FAILURE MODES EFFECTS ANALYSIS (FMEA) – CRITICAL HARDWARE
NUMBER: M8-1MR-BM009-X

SUBSYSTEM NAME: MECHANICAL - EDS

REVISION: 1 9/1/95

		PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
LRU	:	ASSY, DISPLACEMENT SENS/LOCKING NPO-ENERGIA	33U.5325.005 33U.5325.005
LRU	:	ASSY, DISPLACEMENT SENS/LOCKING NPO-ENERGIA	33U.5325.005-01 33U.5325.005-01
SRU	:	FIXER NPO-ENERGIA	33Y.6662.002 33Y.6662.002

PART DATA

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
DISPLACEMENT SENSOR/LOCKING (DIFFERENTIAL) ASSEMBLY FIXER

REFERENCE DESIGNATORS:

QUANTITY OF LIKE ITEMS: 2
TWO

FUNCTION:
CONTAINED WITHIN THE EACH DISPLACEMENT SENSOR/LOCKING ASSEMBLY OF THE DIFFERENTIAL, THE FIXER BYPASSES THE SPRING MECHANISM TO ALLOW DIRECT COUPLING OF THE DIFFERENTIAL ASSEMBLY TO LOCK THE DOCKING RING IN ITS ALIGNED POSITION. WHEN POWER IS APPLIED TO THE FIXER WINDINGS A MAGNETIC FIELD IS CREATED WHICH EXTENDS A ROD TO MECHANICALLY COUPLE THE TWO INDIVIDUAL DIFFERENTIAL SEGMENTS TO PROVIDE SYNCHRONIZED ROTATION, (LIMITING RING MOVEMENT IN THE PITCH AND YAW DIRECTIONS), THUS MAINTAINING THE RING IN ITS ALIGNED POSITION (ALIGNMENT IN RESPECT TO ITS OWN MECHANISM). WHEN POWER IS REMOVED, A SPRING RETRACTS THE ROD WHICH UNCOUPLES BOTH DIFFERENTIAL SEGMENTS, ALLOWING THE DIFFERENTIAL TO MOVE NORMALLY.

SERVICE IN BETWEEN FLIGHT AND MAINTENANCE CONTROL:
SERVICEABILITY CONTOL, DOCKING WITH CALIBRATING DOCKING MECHANISM.

MAINTAINABILITY
REPAIR METHOD - NONE (REPAIRING IN MANUFACTURING CONDITIONS ONLY).

REFERENCE DOCUMENTS: 33U.5325.005
33U.5325.005-01
33U.6662.002

FAILURE MODES EFFECTS ANALYSIS (FMEA) – CIL FAILURE MODE
NUMBER: M8-1MR-BM009- 01

REVISION# 1 9/1/95

SUBSYSTEM NAME: MECHANICAL - EDS
LRU: DISPLACEMENT SENSOR/LOCKING ASSEMBLY CRITICALITY OF THIS
ITEM NAME: FIXER, DIFFERENTIAL FAILURE MODE: 2R3

FAILURE MODE:
FAILS TO LOCK

MISSION PHASE:
OO ON-ORBIT

VEHICLE/PAYLOAD/KIT EFFECTIVITY: 104 ATLANTIS

CAUSE:
STRUCTURAL FAILURE DUE TO MECHANICAL/THERMAL SHOCK OR MANUFACTURE/ MATERIAL DEFECT, OPEN WINDINGS, SHORT BETWEEN WINDINGS; MECHANICAL JAMMING DUE TO CONTAMINATION

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

CRITICALITY 1R2 DURING INTACT ABORT ONLY (AVIONICS ONLY)? N/A

REDUNDANCY SCREEN A) PASS
B) FAIL
C) PASS

PASS/FAIL RATIONALE:
A)

B)
FAILS REDUNDANCY SCREEN "B" SINCE A SINGLE FIXER FAILING TO LOCK (MECHANICALLY) IS NOT DETECTABLE IN FLIGHT.

