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STATUS OF SPARE AND FLIGHT ASSIGNED IMUs - 17 DEC. 1973

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Max Lynn supplied a major portion of the information required in the preparation of this report.

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I. Introduction

A. General

This memo contains the status of each flight assigned and spare IMU (pages 6 to 15. The status lists IRIG and PIPA performance problems for all potential flight IMUs. The IMUs are tabulated in order of increasing serial number. The conclusions for each IMU are supported by noted performance problems. A series of performance limits were generated from Apollo gyro population studies* to flag actual or potential problem units. Units exhibiting statistical parameters above the performance limits are indicated as sigma, RMSSD, or range instabilities. The limits are conservative but allow units to requalify if more recent data (last nine points) are within limits. Appendix A summarizes these results.

For each IMU the pertinent problems are tabulated and as a conclusion the flightworthy status is given with suggested diagnostic tests where applicable.

All IMUs are summarized in Table A according to their flight quality status. Problem instruments are indicated by an asterisk.

IRIGs (with recommended diagnostic tests)

Gyros exhibiting an ADIA instability should be subjected to bearing diagnostic tests to distinguish between a wheel and a gravity transient problem. Wattmeter, ball beat frequency and run-down time are suggested tests.

Units exhibiting a BD and/or ADSRA instability should be subjected to damping fluid diagnostic tests such

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* ISS Memo #999, "Drift Statistics and Flightworthy Recommendations of IRIGS Assigned to Flight Quality IMUs."

as float freedom and gravity transient.

Since the present short term transient test does not adequately evaluate the cause of a gravity sensitive drift change, it is suggested that a more complete diagnostic test be implemented. Changes in gravity sensitive drift can be caused by a structural movement of the center of gravity, fluid filling a float cavity, or a gravity transient either of a short or long time constant. Changes in gravity sensitive drift due to fluid filling cavities or float structural changes should stabilize with time and will thus result in a stable drift level change. Distinguishing gravity transient problems from a fluid contamination requires, in addition to the short term (30 minute) transient test presently run, drift measurements after long storage periods (more than a week). Storage positions should be recorded between tests and more than one storage orientation is necessary.

B. PIPAs

(1) Bias and SF Shifts

With regard to accelerometer bias, shifts occurring across test configuration changes appear to be common to some IMUs. These systems will probably show additional bias shifts across spacecraft installation or other configuration changes. A flight compensation will have to be selected after spacecraft installation to allow for this expected bias shift. In spite of these shifts (indicated by ** in the IRIG and PIP Performance Problem Section), the PIPA should perform well in flight.

Many PIPAs had a considerable number of shifts in their scale factor and bias terms. Most of these shifts were caused by a test and/or configuration change or were induced and later corrected by degaussing. In view of the above, only those shifts occurring since the latest degaussing and adjustment are noted in the IRIG and PIP Performance Problems section. For reference and to aid in assessing the status of each PIP, the maximum shifts in scale factor

and bias prior to the latest degaussings are tabulated in Appendix B.

The six point transient tests for accelerometers with unexplained bias or scale factor shifts should be carefully reviewed. The results of six point transient tests on PIPAs are presented as Appendix E.

(2) Diagnostic tests

The six point transient specification is 0.36 cm/sec^2. However, experience has shown that good units will typically exhibit peak transients of less than 0.10 cm/sec^2. Consistent peak transient measurements $>$ 0.10 cm/sec^2 are indicative of excessive gas within the damping fluid. Continued deterioration is expected. Accelerometers exhibiting repeated bias instabilities and six point transients consistently greater than 0.1 cm/sec^2 should be removed. Units with initial indications of bias instabilities or a single 6 point transient $>$ 0.1 cm/sec^2 should be subjected to additional bias and six point transient measurements.

