JET PROPULSION LABORATORY

INTEROFFICE MEMORANDUM
JAR: 92-53
November 20, 1992

TO:

FROM: J. A. Roberts

SUBJECT: Magellan Lessons Learned

In reviewing JPL D-9643, Magellan Lessons Learned, certain lessons learned have been identified for inclusion into the Spaceflight Significant Event File. Dr. Srinivas Mohan has been assigned to develop an event for Magellan Lesson 1-7 and has requested the following:

Background information
Reference material
Material discussed at the project reviews
How the problem surfaced
PDR and CDR notes that are available.

Assistance in providing this information to Dr. Mohan will be appreciated. Dr. Mohan may be reached at extension 4-1245

D-66274

MAGELLAN

LESSONS-LEARNED WORKSHOP

WEDNESDAY, DECEMBER 11, 1991

SESSION 1: SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

8:30 AM TO 12:00 NOON

SESSION 2: ASSEMBLY, TEST AND LAUNCH OPERATIONS

1:00 PM TO 4:30 PM

MAGELLAN

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INTRODUCTION

WORKSHOP OBJECTIVES:

1. ENCAPSULATE MAGELLAN EXPERIENCE INTO CONCISE RECOMMENDATIONS FOR FUTURE JPL PROJECTS.
2. CONCENTRATE ON ITEMS THAT WILL:
   - INCREASE MISSION SUCCESS
   - REDUCE RISK OF OPERATIONS
   - REDUCE OVERALL COST OF PROGRAM
3. SELECT THE KEY ITEMS THAT HAVE THE GREATEST POTENTIAL FOR POSITIVE IMPACT ON FUTURE PROJECTS.

WHAT WE ARE NOT HERE TO DO:

1. CRITCIZE EACH OTHER FOR PAST MISTAKES.
2. MAKE MAGELLAN BETTER, RETROACTIVELY.
3. RE-OPEN OLD ISSUES (OLD WOUNDS ?) JUST TO MAKE A POINT.

FOCUS ON THE FUTURE

INTRODUCTION

WORKSHOP PROCEDURE:

1. WALK THROUGH RECOMMENDATION CHARTS IN ORDER OF PACKAGE:

   - SOLICIT AGREEMENT/DISAGREEMENT FROM AUDIENCE.
   - CORRECT ON-SCREEN ANY MAJOR ERRORS.
   - NOTE ANY ADDITIONS OF MAGELLAN EXAMPLES TO RATIONALE.
   - MAKE NOTE OF ANY STRONG MINORITY OPINIONS.
   - THERE IS ABOUT 6-MINUTES PER ITEM ON AVERAGE.

2. ASSIGN A "VALUE" TO RECOMMENDATION ACCORDING TO TABLE ON NEXT PAGE. THERE ARE 3 CATEGORIES.

3. IF A WALK-ON IS CLOSELY RELATED TO AN ITEM UNDER DISCUSSION, BRING IT UP THEN. IF NOT, SAVE IT FOR THE "WALK-ON TOPICS" PART OF THE SESSION.

4. LOOK AHEAD, IF THE ITEM UNDER DISCUSSION IS NOT OF INTEREST. (BE PREPARED TO CONTRIBUTE WHEN YOUR ITEM COMES)

5. THE SUMMARY PERIOD WILL ATTEMPT TO DETERMINE THE ITEMS OF GREATEST POTENTIAL IMPACT.

LESSON-LEARNED VALUE ASSIGNMENT

	A	B	C
1. APPLICABILITY TO FUTURE PROJECTS	APPLICABLE TO ALL OR NEARLY ALL PROJECTS AND TO MULTIPLE AREAS WITHIN A PROJECT	APPLICABLE TO MANY PROJECTS (BUT NOT ALL) WITH POTENTIAL TO APPLY TO SEVERAL AREAS.	APPLICABLE TO ONLY A FEW PROJECTS OR APPLICABILITY ONLY TO ONE AREA
2. POTENTIAL INCREASE TO MISSION SUCCESS AND/OR REDUCTION OF RISK	HIGH PROBABILITY OF INCREASING MISSION SUCCESS OR REDUCING RISK OF OPERATIONS	POSSIBLE BENEFIT TO PROJECT IF IMPLEMENTED BY INCREASING SUCCESS OR REDUCING RISK	NO OR VERY SMALL IMPACT ON MISSION SUCCESS OR RISK REDUCTION
3. POTENTIAL CONTRIBUTION TO REDUCING TOTAL COSTS	MAJOR COST REDUCTION IS A DEFINITE POSSIBILITY	SOME COST REDUCTION IS POSSIBLE.	NO COST ADVANTAGES OR AN EXPECTED INCREASE TO COST

SESSION 1

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

AGENDA	TIME ALLOCATED
INTRODUCTION	8:30 - 8:40
PROGRAM PHILOSOPHY ISSUES	8:40 - 9:20
CONTRACTUAL ISSUES AND TECHNICAL MONITORING	9:20 - 10:10
FLIGHT SOFTWARE & FAULT PROTECTION ISSUES	10:10 - 10:55
FLIGHT HARDWARE RELATED ISSUES	10:55 - 11:20
WALK-ON TOPICS	11:20 - 11:40
SUMMARY	11:40 - 12:00

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

PEOPLE WHO CONTRIBUTED ITEMS TO THIS SESSION:

VERBAL INTERVIEWS:

JOE PLAMONDON
GARY PARKER
KARL BOUVIER
ED LITTY
RON BANES
PHIL BRISENDINE
JOE SAVINO
NATE BURROW
CHARLIE BROWN (PHONE)
JOHN SLONSKI

WRITTEN INPUTS:

ED KELLUM
JOE SAVINO
JIM NEUMAN
NATE BURROW
EILEEN DUKES
ERIC SEALE
KARL BOUVIER
CONRAD WONG
RON BANES
FRED HAMBLEN
KEVIN McNEILL
DAVE CWYNAR
DON MARQUET
DONNA SEXTON-PACKARD
JOE BUESCHER

PROGRAM PHILOSOPHY ISSUES DURING SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: DEVELOP A WRITTEN JPL POLICY DEFINING THE CRITERIA FOR USE OF PROTOFLIGHT COMPONENTS VERSUS THE NEED TO BUILD A DEVELOPMENT UNIT. EACH ELEMENT OF A SPACECRAFT SHOULD BE EVALUATED INDIVIDUALLY AGAINST THE CRITERIA CHECKLIST BEFORE PROTOFLIGHT STATUS IS GRANTED.

RATIONALE: MAGELLAN MECHANISMS ALL HAD DESIGN DEVELOPMENT UNITS AND HAVE EXPERIENCED NO IN-FLIGHT PROBLEMS. THE REMs WERE DECLARED PROTOFLIGHT (WITHOUT A DEVELOPMENT UNIT) AND HAD PROBLEMS IN FLIGHT.

OTHER EXAMPLES?

VALUE = A B B

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: DO NOT DELETE ENGINEERING MODELS (EM) FOR MAJOR DEVELOPMENTS. IF THE EM IS DELETED, THEN MORE DESIGN EFFORT NEEDS TO BE EXPENDED TO ANALYZE AND TEST THE DEVELOPMENT UNIT.

RATIONALE: THE RADAR SENSOR ENGINEERING MODEL (EM) WAS DELETED DUE TO COST CONSTRAINTS. THE RESULT WAS A VERY IMMATURE AND POORLY TESTED DESIGN. THIS DESIGN WAS THEN USED TO BUILD THE FLIGHT UNITS. THIS CAUSED CHANGES TO BE INCORPORATED ON FLIGHT HARDWARE LATE IN THE PROGRAM (AVERAGING 300 CHANGES PER MONTH) WITH THE RESULTANT HIGH COST. THE DEVELOPMENTAL MODEL BREADBOARD TESTING PROGRAM WAS WEAK FURTHER COMPOUNDING THE PROBLEM. DUE TO SCHEDULE SLIPPAGES AND FORCED WORKAROUNDS, SOME UNITS LATER DID HAVE ENGINEERING MODELS BUILT. THE COST SAVING PLANNED WAS NOT REALIZABLE AND, IN THE END, DELETION OF THE EM RESULTED IN A HIGHER DEVELOPMENTAL COST.

VALUE = A B C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: MINIMIZE TECHNOLOGY DEVELOPMENT ON A FLIGHT PROJECT. USE EXISTING PROVEN TECHNOLOGY WHEN IT MEETS THE REQUIREMENTS RATHER THAN DEVELOPING NEW TECHNOLOGY. IF DEVELOPMENT MUST BE DONE, IT NEEDS TO BE WIDELY RECOGNIZED, THE RISK QUANTIFIED, AND ADDITIONAL PLANNING FOR THE UNEXPECTED ACCOMPLISHED. (E.G. ADDITIONAL TESTING PLANNED)

RATIONALE: THE USE OF ASTROQUARTZ BLANKETS ON MAGELLAN WAS IN ACTUALITY TECHNOLOGY DEVELOPMENT. NUMEROUS PROBLEMS WERE EXPERIENCED IN DEVELOPMENT (E.G. BLANKET FRAYING, LAYER DEBONDING) AND IN FLIGHT (E.G. HOT SPACECRAFT SURFACES, PARTICLE SHEDDING IN STAR SCANNER FIELD OF VIEW.) ADDITIONAL TESTING MIGHT HAVE CAUGHT THESE.

VALUE = B B B

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: FOR COMPONENTS INHERITING "EXISTING DESIGNS" FROM OTHER PROGRAMS, THE PROJECT NEEDS TO PENETRATE THOSE DESIGNS FOR FULL UNDERSTANDING OF THEIR HISTORY AND LIMITATIONS. WE SHOULD NOT ACCEPT THAT JUST BECAUSE A DESIGN ACTUALLY FLEW, IT WILL WORK CORRECTLY FOR OUR MISSION AND ENVIRONMENT.

RATIONALE: SOMEONE KNEW FROM PRIOR FLIGHTS THAT THE MAGELLAN STAR SCANNER WAS SENSITIVE TO HIGH ENERGY PROTONS. IF WE HAD DISCOVERED THIS FACT EARLY ENOUGH, THE CRUISE STAR SCAN FALSE INTERRUPT PROBLEMS MIGHT HAVE BEEN MITIGATED. SIMILARLY, THE POWER DISTRIBUTION UNIT DESIGN HAD BEEN FLOWN BY LOCKHEED, HOWEVER DURING DEVELOPMENT, THE UNIT HAD TO BE RETURNED TO THE VENDOR MULTIPLE TIMES TO CORRECT MAGELLAN APPLICATION PROBLEMS. THESE RETURNS MIGHT HAVE BEEN ELIMINATED IF EARLY INVESTIGATION OF THE PRIOR DESIGN HAD BEEN THOROUGH. A THIRD EXAMPLE IS THE ODETICS TAPE RECORDER THAT EXHIBITED SIMILAR DATA CORRUPTION PROBLEMS ON THE GEOSAT SPACECRAFT IN 1987.

VALUE = A A C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: WHENEVER A SUBSYSTEM IS PLANNED TO BE ASSEMBLED FROM A MIXTURE OF INHERITED COMPONENTS FROM DIFFERENT PROGRAMS, INHERITED DESIGNS, AND NEW BUILDS, A VERY STRONG SYSTEMS ENGINEERING DESIGN MUST BE ACCOMPLISHED UP FRONT TO AVOID SERIOUS PROBLEMS DURING DEVELOPMENT.

RATIONALE: THE MAGELLAN ELECTRICAL POWER SUBSYSTEM EXPERIENCED NUMEROUS PROBLEMS IN DEVELOPMENT DUE TO INSUFFICIENT SYSTEMS ENGINEERING.

- PCU AND SRU FROM P-80 PROGRAM
- INVERTER, PSU AND PDU FROM GALILEO
- POWER REQUIREMENTS DETERMINED BY INHERITED EQUIPMENT (E.G. AACS & CDS)

PROBLEMS EXPERIENCED IN POWER REGULATION SCHEME, ADDITION OF SOFT GROUND, AND FAULT PROTECTION FOR THE PYRO SWITCHING UNIT. CHANGES TO THE DESIGN TO FIX THESE PROBLEMS CAUSED A SIGNIFICANT INCREASE IN COST. (E.G. MODIFICATION TO THE SIGNAL CONDITIONING UNIT.)

VALUE = A B B

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: THE PRIME CONTRACTOR SHOULD HAVE AN ON-PROJECT DESIGN REVIEW TEAM DESIGNATED EARLY IN THE PROGRAM TO ADJUDICATE BETWEEN WORK UNITS. SUCH METHODS TO RESOLVE PROBLEMS SHOULD BE FORMAL AND VISIBLE TO JPL REPRESENTATIVES.

RATIONALE: SOME DISAGREEMENTS BETWEEN WORK UNITS WERE NOT SOLVED IN A TIMELY AND COST EFFECTIVE MANNER, AND MANY HAD TO COMPETE FOR PROGRAM MANAGERS TIME FOR A RESOLUTION. THE COMPROMISE RESOLUTIONS WERE NOT ALWAYS VISIBLE TO JPL, AND MAY NOT HAVE ALWAYS BEEN CORRECT FOR THE SITUATION.

VALUE = B B B

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: DURING SPACECRAFT DESIGN, SEPARATE THE CHIEF ENGINEER FUNCTION FROM THE SYSTEMS ENGINEERING MANAGEMENT FUNCTION TO ALLOW THE CHIEF ENGINEER TO CONCENTRATE 100% ON THE TECHNICAL ISSUES OF SPACECRAFT DESIGN.

RATIONALE: MAGELLAN SPACECRAFT DESIGN USED THIS APPROACH TO GREAT BENEFIT.

VALUE = A B C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: FOR EACH WORK UNIT, A SUBSYSTEM COGNIZANT ENGINEER SHOULD BE ASSIGNED TO FOLLOW THE SUBSYSTEM PROGRESS FROM REQUIREMENTS AND DESIGN TO DELIVERY. THIS IS ESPECIALLY IMPORTANT FOR ONE-OF-A-KIND BUILDS. SUBCONTRACTORS SHOULD FOLLOW THIS PROCEDURE ALSO.

RATIONALE: MAGELLAN EXAMPLES: THE DMS (TAPE RECORDER) COGNIZANT ENGINEER DID NOT FOLLOW THE RECORDER THROUGH TO DELIVERY. THE MOTOROLA CHIEF DESIGN ENGINEER FOR THE TRANSPONDER DID NOT FOLLOW IT THROUGH DEVELOPMENT.

ALTHOUGH PERHAPS NOT CONNECTED, THESE ARE OUR TWO SPACECRAFT HARDWARE FAILURES.

VALUE = A B C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: ENSURE THAT PROPER ANALYSIS IS RE-DONE WHEN DESIGN CHANGES ARE MADE. THIS SHOULD BE ACCOMPLISHED EARLY ENOUGH TO IMPLEMENT THE NECESSARY MODIFICATIONS IF PROBLEMS ARE DISCOVERED.

RATIONALE: THE SOLAR CELLS ON THE MAGELLAN SOLAR PANELS WERE CHANGED FROM 2cm x 4cm TO 4cm x 4cm IN SIZE, BUT THE SAME INTERCONNECTS WERE USED. ANALYSIS INDICATED THAT FLEXURE OF PANELS MIGHT CAUSE A DISCONNECT AS EARLY AS CYCLE 4, BUT NO CHANGES COULD BE MADE BECAUSE THE ANALYSIS WAS COMPLETED TOO LATE (I.E. TOO CLOSE TO LAUNCH.)

VALUE = B A C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: AT THE END OF PHASE B, PROGRAM MANAGEMENT SHOULD PERFORM A "COMPRESSION STROKE" ON THE PROGRAM BY ASKING WHAT MISSION COULD BE ACCOMPLISHED FOR HALF THE PRICE, FORCING THE ISSUE OF MISSION SIMPLIFICATION.

RATIONALE: THE CANCELLATION OF VOIR AND SUBSEQUENT RESURRECTION OF VRM (AKA MAGELLAN) FORCED US TO DESIGN A MUCH LOWER COST MISSION THAT IN THE END, ACCOMPLISHED NEARLY THE SAME OBJECTIVES AS THE ORIGINAL. EVEN THOUGH MAGELLAN SUFFERED COST GROWTH, THE SUPER ELEGANT VOIR WOULD HAVE BEEN A BILLION DOLLAR PLUS MISSION, WITH NO GREATER SUCCESS. THE EXTERNALLY-FORCED MAGELLAN "COMPRESSION STROKE" CAUSED INTENSE PRESSURE ON THE TEAM, BUT THEY EMERGED WELL AND TESTED BY FIRE.

VALUE = A B A

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: PROJECTS NEED TO FIND WAYS TO DESIGN THE SPACECRAFT FLIGHT SYSTEM AND THE MISSION OPERATIONS SYSTEM TOGETHER, WITH COST MINIMIZATION AS A PROJECT OBJECTIVE. DECISIONS MADE IN SPACECRAFT DESIGN SHOULD BE CONSIDERED FOR THEIR SUBSEQUENT MOS IMPACT.

A MISSION OPERATIONS CONCEPT DOCUMENT SHOULD BE WRITTEN EARLY AND MADE AVAILABLE TO SPACECRAFT DESIGNERS.

RATIONALE: USUALLY, THE SPACECRAFT IS DESIGNED FIRST, AND SOMETIME LATER, THE MOS IS DESIGNED. MANY TIMES, DECISIONS MADE IN SPACECRAFT DESIGN REQUIRE DIFFICULT AND COSTLY IMPLEMENTATIONS IN THE COMMAND AND TELEMETRY SYSTEMS ON THE GROUND, WHEREAS A DIFFERENT BUT EQUALLY SUFFICIENT SOLUTION FOR THE SPACECRAFT WOULD REDUCE THE COMPLEXITY ON THE GROUND. EVEN IN CASES WHERE THE SPACECRAFT AND MOS DESIGNS PROCEED TOGETHER, SPACECRAFT ACTIVITY WINS THE COMPETITION FOR RESOURCES, MOS HAVING MUCH LOWER PRIORITY. MAGELLAN EXPERIENCED SOME OF THIS.

VALUE = A B A

CONTRACTUAL ISSUES AND TECHNICAL CONTRACT MONITORING DURING SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: JPL NEEDS TO ESTABLISH AN ENVIRONMENT OF TEAMWORK AND MUTUAL RESPECT WITH ITS PRIME CONTRACTORS. THE STRENGTHS OF BOTH ORGANIZATIONS SHOULD BE USED WHERE NEEDED TO SOLVE PROBLEMS. CONTRACTORS SHOULD BE ENCOURAGED TO ASK FOR JPL HELP IN AREAS WHERE THEY CAN CONTRIBUTE.
COROLLARY: THE CONTRACT (AND AWARD FEE PROCESS) SHOULD BE STRUCTURED TO ACCOMMODATE THIS.