C)

METHOD OF FAULT DETECTION:
SENSORS WILL MONITOR POWER TO ALL FIXERS AND PROVIDE THE INFORMATION FOR GROUND MONITORING THROUGH TELEMETRY DATA. FLIGHT CREW WOULD NOT BE ABLE TO DETECT A SINGLE FIXER FAILING TO LOCK. HOWEVER, VISUAL OBSERVATION OF THE DOCKING PROCESS MAY DETECT THE EFFECT OF A FAILURE TO LOCK BOTH DIFFERENTIAL FIXERS.

- FAILURE EFFECTS -

(A) SUBSYSTEM:
BOTH DIFFERENTIAL SEGMENTS WILL NOT ROTATE TOGETHER. FIRST FIXER FAILURE - LOSS OF PARTIAL CAPABILITY TO LIMIT PITCH AND YAW MOVEMENT OF THE DOCKING RING. NO EFFECT SINCE THIS MOVEMENT OF THE ENTIRE RING IS LIMITED BY THE REMAINING DIFFERENTIAL FIXER. DYNAMICS OF CAPTURE WILL BE DIFFERENT GIVEN A SINGLE FIXER FAILURE. SECOND FIXER FAILURE - WORST CASE. LOSS OF

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CAPABILITY TO ALIGN THE DOCKING RING IN THE ROLL AND TRANSLATIONAL DIRECTIONS.

(B) INTERFACING SUBSYSTEM(S):
NO EFFECT ON INTERFACING ORBITER SUBSYSTEMS.

(C) MISSION:
POTENTIAL LOSS OF DOCKING FOLLOWING SECOND FIXER FAILING TO LOCK.

(D) CREW, VEHICLE, AND ELEMENT(S):
NO EFFECT ON CREW AND VEHICLE.

(E) FUNCTIONAL CRITICALITY EFFECTS:
FIRST FIXER FAILURE - LOSS OF PARTIAL CAPABILITY TO LIMIT PITCH AND YAW MOVEMENT OF THE DOCKING RING. SECOND FIXER FAILURE - WORST CASE, LOSS OF CAPABILITY TO ALIGN THE DOCKING RING IN THE ROLL AND TRANSLATIONAL DIRECTIONS FOR MATING AND STRUCTURAL LATCHING OF THE INTERFACE. LOSS OF CAPABILITY TO PERFORM DOCKING RESULTING IN LOSS OF MISSION OBJECTIVES.

DESIGN CRITICALITY (PRIOR TO OPERATIONAL DOWNGRADE, DESCRIBED IN F): 2R3

(F) RATIONALE FOR CRITICALITY CATEGORY DOWNGRADE:
N/A (THERE ARE NO WORKAROUNDS TO CIRCUMVENT THIS FAILURE.)

-DISPOSITION RATIONALE-

(A) DESIGN:
THE DIFFERENTIAL FIXER ALLOWS FOR PITCH AND YAW MOVEMENT OF THE RING ONLY. REDUNDANT WINDINGS, POWERED BY SEPARATE SOURCES, ARE PROVIDED FOR LOCKING OF FIXERS. DIFFERENTIAL ASSEMBLY IS COMPLETELY ENCASED TO PREVENT THE INTRODUCTION OF CONTAMINATION LARGE ENOUGH TO CAUSE THE FIXER TO JAM IN THE UNLOCKED POSITION.

LOAD ANALYSIS HAS SHOWN THAT THE CENTERING SPRINGS WILL HELP ALIGN THE RING.

(B) TEST:
DOCKING MECHANISM ACCEPTANCE TESTS:

1. ELECTRICAL SCHEMATIC CHECKOUT - CONTACT RESISTANCE ON EACH PIN OF THE CONNECTOR WHICH IS ELECTRICALLY TIED TO EACH FIXER IS CHECKED. THIS TEST VERIFIES CONTINUITY THROUGH THE FIXER WINDINGS.

