FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL FAILURE MODE
NUMBER: 05-2C-22200-02

REVISION# 3 05/17/91 R

SUBSYSTEM: COMM & TRACK: TACAN
LRU :TACAN SET
ITEM NAME: TACAN

CRITICALITY OF THIS FAILURE MODE: 1R2

FAILURE MODE:
ERRONEOUS OUTPUT

MISSION PHASE:
PL PRELAUNCH
LO LIFT-OFF
OO DE-ORBIT

■ VEHICLE/PAYLOAD/KIT EFFECTIVITY: 102 COLUMBIA
: 103 DISCOVERY
: 104 ATLANTIS
: 105 ENDEAVOUR

CAUSE:
VIBRATION, TEMPERATURE, MECHANICAL SHOCK, CONTAMINATION, MISHANDLING.

■ CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN A) PASS
B) PASS
C) PASS

PASS/FAIL RATIONALE:
A)

B)

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:
LOSS OF REDUNDANCY PATH.

(B) INTERFACING SUBSYSTEM(S):
ANY ERRONEOUS DATA FROM ONE TACAN UNIT, INCLUDING LOCK-ON TO THE WRONG GROUND STATION DUE TO FREQUENCY SHIFT, WILL BE DISCARDED BY REDUNDANCY MANAGEMENT (RM), AND THE OUTPUTS FROM THE TWO REMAINING TACAN'S WOULD BE USED. A SECOND ERRONEOUS OUTPUT FAILURE WILL CAUSE AN RM DILEMMA.

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL FAILURE MODE
NUMBER: 05-2C-22200-02

(C) MISSION:
NO EFFECT.

(D) CREW, VEHICLE, AND ELEMENT(S):
POSSIBLE LOSS OF CREW/VEHICLE AFTER A SECOND ERRONEOUS OUTPUT FAILURE DUE TO THE INABILITY TO MAKE THE LANDING SITE.

(E) FUNCTIONAL CRITICALITY EFFECTS:

- DISPOSITION RATIONALE -

■ (A) DESIGN:
THE TACAN (MC409-0014-0006, OLD TYPE) IS OFF THE SHELF PROCUREMENT WITH MORE THAN 25,000 UNITS FABRICATED WITHOUT MAJOR DESIGN CHANGE OR SIGNIFICANT FAILURE HISTORIES. ORIGINALLY DESIGNED (1968) FOR MILITARY AIRCRAFT USE AND WAS BUILT PER MIL SPECS IN EFFECT AT THAT TIME. BECAUSE OF INHERENT SINGLE FAILURE POINTS, THE TACAN SYSTEM WAS IMPLEMENTED ON THE ORBITER AS THREE REDUNDANT END-TO-END STRINGS WITH GPC SOFTWARE CONTROL, SELECTION AND EDITING OF DATA. MILITARY AND OPPL APPROVED PARTS, MATERIALS AND PROCESSES WERE USED. NASA SOLDERING REQUIREMENTS & EEE PARTS TRACEABILITY HAVE BEEN WAIVED FOR THE TACAN PER OVEI PARA.3.5.17 (REGARDING SOLDERING) AND PER IPAR RIBC-01E, AMENDMENT A (REGARDING EEE PARTS).

THE NEWLY DESIGNED TACAN (MC409-0184-0001) IS ALSO OFF THE SHELF AND IS AN ALL SOLID STATE DESIGN. THIS UNIT WAS DESIGNED IN 1988 FOR USE IN MILITARY AIRCRAFT AND BUILT TO MILITARY SPECIFICATIONS. THE TACAN BEING BUILT TO MILITARY SPECIFICATIONS PROVIDED THE JUSTIFICATION FOR THE NASA SOLDERING REQUIREMENTS AND EEE PARTS TRACEABILITY TO BE WAIVED. THE NEW TACAN HAS AN MTBF IN EXCESS OF 3800 HOURS. THIS TACAN ASSEMBLY IS CONVECTION COOLED (DOES NOT REQUIRE SUCTION AIR) AND OPERATES FROM A 28 VOLTS DC RATHER THAN 120 VAC, 400 Hz (OLD TACAN).