RATIONALE: THIS CONCEPT WORKED REASONABLY WELL WITH MARTIN MARIETTA; NOT QUITE SO WELL WITH HUGHES.

POSITIVE EXAMPLES:

- THE CPAF CONTRACT STRUCTURE ALLOWED THE FLEXIBILITY TO GET THE JOB DONE RIGHT.
- COOPERATIVE WORK TO GET THE STRUCTURAL VERIFICATION PLAN APPROVED BY JSC PRIOR TO LAUNCH
- REM TESTING AT EDWARDS AFB DURING CRUISE
- AACS MEMORY CHIP TESTING AFTER VOI BACK-UP MEMORY GLITCH.

VALUE = A B B

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: DO NOT ALLOW CONTRACTORS TO LET OUT-OF-HOUSE (TO A SUBCONTRACTOR) A SYSTEMS LEVEL INTEGRATION FUNCTION.

RATIONALE: FOR SUBCONTRACTED SYSTEMS-LEVEL INTEGRATION ACTIVITIES, NEITHER THE PRIME NOR JPL CAN MAINTAIN QUALITY CONTROL OVER THE SYSTEMS ENGINEERING AND INTEGRATION FUNCTIONS. SUBCONTRACTOR REVIEWS, IN GENERAL, ARE NOT SUFFICIENT TO DISCOVER PROBLEMS. MAGELLAN ROCKET ENGINE MODULES WERE GIVEN TO ROCKET RESEARCH. THEIR THERMAL ANALYSIS WAS NOT SUFFICIENTLY COMPLETE TO CATCH THE REM OVERHEATING PROBLEM THAT DEVELOPED IN CRUISE.

VALUE = A B B

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: JPL SHOULD NOT PROVIDE GFP HARDWARE (OR SOFTWARE?) TO A CONTRACTOR UNLESS SPECIAL PROVISIONS ARE MADE IN THE CONTRACT TO ALSO PROVIDE ALL OR SOME OF THE FOLLOWING:

1. UP-TO-DATE DOCUMENTATION (BOTH DESIGN AND BUILD)
2. UNIT REPLACEABLE SPARE COMPONENTS
3. ACCESS TO KNOWLEDGEABLE REPAIR PERSONNEL
4. SUPPORT FOR MODIFICATIONS

RATIONALE: MAGELLAN USED NUMEROUS GFP COMPONENTS, MOST WITH INADEQUATE DOCUMENTATION, NO SPARES AND MINIMAL REPAIR CAPABILITY.

VALUE = B B C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: JPL TECHNICAL DIVISIONS SHOULD BE MORE PROACTIVE WITH CONTRACTORS IN MAKE-BUY DECISIONS ON COMPONENTS OR SUBSYSTEMS.

COROLLARY: THE CONTRACT STRUCTURE MAY REQUIRE MODIFICATION TO ACCOMMODATE THIS.

RATIONALE: SOME MANUFACTURING DIFFICULTIES WERE EXPERIENCED ON MAGELLAN DUE TO SUBCONTRACTOR'S INABILITY TO PERFORM TO SCHEDULE AND COST. EXAMPLE: BATTERY CASES.

VALUE = B B C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: CAREFULLY CONSTRUCT AWARD FEE IN THE CONTRACT OF A PRIME CONTRACTOR SUCH THAT THERE ALWAYS REMAINS AN INCENTIVE TO GET THE JOB DONE. JPL SHOULD RETAIN ADAPTIVE CONTROL OF AWARD FEES, PERMITTING SUBJECTIVE EVALUATIONS.

RATIONALE: THE CONSTRUCTION OF THE MAGELLAN AWARD FEE FOR THE MARTIN MARIETTA CONTRACT WAS COUNTER TO WHAT HAD TO BE DONE IN 1987 AND 1988. IT WAS SET UP SUCH THAT "IF YOU OVERRUN, YOU GET ZERO FEE", WHICH ELIMINATES THE INCENTIVE TO PERFORM OR TO SOLVE PROBLEMS. (FORTUNATELY, MARTIN IGNORED THIS AND PERFORMED ANYWAY.)

THE CONSTRUCTION OF THE AWARD FEE PROCEDURE FOR THE HUGHES RADAR CONTRACT WAS TOO RESULTS-ORIENTED, PROHIBITING MEASUREMENT OF INTERNAL RELEVANT FACTORS.

VALUE = A B C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: JPL SHOULD NOT FORCE A "JPL STANDARD" PROBLEM OR FAILURE REPORTING SYSTEM ON ITS CONTRACTORS. THE CONTRACTOR'S EXISTING PROCESS SHOULD BE EXAMINED AND SUGGESTIONS MADE (IF NECESSARY) TO MAKE PROGRAM-SPECIFIC MODIFICATIONS TO SATISFY JPL NEEDS.

RATIONALE: MAGELLAN USED THE MARTIN MARIETTA ANOMALY REPORTING SYSTEM (MARS) WITHOUT REQUESTING MODIFICATIONS. SELECTED MARS WERE TURNED INTO JPL PFRs, CREATING DUPLICATE SETS OF PAPERWORK. MOST OTHER MARS WERE ONLY "INSPECTION REPORTS" AND SHOULD HAVE BEEN CLASSIFIED DIFFERENTLY.

VALUE = A C B

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: CAREFULLY SELECT THE JPL CONTRACT MONITORS FOR EACH WORK UNIT CONSIDERING THE NATURE OF THE SUBSYSTEM'S COMPLEXITY AND DIFFICULTY TO BUILD. THE MORE SENIOR PEOPLE SHOULD HANDLE THE MOST DIFFICULT/COMPLEX SUBSYSTEMS. FUNCTION EXPERTS MAY NEED TO BE USED (PERHAPS PART-TIME SHARING OVER SEVERAL PROJECTS) FOR CERTAIN VERY COMPLEX SPACECRAFT FUNCTIONS.

RATIONALE: SUBSYSTEM MONITORING OF THE MARTIN MARIETTA CONTRACT WORKED WELL WITH THE SENIOR PEOPLE; NOT SO WELL WITH JUNIOR PEOPLE. A SECTION "FUNCTION EXPERT" WAS DEVELOPED FOR FAULT PROTECTION WHICH YIELDED BENEFIT IN FAULT PROTECTION DESIGN. A SIMILAR EXPERT IN ATTITUDE DETERMINATION WOULD HAVE BEEN HELPFUL.

FOR THE HUGHES RADAR CONTRACT, JPL EARLY TECHNICAL PENETRATION WAS INADEQUATE TO ALLOW EARLY DETECTION OF PROBLEMS TO COME. JPL DID NOT STAFF TO ORIGINAL PLAN.

VALUE = B B C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: ENCOURAGE CONTRACTORS TO HOLD INFORMAL DISCUSSIONS WITH THE JPL WORK UNIT REPRESENTATIVE PRIOR TO EACH FORMAL MANAGEMENT REVIEW. DETAILS OF PROBLEMS AND RECOVERY EFFORTS SHOULD BE MUTUALLY DISCUSSED BEFORE FORMAL PRESENTATIONS.

RATIONALE: MOST MAGELLAN SPACECRAFT DEVELOPMENT WORK UNITS HELD SPLINTER SESSIONS WITH THE JPL WORK UNIT TECHNICAL MONITOR PRIOR TO EACH MONTHLY MANAGEMENT REVIEW. IN GENERAL, THESE WERE OPEN AND CANDID WORK UNIT PROGRESS REVIEWS THAT WORKED WELL FOR MAGELLAN. THE JPL REPRESENTATIVE WAS NOT SUBSEQUENTLY SURPRISED BY THE MATERIAL PRESENTED AT THE FORMAL MMR. THIS FOSTERED A TEAM SPIRIT DURING DEVELOPMENT.

VALUE = A C C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: JPL MONITORING OF CONTRACTED EFFORT SHOULD REQUIRE SCHEDULE HISTORY TO BE MAINTAINED. SCHEDULE SLIPS SHOULD BE SHOWN AND NOT JUST UPDATED EACH MONTH. DIFFERENTIATION SHOULD BE MADE BETWEEN SLIPS DUE TO LATE INPUT VERSUS SLIPS FROM LATE PERFORMANCE.

RATIONALE: MANY SCHEDULES TRACKED MONTHLY WERE SIMPLY UPDATED TO SHOW NEW COMPLETION DATES WITHOUT INDICATING THE SLIP. THIS CAUSES A LOSS OF VISIBILITY INTO DEVELOPING PROBLEMS. (SOME WORK UNITS DID THIS BETTER THAN OTHERS)

VALUE = B B C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: JPL SHOULD REVIEW CONTRACTORS' KEY PERSONNEL. RECOMMENDED CHANGES SHOULD BE PRESENTED TO THE CONTRACTOR. THE CONTRACT SHOULD NOT BE EXECUTED UNTIL JPL IS SATISFIED WITH THE PERSONNEL QUALIFICATIONS. (I.E. MAKE A PART OF NEGOTIATIONS.)

RATIONALE: DURING THE RE-CLASSIFICATION OF THE PROGRAM FROM VOIR TO VRM, HUGHES CHANGED THE PERSONNEL ON THEIR TEAM. AS A RESULT, THE TECHNICAL HEAD START THAT APPEARED IN THE PROPOSAL WAS NOT THERE AND MUCH OF THE ENGINEERING HAD TO BE RE-DONE, INCLUDING BRINGING THE DIGITAL UNIT IN-HOUSE AT JPL.

VALUE = A B C

FLIGHT SOFTWARE AND FAULT PROTECTION ISSUES DURING SPACECRAFT FLIGHT SYSTEMS DEVELOPMENT

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: DESIGN WALKTHROUGHS SHOULD BE HELD FOR ALL PHASES OF ALGORITHM AND FLIGHT SOFTWARE DEVELOPMENT. THESE MUST INCLUDE A HARDWARE ENGINEERING REVIEW OF ALL MATH MODELS USED IN DESIGN ANALYSIS SIMULATIONS AND IN FLIGHT SOFTWARE. THESE SHOULD BE ATTENDED BY HARDWARE COG E, SOFTWARE DEVELOPERS, ALGORITHM ANALYSTS AND SYSTEMS ENGINEERS.

RATIONALE: MAGELLAN ATTITUDE AND ARTICULATION CONTROL FLIGHT SOFTWARE DEVELOPMENT DID THIS WELL, RESULTING IN MORE EFFICIENT AND COST-EFFECTIVE FLIGHT SOFTWARE

VALUE = B A C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: DEVELOP, DOCUMENT AND IMPLEMENT A PROCESS FOR MAINTAINING MARGIN ESTIMATES FOR FLIGHT SOFTWARE DEVELOPMENT. SOFTWARE METRICS SHOULD BE DEFINED AGAINST WHICH TO REGULARLY MEASURE PROGRESS. RATIONALE SHOULD BE SPECIFIED FOR TOLERANCES ON ESTIMATES DURING DIFFERENT PHASES.

RATIONALE: THE AACS FLIGHT SOFTWARE DEVELOPMENT WORK UNIT DID THIS RIGHT. TOLERANCES WERE ESTABLISHED EARLY, DEFINED CAREFULLY, AND DECREASED WITH TIME AS THE SOFTWARE MATURED. THIS GAVE REALITY TO THE SOFTWARE ESTIMATES. SOFTWARE METRICS WERE BOTH IMAGINATIVE AND INFORMATIVE.

VALUE = C B B

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: FOR CRITICAL FLIGHT SOFTWARE FUNCTIONS WHERE SUBTILE ERRORS MAY NOT BE VISIBLE IN SYSTEMS TESTING, AN INDEPENDENT CODING OF KEY ALGORITHMS SHOULD BE PERFORMED TO COMPARE NUMERICAL OUTPUT WITH THAT FROM FLIGHT CODE. THIS SOFTWARE IS NOT ELEGANT, FORMAL OR COMPACT AND IS NOT SUBJECT TO PROJECT CONTROLS.

RATIONALE: IN THE MAGELLAN AACS SYSTEM, MANY SMALL FACTORS CONTRIBUTE TO THE ATTITUDE DETERMINATION ACCURACY NECESSARY FOR MAPPING THE PLANET. MOST OF THESE ARE TOO SMALL AND SUBTILE TO BE ABLE TO VERIFY DURING EITHER FLIGHT SYSTEMS TEST OR COMPUTER SIMULATION. THE AACS GROUP EFFECTIVELY USED INDEPENDENTLY CODED SOFTWARE TO VERIFY THE CORRECTNESS OF FLIGHT ALGORITHMS.

VALUE = C A C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: DEVELOP A FLIGHT SOFTWARE DESIGN THAT PROTECTS FROM ASYNCHRONOUS INTERUPTS. (E.G. GRACOS) AVOID COMMON STACKS AND REGISTERS. MAKE SURE OVERWRITES CANNOT OCCUR.

RATIONALE: THE FIVE LOSS-OF-SIGNAL ANOMALIES DURING THE MAGELLAN PRIME MISSION WERE AACS RUNAWAY PROGRAM EXECUTIONS (RPE) RESULTING FROM IMPROPER ASYNCHRONOUS INTERRUPT HANDLING LOGIC.

VALUE = B A C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: START EARLY TO MAINTAIN A DATABASE FOR CONFIGURATION CONTROL OF FLIGHT SOFTWARE PARAMETERS. CONDUCT PARAMETER REVIEWS AT VARIOUS STAGES OF DEVELOPMENT AND MISSION PREPARATION TO VALIDATE EXPECTED VALUES OF PARAMETERS, AND THEIR USE IN FLIGHT OPERATIONS PLANS AND FLIGHT SOFTWARE CODE. CONTROL OF CERTAIN TEST SOFTWARE PARAMETERS IS ALSO IMPORTANT.

RATIONALE: MAGELLAN HAD 1700 PARAMETERS THAT COULD BE CHANGED IN-FLIGHT. MANAGING THE VALUES FOR THESE PARAMETERS WAS RECOGNIZED TO BE A FORMIDABLE TASK AND A SERIES OF PARAMETER REVIEWS WAS INSTITUTED. THIS ACTIVITY PROVED EXTREMELY BENEFICIAL, ALTHOUGH BEGUN TOO CLOSE TO LAUNCH.

VALUE = B A C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: AS ON-BOARD FAULT PROTECTION COMPLEXITY INCREASES WITH EVER GROWING FLIGHT COMPUTER MEMORY SIZE AND CAPABILITY, SPACECRAFT FAULT PROTECTION SHOULD BE TREATED LIKE ANOTHER SUBSYSTEM WITH ITS OWN REQUIREMENTS REVIEW, PDR AND CDR. SYSTEM-LEVEL DESIGN WALKTHROUGHS ARE ESSENTIAL. BEGIN FAULT PROTECTION DESIGN EARLY IN THE PROGRAM.

RATIONALE: MAGELLAN, UNLIKE ITS PREDECESSORS VOYGER AND VIKING, HAD MULTIPLE LEVELS OF SPACECRAFT FAULT PROTECTION AND NUMEROUS INTERACTIONS WITH VARIOUS SPACECRAFT STATES. THIS COMPLEXITY MADE NECESSARY INDEPENDENT FAULT PROTECTION REVIEWS, WHICH PROVED VERY BENEFICIAL.

FAULT PROTECTION DESIGN ON MAGELLAN COULD HAVE SIGNIFICANTLY BENEFITED BY STARTING EARLIER, IN PARALLEL WITH SUBSYSTEM DESIGNS.

VALUE = A A C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: ROM IS NECESSARY, EXPECIALLY ROM FAULT PROTECTION. IT PROVIDES A SYSTEM-LEVEL SAFETY NET.

RATIONALE: AT ONE TIME, MAGELLAN WAS GOING TO REMOVE AACS ROM FROM THE DESIGN DUE TO DELIVERY SCHEDULE PROBLEMS. IT WAS "ONLY A THOUSAND WORDS." WITHOUT ROM SAFING MAGELLAN WOULD NEVER HAVE MAPPED VENUS.

VALUE = A A C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: ESTABLISH INFORMAL CONTROLS FOR THE DEVELOPMENT OF TEST SOFTWARE SUCH THAT ITS SCHEDULE IS MAINTAINED AND DOESN'T IMPACT FLIGHT HARDWARE/SOFTWARE SCHEDULES. APPLY SOFTWARE MANAGEMENT TOOLS TO MAINTAIN THE RIGOR WITHOUT THE FORMALITY.

RATIONALE: WHEN TEST SOFTWARE IS NOT SUBJECT TO RIGOROUS CONTROLS SIMILAR TO FLIGHT SOFTWARE, IT CAN LEAD TO A DISREGARD OF PRUDENT SOFTWARE MANAGEMENT. THIS RESULTS IN PROBLEMS WITH TEST SOFTWARE THAT IMPACTS THE PROGRESS OF THE FLIGHT SYSTEMS.

VALUE = C C B

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: PLAN TO OVERSIZE TEST COMPUTERS TO BE PREPARED FOR THE UNKNOWN DURING SOFTWARE DEVELOPMENT. HARDWARE IS ALWAYS LESS EXPENSIVE THAN SOFTWARE.

RATIONALE: SIZE AND THROUGHPUT LIMITATIONS OF THE PDP 11/44 COMPUTER IN THE MAGELLAN LTS/SE USED FOR SUBSYSTEM TESTING, CAUSED AND INORDINATE EXPENDITURE OF TEST SOFTWARE PROGRAMMING TIME TO OVERCOME THOSE LIMITATIONS.

VALUE = C C B

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: PRIOR TO ACCEPTING SOFTWARE FOR INHERITANCE OR REUSE FROM ANOTHER PROJECT, AN IN DEPTH UNDERSTANDING OF REQUIREMENTS FOR BOTH SOFTWARE AND HARDWARE SHOULD BE ATTAINED.

RATIONALE: THE MAGELLAN AACS TEST S/W ORIGINALLY RELIED ON HEAVY INHERITANCE FROM GALILEO WITH SOME MODIFICATION. BASED ON THIS, MARTIN MARIETTA PURCHASED TWO PDP-11/44'S FOR DEVELOPMENT AND EXECUTION OF THIS S/W. AS DEVELOPMENT PROGRESSED, LESS THAN 20% OF THE GALILEO S/W WAS INHERITED. THE PDP-11/44 PROVED TO BE SLOWER THAN THE PDP-11/60 USED ON GALILEO, RESULTING IN CONSIDERABLE EFFORT JUST TO GET THE MAGELLAN S/W TO EXECUTE. TOGETHER, THESE TWO FACTORS RESULTED IN COST OVERRUNS, LATE DELIVERY AND INCOMPLETE S/W, AND CONTINUES TO IMPACT S/W EFFORTS DURING OPERATIONS. BETTER UNDERSTANDING OF THIS TASK WOULD HAVE INDICATED A DIFFERENT COMPUTER WITH A NEW DEVELOPMENT EFFORT TO BE COST EFFECTIVE.