TABLE A

STATUS OF INERTIAL INSTRUMENT ASSIGNMENTS

IRIGS			PIPAS			G&N IMU		
X	Y	Z	X	Y	Z	S/N	S/N	VEHICLE
SYSTEMS WITH NO APPARENT PROBLEMS								
8A117	8A102	8A101	3AP333	3AP334	3AP335	222	34	CM-118
8A208	8A209	8A207	2AP186	3AP307	2AP175	N/A	44	CM
SYSTEMS WITH RECOMMENDED DIAGNOSTICS								
10A1	10A40 10A7*	10A5	2AP165	2AP284R	2AP267	N/A	35	CM
SYSTEMS WITH RECOMMENDED REMOVALS								
8A142	8A136**	8A143	2AP219R	2AP189	2AP209	N/A	9	CM
8A128	8A121	8A120	2AP110R	2AP276**	2AP282	213	25	CM-119
8A114	8A115	8A109**	3AP325	2AP261	2AP148	N/A	30	CM

TENTATIVE ASSIGNMENTS

SKYLAB IV - IMU S/N 34
RESCUE VEHICLE - IMU S/N 25

* DIAGNOSTICS RECOMMENDED
10A7 - BD INSTABILITY HAS BEEN OBSERVED. SEE PG 13.

**REMOVAL AND/OR DIAGNOSTICS RECOMMENDED
8A136 - LARGE ADIA INSTABILITY - POTENTIAL WHEEL PROBLEM. SEE PG
2AP276 - LARGE BIAS AND SCALE FACTOR RAMP. SEE PG 9.
8A109 - LARGE BD INSTABILITY. SEE PG 10.

3. IRIG AND PIP PERFORMANCE PROBLEMS

Problems and comments for each IMU represented in Table A are tabulated on the following pages. The IMUs are reviewed in order of increasing serial number.

COMMAND MODULE

IRIG AND PIP PERFORMANCE PROBLEMS

IMU S/N 9 (LAST TEST DATE-IRIGS-18SE73;PIPAS-25SE73)

IRIGS	DATE	PROBLEM	TOTAL WHEEL HOURS
X (8A142)			1145
		WAIVERS:E1444,E1477,E1482	
		NBD (RMSSD) BORDERLINE	
Y (8A136)			1616
	09JL70	ADIA (D1)= 23.6 MERU/G	
	17DE70	ADSRA (D1)=15 MERU/G	
	17DE70	DELTA ADIA=16.1 MERU/G	
	21AP71	ADIA (D1)= 18.4 MERU/G	
		ADIA (RMSSD) BORDERLINE	
Z (8A143)			1795
		ACCEPTED ON WAIVER E-1481	
		PRELOADING PROBLEMS	

COMMENTS: GRAVITY TRANSIENT TESTS ON 14AP70 AND 28DE70 SHOWED NO FLUID PROBLEMS FOR THE Y AND Z GYROS. GRAVITY TRANSIENT TESTS ON 140C71 AND 12NO72 SHOWED NO FLUID PROBLEMS. AS OF 20JA72 BALLBEAT DATA FOR THE Y GYRO INDICATES A SUBSTANDARD WHEEL.

PIPAS	DATE	PROBLEM	AGE IN MONTHS
X (2AP219R)			56
	19SE73	DELTA 1G BIAS= .40 CM/SEC SQ.	
Y (2AP189)			92
	13JL70	DELTA 1G BIAS= .47 CM/SEC SQ.	
		(SEE APPENDIX B)	
Z (2AP209)			91
	13JL70	DELTA 1G BIAS= .36 CM/SEC SQ.	
	10NO72	DELTA 1G BIAS= .36 CM/SEC SQ.	
		(SEE APPENDIX B)	

CONTINUED

IMU S/N 9 (CONTINUED)

COMMENTS: NULL RESOLUTION TEST RUN ON 19JA73 FOR X PIPA. RESELECTED R-14 AND RERAN NULL RESOLUTION TEST ON 05FE73.