2. INSULATION ELECTRICAL RESISTANCE TEST - THE INSULATION RESISTANCE AND ELECTRICAL STRENGTH OF INSULATION CHECKOUT OF EACH PIN OF EACH FIXER CONNECTOR TO THE APDA HOUSING WILL VERIFY THAT THE FIXER WINDINGS ARE NOT ELECTRICALLY SHORTED TO GROUND.

3. FIXER FUNCTIONAL PERFORMANCE TEST - OPERATION AND CURRENT TO EACH FIXER IS VERIFIED DURING RING EXTENSION FROM FINAL TO INITIAL POSITION. OPERATION OF BOTH FIXERS IS VERIFIED SIMULATANEOUSLY.

4. DOCKING MECHANISM CHECKOUT (STATIC) TEST - RING IS EXTENDED AND RETRACTED AS NECESSARY TO FULLY TEST ITS OPERATION DURING A SINGLE

DOCKING. FIXERS ARE TURNED ON DURING RING MOVEMENT. FORCE IS APPLIED TO THE RING TO SIMULATE LOADS THAT CAN OCCUR DURING RING CAPTURE AND MATING OF THE TWO MECHANISMS WITH FIXERS ON. THIS TEST WILL VERIFY PROPER OPERATION OF THE FIXERS UNDER LOAD AND NO-LOAD CONDITIONS.

5. VIBRORESISTENT TEST - APDS SUBJECTED TO THE FOLLOWING VIBRATION LEVELS FOR 2 MINUTES PER AXIS:

FREQUENCY (HZ)	SPECTORAL DENSITY ACCELERATION
FROM 20 TO 80	INCREASING, 3DB OCTAVE TO $0.04G^2/HZ$
FROM 80 TO 350	PERMANENT $0.04G^2/HZ$
FROM 350 TO 2000	DECREASING 3DB OCTAVE WITH $0.04G^2/HZ$

SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT TEST, AN INSULATION RESISTANCE TEST, AND FUNCTIONAL CHECK ARE PERFORMED, PER ATP'S #1, #2, & #3 ABOVE, TO VERIFY PROPER OPERATION OF THE FIXERS.

6. THERMO VACUUM TEST - DOCKING OF THE MECHANISM IS THERMALLY CYCLED FROM +20°C TO -50/-55°C TO +50/+55°C TO +20°C IN A VACUUM AT 10^{-4} TO 10^{-5} TORR. DWELL AT EACH TEMPERATURE AND BETWEEN OPERATIONS AT EACH TEMPERATURE IS A MINIMUM OF 60 MINUTES AFTER STABILIZATION. OPERATIONS INCLUDES PERFORMING DOCKING WHICH IS ACCOMPLISHED AT A SPEED OF 0.15M/SEC BETWEEN THE SIMULATOR AND MOVEABLE PLATFORM (CONTAINING THE DOCKING MECHANISM). PROPER OPERATION OF THE FIXERS IS VERIFIED DURING RING EXTENSION/ RETRACTION AND DOCKING FOR A TEMPERATURE RANGE OF -50°C/-55°C TO 50°C/55°C.

7. CONTROLLED DOCKING TEST - CONTROLLED DOCKING IS PERFORMED FOLLOWING INSTALLATION INTO THE ORBITER TO VERIFY PROPER RETRACTION OF THE DOCKING MECHANISM. THIS TESTS WILL VERIFY PROPER OPERATION OF THE FIXERS DURING RING EXTENSION/ RETRACTION.

DOCKING MECHANISM QUALIFICATION TESTS:

1. ELECTRICAL CIRCUIT TEST - CONTACT RESISTANCE ON EACH PIN OF THE CONNECTOR WHICH IS ELECTRICALLY TIED TO EACH FIXERS MOTOR IS CHECKED. THIS TEST VERIFIES CONTINUITY THROUGH THE FIXER WINDINGS.