VALUE = C C B

FLIGHT HARDWARE RELATED ISSUES DURING SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: VENDOR SUBCONTRACTOR REQUIREMENTS SPECIFICATIONS FOR CERTAIN COMPONENT MANUFACTURE MUST CLEARLY IDENTIFY THE DIFFICULT OR SPECIAL NATURE OF THE TASK, TO PREVENT COST OVERRUNS.

RATIONALE: A BATTERY PACKAGING TECHNIQUE FROM VIKING WAS SELECTED FOR THE BATTERY CHASSIS AND THE REQUIREMENTS DOCUMENT WAS NOT SUFFICIENTLY DETAILED TO REFLECT THE VERY DIFFICULT MACHINING JOB. THIS LED TO BOTH COST AND SCHEDULE PROBLEMS.

VALUE = C B B

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: STRIVE TO STREAMLINE THE PROCESS FOR CERTAIN SUBSYSTEMS TECHNICAL REPORTS SUCH AS WORST-CASE ANALYSIS, FMEA REPORTS, AND RELIABILITY ANALYSIS REPORTS. JPL SHOULD TRUST ITS CONTRACTOR FOR THESE WITHOUT HAVING TO APPROVE EVERYTHING. (MAY HAVE TO ACCEPT INCREASED RISK, ESPECIALLY TO ACHIEVE LOW COST.)

RATIONALE: MAGELLAN REQUIRED JPL REVIEW AND APPROVAL ON MOST OF THESE ANALYSIS REPORTS ADDING TIME DELAY AND ADDITIONAL COST.

VALUE = B C B

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: CONDUCT SINGLE POINT FAILURE REVIEWS

RATIONALE: MAGELLAN HELD AN INITIAL OVERALL SINGLE POINT FAILURE REVIEW AND THEN LATER HAD FOCUSED REVIEWS FOR CRITICAL PHASES. ALL WERE WORTHWHILE.

VALUE = C A C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: INVESTIGATE NEW AND UNIQUE COMPONENTS TO THE LEVEL REQUIRED TO FULLY UNDERSTAND THEIR OPERATION AS WELL AS ANY REQUIRED PROTECTIVE MEASURES PRIOR TO INTEGRATION AND TESTING. ALSO, HAVE MORE HIGHLY QUALIFIED PERSONNEL ON HAND, AT LEAST IN A SUPERVISORY ROLE DURING INTEGRATION AND HANDLING OF UNIQUE HARDWARE.

RATIONALE: FAILURE TO FULLY UNDERSTAND REACTION WHEEL CIRCUITRY RESULTED IN DAMAGE TO A PROTOTYPE, WHEN ALLOWED TO FREELY SPIN DOWN. UNKNOWN TO THE PROJECT, IT BECAME A GENERATOR IF POWER IS TOTALLY REMOVED. DUE TO THIS LACK OF UNDERSTANDING, THE S/C WIRING HAD TO BE REDESIGNED TO PRECLUDE DAMAGE IF POWER WAS LOST IN FLIGHT.

LACK OF EXPERIENCE RESULTED IN CONNECTION OF THE PDP-11 TO AN INCORRECT POWER SOURCE IN THE CLEAN ROOM, DAMAGING IT.

ON ONE OCCASION A MORE EXPERIENCED PERSON ASKED TO TAKE THE EXTRA TIME TO RECHECK A CABLE HARNESS AFTER A LENGTHY STORAGE, PRIOR TO CONNECTION TO FLIGHT EQUIPMENT. AN ELECTRICAL SHORT WAS FOUND THAT WOULD HAVE RESULTED IN DAMAGE TO HARDWARE.

VALUE = B B C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: SELECT ACS SENSORS (AND ACTUATORS) APPROPRIATE FOR THE TYPE OF PLATFORM.

RATIONALE: THE MAGELLAN STAR SCANNER WAS DESIGNED FOR USE ON A SPIN-STABILIZED SPACECRAFT, NOT A 3-AXIS STABILIZED PLATFORM. ALTHOUGH THIS WAS A COST SAVINGS AT THE TIME, IT HAS GREATLY COMPLICATED OPERATIONS BY REQUIRING SPECIAL STAR SCAN MANEUVERS, STAR SCAN SELECTION MAINTENANCE, SEQUENCE CONSTRAINTS, DECREASED MAPPING TIME, ETC.

VALUE = C B B

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: AVOID THE USE OF GLASS-FIBER MAT THERMAL TREATMENTS WHEREVER POSSIBLE - THESE MATERIALS GENERATE LARGE QUANTITIES OF DUST, WHICH WILL CAUSE PROBLEMS WITH ANY NEARBY OPTICAL SENSORS

RATIONALE: BLANKETS MADE FROM GLASS FIBERS ARE NOTORIOUS DUST PRODUCERS. ATLO TECHNICIANS WERE AWARE OF THAT BEFORE LAUNCH. THAT KNOWLEDGE, THOUGH, DID NOT "TRICKLE UP" INTO THE RANKS OF EITHER ENGINEERING OR MANAGEMENT. GLASS DUST FROM ASTROQUARTZ BLANKETS CAUSED MAGELLAN SEVERE PROBLEMS WITH STAR SCANS UNTIL AN OPERATIONAL WORK-AROUND WAS DESIGNED. RECENT ANALYSIS OF LDEF MATERIALS ALSO SUGGESTS A HUBBLE REPAIR MISSION MAY STIR UP GLASS DUST FROM INTERNAL BETA CLOTH THERMAL BLANKETS.

VALUE = B A C

SPACECRAFT FLIGHT SYSTEM DEVELOPMENT

RECOMMENDATION: NEGOTIATE MARGINS AND ENVIRONMENTAL PARAMETERS WITH PROGRAM SYSTEMS ENGINEERING AND JPL COUNTERPARTS EARLY. THIS WILL AID IN ESTABLISHING THE WIDEST POSSIBLE PARAMETER RANGES. (E.G. TEMPERATE RANGES)

RATIONALE: MAGELLAN THERMAL WORKED WITH THEIR JPL COUNTERPARTS EARLY AND KEPT THEM INFORMED AND INVOLVED IN THE DECISIONS MADE. THIS MADE FOR WELL INFORMED CUSTOMER CONTACTS AND FEW SUPRISES AT MONTHLY MEETINGS.

VALUE = A C B

SESSION 2

ASSEMBLY, TEST AND LAUNCH OPERATIONS

AGENDA	TIME ALLOCATED
INTRODUCTION	1:00 - 1:10 PM
PROGRAM PHILOSOPHY ISSUES	1:10 - 2:10
TESTING ISSUES	2:10 - 3:20
ASSEMBLY ISSUES	3:20 - 3:35
LAUNCH OPERATIONS ISSUES	3:35 - 3:50
WALK-ON TOPICS	3:50 - 4:10
SUMMARY	4:10 - 4:30

ASSEMBLY, TEST AND LAUNCH OPERATIONS

PEOPLE WHO CONTRIBUTED ITEMS TO THIS SESSION:

VERBAL INTERVIEWS:

JOE PLAMONDON
GARY PARKER
KARL BOUVIER
RON BANES
PHIL BRISENDINE
JOE SAVINO
NATE BURROW
JULIE WEBSTER
CHARLIE BROWN (PHONE)
CHUCK REYNOLDS (PHONE)

WRITTEN INPUTS

JIM NEUMAN
FRANK McKINNEY
NATE BURROW
LAD CURTIS
JOE BUESCHER

PROGRAM PHILOSOPHY ISSUES

DURING ATLO

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: CONSIDER USE OF A MODIFIED PROTOFLIGHT APPROACH TO SPACECRAFT PROGRAMS WHICH BUILDS ONE FLIGHT SYSTEM, AND A SEPARATE NON-FLIGHT STRUCTURE AND CABLE HARNESS TO SUPPORT EARLY HARDWARE AND SOFTWARE INTEGRATION.

RATIONALE: MAGELLAN ATTEMPTED TO DEVELOP ONLY THE SINGLE FLIGHT UNIT AND PERFORM ALL NECESSARY TESTING SEQUENTIALLY. EARLY INTEGRATION OF SUBSYSTEMS COULD HAVE BEEN ACCOMPLISHED ON A REPRODUCTION STRUCTURE AND CABLE HARNESS AVOIDING THE ADDITIONAL WORK OF DISASSEMBLING THE SPACECRAFT FOR MODAL SURVEY.

THE STRUCTURAL TEST ARTICLE COULD HAVE BEEN ELIMINATED.

VALUE = B C A

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: SCHEDULE THE ASSEMBLY AND SYSTEM TEST ACTIVITIES FOR ONLY 2 SHIFTS PER DAY AND FIVE DAYS PER WEEK. THIS LEAVES MARGIN FOR EXPANSION WHEN THE SCHEDULE IS THREATENED. STAFF SHIFTS SUCH AS TO AVOID EXCESSIVE OVERTIME.

RATIONALE: FOR MANY PERIODS, MAGELLAN PLANNED AND STAFFED THREE SHIFTS PER DAY AND SEVEN DAYS A WEEK. NOT ONLY DID THIS LEAVE NO SCHEDULE ROOM TO ABSORB PROBLEMS, BUT USAGE OF PERSONNEL ON THIRD SHIFTS AND WEEKENDS WAS NOT EFFICIENT, LEADING TO HIGHER COST. IF ALSO CONTRIBUTED TO EXCESSIVE FATIGUE FOR PERSONNEL WORKING ON FLIGHT HARDWARE.

VALUE = A C A

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: PROJECT MANAGEMENT MUST BE RECEPTIVE TO NUMEROUS REPLANS DURING ASSEMBLY AND SYSTEM TESTS IF THE OVERALL SCHEDULE IS TO BE MAINTAINED AND MAXIMUM TESTING ACCOMPLISHED.

RATIONALE: THE MAGELLAN PROGRAM DURING ITS LAST YEAR BEFORE LAUNCH WAS ABLE TO MAINTAIN MOMENTUM BY A CONTINUOUS PROCESS OF PLANNING BASED ON THE PRESENT CONDITION OF THE HARDWARE AND SOFTWARE, LESSONS LEARNED FROM PREVIOUS TESTS AND THE CURRENT ASSESSMENT OF WHAT MUST BE DONE TO MEET THE CRITICAL REQUIREMENTS OF THE VERIFICATION PROGRAM.

VALUE = A B A

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: PLAN TO MINIMIZE TIME AT THE LAUNCH SITE. DEVELOP A "SHIP AND SHOOT" PHILOSOPHY. TRANSFER TO THE LAUNCH SITE ONLY THE NECESSARY HANDS-ON PERSONNEL AND MANAGEMENT, AND MINIMIZE LAUNCH SUPPORT EQUIPMENT.

RATIONALE: MUCH OF MAGELLAN TESTING DONE AT KCS WOULD HAVE BEEN ACCOMPLISHED LESS EXPENSIVELY IN DENVER PRIOR TO SHIPMENT.

VALUE = A C A

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: WORK HARD AT TEAM BUILDING TO ACCOMPLISH AN EFFECTIVE MERGE OF THE VARIOUS DISCIPLINES NEEDED BY AN ATLO OPERATION.

RATIONALE: MAGELLAN ACHIEVED A GOOD MELD OF MULTI-DISCIPLINE SUBSYSTEMS ENGINEERS, SCIENCE SYSTEM DEVELOPERS, ENVIRONMENTAL TEST LABORATORY TECHNICIANS, PRODUCT ASSURANCE, TRANSPORTATION AND HANDLING, AND JPL TEAM MEMBERS.

VALUE = A A B

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: USE THE MISSION OPERATIONS SYSTEM AND TEAM FOR ALL LAUNCH OPERATIONS AND TO SUPPORT AS MUCH PRE-LAUNCH TESTING AS POSSIBLE.

RATIONALE: MAGELLAN UTILIZED MISSION OPERATIONS PEOPLE AND GROUND SYSTEMS ONLY TO A LIMITED EXTENT, BUT THE BENEFIT FROM THIS EXPERIENCE WAS STILL VISIBLE DURING IN-FLIGHT MISSION OPERATIONS.

VALUE = A B B

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: JPL SHOULD BECOME MORE INVOLVED WITH CONTRACTORS' MANAGEMENT WHEN THERE IS RESOURCE COMPETITION (FACILITIES, LABORATORIES, EQUIPMENT, ETC) WITH OTHER PROGRAMS. NEED TO ASSIST IN RESOLVING PRIORITY ISSUES.

RATIONALE: THERE WERE SEVERAL INSTANCES DURING MAGELLAN MANUFACTURING, ASSEMBLY & TEST WHERE CONFLICTS WITH OTHER MARTIN MARIETTA PROGRAMS CAUSED REPLANS OF MAGELLAN ACTIVITY

VALUE = B B B

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: WHENEVER POSSIBLE, BUILD COMPONENT ALL IN ONE PHYSICAL LOCATION.

RATIONALE: THE MAGELLAN ELECTRICAL POWER SUBSYSTEM WAS BUILT IN TWO DIFFERENT LOCATIONS AND THEN ASSEMBLED WITH OTHER INHERITED COMPONENTS, RESULTING IN MANY PROBLEMS.
THE SOLAR PANEL SUBSTRATE CONSTRUCTION/LAMINATING WAS DONE IN ONE LOCATION. THE MOUNTING OF CELLS WAS DONE ELSEWHERE.

VALUE = B C C

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: FOR PRELAUNCH SPACECRAFT SYSTEMS TESTING, USE ENGINEERS FOR TEST OPERATORS OF THE MOST COMPLEX SUBSYSTEMS, RATHER THAN TECHNICIANS.

RATIONALE: FOR AACS, CDS, THERMAL AND SYSTEMS ENGINEERING, MAGELLAN USED SUBSYSTEM ENGINEERS RATHER THAN TECHNICIANS FOR TESTING OPERATIONS. THIS HAD TWO BENEFITS:

1. BETTER AND FASTER TROUBLESHOOTING
2. CREATED A VERY EXPERIENCED TEAM WHICH TRANSITIONED INTO FLIGHT OPERATIONS

VALUE = A B C

ATLO TESTING ISSUES

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: SYSTEMS AND SUBSYSTEMS ENGINEERS NEED TO PAY PARTICULAR ATTENTION TO DEVELOPING CLEAR AND COMPLETE TEST REQUIREMENTS FOR ALL ASPECTS OF TESTING. IT IS DIFFICULT TO HAVE A WELL-DEFINED AND WELL-PLANNED TEST PROGRAM WHEN TEST REQUIREMENTS ARE POORLY DEFINED.

RATIONALE: A VERIFICATION PLAN FOR SYSTEM LEVEL REQUIREMENTS WAS NOT ACCOMPLISHED SERIOUSLY. CONSEQUENTLY, SYSTEM TEST REQUIREMENTS WERE INITIALLY POORLY DEFINED. THIS RESULTED IN SIGNIFICANTLY MORE EFFORT THAN NECESSARY TO DEVELOP AND APPROVE ATLO TEST PLANS AND PROCEDURES. THE TEST REQUIREMENTS HAD TO BE CLEANED UP FIRST.

VALUE = A B B

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: DO A VERY SYSTEMATIC AND THOROUGH SUBSYSTEM INTEGRATION TO CHARACTERIZE INTERFACES AND FUNCTIONAL PERFORMANCE PRIOR TO MOVING TO SPACECRAFT SYSTEMS TEST. THIS IS TRUE EVEN FOR SUBSYSTEMS WITH "INHERITED" COMPONENTS.

RATIONALE: THE SUBSYSTEM INTEGRATION TEST FOR THE ELECTRICAL POWER SUBSYSTEM WAS ELIMINATED TO SAVE COST AND SCHEDULE. ITS FIRST SYSTEM TEST WAS ON THE SPACECRAFT. THE SUBSEQUENT TROUBLESHOOTING OF EPS PROBLEMS TOOK A LOT OF SPACECRAFT TIME AND COST THE PROGRAM IN BOTH SCHEDULE AND MONEY.

FOR THE OTHER MAGELLAN SUBSYSTEMS, THIS INTEGRATION PROVIDED A BASELINE FOR PERFORMANCE DURING SUBSEQUENT SYSTEM INTEGRATION AND ANY POTENTIAL DEGRADATION DURING SYSTEM ENVIRONMENTAL TESTING.

VALUE = A B B

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: DURING SUBSYSTEMS TESTING, INTERFACE TESTING WITH THE FLIGHT COMPUTER SHOULD BE DONE AS EARLY AS POSSIBLE. THEN, IN SYSTEMS TEST, AT LEAST ONE TEST SHOULD BE RUN WHERE ALL NON-FLIGHT ACCESS IS REMOVED.

RATIONALE: MAGELLAN RF SUBSYSTEM TESTING WAS DONE WELL. EARLY INTERFACE TESTING WITH THE FLIGHT COMPUTER WAS VERY VALUABLE. PLUGS-OUT TESTING WITH ALL DIRECT MEMORY ACCESS AND AUXILIARY INPUT REMOVED PROVIDED VALUABLE DATA. ALSO THE USE OF THE RF SUBSYSTEM DURING SPACECRAFT SYSTEM TESTS, WHERE SPACECRAFT COMMANDS WERE SENT, WAS A SIGNIFICANT PLUS FOR THE TEST PROGRAM.

VALUE = B B C

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: FOR SUBSYSTEM TESTING, UNDERSTAND AND CHARACTERIZE THE TEST SETUP AND ASSOCIATED GROUND SYSTEM TO THE POINT THAT PROBLEMS DISCOVERED DURING THE TEST CAN BE QUICKLY ISOLATED TO FLIGHT SYSTEM OR TEST SYSTEM.

RATIONALE: MAGELLAN HIGH GAIN ANTENNA TESTING EXPERIENCED RF BREAKDOWN OF FEEDTHRU CONNECTORS ON THE TEST SETUP.

VALUE = B B C

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: WHENEVER POSSIBLE, RUN DEVELOPMENT TESTS ON FULL SIZE COMPONENTS.

RATIONALE: THE MAGELLAN SOLAR PANEL DEVELOPMENT TESTS WERE RUN ON ONE-QUARTER SIZE PANELS. NO PROBLEMS WERE EVIDENT. THE ACTUAL PANEL IN SOLAR THERMAL VACUUM TESTING DELAMINATED THE PANEL STRUCTURE. (DUE TO TOO LOW A TEMPERATURE ADHESIVE TO BOND KAPTON TO ALUMINUM.)