SUMMARY:

1. STABILITY OF THE COMPONENT RETEST BIAS DATA ON THE X-PIPA (2AP196R) REMAINS QUESTIONABLE.
2. Y-PIPA IG BIAS PROBLEM (MINOR)
3. Z-PIPA IG BIAS PROBLEM (MINOR)

CONCLUSIONS:

A. DIAGNOSTIC TESTING FOR THE Y-GYRO INDICATES A SUBSTANDARD WHEEL. THE RELIABILITY OF THE Y IRIG IS CONSIDERED QUESTIONABLE AND SHOULD NOT BE USED IN A FLIGHT SYSTEM IF ADDITIONAL INVENTORY IS AVAILABLE.
B. QUESTIONABLE BIAS DATA FOR THE X-PIPA.

COMMAND MODULE

IRIG AND PIP PERFORMANCE PROBLEMS

IMU S/N 25 (LAST TEST DATE-09DE73)

IRIGS	DATE	PROBLEM	WHEEL HOURS
X (8A128)		N/A	2726
Y (8A121)		N/A	2202
Z (8A120)		N/A	2255

COMMENTS: IRIGS ASSIGNED ON 09AP73.GRAVITY TRANSIENT TESTS ON 06JA70.07AU70,30MR72 AND 11MY73 SHOWED NO FLUID PROBLEMS.

PIPAS	DATE	PROBLEM	AGE IN MONTHS
X (2AP110R)		(SEE APPENDIX B)	58
Y (2AP276)	01JL68	**1G BIAS (D1)=.52 CM/SEC SQ. ABNORMAL PERFORMANCE DATA RAMPING BIAS AND SCALE FACTOR	85
Z (2AP282)	25MY67	**1G BIAS (D1)=.66 CM/SEC SQ	83

** THE SHIFT IN PIPA DATA OCCURRED ACROSS LOCATION AND/OR TEST CONFIGURATION CHANGE AND IS PROBABLY DUE TO SAID CHANGE.

COMMENTS: NULL RESOLUTION TEST ON X PIPA ON 14JE72. THE Y PIPA HAS EXHIBITED ABNORMAL LONG TERM PERFORMANCE TRENDS.

SUMMARY:

1. ABNORMAL PERFORMANCE DATA FOR THE Y-PIPA.

CONCLUSIONS:

A. REMOVE Y-PIPA AT THE EARLIEST POSSIBLE TIME TO OBTAIN THE MAXIMUM QUANTITY OF PERFORMANCE DATA FOR THE REPLACEMENT INSTRUMENT.

IRIG AND PIP PERFORMANCE PROBLEMS

IMU S/N 30 (LAST TEST DATE:IRIGS-050C73;PIPAS-110C73)

IRIGS	DATE	PROBLEM	WHEEL HOURS
X (8A114)			2630
		N/A	
Y (8A115)			2605
		N/A	
Z (8A109)			2492
	22DE69	NBD (D1)= 6.1 MERU	
	01DE72	NBD (D1)=10.9 MERU	
	040C73	DELTA NBD= 5.3 MERU	
		NBD (RANGE) INSTABILITY	
		NBD (SIGMA) INSTABILITY	
		NBD (RMSSD) INSTABILITY	

COMMENTS: IRIGS ASSIGNED 17NO72. GRAVITY TRANSIENT TESTS ON 14DE72 SHOWED NO FLUID PROBLEMS.THE X AND Y IRIGS WERE STORED FOR 30 DAYS AT 30 DEG F.

PIPAS	DATE	PROBLEM	AGE IN MONTHS
X (3AP325)			76
		N/A	
Y (2AP261)			86
		N/A	
Z (2AP148)			96
		N/A	

COMMENTS: PERFORMANCE OF ACCELEROMETERS IS ADEQUATE.

SUMMARY:

1. NBDZ INSTABILITIES (SIGNIFICANT)

CONCLUSIONS:

A. THE Z-GYRO REQUIRES DIAGNOSTIC TESTS ASSOCIATED WITH BIAS INSTABILITIES. (REMOVAL RECOMMENDED)

NOTE: SEE INTRODUCTION FOR RECOMMENDED DIAGNOSTIC TESTING.