2. INSULATION ELECTRICAL RESISTANCE TEST - THE INSULATION RESISTANCE AND ELECTRICAL STRENGTH OF INSULATION CHECKOUT OF EACH PIN OF EACH FIXER CONNECTOR TO THE APDA HOUSING WILL VERIFY THAT THE FIXER MOTOR WINDINGS ARE NOT ELECTRICALLY SHORTED TO GROUND.

3. OPERATIONAL CAPABILITY TEST - FIXER OPERATION VERIFIED BY THE FOLLOWING TWO TESTS:

FIXER LIMIT LOAD TEST - WITH FIXERS ENGAGED A 500 KGF LOAD IS APPLIED PARALLEL TO THE SEAL INTERFACE; THEN A 350 KGF-M MOMENT ABOUT THE X, Y, AND Z AXIS IS APPLIED AND SYSTEM IS INSPECTED FOR EVIDENCE OF DAMAGE OR DEGRADATION.

FIXER ULTIMATE LOAD TEST - WITH FIXERS ENGAGED A 700 KGF LOAD IS APPLIED PARALLEL TO THE SEAL INTERFACE: THEN A 500 KGF-M MOMENT

ABOUT THE X, Y, AND Z AXIS IS APPLIED AND SYSTEM IS INSPECTED FOR EVIDENCE OF DAMAGE OR DEGRADATION.

4. SHOCK AND SAWTOOTH LOADING STRENGTH TEST - DOCKING MECHANISM IS SUBJECTED TO 20G TERMINAL SAWTOOTH SHOCK PULSES IN EACH AXIS, 3 PULSES IN EACH DIRECTION FOR A TOTAL OF 6 PULSES/AXIS. AFTER COMPLETION AN INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT CHECK TEST, INSULATION RESISTANCE TEST, AND OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP TESTS #1, #2, AND #3 ABOVE, ARE PERFORMED TO VERIFY PROPER FIXER OPERATIONS DURING RING MOVEMENT.

5. TRANSPORTABILITY STRENGTH TEST - SHIPPING LOADS ARE SIMULATED ON A VIBRATING TABLE TO VERIFY THAT THE DOCKING MECHANISM WILL NOT BE DAMAGED DURING SHIPMENT. THIS TEST IS CONDUCTED UNDER THE CONDITIONS CONTAINED IN THE FOLLOWING TABLE.

VIBRATION ACCELER DIRECTION	VIBRATION ACCELER AMPLITUDE	FREQUENCY SUBBAND, HZ					TOTAL TEST DURATION	
		5-7	7-15	15-30 .	30-40	40-60		
		TEST DURATION, MIN					HR	MIN
ALONG X-AXIS	1.4	–	4	–	–	–	–	4
	1.2	76	93	32	61	39	5	7
ALONG Y-AXIS	1.1	–	4	–	–	–	–	4
	1.0	13	16	7	10	7	–	53
ALONG Z-AXIS	1.1	–	4	–	–	–	–	4
	1.0	32	40	16	26	16	2	10

SUBSEQUENT TO THIS TEST AN INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT CHECK TEST, INSULATION RESISTANCE TEST, AND OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP TESTS #1, #2, AND #3 ABOVE, ARE PERFORMED TO VERIFY PROPER FIXER OPERATIONS DURING RING MOVEMENT.

6. VIBRATION STRENGTH TEST - APDS SUBJECTED TO THE FOLLOWING VIBRATION LEVELS IN EACH AXIS FOR A 400 SECOND DURATION.

FREQUENCY (HZ)	SPECTORAL DENSITY ACCELERATION
FROM 20 TO 80	INCREASING, 3DB OCTAVE TO $0.067G^2/HZ$
FROM 80 TO 350	CONSTANT $0.067G^2/HZ$
FROM 350 TO 2000	DECREASING 3DB OCTAVE WITH $0.067G^2/HZ$

SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT CHECK TEST, INSULATION RESISTANCE TEST, AND OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP TESTS #1, #2, AND #3 ABOVE, ARE PERFORMED TO VERIFY PROPER FIXER OPERATIONS DURING RING MOVEMENT.