VALUE = B B C

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: USE THE RF COMMAND SUBSYSTEM DURING SYSTEM TEST AND SEND MULTIPLE COMMANDS, NOT JUST SINGLE NO-OP COMMANDS.

RATIONALE: FOR MANY OF THE TESTS, MAGELLAN USED THE FLIGHT RF COMMAND SUBSYSTEM AND THE ACTUAL COMMAND DATABASE TO NOT ONLY TEST THE SUBSYSTEM, BUT TO FERRET OUT ERRORS IN COMMAND AND SEQUENCING SOFTWARE AND IN OPERATIONS PROCEDURES.

VALUE = B B C

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: DON'T DO SYSTEM LEVEL ENVIRONMENTAL WORKMANSHIP TESTS. FERRET OUT WORKMANSHIP DEFECTS AT THE SUBSYSTEM LEVEL PRIOR TO SYSTEM INTEGRATION

RATIONALE: MAGELLAN'S SYSTEM LEVEL ENVIRONMENTAL TESTS WERE DESIGNED TO DUPLICATE THE EXPECTED MISSION ENVIRONMENT (WITH SOME MARGIN) AND AS SUCH DID NOT EXPOSE THE SUBSYSTEMS TO LEVELS OR VARIATIONS NECESSARY TO DRIVE OUT WORKMANSHIP PROBLEMS.

THE MAGELLAN SPACECRAFT WAS COMPLETELY DISASSEMBLED FOLLOWING THE SYSTEM ENVIRONMENTAL TESTS.

VALUE = A C A

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: CONDUCT STRUCTURAL STATIC LOADS TESTS ONLY IF MASS CONSTRAINTS FORCE A MINIMUM DESIGN MARGIN.

RATIONALE: MAGELLAN'S NON-DESTRUCTIVE TESTS AND PROCESS CONTROLS PROVIDED PROOF OF WORKMANSHIP AND MITIGATED THE NEED FOR A STATIC LOADS TEST.

THE MAGELLAN MODAL SURVEY AND ACOUSTIC TEST DEMONSTRATED THAT LOADS DURING THE LAUNCH PHASE WOULD NOT EXCEED THE EXPECTED VALUE.

BECAUSE OF SCHEDULE CONSTRAINTS, MAGELLAN BUILT A STRUCTURAL TEST ARTICLE TO CONDUCT STATIC LOADS TESTING, ADDING COST TO THE PROGRAM.

VALUE = B B A

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: SIMPLIFY SOLAR THERMAL VACUUM TESTING TO THAT NECESSARY TO VERIFY THE THERMAL MODELS.

RATIONALE: FOR MAGELLAN, ONE HOT AND ONE COLD CASE COULD HAVE PROVIDED SUFFICIENT DATA TO VERIFY THE THERMAL MODEL AND CHARACTERIZE SYSTEM PERFORMANCE. MAGELLAN SPENT 30 DAYS IN THE SOLAR THERMAL VACUUM CHAMBER AND YET INTENSE CHARACTERIZATION WAS STILL NECESSARY IN FLIGHT. (SEE ALSO ITEM ATLO - 23)

VALUE = A C A

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: SOLAR THERMAL VACUUM TESTING OF COMPLEX FORMS AND ANY EXPOSED METAL SURFACES SHOULD BE DONE AT MULTIPLE ATTITUDES WITH RESPECT TO THE SUN.

RATIONALE: THE MAGELLAN ROCKET ENGINE MODULES (REMs) WERE NOT TESTED AT THE SUBCONTRACTOR LEVEL WITH SOLAR ILLUMINATION. MAGELLANS STV DID NOT EXPOSE MUCH OF THE REMs TO SOLAR ILLUMINATION AND WERE A MAJOR PROBLEM UNTIL ADDITIONAL TESTING WAS DONE AT EDWARDS AFB AFTER LAUNCH. ALSO THE MGA EXPERIENCED A SOLAR ENTRAPMENT PROBLEM SIMILAR TO REMs. THE AFT END OF THE SPACECRAFT, WHERE THE IUS AND THE SRM SEPARATION PADS WERE LOCATED, ALSO EXPOSED METAL (ALTHOUGH SUPPOSEDLY CLEAR ANODIZED) AND WERE NOT ADEQUATELY CHARACTERIZED PRIOR TO LAUNCH. THIS CAUSED THE MAGELLAN TEAM TO DEVELOP AN ADDITIONAL MAPPING SEQUENCE IN AN ACCELERATED SCHEDULE TO COOL DOWN THE AFT END OF THE SPACECRAFT.
(SEE ALSO ITEM ATLO-22)

VALUE = B B C

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: UNPROVED EXTERNAL SURFACES (E.G. FROSTED OSRS) SHOULD BE EXTENSIVELY TESTED IN A REPRESENTATIVE TEST CONFIGURATION (E.G. WITH ADHESIVES AND SOLAR) SO THAT DEGRADATION IN OPTICAL PROPERTIES CAN BE PROPERLY CHARACTERIZED.
EXPOSED METAL SURFACES (REMS, SRM ADAPTER RING, ETC) SHOULD ALWAYS BE TESTED IN A SOLAR ENVIRONMENT.

RATIONALE: THE OSRS WERE NOT PROPERLY TESTED BEFORE FLIGHT AND HAVE MADE THE THERMAL SUBSYSTEM THE MOST CONSTRAINING SUBSYSTEM ON THE SPACECRAFT. THERE IS SPECULATION THAT THE EXCESSIVE DEGRADATION BEING SEEN IS DUE TO SOME KIND OF INTERACTION OF THE ADHESIVES WITH THE OPTICAL SURFACES. THE EXPOSED METAL SURFACES HAVE ALSO BEEN A SOURCE OF PROBLEMS. (E.G. THE REMS AND THE INFERIOR CONJUNCTION PROBLEMS WITH THE SRM ATTACHMENT RING.)

VALUE = B B C

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: DEVELOP A TOP-DOWN PLAN FOR EACH SUBSYSTEM TO VERIFY THE ELECTRICAL PHASING. (I.E. POLARITY CHECKING). DEFINITIONS OF + AND -, CLOCKWISE AND COUNTERWISE, LEFT AND RIGHT, ETC NEED TO BE CLEARLY DEFINED AND UNDERSTOOD BY EVERYONE EARLY IN THE PROGRAM. TESTING SHOULD BE PLANNED AT SEVERAL STAGES DURING DEVELOPMENT AND A TRUE END-TO-END TEST CONDUCTED THAT INVOLVES BOTH FLIGHT HARDWARE AND SOFTWARE. THE EFFECT OF TEST EQUIPMENT ON PHASING NEEDS TO BE FACTORED IN TO TEST PLANNING. PHASING DATA IN DOCUMENTATION SHOULD BE KEPT UP-TO-DATE.

RATIONALE: THE MAGELLAN AACS GROUP PLANNED AND ACCOMPLISHED PHASING VERIFICATIONS VERY WELL, YIELDING A RELIABLE SYSTEM. AS AN EXAMPLE, WE WERE CONFIDENT THAT THE STAR SCANNER PHASING WAS CORRECT WHEN THE FIRST STARCAL AFTER DEPLOYMENT FROM THE SHUTTLE FAILED, DESPITE THE STU SUBCONTRACTOR INSISTING IT WAS INCORRECT. THIS CONFIDENCE ALLOWED US TO COMMAND A CORRECT STARCAL.

VALUE = C A C

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: DEVELOP A SCRIPT OR COMMAND FILE WHICH CAN QUICKLY AND SAFELY CONFIGURE THE SPACECRAFT FROM ANY UNKNOWN STATE TO ANY REFERENCE STATE. (I.E. LAUNCH, CRUISE, ON-ORBIT OPS)

RATIONALE: MOST ATLO PROCEDURES AND SEQUENCE TESTS REQUIRE A WELL DEFINED SPACECRAFT CONFIGURATION. MAGELLAN'S "CONFIG SCRIPT" ENABLED ATLO PERSONNEL (AND PROCEDURE AUTHORS) TO NOT WORRY ABOUT HOW TO TRANSITION FROM A PREVIOUS TEST'S FINAL STATE TO THE NEXT TEST'S INITIAL STATE. SAVINGS WERE REALIZED IN RISK, TIME, AND COST.

VALUE = B B B

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: THE TESTING OF SPACECRAFT FAULT PROTECTION (FP) IS MOST EFFICIENT AND EFFECTIVE USING THE FOLLOWING GUIDELINES:

1. USE A BUILDING-BLOCK APPROACH WHERE DIFFERENT ASPECTS OF FP ARE TESTED ON DIFFERENT TEST BEDS.
2. PRE-TEST FP TESTS ON A TEST BED BEFORE EXECUTING ON THE SPACECRAFT. (TEST SEQUENCE AND INJECTED FAULT INDEPENDENTLY AT FIRST.)
3. STRICTLY MAINTAIN PROCEDURE DEVELOPMENT FOLDERS
4. MAKE SURE AT LEAST ONE TEST IS WITH FINAL FLIGHT S/W.
5. MAKE FP DESCRIPTION DOCUMENT AVAILABLE TO TEST PERSONNEL.

RATIONALE: THESE GUIDELINES WERE USED EFFECTIVELY BY MAGELLAN. SVL FP PRE-TESTING SAVED CONSIDERABLE TIME IN THE SPACECRAFT CRITICAL PATH.

VALUE = C B B

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: BUILD A SYSTEM TEST BED TO USE FOR EARLY HARDWARE/SOFTWARE INTEGRATION AND RETAIN FOR USE DURING MISSION OPERATIONS FOR VERIFICATION OF COMMAND SEQUENCES AND FLIGHT SOFTWARE CHANGES.

RATIONALE: MAGELLAN INITIALLY DID NOT PLAN TO HAVE A SYSTEM TEST BED, BUT FINALLY CABLED THE AACS AND CDS TEST BEDS TOGETHER, ADDED A SIMULATION SYSTEM FOR THE REST OF THE SPACECRAFT AND RETAINED THE RESULTING SYSTEMS VERIFICATION LABORATORY IN OPERATIONS. FROM MAGELLAN'S EXPERIENCE, SEQUENCE SIMULATION IS MANDATORY TO MAINTAIN THE INTEGRITY OF MISSION OPERATIONS.

VALUE = B A C

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: STRIVE TO UTILIZE THE SAME (OR A VERY SIMILAR DERIVED VERSION) TELEMETRY PROCESSING SYSTEM IN ATLO AS IN MOS. THE ENHANCED CAPABILITIES WILL HELP ATLO AND THE FAMILIARITY WILL ASSIST PERSONNEL TRANSITION TO MOS. THIS APPLIES TO BOTH S/C TEST EQUIPMENT AS WELL AS A VERIFICATION TEST BED.

COROLLARY: AUTOMATE THE TEST ANALYSIS PROCESS

RATIONALE: DURING ATLO, THE TELEMETRY DATA FROM THE S/C, WAS COLLECTED BY STDPS, WHICH WAS HARD TO USE AND HAD LIMITED CAPABILITIES. THE SVL DURING ATLO COLLECTED DATA BY PRINTING OUT A LIMITED NUMBER OF E-VALUES ONCE A MAJOR FRAME. THIS MEANT PROBLEM DISCOVERY WAS DELAYED UNTIL TESTING ON THE S/C OR WENT UNDISCOVERED. AFTER LAUNCH A TELEMETRY PROCESSING SYSTEM WAS IMPLEMENTED WHICH HAD CAPABILITIES SIMILAR TO SFOC BUT DOES NOT USE A CDB. THIS NEW SYSTEM HAS INCREASED THE ANALYSIS CAPABILITY OF THE SVL AND HAS REDUCED THE TIME AND PERSONNEL REQUIRED FOR THIS ANALYSIS.

VALUE = B A C

SPACECRAFT ASSEMBLY ISSUES

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: ALWAYS HAVE THE COGNIZANT ENGINEER PRESENT ON THE FLOOR WHEN CONDUCTING ASSEMBLY OPERATIONS.

RATIONALE: THE MAGELLAN SOLID ROCKET MOTOR SAFE AND ARM MECHANICAL CONNECTIONS WERE INITIALLY MADE INCORRECTLY AT KSC. THE COG E WAS IN PASADENA ON OTHER BUSINESS.

THE MAGELLAN THERMAL ENGINEERS WERE PRESENT AND DID MOST OF THE BLANKET INSTALLATION THEMSELVES OR ASSISTED THE BLANKET SUBCONTRACTORS.

VALUE = B B C

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: PAY PARTICULAR ATTENTION TO REQUIREMENTS THAT SPECIFY HOW TO ASSEMBLE COMPONENTS. ASSEMBLY TECHNIQUES SHOULD BE DESIGNED AROUND WORST-CASE OPERATIONAL CONDITIONS.

RATIONALE: POWER CONTROL UNIT RING TERMINALS WERE SOLDERED BEFORE BEING BOLTED DOWN. LUMPS OF SOLDER GAVE POOR ELECTRICAL CONNECTIONS FOR WORST-CASE CONDITIONS. THIS ASSEMBLY TECHNIQUE ASSUMED THAT THE MAXIMUM CURRENT LOAD WAS THE MOST STRINGENT REQUIREMENT WHEN UPON FURTHER ANALYSIS, THE TRICKLE CHARGE WAS MORE CHALLENGING.

VALUE = A B B

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: DON'T PERFORM BLIND ELECTRICAL CONNECTIONS DURING ASSEMBLY OR SYSTEM TESTS WHEN LIVE POWER IS PRESENT. BATTERY AND TEST CONNECTORS SHOULD ALL BE SCOOP-PROOF.

RATIONALE: MAGELLAN, UNDER SCHEDULE PRESSURE, FAILED TO REMOVE A COVER PLATE AND PERFORMED A BLIND BATTERY CONNECTION INCORRECTLY, DAMAGING THE SPACECRAFT

VALUE = A A C

LAUNCH OPERATIONS ISSUES

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: CONSULT PRIOR MISSIONS THAT HAVE FLOWN ON THE SPACE SHUTTLE (SIR, MGN, GLL, ULS) TO ACCURATELY SCOPE THE AMOUNT OF WORK TO BE DONE.

RATIONALE: MAGELLAN DIDN'T TAKE ADVANTAGE OF THE SIR A AND B MISSIONS' EXPERIENCE AND SEVERELY UNDERSCOPED THE WORK TO BE ACCOMPLISHED TO FLY AS A PAYLOAD ON THE SHUTTLE. KSC INTERFACES WERE DIFFICULT AND TIME CONSUMING. FACILITIES, MEETINGS, PLAN GENERATION, AND DOCUMENT REVIEW WERE ALL UNDERSCOPED.

VALUE = C B C

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: FOR ANY FUTURE JPL MISSIONS FLOWN ON THE SPACE SHUTTLE (E.G. SIR-C) THE PROJECT NEEDS TO BE PROACTIVE WITH JSC IN WORKING STS INTERFACES (E.G. STRUCTURAL VERIFICATION, FAILURE MECHANISMS, SAFETY, PROCEDURE DEVELOPMENT, ETC) TO SMOOTH THE MISSION OPERATIONS INTERFACE. JPL ALSO NEEDS TO RECOGNIZE AND PLAN FOR THE SIGNIFICANT AMOUNT OF WORK INVOLVED IN LAUNCHING ON THE SHUTTLE.

RATIONALE: MAGELLAN WORKED THIS INTERFACE WELL, WHICH MADE JSC PRO-MAGELLAN AND IN OUR CAMP ON MANY ISSUES. HOWEVER THE PROJECT UNDERSCOPED THE EFFORT REQUIRED TO ACHIEVE A SUCCESSFUL LAUNCH.

VALUE = C B C

ASSEMBLY, TEST AND LAUNCH OPERATIONS

RECOMMENDATION: REALIZE AND PLAN FOR THE ADDITIONAL ACTIVITY ASSOCIATED WITH FORMAL REVIEWS AND ACTION ITEM CLOSEOUTS, ESPECIALLY THOSE OCCURRING JUST PRIOR TO LAUNCH.

RATIONALE: THE TIME TO CREATE PRESENTATION MATERIALS, PARTICIPATE IN FORMAL REVIEWS AND ANSWER ACTION ITEMS TOOK AWAY FROM ACTUAL SPACECRAFT AND TEAM PREPARATION FOR MAGELLAN LAUNCH. THIS EFFORT WAS UNDERSCOPED AND AS A CONSEQUENCE, MUCH WORK WAS POSTPONED UNTIL AFTER LAUNCH WHICH SHOULD HAVE BEEN ACCOMPLISHED BEFORE

VALUE = A C C

MAGELLAN

LESSONS-LEARNED WORKSHOP

THURSDAY, DECEMBER 12, 1991

SESSION 3: MISSION OPERATIONS SYSTEM DEVELOPMENT

8:30 AM TO 12:00 NOON

SESSION 4: MISSION OPERATIONS CONDUCT

1:00 PM TO 4:30 PM

MAGELLAN

LESSONS-LEARNED WORKSHOP

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1:00 PM TO 4:30 PM

INTRODUCTION

WORKSHOP PROCEDURE:

1. WALK THROUGH RECOMMENDATION CHARTS IN ORDER OF PACKAGE:

   - SOLICIT AGREEMENT/DISAGREEMENT FROM AUDIENCE.
   - CORRECT ON-SCREEN ANY MAJOR ERRORS.
   - NOTE ANY ADDITIONS OF MAGELLAN EXAMPLES TO RATIONALE.
   - MAKE NOTE OF ANY STRONG MINORITY OPINIONS.
   - THERE IS ABOUT 6-MINUTES PER ITEM ON AVERAGE.

2. ASSIGN A "VALUE" TO RECOMMENDATION ACCORDING TO TABLE ON NEXT PAGE. THERE ARE 3 CATEGORIES.

3. IF A WALK-ON IS CLOSELY RELATED TO AN ITEM UNDER DISCUSSION, BRING IT UP THEN. IF NOT, SAVE IT FOR THE "WALK-ON TOPICS" PART OF THE SESSION.