SKYLAB IV

IRIG AND PIP PERFORMANCE PROBLEMS

IMU S/N 34 (LAST TEST DATE:14NO73)

IRIG	DATE	PROBLEM	TOTAL WHEEL HOURS
X (8A117)			2385
	05FE70	ADIA (D1)=17.9 MERU/G	
	11AU70	DELTA NBD= 5.5 MERU	
		NBD (RMSSD) BORDERLINE	
		ADIA (RMSSD) BORDERLINE	
Y (8A102)			2363
		ACCEPTED ON WAIVERS - C1241	
		RMS DEV. OF RDT=5.7 SEC	
		(SPEC.=5.0 SEC)	
		C1234 NYLASINT RETAINERS IN	
		LIEU OF SPECIFIED PART	
		E1412 AXIAL COMPLIANCE O.O.S.	
	13AU69	ADIA (D1)=17.8 MERU/G	
	20AU70	ADIA (D1)=20.1 MERU/G	
	21JE71	DELTA NBD= 5.9 MERU	
Z (8A101)			2377
		ACCEPTED ON WAIVERS - C1231	
		NYLASINT RETAINERS IN LIEU OF	
		SPECIFIED PART.	
		E1415 AXIAL COMPLIANCE O.O.S.	
	13AU69	DELTA ADSRA=12.3 MERU/G	

COMMENTS: ADIAY INSTABILITY. MW AND BALL BEAT DATA TAKEN MAY 1972 SHOWED THAT THERE WERE NO WHEEL PROBLEMS FOR THE Y IRIG. GRAVITY TRANSIENT TEST ON X IRIG-19NO71,Y IRIG-12MY70. AND Z IRIG-13MY70 AND Y,Z IRIGS ON 25JE71,26SE72,AND 25AP73 SHOWED NO FLUID PROBLEMS. GRAVITY TRANSIENT TEST ON X IRIG,8A117, SHOWED A 10 MERU TRANSIENT.

PIPAS	DATE	PROBLEM	AGE IN MONTHS
X (3AP333)			76
	19MR69	**DELTA 1G BIAS=.41 CM/SEC. SQ.	
	13AP73	**DELTA 1G BIAS=.49 CM/SEC. SQ.	
Y (3AP334)			76
	19MR69	**1G BIAS (D1)=.50 CM/SEC. SQ.	

CONTINUED

IMU 34 (CONTINUED)

Z (3AP335) 76

N/A

COMMENTS: PERFORMANCE OF THE ACCELEROMETERS IS ADEQUATE.

** THE SHIFT IN PIPA DATA OCCURRED ACROSS LOCATION AND/OR TEST CONFIGURATION CHANGE AND IS PROBABLY DUE TO SAID CHANGE.

SUMMARY:

1. ALTHOUGH ALL GYROS HAVE EXHIBITED BIAS AND DRIFT INSTABILITIES THE SYSTEM IS CONSIDERED ADEQUATE TO MEET MISSION REQUIREMENTS.

IRIG AND PIP PERFORMANCE PROBLEMS

IMU S/N 35 (LAST TEST DATE:24AU73)

IRIGS	DATE	PROBLEM	TOTAL WHEEL HOURS
X (10A-1)		N/A	865
Y (10A-7) 10A40	24AU73	NBD (D1)= 6.0 MERU NBD (RANGE) INSTABILITY NBD (SIGMA) BORDERLINE NBD (RMSSD) BORDERLINE ADSRA (RMSSD) BORDERLINE	670
Z (10A-5)		N/A	492

COMMENTS: IRIGS ASSIGNED 11MY73.

PIPAS	DATE	PROBLEM	AGE IN MONTHS
X (2AP165)	08FE71	**1G BIAS (D1)=0.71 CM/SEC.SQ.	95
Y (2AP284R)		(SEE APPENDIX B)	55
Z (2AP267)	08FE71	**DELTA 1G BIAS=0.44 CM/SEC.SQ.	86

** THE SHIFT IN PIPA DATA OCCURRED ACROSS LOCATION AND/OR TEST CONFIGURATION CHANGE AND IS PROBABLY DUE TO SAID CHANGE.

COMMENTS: PIPAS ASSIGNED 17MY73.
PERFORMANCE OF THE ACCELEROMETERS IS ADEQUATE.