7. APDS SERVICEABILITY TEST IN A SIX-DEGREE-OF-FREEDOM DYNAMIC TEST - THE SIX-DEGREE-OF-FREEDOM DYNAMIC TEST VERIFIES APDS DOCKING AND UNDOCKING OPERATIONS UNDER CLOSE-TO-FULL-SCALE CONDITIONS. STATIC MOTION OF ENTITIES IS SIMULATED UNDER SPECIFIC INERTIAL AND GEOMETRICAL PARAMETERS FOR VARIOUS INITIAL CONDITIONS FOR MIR/SHUTTLE DOCKING. A TOTAL OF 20 DOCKINGS IS PERFORMED. FIXER

OPERATION VERIFIED DURING EXTENSION OF DOCKING RING TO INITIAL POSITION. SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT CHECK TEST, INSULATION RESISTANCE TEST, AND OPERATIONAL CAPABILITY TEST ARE PERFORMED, AS DEFINED IN QTP TESTS #1, #2, AND #3 ABOVE, TO VERIFY PROPER FUNCTIONING OF FIXERS DURING RING MOVEMENT AND DOCKING OPERATIONS.

8. COLD AND HEAT RESISTANCE TEST - DOCKING OF THE MECHANISM IS THERMALLY CYCLED, UNDER LOAD CONDITIONS, FROM +20°C TO -50/-55°C TO +50/+55°C TO +20°C IN A VACUUM AT 10^{-4} TO 10^{-5} TORR. DWELL AT EACH TEMPERATURE AND BETWEEN OPERATIONS AT EACH TEMPERATURE IS A MINIMUM OF 60 MINUTES AFTER STABILIZATION. FIVE CYCLES WERE PERFORMED AGAINST THE GUIDE RING EXTEND AND FINAL POSITION MECHANICAL STOPS FOR 10 SECONDS EACH. DOCKING PARAMETERS ARE SHOWN IN THE FOLLOWING TABLE.

SEQ NO.	DOCKING RATE, M/S	SIMULATOR ROTATIONAL ANGLE		TEMP °C	VOLTAGE VOLTS	PRESS INTEGRITY CHECKOUT
		PITCH	ROLL			
1	0.10	0°	0°	25 +/-10	23	YES
2	0.10	0°	4°	25 +/-10	34	NO
3	0.12	4°	4°	25 +/-10	27	NO
4*	—	—	—	+60+/-5	—	YES
4	0.10	4°	0°	+50+/-5	27	YES
5*	—	—	—	-(60+/-5)	—	YES
5	0.10	4°	0°	-(30+/-5)	27	YES
6*	—	—	—	+60+/-5	—	YES
6	0.12	0°	4°	+50+/-5	23	YES
7*	—	—	—	-(60+/-5)	—	YES
7	0.10	0°	4°	-(30 +/-5)	23	YES
8*	—	—	—	+60+/-5	—	YES
8	0.12	4°	4°	50 +/-5	34	YES
9*	—	—	—	-(60+/-5)	—	YES
9	0.12	4°	4°	-(30 +/-5)	34	YES
10*	—	—	—	+60+/-5	—	YES
10	0.10	4°	0°	+50+/-5	27	YES
11*	—	—	—	-(60+/-5)	—	YES
11	0.10	0°	4°	-(30 +/-5)	27	YES
12*	—	—	—	+60+/-5	—	YES
12	0.10	0°	4°	+50+/-5	27	YES
13*	—	—	—	-(60+/-5)	—	YES
13	0.12	4°	4°	-(30 +/-5)	27	YES
14*	—	—	—	+60+/-5	—	YES
14	0.12	4°	4°	+50+/-5	27	YES
15	0.12	4°	4°	+25+/-10	23	YES

*MC621-0087-2001, -4001, & -5001 ONLY

AFTER COMPLETION AN INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT CHECK TEST, INSULATION RESISTANCE TEST, AND OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP TESTS #1, #2, AND #3 ABOVE, ARE PERFORMED TO VERIFY PROPER FIXER FUNCTIONING DURING RING MOVEMENT AND DOCKING OPERATIONS.