4. LOOK AHEAD, IF THE ITEM UNDER DISCUSSION IS NOT OF INTEREST. (BE PREPARED TO CONTRIBUTE WHEN YOUR ITEM COMES)

5. THE SUMMARY PERIOD WILL ATTEMPT TO DETERMINE THE ITEMS OF GREATEST POTENTIAL IMPACT.

LESSON-LEARNED VALUE ASSIGNMENT

	A	B	C
1. APPLICABILITY TO FUTURE PROJECTS	APPLICABLE TO ALL OR NEARLY ALL PROJECTS AND TO MULTIPLE AREAS WITHIN A PROJECT	APPLICABLE TO MANY PROJECTS (BUT NOT ALL) WITH POTENTIAL TO APPLY TO SEVERAL AREAS.	APPLICABLE TO ONLY A FEW PROJECTS OR APPLICABILITY ONLY TO ONE AREA
2. POTENTIAL INCREASE TO MISSION SUCCESS AND/OR REDUCTION OF RISK	HIGH PROBABILITY OF INCREASING MISSION SUCCESS OR REDUCING RISK OF OPERATIONS	POSSIBLE BENEFIT TO PROJECT IF IMPLEMENTED BY INCREASING SUCCESS OR REDUCING RISK	NO OR VERY SMALL IMPACT ON MISSION SUCCESS OR RISK REDUCTION
3. POTENTIAL CONTRIBUTION TO REDUCING TOTAL COSTS	MAJOR COST REDUCTION IS A DEFINITE POSSIBILITY	SOME COST REDUCTION IS POSSIBLE.	NO COST ADVANTAGES OR AN EXPECTED INCREASE TO COST

MISSION OPERATIONS SYSTEM DEVELOPMENT

PEOPLE WHO CONTRIBUTED ITEMS TO THIS SESSION:

VERBAL INTERVIEWS:

AL CONRAD
MIKE STEWART
JIM McCLURE
MIKE JONES
CHUCK REYNOLDS (SFOC)
RAY MORRIS
JODY GUNN
JERRY CLARK
JOHN SLONSKI
DAVE WOERNER

WRITTEN INPUTS

BOB POLANSKY
FRED MILLER
JOHN McNAMEE
JODY GUNN
MIKE JONES
ALLEN CHEUVRONT
KEN REHM
JOE BUESCHER
KYLE MARTIN
ALLEN BUCHER

PROGRAM PHILOSOPHY ISSUES

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: PROJECTS NEED TO FIND WAYS TO DESIGN THE SPACECRAFT FLIGHT SYSTEM AND THE MISSION OPERATIONS SYSTEM TOGETHER, WITH COST MINIMIZATION AS A PROJECT OBJECTIVE. DECISIONS MADE IN SPACECRAFT DESIGN SHOULD BE CONSIDERED FOR THEIR SUBSEQUENT MOS IMPACT.

RATIONALE: USUALLY, THE SPACECRAFT IS DESIGNED FIRST, AND SOMETIME LATER, THE MOS IS DESIGNED. MANY TIMES, DECISIONS MADE IN SPACECRAFT DESIGN REQUIRE DIFFICULT AND COSTLY IMPLEMENTATIONS IN THE COMMAND AND TELEMETRY SYSTEMS ON THE GROUND, WHEREAS A DIFFERENT BUT EQUALLY SUFFICIENT SOLUTION FOR THE SPACECRAFT WOULD REDUCE THE COMPLEXITY ON THE GROUND. EVEN IN CASES WHERE THE SPACECRAFT AND MOS DESIGNS PROCEED TOGETHER, SPACECRAFT ACTIVITY WINS THE COMPETITION FOR RESOURCES, MOS HAVING MUCH LOWER PRIORITY. MAGELLAN EXPERIENCED SOME OF THIS.

VALUE = A B A

1° / spc

Ken — Telemetry

— SEQ — Command Structure

Fred —

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: DEVELOP AN OPERATIONS CONCEPT DOCUMENT AT THE BEGINNING OF THE PROGRAM. IT SHOULD SUMMARIZE THE OBJECTIVES AND CONSTRAINTS OF THE MISSION; DOCUMENT THE INTENDED OPERATIONAL APPROACHES; AND DEFINE HOW USERS WILL OPERATE AND MAINTAIN BOTH SPACECRAFT AND MOS. THIS DOCUMENT WILL GUIDE THE PROGRAM DESIGN (BOTH SPACECRAFT AND MOS) TO ONES THAT WILL SATISFY THE OBJECTIVES, KEEPING THE FOCUS ON SYSTEM OPERABILITY.

RATIONALE: MAGELLAN DID NOT HAVE SUCH A DOCUMENT. THE SCIENCE AND MISSION PLANS WHICH CAME LATER IDENTIFIED MISSION OBJECTIVES BUT DID NOT ADDRESS OPERATIONAL APPROACHES. AN OPERATIONS CONCEPT WOULD HAVE GIVEN A COMMON STARTING REFERENCE FOR ALL THE FUNCTIONAL REQUIREMENTS AND INTERFACE REQUIREMENTS DOCUMENTS AND OPERATIONS PLANS DEVELOPED LATER. IT MIGHT ALSO HAVE SENSITIZED THE SPACECRAFT DESIGNERS TO OPERATIONS ISSUES EARLIER.

VALUE = A B C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: FOR PROJECTS WILLING TO ACCEPT HIGHER RISK IN EXCHANGE FOR LOWER COST, THE RISK VERSUS COST TRADES NEED TO BE MADE EARLY AND DOCUMENTED CLEARLY, SO THAT LATER, NASA MANAGEMENT AND THE VARIOUS REVIEW BOARDS WILL REMEMBER AND CONSIDER THIS SCOPE IN THEIR ACTIONS.

RATIONALE: MAGELLAN, WHEN RESURRECTED FROM VOIR AS THE VENUS RADAR MAPPER, WAS INTENDED TO BE A LOW COST MISSION WHERE MISSION OPERATIONS SHORT CUTS THAT ADDED SOME RISK COULD BE TAKEN IN THE INTEREST OF COST SAVINGS. HOWEVER, WHEN CRITICAL REVIEWS WERE HELD, REVIEW BOARDS AND MANAGEMENT DECISIONS FORCED OPERATIONS DOWN THE PATH OF A "CLASS A" MISSION.

VALUE = A C A

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: PLACE GDS SUBSYSTEMS DEVELOPMENT UNDER MANAGEMENT OF THE USING TEAM. THE USERS KNOW WHAT THEIR SOFTWARE MUST DO. A GDS ORGANIZATION STILL SHOULD REMAIN TO MONITOR ADHERENCE TO FORMAT AND COMPLETENESS OF SOFTWARE DOCUMENTATION AND CONDUCT SYSTEMS LEVEL TESTING. TEAM STAFFING LEVELS SHOULD REFLECT THE NEED TO PERFORM BOTH THE SOFTWARE AND OPERATIONAL JOBS.

RATIONALE: MAGELLAN'S GROUND DATA SUBSYSTEMS WERE DIVIDED ABOUT EQUALLY BETWEEN THOSE WHERE THE TEAM CHIEF HAD CONTROL OF THE SOFTWARE DEVELOPMENT AND THOSE WHERE SOFTWARE WAS DEVELOPED IN A COMPLETELY SEPARATE ORGANIZATION AND THE TEAM USERS HAD LITTLE VOICE. THOSE UNDER THE TEAM'S AUTHORITY SEEMED TO HAVE FEWER PROBLEMS DURING OPERATIONS. THOSE IN SEPARATE ORGANIZATIONS WERE IN MANY CASES, INSUFFICIENTLY RESPONSIVE TO TEAM NEEDS, OR CREATED THEIR OWN AGENDAS.

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: DEFINE STANDARD PROCESSES, SCHEDULES AND DOCUMENT FORMATS EARLY IN THE DESIGN AND ENFORCE THEM.

RATIONALE: MAGELLAN MOS DEFINED AND ENFORCED STANDARDS FOR:

- ALL REVIEW PROCESSES (PDR, CDR, ATR, ETC)
- DOCUMENTATION (CONTENT & FORMAT FOR DESIGN BOOK, SFOP)
- CONFIGURATION CONTROL (AND CCB PROCEDURE)
- HIERARCHICAL SET OF SCHEDULES

THESE IMPROVED EFFICIENCY DURING MOS DEVELOPMENT.

VALUE = ~~C~~ A B ~~C~~ A

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: DEVELOP A NETWORKED SET OF MOS SCHEDULES FOR PRE-LAUNCH DEVELOPMENT AND DEFINE A CONSISTENT SET OF MILESTONES FOR APPLICATION ACROSS ALL IMPLEMENTATION ELEMENTS OF THE MOS.

RATIONALE: MAGELLAN SCHEDULES WERE NOT NETWORKED AT ANY LEVEL AND NO CONSISTENT SET OF SCHEDULE MILESTONES WERE DEFINED TO APPLY TO ALL ELEMENTS. SCHEDULE SLIPS WERE ALLOWED WITHOUT MANAGEMENT ASSESSMENT OF THE IMPACT.

VALUE = A B~~$~~A

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: FOR ACTIVITIES THAT ARE DELAYED DUE TO HIGHER PRIORITY, MAKE-PLAY SITUATIONS, PLANS SHOULD BE IDENTIFIED TO RESOLVE THEM (EITHER DISCARD OR DEVELOP ACCOMPLISHMENT SCHEDULE) AT THE TIME OF THE POSTPONEMENT.

Don't delay things

RATIONALE: AS LAUNCH APPROACHED, MANY MOS DEVELOPMENT TASKS WERE "TOSSED OVER THE FENCE" TO BE ACCOMPLISHED DURING CRUISE, WITHOUT FURTHER CONSIDERATION OF FUTURE SCHEDULE AND MANPOWER IMPACTS. SOME WERE NEVER ACCOMPLISHED; OTHERS RAN INTO SIMILAR SCHEDULE CRUNCHES LATER.

VALUE = A B C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: REFLECT APPROVED CHANGE PAPER IN CORRESPONDING CHANGE TO BUDGET ACCOUNTS.

RATIONALE: FOR MAGELLAN, THERE WAS MINIMAL ATTEMPT TO LINK APPROVED CHANGE SUMMARIES TO THE CORRESPONDING BUDGETS. THIS LED TO OVERRUNS, SCHEDULE SLIPS AND INAPPROPRIATE PRIORITIZATION OF WORK TO BE DONE.

VALUE = A C B

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: DEVELOP EARLY THE SYSTEM LEVEL REQUIREMENTS FOR THE MOS, INCLUDING THOSE DEFINING THE TEAMS AND GDS SUBSYSTEMS. THEN, THE DETAILED TEAM REQUIREMENTS SHOULD BE A LEVEL ABOVE THE SUBSYSTEM REQUIREMENTS WITH REQUIREMENTS TRACEABILITY APPROPRIATELY INDICATED.

RATIONALE: FOR MAGELLAN, FEW SYSTEM REQUIREMENTS WERE DEFINED, MOSTLY THOSE ALLOCATED TO TEAMS AND SUBSYSTEMS, ALTHOUGH THE TEAMS AND SUBSYSTEMS THEMSELVES WERE NOT IDENTIFIED AT THIS LEVEL. REQUIREMENTS DOCUMENTS FOR TEAMS AND SUBSYSTEMS WERE ON THE SAME LEVEL, MAKING TRACEABILITY DIFFICULT IF NOT IMPOSSIBLE.

VALUE = A C C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: IN AN EFFORT TO REDUCE THE COST OF IMPLEMENTATION, DON'T ELIMINATE SYSTEM ENGINEERING.

RATIONALE: IN AN EFFORT TO SAVE DEVELOPMENT COSTS THE ORIGINAL DEVELOPMENT OF THE CD-ROM SCIENCE DATA PRODUCT CAPABILITY WAS NOT SYSTEM ENGINEERED AND WAS IMPLEMENTED ON AN UNCONTROLLED "BEST EFFORTS" BASIS. JPL SUFFERED UNNECESSARY EMBARRASSMENT BECAUSE THE CAPABILITY TO BE IMPLEMENTED AND THE TIMETABLE BY WHICH IT WAS TO BE IMPLEMENTED WAS NOT WELL UNDERSTOOD BY PARTIES NOT DIRECTLY INVOLVED. HEADQUARTERS AND SCIENCE EXPECTATIONS WERE GREATER THAN THE IMPLEMENTING PARTIES COULD HAVE MET.

VALUE = A B C

ORGANIZATIONAL ISSUES

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: MAXIMIZE ~~THE NUMBER~~ OF SPACECRAFT ENGINEERS FROM SPACECRAFT SYSTEM DEVELOPMENT AND TEST CARRIED OVER ONTO THE FLIGHT TEAM.

ALSO, RETAIN SOME OF THE FLIGHT AND GROUND SOFTWARE DEVELOPERS ON THE FLIGHT TEAM FOR SOFTWARE MAINTENANCE AND INTERFACING WITH THE SFOC SYSTEM.

RATIONALE: THE EXPERIENCE GAINED BY THE SPACECRAFT ENGINEERS DURING S/C DEVELOPMENT AND TEST WAS INVALUABLE WHEN MAGELLAN EXPERIENCED INFLIGHT ANOMALIES.

FLIGHT SOFTWARE ENGINEERS WERE INDISPENSABLE IN DEALING, WITH THE MANY CHANGES IN BOTH OF THE FLIGHT SOFTWARE SYSTEMS DURING MAGELLANS' PRIME MISSION. GROUND SOFTWARE ENGINEERS HAVE BEEN ABLE TO ENHANCE THE FLIGHT TEAM'S CAPABILITIES THROUGH AUTOMATION DEVELOPMENT. ALSO, SPACECRAFT TEAM SOFTWARE ENGINEERS WERE CRUCIAL IN INITIALIZING THE UNIX-INTENSIVE SFOC SYSTEM FOR OPERATIONS.

VALUE = A B B

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: MAKE THE MOS DESIGN TEAM A SKELETON OF THE FLIGHT OPERATIONS TEAM BY APPOINTING TEAM CHIEFS AND GDS SUBSYSTEMS ENGINEERS EARLY. THIS MAKES THE TRANSITION TO OPERATIONS EASIER, AND RESULTS IN EARLIER DESIGNS OF OPERATIONAL PRODUCTS.

RATIONALE: MAGELLAN FOUND THIS APPROACH TO BE VERY BENEFICIAL.

VALUE = A B C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: AFTER CAREFUL CONSIDERATION OF VARIOUS ORGANIZATIONAL MODES, PICK AN MOS ORGANIZATION EARLY AND STICK TO IT. ~~THIS IS BETTER THAN CONTINUAL CHANGE SEARCHING FOR THE OPTIMAL ORGANIZATION.~~

RATIONALE: MAGELLAN WENT THROUGH SEVERAL CHANGES IN ORGANIZATION MOST OF WHICH WERE DISRUPTIVE. FOR EXAMPLE, WHERE TO PUT THE MISSION PLANNING FUNCTION; AND WHETHER OR NOT TO HAVE A RADAR OFFICE. A POSITIVE EXAMPLE IS THE UPLOAD PREPARATION GROUP IN THE SPACECRAFT TEAM. NOT HAVING A SEPARATE SEQUENCING TEAM WAS A JPL ANOMALY, BUT WE MADE IT WORK AND WERE BETTER OFF NOT MAKING SEVERAL CHANGES SEARCHING FOR A BETTER WAY.

VALUE = A C C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: HAVE THE TDA MANAGER REPORT TO THE MOS MANAGER DURING DEVELOPMENT, NOT THE PROJECT MANAGER.

RATIONALE: INTERFACES WITH THE DSN, A PART OF THE MOS, SHOULD BE HANDLED AT A LEVEL COMPATIBLE WITH OTHER MOS COMPONENTS, MAKING RESOLUTION OF PROBLEMS EASIER. MAGELLAN DID NOT DO THIS.

VALUE = B C C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: PUT ALL SEQUENCING-RELATED SOFTWARE UNDER ONE COGNIZANT ENGINEER.

RATIONALE: MAGELLAN HAD THREE DIFFERENT ENGINEERS RESPONSIBLE FOR THE SGS, MSDS, AND SEGS. THIS MADE IT DIFFICULT TO MAKE TRADE-OFFS BETWEEN THEM. VOYAGER HAD POINTER, SCANOPS, SEQGEN, SEQTRAN AND SEGS ALL UNDER ONE COG E, WHICH WORKED MUCH BETTER.

VALUE = B B

MOS DESIGN ISSUES

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: USE DISTRIBUTED COMPUTER SYSTEMS FOR MOS DESIGNS. THIS PROVIDES STANDARDIZATION AND GROWTH POTENTIAL, AND PROVIDES A HOST FOR RELOCATING SOFTWARE FROM EXPENSIVE MAINFRAMES.

RATIONALE: THE SFOC DISTRIBUTED DATA SYSTEM WAS A PLUS FOR MAGELLAN IN SPITE OF THE INITIAL START-UP PROBLEMS. ALSO BOTH NAVIGATION AND THERMAL ANALYSIS SOFTWARE WERE RE-HOSTED FROM MAINFRAME COMPUTERS TO SUN SYSTEMS RESULTING IN A SIGNIFICANT SAVINGS TO THE PROJECT.

VALUE = A C B

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: CONDUCT EARLY WALKTHROUGHS OF SIMULATED DELIVERIES USING EITHER REAL OR SIMULATED INTERFACE PRODUCTS BETWEEN TEAMS.

RATIONALE: MAGELLAN CONDUCTED SEVERAL "INTERFACE FAIRS" EARLY IN THE MOS DEVELOPMENT PROCESS. THESE ROUND-THE-TABLE DISCUSSIONS OF THE CONTENT, FORMAT AND DELIVERY FREQUENCY OF DATA PRODUCTS HELPED DEVELOPMENT OF OPERATIONS PROCEDURES AND DROVE OUT INTERFACE PRODUCT PROBLEMS EARLY.

VALUE = A B B

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: ENSURE MISSION CONTROLLERS ARE BROUGHT ON THE FLIGHT TEAM SUFFICIENTLY EARLY TO OBTAIN SPACECRAFT SUBSYSTEM FAMILIARIZATION TRAINING. THIS COULD BE ACCOMPLISHED BY AT LEAST THREE DIFFERENT METHODS: 1) PROVIDE EARLY SPACECRAFT TRAINING SESSIONS; 2) PLAN TO STAFF THE MISSION CONTROL TEAM PARTIALLY WITH PEOPLE FROM THE SPACECRAFT DEVELOPMENT OR ATLO AREAS; OR, 3) PROVIDE MISSION CONTROLLERS TO ATLO TO ASSIST IN SPACECRAFT TESTING.

COROLLARY: PUT THIS SUPPORT FOR MISSION CONTROLLER DEVELOPMENT IN THE SPACECRAFT DEVELOPER'S CONTRACT.

RATIONALE: MAGELLAN DID NOT DO A GOOD JOB OF TRAINING MISSION CONTROLLERS ON SPACECRAFT OPERATION UNTIL FAR AFTER IT WAS REALLY NEEDED.

