MPL Uplink Log; MPL Uplink Summary–EDL Uplinks; MPL Uplink Summary–Landed Prep Uplinks; MPL File Interchange System (FIS) Access Information.

MPL Uplink logs — via Kyle Martin e-mail 02/02/00 including the following files: MPL Uplink Logs — via Kyle Martin e-mail 02/02/00, including: MPL UL Log.xls MPL Uplink Log; MPL edl_uplink_sum.xls MPL Uplink Summary — EDL Uplinks; MPL landed_prep_uplink_sum.xls MPL Uplink Summary — Landed Prep Uplinks; MPL FIS Access.doc MPL FIS Access Information.

MPL Uplink Loss Response Timer — Change control package, LMA Meeting 01/31/00.

MPL Zero-G Fuel Transfer During Design and Development — via Lad Curtis e-mail of 02/17/00; info from Tim Martin.

MPL/DS2 Aero Environment Splinter, Entry Body Mass Properties — Kim Barnstable, February 1st, 2000, viewgraph presentation to Environment and Landing Site Review Team at LMA, February 1, 2000.

MPL/DS2 Review — Environment Review Team Session #1 Agenda — Charles Whetsel, January 24, 2000.

MPL/DS2 Review — Environment Review Team Session #2 Agenda — Charles Whetsel, February 1, 2000.

MPS Landing Radar Overview — John Cuseo and Dave Cwynar, 01/25/00, viewgraph presentation at LMA.

MSP Landed STV Test Profile — Handout, LMA Meeting 02/01/00.

MSP Lander Flight Propellant Load — J. Greg McAllister, 3/9/00, memo to L. Curtis, K. Barnstable, J. Lenada, C. Cooley.

MSP Lander Propellant Differential Draining Analysis — Timothy Martin, 1/17/97, memo to D. Doub, G. McAllister, P. Sutton.

MSP Lander Propellant Transfer Analysis Update – Rev A — Timothy Martin, 10/24/97, memo to D. Doub, G. McAllister, P. Sutton, W. Willcockson, L. Curtis.

MSP Lander Verification Report VR006, circa Dec 97.

MSP Telecom Subsystem CDR Peer Review, D-14526, dated 13 November 1996.

MSP’98 Propulsion Subsystem CDR Peer Review — 10/29/96, CDR Peer Review on 10/23/96, LMA.

MSP99-4070, Mars Polar Lander, Descent Thruster MR-107N, Cold Start Verification Test Report — 11/97, Tim Fischer, Kevin Johnson, LMA Propulsion PDO.

NASA Administrator’s Weekly Topics: Fault-tree Analysis, 20 January 2000.

New Millennium DS2 Failure Review handout package, by Tom Rivellini, January 13, 2000, 86 pages.

Operational Process & Validation — Handout, DS2 Briefing 01/13/00.

Parachute Lengths — Milt Hetrick, 2/14/00, e-mail regarding the distance from the center-of-pressure of the chute to the MPL.

Parachute Propellant Transfer, LMA e-mail, M. Hetrick to J. Leising, 3/10/00.

Parachute System — Lad Curtis, 01/12/00 e-mail message describing telecon with Leff Lavell.

Plumes — Milt Hetrick, 3/8/00, e-mail.

Possible Failure Modes — Handout, DS2 Briefing 01/13/00.

Post-Landing Loss of Signal Fault Tree — Handout, LMA meeting 01/31/00.

Post-Landing Loss of Signal Fault Tree — Steve Jolly, 01/05/00 viewgraph presentation to Board at LMA.

Power & Pyro: Answers to Questions — Lad Curtis e-mail of 02/11/00 re: coaxial switches, system design changes for MSP ’01, Radar tests. Includes viewgraph presentation to MPIAT on 01/20/00 re: comparison of MSP ’98 with MSP ’01 (file name = 15MSP01).

Presentation — MPL Aeroshell Environments and TPS Design, — Willcockson, Edquist, and Thornton, February 1, 2000, viewgraph presentation to Environment and Landing Site Review Team at LMA, February 1, 2000.

Propulsion EDL Timeline — via Lad Curtis e-mail of 02/11/00, Greg McAllister.

Radar Test Review — John Cuseo and Brad Haack, 01/25/00, viewgraph presentation at LMA.

Re: Actions from 1/24 MPL/DS2 Landing Site Splinter, Ken Herkenhoff to Charles Whetsel, March 7, 2000, Email Correspondence.

Re: MPL Landing Site… [Absence of Terracing] — Tom Duxburry to Charles Whetsel, February 11, 2000, Email correspondence.

Recommended Environments and Design ranges for the Mars Microprobe — Sue Smrekar and George Powell, Feb. 19, 1997, revised Aug. 12, 1997, Memorandum.

Reply to Inadequate Thermal Margin and Deviation from Accepted Design Practice — Lad Curtis, 3/6/00, e-mail with attachment regarding Temperature Margin Management on Wetted Propulsion Components and MPL by Kevin Miller, 3/6/00.

Report on the Loss of the Mars Climate Orbiter Mission – JPL Special Review Board, JPL internal document, JPL D-18441, November 11, 1999.

Results of July 18–19, 1996 MR Compatibility Test at Lockheed Martin Astronautics, Denver , Colorado, Release July 25, 1996.

Results of May 31, 1996 MR Compatibility Test at Lockheed Martin Astronautics, Denver, Colorado, Release July 2, 1996.