■ (B) TEST:
A 96 HOUR BURN-IN IS PERFORMED ON EACH UNIT (OLD OR NEW TYPE) PRIOR TO ITS FIRST FORMAL ATP. THE BURN-IN REQUIRES TEMPERATURE CYCLING AND VIBRATION TO LOCATE INFANT MORTALITY FAILURES. THE ACCEPTANCE TESTING OF ALL UNITS INCLUDES EXAMINATION OF PRODUCT, THERMAL, VIBRATION AND PERFORMANCE TESTING. QUALIFICATION WAS PERFORMED BY SIMILARITY TO THE TESTED MILITARY DESIGN, EXCEPT THAT RANDOM VIBRATION WAS PERFORMED TO ORBITER REQUIREMENTS. DEVELOPMENTAL TESTING INCLUDED INTERFACING WITH

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL FAILURE MODE
NUMBER: 05-2C-22200-02

THE ADVANCED DEVELOPMENT LABORATORY AND INTEGRATION TESTING AT THE SHUTTLE AVIONICS INTEGRATION LABORATORY. FURTHER TESTING WAS PERFORMED AT PALMDALE TO VERIFY PROPER PERFORMANCE ON THE ORBITER AND THE OPERATION DURING APPROACH AND LANDING TEST DEMONSTRATED PERFORMANCE IN FLIGHT. PRIOR TO INITIAL SPACE FLIGHT OF EACH VEHICLE ALL PERTINENT PARAMETERS WERE VERIFIED.

GROUND TURNAROUND TEST
TACAN SELF TEST, TACAN RANGE, BEARING ACCURACY, POWER OUTPUT, FLAGS VERIFICATION AND TACAN GROUND STATION INTERFACE VERIFICATION - PERFORMED EVERY FLIGHT.

(C) INSPECTION:
RECEIVING INSPECTION (OLD AND NEW TYPES)
INCOMING MATERIAL IS VERIFIED BY RECEIVING INSPECTION. CERTIFICATION RECORDS AND TEST REPORTS ARE MAINTAINED CERTIFYING MATERIALS AND PHYSICAL PROPERTIES.

CONTAMINATION CONTROL (OLD AND NEW TYPES)
QC INSPECTS IN-PROCESS ASSEMBLIES 100% TO ASSURE LACK OF CONTAMINANTS. ALL PRINTED WIRING BOARDS ARE CLEANED, USING AN AUTOMATIC IN-LINE WASHER, TO ASSURE DECONTAMINATION IMMEDIATELY FOLLOWING THE SOLDERING PROCESS.

ASSEMBLY/INSTALLATION (OLD AND NEW TYPES)
DETAILED INSPECTION PERFORMED ON ALL ASSEMBLIES AND DETAIL PARTS PRIOR TO NEXT ASSEMBLY. KITTING, SOLDERING, M&P, AND SHOP TRAVELERS ARE VERIFIED BY INSPECTION. MAINTENANCE OF ESD PREVENTION CONTROLS MONITORED AND VERIFIED BY QC. TORQUING OPERATIONS ARE VERIFIED BY INSPECTION.

CRITICAL PROCESSES (OLD AND NEW TYPES)
SPECIAL PROCESSES (SOLDERING AND CONFORMAL COATING) ARE CONTROLLED AND MONITORED BY QUALITY ENGINEERING, AND THE PERFORMANCE OF SPECIAL PROCESSES IS WITNESSED BY INSPECTION.

TESTING (OLD AND NEW TYPE)
BURN-IN, ATP, INCLUDING ACCEPTANCE VIBRATION AND ACCEPTANCE THERMAL

TESTING, ARE VERIFIED BY QUALITY ENGINEERING.

HANDLING/PACKAGING (OLD AND NEW TYPE)
HANDLING OF ELECTROSTATIC-SENSITIVE DEVICES IS MONITORED AND VERIFIED BY QC; GROUNDING WRIST STRAPS ARE UTILIZED.