VALUE = A C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: DURING DEVELOPMENT, TEST, AND OPERATIONS THERE SHOULD BE AN INDIVIDUAL AT EACH REMOTE SITE ASSIGNED AS THE FOCAL POINT FOR ALL DATA NETWORK RELATED ISSUES. RESPONSIBILITIES SHOULD INCLUDE LAN AND COMPUTER HARDWARE INSTALLATION (AND ASSOCIATED VERIFICATION) AND ANOMALY RESOLUTION.

RATIONALE: A SINGLE POINT OF CONTACT (I.E. THE SYSTEM ADMINISTRATOR) AT EACH SITE GREATLY REDUCED THE AMOUNT OF TIME SPENT TRYING TO CONTACT EACH INDIVIDUAL AT A REMOTE SITE TO DETERMINE IF THEIR WORKSTATION WAS FUNCTIONING CORRECTLY.

VALUE = B C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: DO AWAY WITH MAGNETIC TAPES. DESIGN DATA STORAGE AND TRANSFER AROUND HIGH DENSITY ~~OPTICAL~~ MEDIA.

RATIONALE: AT MAGELLAN'S HIGH SCIENCE DATA RATE AND TOTAL DATA QUANTITY, TAPES ARE NOT EFFICIENT MEDIA.

VALUE = A C B

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: PERFORM PRE-LAUNCH CONTINGENCY PLANNING AT A HIGH LEVEL. IT IS MORE IMPORTANT TO COVER MANY POSSIBLE CONTINGENCY SITUATIONS AT A CURSORY LEVEL THAN TO DELVE INTO THE DETAILS OF A VERY FEW. THE THINKING PROCESS IS MORE IMPORTANT THAN THE WRITTEN PLAN.

RATIONALE: FROM MAGELLAN'S EXPERIENCE, THE CONTINGENCY SITUATIONS THAT DEVELOPED WERE ALWAYS DIFFERENT THAN THOSE CONSIDERED PRE-LAUNCH. THE CONTINGENCY PROCESS, HOWEVER, HELPED IN DEVELOPING THE LOSS-OF-SIGNAL RECOVERY PLANS DURING FLIGHT OPERATIONS.

VALUE = A B C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: A MISSION SHOULD CAREFULLY EXAMINE ITS TRACKING REQUIREMENTS IF SOMETHING MORE THAN DOPPLER TRACKING IS REQUESTED. A CAREFUL ANALYSIS OF THE TRADE-OFFS BETWEEN ACCURACY REQUIREMENTS, ALTERNATIVE DATA TYPES, FLIGHT TEAM OPERATIONAL IMPACTS, AND DSN LOADING PROJECTIONS MUST BE MADE.

RATIONALE: MAGELLAN, WITH ITS PRECISION REQUIREMENTS ON SPACECRAFT POSITION AND POINTING FOR MAPPING OPERATIONS, INITIALLY THOUGHT VLBI TRACKING WOULD BE NECESSARY, AT THE ADDED EXPENSE OF MULTIPLE, SIMULTANEOUS TRACKING ANTENNAS. AS IT HAPPENED, DIFFERENCED DOPPLER (2-WAY AND 3-WAY) WAS DETERMINED TO BE SUFFICIENT.

VALUE = C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: FOR FUTURE MISSIONS WITH SPACECRAFT IN HIGH DYNAMIC ENVIRONMENTS (SUCH AS CLOSE ORBITERS) WHICH REQUIRE ACCURATE POSITION PREDICTIONS OVER EXTENDED ON-BOARD SEQUENCE EXECUTION PERIODS, THE FOLLOWING SHOULD BE ACCOMPLISHED PRE-LAUNCH:

1. DYNAMIC MODELS (E.G. GRAVITY FIELDS) SHOULD BE CAREFULLY INVESTIGATED FOR DEFICIENCIES AND PLANS INITIATED FOR MODEL IMPROVEMENT.

2. THE SEQUENCE GENERATION LEAD TIME SHOULD BE SHORTENED AS MUCH AS POSSIBLE AND STILL SATISFY REQUIREMENTS.

3. A SEQUENCE TWEAKING PROCESS SHOULD BE DESIGNED INTO THE SPACECRAFT AND GROUND PROCESSES TO MAKE CHANGING ON-BOARD NAVIGATION PARAMETERS OPERATIONALLY SIMPLE.

RATIONALE: MAGELLAN'S LONG LEAD TIME FOR SEQUENCE GENERATION ALONG WITH THE DYNAMIC CLOSE-APPROACH ELLIPTICAL ORBIT POSED A SIGNIFICATION CHALLENGE TO NAVIGATION. ALL THREE OF THE ABOVE ITEMS WERE ADDRESSED DURING THE MAGELLAN MISSION AND RESULTED IN SIGNIFICANT IMPROVEMENT IN ORBIT DETERMINATION. IT WOULD HAVE BEEN BETTER STILL IF THEY HAD BEEN ADDRESSED PRE-LAUNCH.

VALUE = C B B

SEQUENCE & COMMAND - RELATED ISSUES

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: BUILD SINGLE-ACTIVITY COMMAND BLOCKS, WITH MINIMAL OPTIONS, THAT CAN BE STACKED TOGETHER IN VARIOUS WAYS TO FORM SEQUENCES. PLAN AND EXECUTE TESTS THAT WILL VERIFY THE RESULTANT SEQUENCES.

RATIONALE: MAGELLAN DEVELOPED LARGE BLOCKS WITH MANY OPTIONS. (EXAMPLE: THE "ORBIT" PROFILE ACTIVITY CALLED JUST TWO BLOCKS TO PERFORM DAILY MAPPING OPERATIONS, "MAPPING" AND "PLAYBACK".) THESE INFLEXIBLE BLOCKS WOULD HAVE WORKED JUST FINE IN A PERFECT WORLD. SINCE MAGELLAN WAS BESET WITH ANOMALIES, THE SEQUENCE GENERATION SOFTWARE ENGINEERS WERE CONTINUALLY MODIFYING BLOCK SOFTWARE TO ACCOUNT FOR ANOMALIES, LIKE "HIDING" FOR THERMAL REASONS. MANY SEQUENCES HAD TO BE HAND-EDITED DUE TO LACK OF FLEXIBLE BLOCKS, INCREASING THE RISK TO THE MISSION.

VALUE = A A B

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: DURING SPACECRAFT DEVELOPMENT, THE PARALLEL DESIGN OF THE COMMAND BLOCKS MUST CONSIDER MISSION OPERATIONS IMPLEMENTATION. AS SOON AS THEY ARE DESIGNED, THE BLOCKS SHOULD BE RELEASED TO MISSION OPERATIONS SOFTWARE ENGINEERS FOR IMPLEMENTATION IN GROUND SOFTWARE. GUIDELINES AND REQUIREMENTS FOR BLOCK DESIGN SHOULD BE WELL DOCUMENTED AHEAD OF TIME.

RATIONALE: THE MAGELLAN COMMAND BLOCKS WERE DESIGNED WITH MINIMAL CONSIDERATION OF IMPLEMENTATION IN THE SEQUENCE GENERATION SUBSYSTEM, WITH MINIMAL INPUT FROM MOS PERSONNEL, AND DELIVERED TOO LATE TO PREVENT SERIOUS SCHEDULE IMPACTS ON THE GROUND SYSTEM. CHANGES TO THE BLOCK DICTIONARY THROUGHOUT THE DEVELOPMENT CYCLE CAUSED A LOT OF RECODING AND RETESTING.

VALUE = B B B

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: DEVISE BOTH A SPACECRAFT SEQUENCING PROCESS AND A SOLID REAL-TIME OR NON-SEQUENCE COMMANDING PROCESS PRIOR TO LAUNCH AND TEST THE ENTIRE PROCESSES THOROUGHLY.

RATIONALE: ALTHOUGH A VERY GOOD SEQUENCING PROCESS WAS DESIGNED, THERE WAS NO DEVELOPED NON-STANDARD COMMAND PROCESS PRIOR TO LAUNCH. MAGELLAN IMPLEMENTED A VERY SYSTEMATIC AND DETAILED PROCESS FOR NON-STANDARD COMMAND UPLOADS APPROXIMATELY HALF WAY THROUGH CRUISE. THIS NEW PROCESS RESULTED IN MANY BENEFITS. FIRST, IT BROUGHT IN THE FLIGHT TEAM AT THE EARLY STAGES OF COMMAND DEVELOPMENT AND SAVED VALUABLE ENGINEERING TIME BY GETTING APPROVAL AT AN EARLY STAGE. SECOND, THIS PROCESS REDUCED COMMAND ERRORS. MANY CHECKS AND BALANCES WERE INCORPORATED TO ENSURE THAT COMMANDS WERE WELL THOUGHT THROUGH AND CORRECTLY IMPLEMENTED. THE MAGELLAN NON-STANDARD COMMAND PROCESS WAS USED MORE FREQUENTLY THAN THE STANDARD SEQUENCE PROCESS, DESPITE PRE-LAUNCH PREDICTIONS. THE STANDARD SEQUENCE PROCESS WAS DEVELOPED PRIOR TO CRUISE AND WAS REEVALUATED PRIOR TO MAPPING OPERATIONS. BY ESTABLISHING THESE UPLINK PROCESSES IN ADVANCE, THE CRUISE SEQUENCE UPLOADS WENT VERY SMOOTHLY AND THE MAPPING SEQUENCES HAVE AND ARE CONTINUING TO PROCEED NOMINALLY.

VALUE = A A C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: PLAN FOR AND DEVELOP A SPACECRAFT SIMULATION CAPABILITY FOR COMMAND SEQUENCE VERIFICATION AND FLIGHT SOFTWARE CHANGE VALIDATION. USE FLIGHT SYSTEM BREADBOARDS WHEREVER POSSIBLE TO REDUCE COST AND IMPLEMENT A "HALT, CHECKPOINT, RESTART" CAPABILITY TO FACILITATE TESTING. IF POSSIBLE, DESIGN THE SYSTEM TO RUN FASTER THAN REAL-TIME.

RATIONALE: INITIALLY, THERE WERE NO PLANS FOR THE MAGELLAN SYSTEMS VERIFICATION LABORATORY, AND WHEN THE NEED WAS RECOGNIZED, THE LAB WAS INCREMENTALLY DEVELOPED WITHOUT A MASTER PLAN. THIS LED TO PARALLEL DEVELOPMENT AND USE, NEEDED CAPABILITIES THAT WERE USUALLY ONE STEP FROM COMPLETION, AND A RESOURCE THAT WAS ALWAYS OVERSUBSCRIBED. EARLY RECOGNITION OF THE NEED FOR THE SVL AND UP-FRONT PLANNING WOULD HAVE REDUCED BOTH THE COST AND THE RISK TO MISSION OPERATIONS.

THE MAGELLAN SVL HAS BEEN AN ESSENTIAL TOOL FOR VERIFICATION OF BOTH COMMAND/SEQUENCE LOADS AND MODIFIED FLIGHT SOFTWARE.

VALUE = A A C

GROUND DATA SYSTEM ISSUES

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: FOR FPSO-PROVIDED COMPONENTS OF THE GROUND DATA SYSTEM FOR FUTURE PROJECTS, THE FOLLOWING STEPS ARE ESSENTIAL TO ACHIEVING A QUALITY PRODUCT ON SCHEDULE AND WITHIN BUDGET:

1. BOTH FPSO AND THE PROJECT MUST ASSIGN SENIOR PERSONNEL WHO WILL COMMIT TO SEE THE COMPONENT THROUGH DESIGN, DEVELOPMENT AND TEST.
2. COMPONENT FUNCTIONAL REQUIREMENTS MUST BE WRITTEN CLEARLY AND COMPLETELY AND MUST BE TESTABLE. THERE MUST BE ONLY ONE FUNCTIONAL REQUIREMENTS DOCUMENT THAT BOTH PARTIES ACCEPT.
3. THE FPSO IMPLEMENTERS (ESPECIALLY PROGRAMMERS) AND THE ULTIMATE PROJECT USERS (FLIGHT TEAM PERSONNEL) NEED REGULAR FACE-TO-FACE DISCUSSIONS DURING IMPLEMENTATION TO VERIFY INTERPRETATION OF REQUIREMENTS.

RATIONALE: THE REQUIREMENTS AND DESIGN PROCESS BETWEEN THE PROJECT AND FPSO FOR THE MAGELLAN TELEMETRY PROCESSING SUBSYSTEM WAS WEAK, CONFUSING AND DIFFICULT TO RESOLVE. PERSONNEL CHANGEOVER WAS RAPID. REQUIREMENTS WERE LATE AND POORLY SPECIFIED, AND MADE CONFUSING BY HAVING BOTH A PROJECT FRD AND SFOC FRDs. DISCUSSIONS BETWEEN IMPLEMENTERS AND USERS WERE DISCOURAGED. AS A RESULT, THE TPS WAS LATE AND OVER BUDGET.

VALUE = B B B

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: FOR GDS DEVELOPMENT EFFORTS, PRIORITIZE WORK AT THE BEGINNING. THIS SHOULD INCLUDE PRIORITIZATION OF REQUIREMENTS TO BE IMPLEMENTED AND TESTS TO BE PERFORMED. PHASED DELIVERIES CONSISTENT WITH THE PRIORITIES SHOULD BE PLANNED.

RATIONALE: THE TENDENCY IS TO PRIORITIZE WHEN DEVELOPMENT FALLS BEHIND SCHEDULE. BY THIS TIME EFFORT HAS USUALLY ALREADY BEEN EXPENDED ON PARTIALLY IMPLEMENTING LOWER PRIORITY ITEMS WHEN THE TIME COULD HAVE BEEN BETTER SPEND WORKING ON HIGHEST PRIORITY ITEMS. THE SFOC MAGELLAN IMPLEMENTATION IS AN EXAMPLE OF THIS. BY THE TIME THE PROJECT WAS ABLE TO DETERMINE THE EXTENT OF THE SLIP IN DEVELOPMENT SCHEDULE, SIGNIFICANT TIME HAD BEEN SPENT ON LOWER PRIORITY ITEMS.

VALUE = B C C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: SEMI-FORMAL REVIEWS WITH BOTH DEVELOPMENT AND OPERATIONS PERSONNEL ON THE REVIEW BOARD FOR GDS SUBSYSTEM DOCUMENTATION AND DELIVERIES CONTRIBUTES TO IMPLEMENTATION OF A SYSTEM THAT IS RESPONSIVE TO OPERATIONAL NEEDS.

RATIONALE: WE CONSISTENTLY FOUND THAT OPERATIONS INVOLVEMENT IN DEFINING SUBSYSTEM REQUIREMENTS WAS ESSENTIAL. HAVING OPERATIONS PERSONNEL ON THE SUBSYSTEM REVIEW BOARDS ENSURES THAT THEY HAVE READ (AND COMMENTED) ON THE PROPOSED REQUIREMENTS.

VALUE = B B C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: KEEP NUMBER OF SIGNATORIES OF SOFTWARE DOCUMENTATION TO A MINIMUM AND HAVE THE DOCUMENTS SIGNED AT THE LOWEST LEVEL OF RESPONSIBILITY THAT MAKES SENSE.

RATIONALE: IN SOME CASES IT TOOK MONTHS TO GET DOCUMENTS THROUGH THE SIGNATURE CYCLE DUE TO THE LARGE NUMBER OF SIGNOFFS REQUIRED. BEFORE MGN MODIFIED ITS POLICY, AN INTERFACE WITH THREE USERS REQUIRED 14 SIGNOFFS ON THE SIS. THE PROCEDURE WAS LATER MODIFIED TO REQUIRE ONLY SUBSYSTEM ENGINEER AND SYSTEM ENGINEER SIGNOFF REDUCING THE REQUIRED NUMBER OF SIGNOFFS BY 8 FOR THE ABOVE EXAMPLE.

VALUE = B C C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: ENSURE THAT INHERITED SOFTWARE IS ACCOMPANIED BY APPROPRIATE DOCUMENTATION OR LAY PLANS TO DEVELOP IT.

RATIONALE: INHERITED SOFTWARE WAS ACCEPTED FROM OTHER PROJECTS WITH INADEQUATE DOCUMENTATION THAT MAGELLAN DID NOT PLAN OR BUDGET TO UPDATE. (E.G. NAV S/S, SGS S/S)

VALUE = C C C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: PLAN TO OVERSIZE GROUND SYSTEM COMPUTERS TO BE PREPARED FOR THE UNKNOWN DURING GROUND SOFTWARE DEVELOPMENT AND MISSION OPERATIONS. HARDWARE IS ALWAYS LESS EXPENSIVE THAN SOFTWARE.

RATIONALE: MIPL ASKED FOR MORE COMPUTER CAPABILITY FOR MAGELLAN DATA PROCESSING THAN MANAGEMENT THOUGHT THEY NEEDED, BUT IT WAS APPROVED ANYWAY. IT TURNED OUT TO BE VERY NECESSARY, AND THE FORESIGHT PREVENTED SERIOUS DIFFICULTIES.

VALUE = B C B

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: POSTPONE GROUND COMPUTER HARDWARE SELECTIONS AS LATE AS POSSIBLE WITHOUT AFFECTING SCHEDULES TO ENSURE THAT LATEST TECHNOLOGY IS USED.

RATIONALE: DMAS HARDWARE SELECTION WAS MADE EARLY, AND MORE EFFICIENT HARDWARE/SOFTWARE WAS AVAILABLE BY FLIGHT TIME.

VALUE = B C C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: HAVE GDS SUBSYSTEMS ENGINEERS HOLD SOFTWARE "WALK-THROUGHS" WITH MOS TEAMS, GDS STAFF PERSONNEL, AND, WHERE APPLICABLE, SCIENCE TEAMS.

RATIONALE: "WALK-THROUGHS" WITHIN IDPS/T WERE HELPFUL AND WOULD HAVE BEEN MORE SO WITH SCIENCE TEAM PARTICIPATION.

THIS ACTIVITY WOULD ALSO MAKE MEETINGS (CCB, ATR) SHORTER SINCE GDS SUBSYSTEMS ENGINEERS WOULD SPEND LESS TIME DEFENDING THEIR TESTING AND IMPLEMENTATION POSITIONS.

VALUE = B B C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: CONSIDER CAREFULLY ANY OPTIONS RELATIVE TO "HARD CODING" OF REQUIREMENTS, AND MAINTAIN FLEXIBILITY IN SOFTWARE/HARDWARE, PARTICULARLY TO BE ABLE TO HANDLE NON-NOMINAL SPACECRAFT PERFORMANCE.

