UNITED STATES GOVERNMENT

Memorandum

TO : PS/Chief
Systems Engineering Division

DATE: August 20, 1965

In reply refer to:
PS5/M295

FROM : PS5/Chief
System Design Branch

SUBJECT: AGC problem

1. There have been computer malfunctions on BP-14 which Guidance and Control Division representatives believe could be the result of EMI.

2. Under controlled EMI tests at the G&C laboratories of MIT a computer malfunction occurred under the ±50 volt powerline transient test and random malfunctions occurred while the computer was operating under uncontrolled EMI conditions. Causes of the random failures are not known. Tests at MIT indicate that the computer susceptibility is improved with an internal ground.

3. MIT and G&C Division representatives are of the opinion the EMI that causes the computer malfunction is not defined by the Apollo EMI specification requirements.

4. The plan for solution to the AGC computer problem is as follows:

   a. Tests will be conducted on BP-14 during the week of August 23, 1965, in which condition will be simulated under which AGC failures have occurred. This will establish a base for modifications and future tests.

   b. Following the above tests the AGC will be removed from BP-14 and modified, if necessary, to include an internal ground and other modifications, and the AGC will be reinstalled.

   c. A second group of tests will be performed on the computer, subsequent to installation of the fuel cells on BP-14. The test results will be compared with the base data established during the week of August 23, 1965, to determine if the computer modifications has corrected the computer EMI problem.

O. O. Ohlsson

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7.7.5

b. G&N Prime Power Requirements and Characteristics (ICD LIS-390-10002)

Discussion: Previous direction to MIT permitted MIT to connect S/C D.C. negative to the computer chassis internal to the computer. The direction violates the single point ground concept used in the LEM. It is also a violation of NASA imposed EMI specification on GAEC. ICD was negotiated incorporating the ground to chassis, since it eliminates certain problems in the computer.

Action: NASA to issue GAEC a waiver to allow this violation of the EMI specification. NASA and GAEC to evaluate change as to acceptability from total S/C standpoint. [Aaron This was well discussed at time decision was made — why keep second guessing?

Discussion: MIT presently needs 25 VDC to the PSA for the IMU to insure the accuracy of the accelerometer and servo loops during the operating modes. GAEC can assure that only 23.5 VDC can be supplied to the PSA.

Action: NASA shall provide direction to MIT subsequent to impact assessment of MIT receiving 23.5 VDC in lieu of 24.5 VDC for the IMU.

c. Component Weights for Design of Supporting Structure (new ICD).

Discussion: GAEC stated that the MIT weight status report had been used as the basis for design loads on component supporting structure. MIT advised that a substantial increase was expected in the weight of the electronic components over the previously reported weight status. For instance, MIT estimated that the weight of the LGC could increase by as much as 25%, whereas GAEC presently has only 10% design margin. MIT furnished ASPO representatives with a list of estimated maximum component weights.

Action: MSC will supply GAEC with component weights for use in design of supporting structure by August 6, 1965. GAEC will document component design weights and other necessary mass properties in an ICD for MIT sign-off by August 16, 1965.

GFE weights to must be specified by NASA to furnish — as a part of their contract. — If this has not been done, its long over due.

Instrumentation Laboratory
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PROGRAM FOR BLOCK I - 100 AGC/EMI CHANGES

References

a. NASA letter EG 44-319-65-494 dated 21 July 1965.

b. Apollo Project Memo #1318 (Enclosure 1).

c. NASA letter EG 42-65-451 dated 2 July 1965.

d. MSC-ASPO-EMI-10A dated 17 October 1963.

In compliance with the requirements of reference (a) the following program is submitted.