SUMMARY:

1. NBDY INSTABILITY

CONCLUSION:

A. THE Y-GYRO REQUIRES DIAGNOSTIC TESTS ASSOCIATED WITH BIAS INSTABILITIES. (REMOVAL NOT RECOMMENDED AT THIS TIME.)

COMMAND MODULE

IRIG AND PIP PERFORMANCE PROBLEMS

IMU S/N 44 (LAST TEST DATE:IRIGS-19NO73;PIPAS-29NO73)

IRIG	DATE	PROBLEM	TOTAL WHEEL HOURS
X (8A208)			1978
	05JE70	DELTA ADSRA=12.4 MERU/G	
	24AU70	DELTA ADSRA=13.4 MERU/G	
	09JA71	ADSRA (D1)=17.4 MERU/G	
	09JA71	DELTA ADIA=16.2 MERU/G	
Y (8A209)			1870
	09JA71	ADIA (D1)=19.2 MERU/G	
	04JE71	DELTA NBD= 5.7 MERU	
	04JE71	ADIA (D1)=17.3 MERU/G	
	17OC72	DELTA NBD= 5.4 MERU	
Z (8A207)			1856
	25AU70	ADSRA (D1)=17.1 MERU/G	
	09JA71	ADIA (D1)=21.6 MERU/G	
		NBD (RMSSD) BORDERLINE	

COMMENTS: IRIGS ASSIGNED ON 11MY73. DATA TAKEN DURING AU70 AND JA71 ARE QUESTIONABLE. RETAINER FREQUENCY ON THE X-GYRO HAS BEEN NONPERIODIC THROUGHOUT THE LIFE OF THIS INSTRUMENT. GRAVITY TRANSIENT TEST ON 22SE73 SHOWED NO FLUID PROBLEMS.

PIPAS	DATE	PROBLEM	AGE IN MONTHS
X (2AP186)			93
	24JL73	**1G BIAS(D1)=0.52 CM/SEC.SQ.	
	15OC73	**DELTA BIAS=0.44 CM/SEC.SQ.	
Y (3AP307)			78
	25AU71	**DELTA SF=380 PPM	
Z (2AP175)			95
		N/A	

** THE SHIFT IN PIPA DATA OCCURRED ACROSS LOCATION AND/OR TEST CONFIGURATION CHANGE AND IS PROBABLY DUE TO SAID CHANGE.

CONTINUED

IMU S/N 44 (CONTINUED)

COMMENTS: PERFORMANCE OF THE ACCELEROMETERS IS ADEQUATE. THE Z-PIPA (2AP-175) WAS INSTALLED 7N073. THE PREVIOUS Z-PIPA (3AP326R) WAS REMOVED FOR FAILING PEAK TRANSIENT TEST (0.47 CM/SEC. SQ.).

CONCLUSION

1. PAST DATA (LAST TWO YEARS) INDICATES ALL INSTRUMENTS ARE FLIGHTWORTHY.

APPENDIX A - PART 1 - ALL TESTS

IRIGS SHOWING DRIFT STATISTICS ABOVE MIT PERFORMANCE LIMITS

UNIT S/N	NBD				ADSRA				ADIA			
	RANGE	SIGMA	RMSSD	N	RANGE	SIGMA	RMSSD	N	RANGE	SIGMA	RMSSD	N
8A101					18.7		4.0	38				
8A102	9.9	2.3		56					27.6		7.0	42
8A109	11.3	2.3	2.6	59								
8A114									29.3	8.2		36
8A115	10.2	2.1		53					32.4	12.1		36
8A117	11.4	2.2		52	20.9	5.3		35				
8A121									30.5	9.8		30
8A136							4.5	24	27.6		8.5	25
8A207					22.2	6.0	4.5	28		8.0	6.4	28
8A208	8.6	2.2		46	23.1	5.2	5.6	32				
8A209	9.1	2.2		46					31.4		6.4	30
10A 7	8.8	2.4	2.0	12			4.5	10				