RATIONALE: MAGELLAN "HARDCODING" IN DMAS CREATED INFLEXIBILITY IN CHANGING OF DATA PRODUCTS. THIS SUBSYSTEM WAS IN THE CENTER OF ALL DATA PRODUCT FLOW, BUT IT WAS DIFFICULT TO INTERFACE, INFLEXIBLE, AND HAD LITTLE CAPABILITY TO PERFORM MATHEMATICAL OPERATIONS.

ALSO, THE SGS HARDCODING OF ITEMS IN COMMAND BLOCKS THAT COULD HAVE BEEN BLOCK OPTIONS DECREASED FLEXIBILITY. AS AN EXAMPLE, THE MAGELLAN CAT. BED HEATER WARM-UP TIME WAS HARD CODED IN THE BLOCK TO BE 90 MINS. THERE WAS NO "OPERATOR OVERRIDE" CAPABILITY FOR THIS CONSTRAINT WHICH FORCED HAND EDIT OF THE FINAL PRODUCT WHEN THERMAL PROBLEMS WITH THE REMS REDUCED WARM-UP TIMES TO 45 MINS.

VALUE = A B C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: BE WARY OF PROMISES THAT EVOLVING INTERNATIONAL STANDARDS ARE "ALMOST" FINALIZED. THIS CAN CREATE A DEVELOPMENT DEPENDENCY THAT THE PROJECT HAS NO CONTROL OVER. RECOMMEND THAT A PROJECT NOT COMMIT TO A STANDARD UNTIL IT IS IN FINAL FORM. PROJECT SHOULD ESTABLISH A NEED DATE AND USE THE "STANDARD" THAT BEST SUITS PROJECT NEEDS ON THAT DATE.

RATIONALE: CHANGES TO THE STANDARD FORMAT DATA UNIT (SFDU) "STANDARD" RESULTED IN UNPRODUCTIVE REWORKING OF DOCUMENTATION AND SOFTWARE CODE.

VALUE = B B C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: ENCOURAGE THE DEVELOPMENT OF PRE AND POST LAUNCH SUPPLEMENTARY ANALYTICAL SOFTWARE TO RELIEVE FLIGHT TEAM ANALYSTS FROM THE TEDIUM OF MANUAL, REPETITIVE OPERATIONS.

Automate

RATIONALE: THROUGH ADDITIONAL AUTOMATION, THE THERMAL GROUP WAS ABLE TO INCREASE THEIR THROUGHPUT FROM ONE PROGRAM RUN PER WEEK PRIOR TO LAUNCH TO ONE PER DAY NOW. ALL SUBSYSTEMS HAVE COME TO DEPEND ON "SEFCHECK" SOFTWARE TO VERIFY SEQUENCES IN THE S/C EVENTS FILE, A STEP PERFORMED MANUALLY DURING MOST OF CRUISE. THESE WOULD NOT HAVE BEEN POSSIBLE WITHOUT ENHANCED AUTOMATION. IT ALSO GREATLY REDUCES THE PROBABILITY OF AN ANALYTICAL ERROR FOR LABOR INTENSIVE TASKS.

Automate

Automate

Automate

VALUE = A B A

RSE input controlled development should allow flexibility

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: DO AS MUCH TESTING ON THE GDS SUBSYSTEM OR PROGRAM SET LEVEL AS EARLY IN THE DEVELOPMENT CYCLE AS POSSIBLE. (I.E. DON'T PUT TESTING THAT CAN BE ACCOMPLISHED EARLIER OFF UNTIL THE SYSTEM TEST PHASE.)

RATIONALE: MAGELLAN ORIGINALLY REQUIRED INTER-SUBSYSTEM TESTING WITH ACTUAL INTERFACING SUBSYSTEMS (AS OPPOSED TO SIMULATED INTERFACES) FOR THE FIRST TIME DURING SYSTEM TEST. THE POLICY WAS LATER CHANGED TO REQUIRE SUBSYSTEMS TO DO TESTING WITH INTERFACING SUBSYSTEMS PRIOR TO DELIVERY FOR SYSTEM TEST. THIS HELPED TO IDENTIFY MORE ANOMALIES PRIOR TO DELIVERY TO FORMAL CHANGE CONTROL.

VALUE = A C C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: USE A COMBINED TEST TEAM APPROACH FOR PROJECT, SFOC, AND DSN TESTING, ALLOWING SINGLE TESTS TO SATISFY THE OBJECTIVES OF MULTIPLE ORGANIZATIONS. THIS REQUIRES GETTING A DSN COMMITMENT TO SUPPORT TESTING EARLY.

RATIONALE: MAGELLAN'S COMBINED TEST TEAM APPROACH, FORGING A LINK BETWEEN THE PROJECT, SFOC AND DSN WAS AN INNOVATION THAT WORKED WELL.

VALUE = A B B

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: SPEND THE NECESSARY TIME TO THOROUGHLY DEFINE THE SOFTWARE MANAGEMENT AND DEVELOPMENT PLAN (SMDP) PRIOR TO BEGINNING ANY SOFTWARE DEVELOPMENT.

RATIONALE: THE WISDOM OF HAVING A THOROUGH PLAN LAID OUT UP FRONT CANNOT BE OVEREMPHASIZED. THE SMDP WAS REFERRED TO CONSTANTLY THROUGHOUT THE DEVELOPMENT EFFORT, AND EVEN THOUGH MINOR UPDATES TO IT WERE REQUIRED, IT STILL SERVES AS A SURPRISINGLY STABLE REFERENCE.

VALUE = A B

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: DEFINE AND DOCUMENT ALL SOFTWARE INTERFACES DURING SOFTWARE REQUIREMENTS GENERATION BY WRITING FORMAL SOFTWARE INTERFACE SPECIFICATION (SIS's).

RATIONALE: FOR SES SOFTWARE ALL SOFTWARE INTERFACES WERE WELL DOCUMENTED IN DETAIL BY FORMAL SISs OR BY FORMAL SOFTWARE REQUIREMENTS (SRDs). DETAILED DEFINITION MEANT NOT ONLY FILE FORM AND CONTENT, BUT ALL RECORD AND FILE STRUCTURES, DATA TYPES, DATA RANGES, VOLUME AND SIZE ESTIMATES, AND ORDER. THE WELL DEFINED INTERFACES FACILITATED THE CODING PHASE, PRODUCING ACCURATE PROGRAM-TO-PROGRAM INTERFACES THAT REQUIRED LITTLE CHANGING.

VALUE = A B B

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: ACHIEVE A ONE-TO-ONE RATIO OF COMPUTING MACHINES TO SOFTWARE DEVELOPERS. CONFIGURE LIKE DEVELOPMENT STATIONS IDENTICALLY.

RATIONALE: DURING SES DEVELOPMENT, EACH OF THE SOFTWARE ENGINEERS HAD THEIR "OWN" PERSONAL COMPUTER TO USE FOR DEVELOPMENT PURPOSES. WITHOUT THE CONTENTION FOR COMPUTING RESOURCES, THE ENGINEERS WERE ABLE TO CONCENTRATE ON PRODUCING THE REQUIRED SOFTWARE PRODUCTS. ALSO BY HAVING ALL DEVELOPMENT STATIONS IDENTICALLY CONFIGURED, SOFTWARE ENGINEERS COULD SHARE PERIPHERIALS AS WELL AS FILES.

VALUE = A C B

MISSION OPERATIONS SYSTEM DEVELOPMENT

<u>RECOMMENDATION</u>: BEFORE THE START OF THE CODING PHASE, ESTABLISH A SET OF GUIDELINES AND RULES FOR SOFTWARE ENGINEERS TO FOLLOW.

<u>RATIONALE</u>: RULES COVERING PROGRAM STRUCTURE, STRONG TYPING AND COMMENTING RULES, PREFACE/PROLOGUE COMMENTARY, CALL/RETURN AND ARGUMENT LIST CONVENTIONS, FILE UNIT STANDARDS, AND STATEMENT NUMBERING WERE ESTABLISHED AND DOCUMENTED. IT APPEARED TO BE OVERLY SIMPLISTIC, OBVIOUS, AND NOT WORTH DOCUMENTING AT THE TIME, BUT PROVED TO BE EXCEPTIONALLY EFFECTIVE IN ACHIEVING UNIFORMITY, ELIMINATING POTENTIAL ERRORS, AND MINIMIZING STYLISTIC BIASES. THIS EFFORT HAS ALSO FACILITATED MAINTENANCE OF THE SOFTWARE PROGRAMS DURING MISSION OPERATIONS.

VALUE = A C B

Programming Standards

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: SPEND THE TIME AND EFFORT TO CAREFULLY SELECT TOOLS FOR THE SOFTWARE DEVELOPMENT ENVIRONMENT WITH ATTENTION PAID TO TOOLS THAT HAVE THE ABILITY TO INCREASE PRODUCTIVITY.

RATIONALE: BOTH THE LAHEY F77L FORTRAN COMPILER AND ITS SOURCE LEVEL DEBUGGER WERE HIGH PRODUCTIVITY ITEMS. THE COMPILER WAS FAST, PRODUCING EFFICIENT CODE. THE ABILITY TO BUILD FULL BREAKPOINT AND MONITORING FEATURES AT THE SOURCE LEVEL PREVENTED SIGNIFICANT TIME LOSSES FROM THE INABILITY TO TRACK DOWN OBTUSE BUGS. THE COMPLETE DEVELOPMENT ENVIRONMENT ALLOWED CONCENTRATION TO BE FOCUSED ON THE MAJOR ALGORITHM AND CODE PROBLEMS ASSOCIATED WITH EACH PROGRAMS' FUNCTIONAL REQUIREMENTS & MINIMIZED DISTRACTION FROM "DETAILS".

VALUE = B C B

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: DEVELOP A METRICS TRACKING SCHEME TO ALLOW ALL ENGINEERS AND MANAGEMENT TO BECOME INVOLVED IN THE STATUS/TRACKING OF INDIVIDUAL RESPONSIBILITIES.

RATIONALE: THE METRICS SCHEME USED BY THE SES DEVELOPERS WAS A LOW LEVEL MANAGEMENT TOOL THAT PROVED TO BE AS USEFUL TO THE INDIVIDUAL ENGINEERS AS IT WAS TO MANAGEMENT. BY REQUIRING THE INDIVIDUALS TO PROVIDE MINUTE TRACKING STATUS ON A WEEKLY BASIS, THEY BECAME PRECISELY AWARE OF HOW THEIR ASSIGNMENT WAS AFFECTING THE AGGREGATED TASK COMPLETION EFFORT. IF SLIPPAGES STARTED TO CREEP IN, THE SOURCE WAS APPARENT AND CORRECTIVE MEASURES ADDRESSED QUICKLY. MOREOVER, BY QUANTIFYING THE AMOUNT OF SLIP, EACH ENGINEER WAS AWARE OF HOW MUCH SCHEDULE HAD TO BE MADE UP AND HOW SOON. EACH INDIVIDUAL ENGINEER WAS ABLE TO SET OR AT LEAST SEE THEIR OWN GOALS FOR MEETING FINAL DEADLINES.

VALUE = A C C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: FOR THE DEVELOPMENT OF SES SOFTWARE, THE SYSTEMS ENGINEER THAT CREATED ALL SYSTEM LEVEL (FUNCTIONAL) SOFTWARE REQUIREMENTS ALSO PERFORMED FINAL QUALIFICATION TESTING.

RATIONALE: BY HAVING THE "SAME" INDIVIDUAL WRITE THE REQUIREMENTS AND PERFORM FINAL TESTING, THE SES SUBSYSTEM HAS EXPERIENCED VERY FEW FAILURES DURING MISSION OPERATIONS. 114 INFORMAL SRS's WERE WRITTEN DURING PRELIMINARY QUALIFICATION TESTING. 2 SRS's WERE WRITTEN DURING FINAL QUALIFICATION TESTING AND ONLY APPROXIMATELY 20 FAILURE REPORTS HAVE BEEN ISSUED DURING THE 3.5 YEAR MISSION OPERATIONS. NOT ENOUGH CAN BE SAID FOR HAVING CLEAR AND CONCISE REQUIREMENTS AND PERSONNEL KNOWLEDGABLE ENOUGH TO PERFORM ROBUST TESTING.

VALUE = A B C

MISSION OPERATIONS SYSTEM DEVELOPMENT

RECOMMENDATION: ATTEMPT TO MAINTAIN CONSISTENT PERSONNEL THROUGHOUT THE ENTIRE SOFTWARE DEVELOPMENT LIFECYCLE.

RATIONALE: SOME SOFTWARE DEVELOPMENT LIFE CYCLES ADVOCATE SEPARATE PERSONNEL FOR REQUIREMENTS, DESIGN AND CODE, AND ACCEPTANCE TEST. FOR THE SES, EACH ENGINEER WAS RESPONSIBLE FOR ALL LIFE CYCLE PRODUCTS BEGINNING WITH REQUIREMENTS AND ENDING WITH PROGRAM LEVEL ACCEPTANCE TESTING. THIS CONSISTENCY PROVIDED A STRONG SOFTWARE GROUP THAT EVENTUALLY TRANSITIONED INTO OPERATIONS, PROVIDING SIGNIFICANT IMPACT TO FLIGHT TEAM OPERATIONS. THE DEVELOPERS FAMILIARITY AND EXPERTISE PLAYED A BIG ROLE IN THE "TEAM" CONCEPT REQUIRED IN A FLIGHT TEAM ENVIRONMENT.

VALUE = A B C

SESSION 4

MISSION OPERATIONS CONDUCT

AGENDA	TIME ALLOCATED
INTRODUCTION	1:00 - 1:10 PM
PROGRAM PHILOSOPHY ISSUES	1:10 - 2:20
OPERATIONAL ISSUES	2:20 - 3:20
GROUND DATA SYSTEM MAINTENANCE ISSUES	3:20 - 3:50
WALK-ON TOPICS	3:50 - 4:10
SUMMARY	4:10 - 4:30

MISSION OPERATIONS SYSTEM DEVELOPMENT

PEOPLE WHO CONTRIBUTED ITEMS TO THIS SESSION:

VERBAL INTERVIEWS:

MIKE STEWART
JIM McCLURE
RAY MORRIS
JODY GUNN
JERRY CLARK
DOUG GRIFFITH
JOHN SLONSKI
DAVE WOERNER

WRITTEN INPUTS

JIM NEUMAN
JODY GUNN
KEN REHM
EILEEN DUKES
ALLEN CHEUVRONT

PROGRAM PHILOSOPHY ISSUES

MISSION OPERATIONS CONDUCT

RECOMMENDATION: PLAN ON CHANGE DURING OPERATIONS, EVEN IN "REPETITIVE" MISSIONS. NOTHING IS EVER AS SIMPLE AS IT SEEMS AT THE PLAN LEVEL. THIS IMPACTS BOTH TEAM STAFFING LEVELS AND ENHANCED GROUND SOFTWARE DESIGNS TO INCLUDE OPTIONS.

RATIONALE: MAGELLAN, PLANNED TO BE REPETITIVE AND BORING, WHERE "EVERY ORBIT LOOKS LIKE EVERY OTHER ORBIT," FOUND THIS NOT TO BE THE CASE. CONSTANT ADAPTION AND CHANGE RESULTED FROM ANOMALIES, BOTH ON THE GROUND AND IN FLIGHT. WE HAD TO MAINTAIN EFFICIENTLY FUNCTIONING GROUND AND FLIGHT SOFTWARE SUPPORT.

VALUE = A A C

MISSION OPERATIONS CONDUCT

RECOMMENDATION: FORCE OPERATIONAL DECISION-MAKING DOWN TO THE LOWEST LEVEL CONSISTENT WITH APPLICATION AND PERSONNEL.

RATIONALE: THE MAGELLAN FLIGHT TEAM SOMETIMES LET MUNDANE ISSUES AND DECISIONS RISE UP TO THE MISSION DIRECTOR, CONSUMING THE TIME OF EVERYONE IN THAT PARTICULAR CHAIN OF COMMAND. FINALLY MAGELLAN REVERSED THE TREND. EXPRESS COMMANDS ARE A GOOD EXAMPLE, WHERE INDIVIDUAL SUBSYSTEM ENGINEERS CAN AUTHORIZE PRE-APPROVED COMMANDS TO BE TRANSMITTED IN CERTAIN INSTANCES.

Example of planned Express Commands

VALUE = A C A

MISSION OPERATIONS CONDUCT

RECOMMENDATION: CAREFULLY DEFINE (AT LEAST QUALITATIVELY) HOW MUCH EFFORT THE PROJECT IS WILLING TO SPEND TO GAIN OR RECOVER SCIENCE DATA. GUIDELINES NEED TO BE DEVELOPED TO FIND THE RIGHT BALANCE BETWEEN EXTRA WORK AND ADDITIONAL DATA.

RATIONALE: MAGELLAN SOMETIMES WENT TO GREAT LENGTHS, INVOLVING A LOT OF WORK BY THE FLIGHT OPERATIONS TEAMS, TO ACHIEVE A SMALL AMOUNT OF SCIENCE DATA. (E.G. TWO-HIDE OPTIMIZATION)

VALUE = A C B

MISSION OPERATIONS CONDUCT

RECOMMENDATION: FOR THOSE MISSIONS INTENDED TO BE TRULY LOW COST, DON'T INSIST ON "ZERO COMMAND ERRORS" BUT CATEGORIZE THEM, ACCEPTING EFFORTS TO MINIMIZE COMMAND ERRORS WITH ZERO AS A GOAL. CONCENTRATE CHECKING EFFORTS TO ELIMINATE THOSE ERRORS THAT MIGHT CAUSE DAMAGE TO THE SPACECRAFT FLIGHT SYSTEM OR MISSION, WHILE BEING LESS CONCERNED ABOUT THOSE THAT HAVE NO CONSEQUENCE TO EITHER.

RATIONALE: ON MAGELLAN, ALL COMMAND ERRORS WERE EQUAL. SO MUCH EFFORT WAS SPENT TRYING TO ELIMINATE ALL TYPES OF COMMAND ERRORS THAT THERE WAS CONCERN THAT A REALLY BIG ONE WOULD SLIP THROUGH. AS LONG AS PEOPLE ARE INVOLVED IN SPACECRAFT COMMAND AND CONTROL, THERE WILL BE HUMAN ERROR. ~~THE OBJECTIVE SHOULD BE TO GUARANTEE TO CATCH ALL THE BIG ONES AND DON'T SWEAT THE LITTLE ONES.~~

VALUE = B C A

MISSION OPERATIONS CONDUCT

RECOMMENDATION: PROVIDE MISSION OPERATIONS COMMAND ASSURANCE (MOCA) SUPPORT AT THE BEGINNING OF OPERATIONS TO FOCUS ON ELIMINATION OF STARTUP ERRORS, AND THEN PHASE OUT. BRINGS PAST EXPERIENCE TO NEW FLIGHT TEAMS.