■ (D) FAILURE HISTORY:
ALL ACCEPTANCE TEST, QUALIFICATION TEST, FIELD, AND FLIGHT FAILURES WERE REVIEWED. THERE HAVE BEEN SIX FAILURES OF THE OLD TYPE (MC409-0014-0006) WHICH RESULTED IN ERRONEOUS OUTPUT. THE FAILURES IDENTIFIED OCCURRED IN CIRCUITRY IDENTICAL TO PRESENT FLIGHT CONFIGURATION. THE NEW TACAN HAS NOT YET BEEN FLOWN ON ANY ORBITER.

OLD:
CAR A86536, A BEARING ERROR OCCURRED AT HIGH SIGNAL LEVEL DURING ATP. THIS PROBLEM WAS ISOLATED TO A TRANSISTOR IN THE AGC CIRCUIT. THE TRANSISTOR WAS REPLACED WITH A NEW DEVICE. SUBSEQUENT TESTING SHOWED THE PROBLEM TO BE RESOLVED. CORRECTIVE ACTION WAS TO IMPLEMENT A TEST IN THE ATP TO VERIFY CORRECT OPERATION WITH STRONG SIGNAL LEVELS. ALL FLIGHT UNITS HAVE HAD THIS CORRECTIVE ACTION.

CAR'S A86707 AND A86313, DURING VEHICLE TESTING AT KSC, SPURIOUS EMISSIONS WERE NOTED DURING FREQUENCY MEASUREMENTS. THE PROBLEM WAS ISOLATED TO A MISADJUSTED VARIABLE CAPACITOR. THE CORRECTIVE ACTION WAS TO IMPLEMENT A TRANSMITTER SPECTRUM TEST DURING ATP. ALL FLIGHT UNITS HAVE SUCCESSFULLY PASSED THIS TEST.

CAR'S A89841 AND AC4323, DURING ATP THE BEARING READING WAS MARGINALLY EXCEEDED. THE PROBLEMS WERE ISOLATED TO SELECT-AT-TEST RESISTORS WHICH WERE IMPROPERLY SELECTED. A PROCEDURE CHANGE WAS IMPLEMENTED TO PROVIDE A MORE ACCURATE MEANS OF SELECTING RESISTORS. NO OTHER FAILURE OF THIS TYPE HAS OCCURRED TO DATE ON THE ORBITER TACAN PROGRAM.

CAR AD1868, THE TACAN HAD AN ERRONEOUS RANGE OUTPUT DATA DURING VEHICLE CHECKOUT. REPEATED TESTING COULD NOT DUPLICATE THE PROBLEM. PROBLEM WAS RESOLVED BY ATTRIBUTING IT TO A TEST ERROR, AND IT WAS DISPOSITIONED AS AN UNEXPLAINED ANOMALY. TACAN SUBSEQUENTLY PASSED ALL ATP TESTS.

NEW:
CAR AD7147, AD7272, AD7288 - DURING ATP TESTING TACAN S/N 0002 AND 0003 HAD A LOW POWER OUTPUT (LESS THAN 800 WATTS) FAILURE. THE FAILURE INVESTIGATION SHOWED THE LOW OUTPUT FAILURES WERE THE RESULT OF DEFECTIVE POWER AMPLIFIER TRANSISTORS. THE CORRECTIVE ACTION REQUIRED A

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL FAILURE MODE
NUMBER: 05-2C-22200-02

DIFFERENT SOURCE (MOTOROLA) AND CHANGES ON THE SCREENING REQUIREMENTS FOR THE TRANSISTORS. IN ADDITION, A MODIFICATION OF THE R.F. ASSEMBLY CIRCUIT WAS MADE TO PROTECT THE POWER AMPLIFIER TRANSISTORS. THE MODIFICATIONS CONSISTED OF THE ADDITION OF R.F. PARASITIC NETWORKS CALLED "SNUBBERS" WHICH WERE ADDED TO STRATEGIC POINTS IN THE STRIPLINE CIRCUIT.