APPENDIX A - PART 2 - LAST NINE POINTS

IRIGS SHOWING DRIFT STATISTICS ABOVE MIT PERFORMANCE LIMITS

UNIT S/N	NBD			ADSRA			ADIA		
	RANGE	SIGMA	RMSSD	RANGE	SIGMA	RMSSD	RANGE	SIGMA	RMSSD
8A109	8.9	3.0	3.0						
8A117			2.2						6.5
8A136									6.4
8A142			2.1						
8A207			2.0						
10A 7	8.4	2.6	2.4			4.7			

APPENDIX B

PIPA SCALE FACTOR AND 1G BIAS SHIFTS

THE FOLLOWING TABLE SHOWS PIPA S.F. AND 1G BIAS SHIFTS AFTER ACCEPTANCE AND FINAL STABILITY TEST (FST) AND BEFORE LATEST DEGAUSSING. SHIFTS WERE NOT TAKEN ACROSS DEGAUSSING AND ADJUSTMENT. THEY WERE TAKEN ACROSS NEGLECTED DATA (NOTE 1).

IMU S/N	AXIS	PIPA	MAXIMUM SHIFT S.F.(PPM)	MAXIMUM SHIFT 1G BIAS(CM/SEC SQ)
9	X	2AP219R	*	*
	Y	2AP189	284	0.97
	Z	2AP209	210	0.56
25	X	2AP110R	283	0.25
	Y	2AP276	*	*
	Z	2AP282	*	*
30	X	3AP325	*	*
	Y	2AP261	*	*
	Z	2AP148	*	*
34	X	3AP333	*	*
	Y	3AP334	*	*
	Z	3AP335	*	*
35	X	2AP165	*	*
	Y	2AP284R	21	1.16
	Z	2AP267	*	*
44	X	2AP186	*	*
	Y	3AP307	*	*
	Z	2AP175	*	*

* NOT APPLICABLE

(NOTE 1) DATA SHOWN IN PARENTHESES IN DELCO "QUARTERLY PERFORMANCE DATA SUMMARY".

APPENDIX C
IRIG INDEX

IRIG S/N	IMU S/N
8A101	34
8A102	34
8A109	30
8A114	30
8A115	30
8A117	34
8A120	25
8A121	25
8A128	25
8A136	9
8A142	9
8A143	9
8A207	44
8A208	44
8A209	44
10A1	35
10A5	35
10A7	35

APPENDIX D

PIPA INDEX

PIPA S/N	IMU S/N
2AP110R	25
2AP148	30
2AP165	35
2AP175	44
2AP186	44
2AP189	9
2AP209	9
2AP219R	9
2AP252	22
2AP261	30
2AP267	35
2AP276	25
2AP282	25
2AP284R	35
3AP307	44
3AP325	30
3AP333	34
3AP334	34
3AP335	34

APPENDIX E

PIPA SIX POINT TRANSIENT DATA

THE FOLLOWING TABLE SHOWS THE MAXIMUM VALUE OF THE PIPA SIX POINT TRANSIENT TEST RECORDED AT DELCO/MILWAUKEE SINCE MAY 1970.

IMU S/N	AXIS	PIPA	DATE	MAXIMUM VALUE (CM/SEC/SEC)
9	X	2AP219R	19JA73	0.05
	Y	2AP189	14JL70	0.18
	Z	2AP209	14JL70	0.06
25	X	2AP110R	11OC71	0.06
	Y	2AP276	05JE72	0.05
	Z	2AP282	28OC71	0.05
30	X	3AP325	11AP73	0.04
	Y	2AP261	05DE72	0.04
	Z	2AP148	12AP73	0.07
34	X	3AP333	13AP73	0.04
	Y	3AP334	16AU73	0.05
	Z	3AP335	16AP73	0.05
35	X	2AP165	19JL73	0.05
	Y	2AP284R	19JL73	0.08
	Z	2AP267	20JL73	0.05
44	X	2AP186	09OC72	0.05
	Y	3AP307	09OC72	0.04
	Z	2AP175	07FE72	0.04