RATIONALE: MAGELLAN HAS HAD MOCA SUPPORT THROUGHOUT OPERATIONS. USEFULNESS APPEARS TO FOLLOW LAW OF DIMINISHING RETURNS. ~~LIMIT IS PROBABLY 3 TO 6 MONTHS.~~

VALUE = A B B

MISSION OPERATIONS CONDUCT

RECOMMENDATION: DEVELOP AND IMPLEMENT A PLAN TO ACHIEVE AS MUCH CROSS-TRAINING AMONG FLIGHT TEAM MEMBERS AS POSSIBLE WITH A GOAL OF COST-REDUCTION THROUGH STAFF MINIMIZATION.

RATIONALE: MAGELLAN FLIGHT TEAM MEMBERS ARE, IN GENERAL, TOO SPECIALIZED. (AS ARE MOST OTHER JPL FLIGHT TEAMS) THE SPACECRAFT TEAM DISCUSSED CROSS-TRAINING MANY TIMES, BUT NEVER SEEMED TO HAVE TIME. THEORETICALLY, THERE IS NO REASON WHY A GOOD SPACECRAFT ENGINEER COULDN'T BE TRAINED TO HANDLE MULTIPLE SUBSYSTEMS. MSDS AND SGS OPERATORS COULD BE CROSS-TRAINED. PERHAPS MSDT AND ~~METEOR~~ IDPT AND SDPT COULD BE CROSS-TRAINED, ~~OR GAMPO LEARN HOW TO OPERATE THE RADAR SYSTEM.~~

VALUE = A B ~~B~~ b

MISSION OPERATIONS CONDUCT

RECOMMENDATION: BE CAREFUL TO ALLOW FOR (POTENTIAL) EXTENDED MISSION PHASES WHEN PLANNING PRIMARY MISSIONS. ~~TAKE LITERALLY THE DIRECTIONS TO "NOT PRECLUDE EXTENDED MISSIONS."~~

RATIONALE: ~~FAILURE TO ALLOW FOR~~ CYCLE-2 EFFECTS IN IMAGE MOSAICKING OPERATIONS CREATED TRANSITION ~~PROBLEMS~~ AT THE END OF CYCLE 1.

COMMAND BLOCKS, AS CODED FOR PRIMARY MISSION, ARE NOT FLEXIBLE ENOUGH TO SUPPORT EXTENDED MISSION OBJECTIVES.

ORBIT NUMBERS GREATER THAN FOUR DIGITS WILL REQUIRE NUMEROUS SOFTWARE CHANGES DURING EXTENDED MISSION.

VALUE = B C C

MISSION OPERATIONS CONDUCT

RECOMMENDATION: BE AWARE OF PERSONNEL NEEDS. SPECIFICALLY, (1) PROVIDE AND ASSIST CAREER ADVANCEMENT PATHS WHEREVER POSSIBLE, AND (2) DO NOT IGNORE THE SOCIAL ASPECT OF TEAM DEVELOPMENT. THIS MEANS TO ENCOURAGE PARTIES, OF COURSE, BUT IT ALSO MEANS TO ENCOURAGE TEAMS TO GIVE SEMINARS ON WHAT THEY DO AND HOW THEY DO IT.

RATIONALE: MAGELLAN RECOGNIZED THIS NEED LATE IN THE OPS PHASE AND LOST SOME KEY PERSONNEL BEFORE SUCH RECOGNITION. EVEN THEN IT WAS A GOOD MORALE BOOSTER.

VALUE = A C C

MISSION OPERATIONS CONDUCT

RECOMMENDATION: KEEP ALL TEAMS (AT one site) OF THE FLIGHT TEAM TOGETHER IN ONE PHYSICAL LOCATION FOR MORE OPERATIONS EFFICIENCY.

RATIONALE: MAGELLAN'S SPACECRAFT TEAM WAS REMOTELY LOCATED WHICH MADE COMMUNICATION DIFFICULT AND INEFFICIENT.

MISSION CONTROL TEAM WAS ON FIRST FLOOR OF SFOF WITH REST OF TEAM ON SECOND FLOOR, WHICH CREATED A SEPARATION.

MAGELLAN'S SCIENCE AREA WAS LOCATED APART (THROUGH 2 LOCKED DOORS) FROM THE REST OF SAMPO, CAUSING COMMUNICATIONS DIFFICULTIES.

(SEE ALSO CHART ON PAGE 13)

VALUE = A B C

MISSION OPERATIONS CONDUCT

RECOMMENDATION: ALLOW PORTIONS OF THE FLIGHT TEAM TO OPERATE FROM A REMOTE LOCATION TO SAVE COST AND RETAIN QUALITY PEOPLE. EMPHASIZE DEVELOPMENT OF HIGH QUALITY COMMUNICATIONS LINKS AND PROCEDURES TO FORCE EXCHANGE OF INFORMATION BETWEEN SITES.

RATIONALE: MAGELLAN'S SPACECRAFT TEAM OPERATED FROM A REMOTE SITE IN DENVER DURING FLIGHT OPERATIONS. THIS ALLOWED A SIGNIFICANT COST REDUCTION AND PERMITTED RETENTION OF A QUALITY TEAM WITH CRITICAL SPACECRAFT DEVELOPMENT EXPERIENCE. THE MAJOR DIFFICULTIES REVOLVED AROUND COMMUNICATIONS BETWEEN PASADENA AND DENVER. THE FOLLOWING CAPABILITIES WERE DETERMINED TO BE ESSENTIAL TO MAKING REMOTE OPERATIONS WORK:

1. A QUICK, CLEAR AND RELIABLE STATION-TO-STATION VOICE NETWORK
2. A QUALITY TELECONFERENCING SYSTEM ALLOWING FULL AUDIO PARTICIPATION IN MEETINGS.
3. REGULAR STATUS REPORTS (BOTH VERBAL AND WRITTEN) ON REMOTE SITE ACTIVITY.

(SEE ALSO CHART PAGE ON 12)

VALUE = A B A

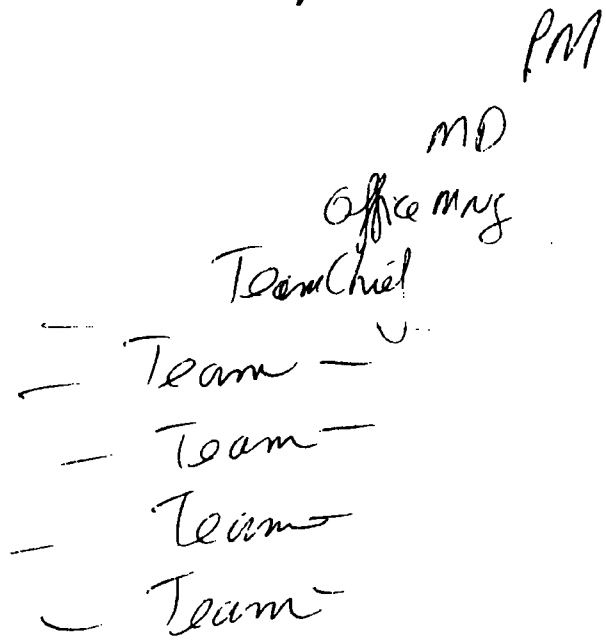
OPERATIONAL ISSUES

MISSION OPERATIONS CONDUCT

RECOMMENDATION: USE "PYRAMID" COMMUNICATIONS TECHNIQUE, WHEREIN MEETINGS ARE USED TO PASS INFORMATION FROM PM TO MD TO OFFICE MGR TO TEAM CHIEF TO WORKERS AND IN THE OPPOSITE DIRECTION.

RATIONALE: MAGELLAN MEETINGS WERE OFTEN POPULATED BY TOO MANY PEOPLE, AND YET OFTEN COMMUNICATIONS DID NOT OCCUR WELL, ESPECIALLY IN THE DOWNWARD DIRECTION.
(SEE ALSO ITEM ON PAGE 16)

VALUE = A B C



MISSION OPERATIONS CONDUCT

RECOMMENDATION: CAREFULLY STRUCTURE MEETINGS SO THAT THEY MINIMIZE WASTED TIME. ISSUE AGENDAS, STATE GOALS, CONSIDER LISTING SEPARATELY THE "REQUIRED ATTENDEES" AND "COME-IF-YOU-WANT ATTENDEES". START MEETINGS ON TIME.

RATIONALE: MAGELLAN MEETINGS WERE PERCEIVED AS INEFFICIENTLY RUN, PERSONNEL FELT THAT THEY WERE REQUIRED TO SIT THROUGH MEETINGS TO SEE IF THERE WAS ANY SUBJECT PERTINENT TO THEM. (SEE ALSO ITEM ON PAGE 15)

VALUE = A C C

MISSION OPERATIONS CONDUCT

RECOMMENDATION: PLAN A SEQUENCING PROCESS THAT ALLOWS LATE BREAKING COMMAND SEQUENCE CHANGES REQUIRING LOW LEVEL SEQUENCE EDITS OR ENTIRE SEQUENCE REDELIVERIES.

RATIONALE: MAGELLAN HAS FOUND THAT LATE, QUICK CHANGES IN THE SEQUENCE WERE NECESSARY TO:

A) RESPOND TO S/C ANOMALIES,
B) CORRECT UNDISCOVERED ON-BOARD SEQUENCE ERRORS,
C) SAVE KEY SCIENCE DATA, OR
D) AVOID POTENTIAL S/C PROBLEMS

VALUE = A C C

MISSION OPERATIONS CONDUCT

RECOMMENDATION: KEEP ALL FLIGHT MEMORIES UP-TO-DATE DURING MISSION OPERATIONS, EVEN IF THEY ARE "OFF-LINE."

RATIONALE: THE MAGELLAN AACS-B MEMORY WAS NOT KEPT UP-TO-DATE AFTER THE SRM SEPARATION EVENT. NEITHER AACS HAD CORRECT GUIDE STARS FOR RAM SAFING AFTER ORBIT INSERTION. THIS IS LIKELY THE REASON RAM SAFING DID NOT WORK DURING THE FIRST RPE.

VALUE = C A C

MISSION OPERATIONS CONDUCT

RECOMMENDATION: IMPLEMENT AN AUTOMATED ON-LINE RELATIONAL DATABASE FOR QUICK ACCESS AT WORKSTATIONS DURING OPERATIONS. THIS IS ESPECIALLY IMPORTANT FOR COMMAND INFORMATION SUCH AS COMMAND AVAILABILITY, STRUCTURE AND USAGE, AND ALSO TO MAINTAIN AN ON-LINE HISTORY OF COMMANDS TRANSMITTED. IT IS ALSO USEFUL FOR TELEMETRY.

RATIONALE: MAGELLAN SPACECRAFT TEAM REALIZED THE NEED FOR THIS DURING PRIME MISSION MAPPING OPERATIONS AND IMPLEMENTED IT FOR EXTENDED MISSION.

VALUE = C A C

MISSION OPERATIONS CONDUCT

RECOMMENDATION: SIMPLIFY THE SFOC WORKSTATION USER INTERFACE TO THE TELEMETRY SYSTEM FOR THE MISSION CONTROLLERS (ACEs), BUT RETAIN THE FLEXIBILITY FOR THE NON REAL-TIME SPACECRAFT TEAM ENGINEER'S ACTIVITY. DESIGN AN AUTOMATED "FRONT-END" PROCESSOR FOR THE CONTROLLERS.

RATIONALE: FOR THE ACEs, THE SFOC WORKSTATION INTERFACE WAS TOO LABOR INTENSIVE, REQUIRING FAR TO MUCH KEYBOARD ENTRY WHICH DETRACTED FROM SPACECRAFT MONITORING. FOR THE SPACECRAFT ENGINEERS, THE FLEXIBILITY OFFERED BY MULTIPLE WINDOWS, USER-CHANGEABLE DISPLAYS, RAPID QUERY ACCESS TO A CENTRAL TELEMETRY DATA BASE, AND OTHER SFOC FEATURES, ALLOWED THE ENGINEERS TO ACCOMPLISH THEIR JOBS QUICKLY AND EFFICIENTLY, ESPECIALLY DURING ANOMALY RESPONSE.

VALUE = C A C

MISSION OPERATIONS CONDUCT

RECOMMENDATION: ONE INDIVIDUAL OR ORGANIZATION SHOULD BE ASSIGNED RESPONSIBILITY FOR TROUBLESHOOTING AN ENTIRE DATA LINK TO REMOTE SUPPORT AREAS RATHER THAN HAVE MANY INDIVIDUALS RESPONSIBLE FOR JUST THEIR PORTION OF THE LINK.

RATIONALE: BEFORE RESPONSIBILITIES WERE CLEARLY UNDERSTOOD FOR THE JPL/DENVER 56 KBPS INTERFACE, THERE WAS CONFUSION AS TO WHO WAS RESPONSIBLE FOR RESOLVING A PARTICULAR ANOMALY. IN SEVERAL INSTANCES EACH OF THE PARTIES RESPONSIBLE FOR A PIECE OF THE FAILED INTERFACE REPORTED THAT THEIR PIECE WAS WORKING AND THAT IT MUST BE ANOTHER PIECE THAT WAS NOT WORKING.

VALUE = B C C

MISSION OPERATIONS CONDUCT

RECOMMENDATION: FOR PROGRAMS HAVING A TEST BED SPACECRAFT SIMULATOR, USE IT AS A TRAINING GROUND FOR REPLACEMENT/ADDITIONAL MISSION OPERATIONS PERSONNEL.

RATIONALE: AS MAGELLAN OPERATIONS PERSONS HAVE LEFT THE PROGRAM OR AS NEW PEOPLE ARE REQUIRED, SVL HAS BEEN INSTRUMENTAL IN PROVIDING PERSONNEL WHO ARE EXPERIENCED IN S/C OPERATIONS TO THE SPACECRAFT SUBSYSTEMS PORTION OF THE FLIGHT TEAM.

VALUE = C B C

GROUND DATA SYSTEM

MAINTENANCE ISSUES

MISSION OPERATIONS CONDUCT

RECOMMENDATION: PLAN AND BUDGET FOR CONTINUED CHANGES TO GDS SOFTWARE AFTER LAUNCH, AND THE ASSOCIATED REDELIVERIES. PLANS SHOULD BE ABLE TO SUPPORT CONCURRENT IMPLEMENTATION, TEST AND FLIGHT OPERATIONS. MOST GDS SUBSYSTEMS WILL REQUIRE AT LEAST ONE ADDITIONAL SUBSYSTEM DELIVERY FOLLOWING THE FIRST OPERATIONAL USE OF A SUBSYSTEM. BUDGETS SHOULD NOT BE STRUCTURED SUCH THAT SUBSYSTEM DEVELOPMENT PERSONNEL ARE PHASED OUT PRIOR TO ACTUAL OPERATIONAL USE OF THE SUBSYSTEM.

RATIONALE: RESOURCE PLANNING FOR SUSTAINING GDS SUBSYSTEM ENGINEERING IN MOST AREAS WAS INADEQUATE, BOTH IN MANPOWER AVAILABLE AND IN COMPUTER RESOURCES. REGARDLESS OF THE QUALITY OF THE IMPLEMENTATION EFFORT THERE IS ALWAYS A NEED FOR OPERATIONAL ENHANCEMENTS OR ANOMALY CORRECTION FOLLOWING FIRST ACTUAL USE. WE NAIVELY ASSUMED THAT ONCE WE WERE FLYING, THE SUBSYSTEM WORK WOULD DROP TO NEAR ZERO. EVERY SUBSYSTEM REQUIRED AT LEASE ONE REDELIVERY FOLLOWING ITS INITIAL USE.

VALUE = A B C

MISSION OPERATIONS CONDUCT

RECOMMENDATION: WHEN IT IS IMPOSSIBLE TO COMPLETELY CHECK OUT A GDS SUBSYSTEM PRIOR TO OPERATIONAL USE DUE TO LACK OF TEST DATA, A PERIOD OF SUBSYSTEM CHECKOUT SHOULD BE OFFICIALLY SCHEDULED DURING WHICH NO ROUTINE OPERATIONAL ACTIVITY IS PLANNED.

RATIONALE: DUE TO LACK OF RADAR TEST DATA IT WAS IMPOSSIBLE TO COMPLETELY CHECKOUT THE SAR DATA PROCESSING SUBSYSTEM PRIOR TO IN-ORBIT-CHECKOUT. A THREE WEEK PERIOD FOLLOWING RECEIPT OF ACTUAL DATA WAS BLOCKED OUT DURING WHICH THE SDPS DEVELOPERS RAN ACCEPTANCE TESTS UNDER A MODIFIED CHANGE CONTROL PROCESS. AT THE CONCLUSION OF THIS PERIOD THE DEVELOPMENT PERSONNEL DOCUMENTED CHANGES MADE TO THE SUBSYSTEM AND DELIVERED THE SUBSYSTEM TO THE CHANGE BOARD. WITHOUT THIS CHECKOUT PERIOD DATA PRODUCTS WITH ANOMALIES WOULD HAVE BEEN PRODUCED WHICH COULD HAVE RESULTED IN REPROCESSING ACROSS THE DOWNLINK PROCESSING SYSTEM.

VALUE = B B C

MISSION OPERATIONS CONDUCT

RECOMMENDATION: CONSIDER MODIFICATION OF THE NATURE OF ACCEPTANCE TEST PLANS AFTER INITIAL SOFTWARE DELIVERY.

RATIONALE: ATPs ARE A NECESSARY AND USEFUL PART OF TESTING. BUT TESTING AN UPGRADE COULD BE DONE LESS RIGOROUSLY THAN AN INITIAL DELIVERY. FULL REGRESSION TESTING IS USUALLY UNNECESSARY AS ONLY A PORTION OF A SOFTWARE SET IS AFFECTED.

VALUE = A C B

MISSION OPERATIONS CONDUCT

RECOMMENDATION: PROVIDE A METHOD ALLOWING SPECIAL DELIVERY OF PORTIONS OF THE GDS QUICKLY DURING OPERATIONS. PUT MORE INTERFACE TESTING RESPONSIBILITY ON THE SUBSYSTEM ENGINEERS.

RATIONALE: MAGELLAN FOUND IT WAS MUCH QUICKER TO UPDATE THE FLIGHT S/W THAN IT WAS TO CORRECT A PROBLEM IN GROUND SOFTWARE (E.G. THE DESAT BLOCK) DUE TO THE COMPLEX GDS TESTING PROCESS.

VALUE = A B B