CAR A07222 - DURING INITIAL ACCEPTANCE TESTING, SERIAL NUMBER 0002 FAILED THE BEARING ACCURACY TEST DUE TO MISCOMMUNICATION BETWEEN TECHNICIANS WORKING ON THE UNIT. A REQUIRED RECALIBRATION WAS NOT PERFORMED, BUT THE REQUIREMENT IS NOW DOCUMENTED AND PERFORMED AS PART OF THE ATP CYCLE.

CAR A06407 - THE SHOCK MOUNT WAS DAMAGED DURING THE QUALIFICATION DESIGN SHOCK TEST. THE TEST REQUIREMENTS WERE CHANGED FROM 20 G'S TO 15 G'S PRIOR TO START OF TESTING, HOWEVER, THE CHANGE WAS NOT COMMUNICATED TO THE PROPER INDIVIDUALS. THE TEST WAS RE-RUN WITH THE MOCK-UP FIRMLY SECURED AT THE LEVEL OF 15 G'S WITH NO FURTHER PROBLEMS.

THE FAILURES THAT RESULTED IN ATP CHANGES HAVE NOT RECURRED SINCE THE CHANGES WERE INCORPORATED. THE UNEXPLAINED ANOMALY COULD NOT BE REPEATED IN SPITE OF EXTENSIVE TESTING AT THE NASA SHUTTLE LOGISTICS DEPOT (NSLD). BASED ON THE ABOVE INFORMATION, IT IS CONCLUDED THAT TACAN'S WHICH SUCCESSFULLY PASS ATP AND SUBSEQUENT TESTING ARE CONSIDERED ACCEPTABLE FOR FLIGHT.

■ (E) OPERATIONAL USE:
LANDING AT NOMINAL END OF MISSION SITES (EDWARDS, KSC, NORTHROP) PROVIDES GROUND BASE RADAR TRACKING DATA AND UPLINK CAPABILITY (NOT AVAILABLE AT ALL SITES) WHICH CAN BE USED FOR A STATE VECTOR UPDATE AS A BACKUP TO TACAN. TACAN REDUNDANCY MANAGEMENT SOFTWARE AUTOMATICALLY SAFES AND/OR RECONFIGURES THE SYSTEM AFTER EACH TACAN FAILURE. NAVIGATION SOFTWARE KALMANN FILTER PROVIDES SOME PROTECTION AGAINST INCORPORATION OF BAD TACAN DATA INTO THE STATE VECTOR. CREW PROCEDURES CALL FOR MANUALLY ATTEMPTING TO RESOLVE A DILEMMA IF THE AUTOMATIC TACAN SELF-TEST CANNOT ISOLATE THE FAILED UNIT. IF RADAR TRACKING DATA AND COMMUNICATIONS WITH THE GROUND ARE AVAILABLE, THE MISSION CONTROL CENTER (MCC) CAN RESOLVE A TACAN DILEMMA AND PROTECT AGAINST USE OF BAD DATA IF THE LAST UNIT FAILS. CREW PROCEDURES CALL FOR DESELECTING A FAILED TACAN IN THE BACKUP FLIGHT SOFTWARE TO PROTECT AGAINST SUBSEQUENT LOSS OF PRIMARY AVIONICS SOFTWARE SYSTEM (PASS). CREW IS TRAINED TO ISOLATE A FAILED TACAN BY COMPARING TACAN DATA WITH NAVIGATION DATA. MCC PERSONNEL ARE TRAINED TO ISOLATE A FAILED TACAN BY COMPARING TACAN DATA WITH RADAR TRACKING DATA.

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL FAILURE MODE
NUMBER: 05-2C-22200-02

- APPROVALS -

RELIABILITY SUPERVISOR	J. R. GODWARD	5/29/91
RELIABILITY ENGINEERING	R. L. PITSINGER	
DESIGN ENGINEERING	W. C. ELDER	5/28/91 (2-28-91)
DESIGN ENGINEERING	W. H. STEPHENS	5/22/91 (3-8-91)
QUALITY SUPERVISOR	J. T. COURSEN	2-28-91
NASA RELIABILITY		9-6-91
NASA SUBSYSTEM MANAGER		9-3-91
NASA QUALITY ASSURANCE		6/11/91