Review of Temperature Margins for Deployment Mechanisms and Separation Devices — via Frank Locatell, 11/22/99 viewgraph presentation to JPL Red Team by Locatell and Kevin Miller (LMA thermal engineer).

RF Switch Materials — via Kyle Martin e-mail of 02/10/00, response from Teledyne re: possible cold welding.

RF Switch Materials — via Kyle Martin e-mail of 02/10/00, response from Teledyne re: possible cold welding.

Sequence C — Sequence of Events, Generated December 1 03:20:20, 1999.

Slosh Model — Philip Good, 01/26/00, report presented at LMA.

Software Development Story to MPIAT — Lad Curtis e-mail of 02/23/00 to John Casani and Al Schallenmuller; also John McNamee responded to same topic.

Standards Document Problem/Failure Reporting System, Guidelines and Procedures, JPL internal document, JPL D-8091, August 1998.

SOL 0 and Landed Init Timeline — Handout, LMA 01/31/00.

SOL 0 to SOL 33 Timeline — Handout, LMA 5/6 January 2000.

Spider Architecture — Handout, LMA Meeting 01/31/00.

Status of Center of Mass Action Items — Glenn A. Macala, 2/28/00, e-mail regarding further update.

STL Sequence Runs — Handout, LMA Meeting 01/31/00.

Structural Test Program Overview — Handout, DS2 Briefing 01/13/00

STV REA Thermocouple Locations — November 1997.

Surface Dust Disturbance and Deposition During Mars ’01 Landing — Carl Guernsey, 4/25/99, memo to Eric Suggs.

Surveyor PDS Analysis — via fax Jim Chapel to Bill Ely and Joe Protola, 01/24/00, presented at LMA.

System and Mission Design Overview — Handout, DS2 Briefing 01/13/00.

Tank Diaphragm Testing – Centaur Tank — Milt Hetrick, 2/15/00, e-mail regarding update on Centaur water hammer testing.

Tank Diaphragm Testing Quick Look Data — via Lad Curtis, e-mail of 03/14/00, presentation by Propulsion PDO and EPL, 03/10/00.

Tank Diaphragm Quick Look Data, Rev. A — LMA presentation, M. Hetrick et al., March 15, 2000.

Tank Line Temperature — via e-mail from Lad Curtis of 02/17/00; responses to queries from Richard Cowley and Jeff Leising. Attachment: TCM and SAM burns. Follow-up e-mail from Kevin Miller of 02/17/00 referring to documentation in ISA #Z54100 closed 11/20/99.

TCM-5 Line Temp Trace — via Lad Curtis e-mail of 02/16/00; Greg McAllister e-mail to Richard Cowley of 02/15; flight data from EDL –1 hr (approx): “MPL Final Contact Data Surrounding Pressurization.”

TCM-5 Rationale – Cross-track Capability — Phil Knocke, February 1, 2000, viewgraph presentation to Environment and Landing Site Review Team at LMA, February 1, 2000.

TD Sensor PIE and Involvement, 25 February 2000, e-mail message from Lad Curtis.

Telecom Action Items from 02/01/00 — via Kyle Martin e-mail of 02/10/00, memo from William Adams and Scott Toro-Allen on remaining action items (includes responses re: what are view angles of all antennas?; if 10 dB down on UHF signal seen at Stanford, what does that mean for comm with other antennas?; is there some off-nominal landing orientation that precludes X-band and UHF comm?).

Telecom Overview — Handout, LMA Meeting 01/31/00.

Telecommunications Subsystem — Handout, DS2 Briefing 01/13/00.

Terminal Descent Phase Overview — John Cuseo, 01/25/00, viewgraph presentation at LMA.

Testing of the MPL 1/2” Pyro Valves in Propellants — via Lad Curtis e-mail of 1/10/00 from George E. Cain e-mail on 1/7/00.

Testing of the MPL 1/2” Pyro Valves in Propellants — via Lad Curtis 01/10/00, memo from George Cain to Lad Curtis of 01/07/00.

The Extent of the Post-Launch MGS Mars Relay Mode Confirmation, John Callas e-mail, 03/09/00.

Throttled Thrusters — Milt Hetrick, 3/8/00, e-mail.

Touchdown Sensor Comments — Lad Curtis e-mail of 02/10/00 re: possible new leg deploy tests; sensor miswiring at ATLO test.

Touchdown Sensor Flow Chart — via e-mail from Lad Curtis of 02/17/00; functional flow chart for TD sensor code.

Touchdown Sensor Leg Deploy Testing — via Lad Curtis 02/09/00, Russ Gehling viewgraph presentation to MPIAT on 02/09/00 (no cover slide on presentation).

Touchdown Sensor PIE and Involvement — Lad Curtis e-mail of 02/25/00 to John Casani et al., re issues surrounding cause of premature descent engine termination.

Touchdown Sensor Tests — via Lad Curtis e-mail of 02/09/00; presentation to MPIAT on 02/09/00 (no cover slide on presentation).

Touchdown Sensor Tests — via Lad Curtis e-mail of 02/17/00; Jeff Bene e-mail of 02/09/00 to Wes Menard re status and charts from Russ Gehling.

Umbilical/Electronics Packaging Design and Verification — Handout, DS2 Briefing 01/13/00.

Why No Downlink Capability During EDL for MPL? — John McNamee to Ed Stone et al., via e-mail, 12/08/99.

Appendix 2

Review Team Members and Consultants

Environment and Landing Site

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