9. TARGET SERVICE LIFE TEST - TESTS ARE PERFORMED TO VERIFY PROPER DOCKING AND UNDOCKING OPERATIONS OVER ITS LIFE OF 100 DOCKINGS. PROPER OPERATION OF THE FIXERS VERIFIED DURING 100 DOCKING AND UNMATING CYCLES (FOR MC621-0087-1001/-3001 UNITS ONLY). FOR MC621-0087-2001, -4001, & -5001 UNITS PROPER OPERATION VERIFIED DURING 388 CYCLES (44 VACUUM/LOAD CYCLES, 16 LOAD CYCLES, & 324 NO-LOAD CYCLES). THESE TESTS INCLUDE RING EXTENSION AND RETRACTION. SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT CHECK TEST, INSULATION RESISTANCE TEST, AND OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP TESTS #1, #2, AND #3 ABOVE, ARE PERFORMED TO VERIFY PROPER FIXER FUNCTIONING DURING RING MOVEMENT AND DOCKING OPERATIONS.

10. CONTROL DISASSEMBLY - UPON COMPLETION OF ALL QUAL TESTING THE DOCKING MECHANISM IS DISMANTLED AND ALL FIXER OPERATING SURFACES ARE CHECKED FOR EVIDENCE OF WEAR OR FAILURE.

OMRSD - TURNAROUND CHECKOUT TESTING IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

(C) INSPECTION:
RECEIVING INSPECTION
COMPONENTS ARE SUBJECTED TO A 100% RECEIVING INSPECTION PRIOR TO INSTALLATION.

CONTAMINATION CONTROL
CORROSION PROTECTION PROVISIONS AND CONTAMINATION CONTROL VERIFIED BY INSPECTION. CHECK OF ROOM CLEANLINESS; PARTS WASHING AND OTHER OPERATIONS OF THE TECHNOLOGICAL PROCESS WHICH PROVIDES CLEANLINESS ARE VERIFIED BY INSPECTION.

CRITICAL PROCESSES
ANODIZING, HEAT TREATING, SOLDERING, CHEMICAL PLATING, AND CURING VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION
TORQUE, ADJUSTMENTS AND TOLERANCES ACCORDING TO TECHNICAL REQUIREMENTS OF THE DRAWINGS ARE VERIFIED BY INSPECTION.

TESTING
ATP/QTP/OMRSD TESTING VERIFIED BY INSPECTION.

HANDLING/PACKAGING
HANDLING/PACKAGING PROCEDURES AND REQUIREMENT FOR SHIPMENT VERIFIED BY INSPECTION.

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(D) FAILURE HISTORY:
DATA ON TEST FAILURES, UNEXPLAINED ANOMALIES, AND OTHER FAILURES EXPERIENCED DURING GROUND PROCESSING OF ODS DOCKING MECHANISMS CAN BE FOUND IN PRACA DATA BASE.

(E) OPERATIONAL USE:
NONE. LOCKED FIXER ON THE REMAINING DIFFERENTIAL WILL RESTRICT PITCH AND YAW MOVEMENT OF THE RING. ALIGNMENT MAY BE LOST FOLLOWING FAILURE OF BOTH FIXERS. HOWEVER THE CENTERING SPRINGS AND DOCKING MECHANISM HYSTERESIS WILL DAMP OUT RELATIVE MOVEMENT OF THE RING AND HELP KEEP RING ALIGNED. THIS ASSUMES THAT NO RING OSCILLATIONS EXIST PRIOR TO RETRACTING THE RING FROM IT'S FORWARD POSITION.

- APPROVALS -

DESIGN ENGINEER	M. NIKOLAYEVA	
DESIGN MANAGER	A. SOUBCHEV	
NASA SS/MA		
NASA SUBSYSTEM MANAGER		