A. IDENTIFICATION OF KNOWN EMI PROBLEMS

The known EMI problems can be categorized as follows:

1. AGC fails ± 50 volt powerline transient test required by Reference (d).

2. AGC is susceptible to fast rise time transient voltage excursions between 0 VDC (signal ground) and case.

3. AGC is susceptible to electromagnetic radiation effects produced during high voltage (5-10KV) high energy (.0025-0.01 joules) static discharges. Such discharges occasionally occur in the Systems Test Laboratory when objects which have been charged to a high potential are allowed to discharge instantaneously into grounded objects near the AGC input/output wiring. Peak voltage levels induced on this wiring with respect to the AGC case exceed the levels induced during the rf radiated susceptibility tests required in Reference (d) by a factor of 100:1 to 1000:1 depending upon the location and nature of the discharge. Tests should be performed on BP-14 and flight configuration spacecraft to determine if this susceptiblilty has been eliminated by the cable shielding which has been implemented and the shading effect of the spacecraft structure.

Results Expected From Changes Required

1. Change (1) will permit successful operation of the AGC when subjected to powerline transients of the nature described in Reference (d).

   In addition, the susceptibility of the AGC to transients between 0 VDC (signal ground) and case is eliminated.

2. Change (2) has been demonstrated in the laboratory to be effective in reducing the effects of transients from spark discharges and relays from upsetting the AGC via the powerlines.

3. Change (3) and (4) have been demonstrated in the laboratory to be effective in reducing the effects of spark discharge transient pickup on AGC signal wiring.

   In addition, the filters on the three S/C signals that are not shielded will block high amplitude fast rise time pulses entering the AGC via these leads.

B. CHANGES REQUIRED

1. The 0 VDC (signal ground) in the AGC will be connected to the case of the computer.

   This change required a design modification to the Power Switch Module (Dwg. #1003819-011) released 2 July 1965 with effectivity AGC-121 and subsequent. Raytheon is preparing a RIB for retrofit of AGC's 117, 112, 120 etc.

   The Block I (100) ICD's were modified to reflect this change at the NAA meetings on 14 and 15 July 1965. GAEC was informed of the change on 22 July 1965.

   MIT system AGE-5 Power Switch Module has been modified in-house and testing is underway. Three production model power switch modules were modified by Raytheon and tested on AGC-105 at MIT. It was found that there was considerable noise reduction on the case of the computer with respect to 0 VDC.

2. The Standy Switch has been redesigned to include filter condensers between the power busses and the AGC case.

   This change ("EMI Capacitor Module Assembly", Dwg. #1003212) is completed and scheduled for release 3 August 1965. Further tests are required to confirm the change. Effectivity of the change will include all Block I (100) AGC's.

3. Redesign of the "Y" harness is necessary to change the method of grounding shields, provide filtering for three S/C signals that are not shielded, move the main panel DSKY power wires into shielded S/C cable, provide improved moisture seal at the connectors, and to provide an overall shield connected to structure ground.

A test cable is being built at MIT to confirm the design changes on AGE-5. Testing of this cable is scheduled to commence the third week in August. Drawings defining the change are in preparation at Raytheon and will be released upon completion of AGE-5 tests. Raytheon is also building a cable for MIT.

The "Y" harness change must be coordinated with the installation of the G&N failure detection module (Night Watchman), NASA DWG. #1003217, since the failure module is used to transpose the wiring back to the DSKY wiring configuration. A failure detection module is being built in-house for MIT AGE-5. Effectivity of the G&N Failure Detection Module Release includes all Block I (100) AGC's.

4. G&N harness (NASA Dwg. #1015056) will be shielded by wrapping with 520-100 EMI/RFI shielding tape. These shields are connected to structure. At the Navigation DSKY, connector pins 1 and 21 must be removed and connected to structure ground.

ACE is preparing a package change for the above which is scheduled for release in August 1965.

C. MIT/IL SYSTEM MODIFICATION & TESTING

Reference (b) establishes the MIT proposed tests for operation and monitoring of the G&N system during integrated S/C tests for EMI.

The proposed tests will be performed in the MIT/IL System Test Laboratory on AGE-5 when the hardware changes noted above are available for installation.

It should be noted that these tests will not necessarily provide complete AGC/EMI sensitivity information because of the uncertain relationship between EMI environments in the S/C and in the systems laboratories and wide variance in the shielding integrity between the two.

The proposed tests to be performed are as follows:

1. Powerline Transient Test Per Reference (d)

The test setup is as shown on the next page.

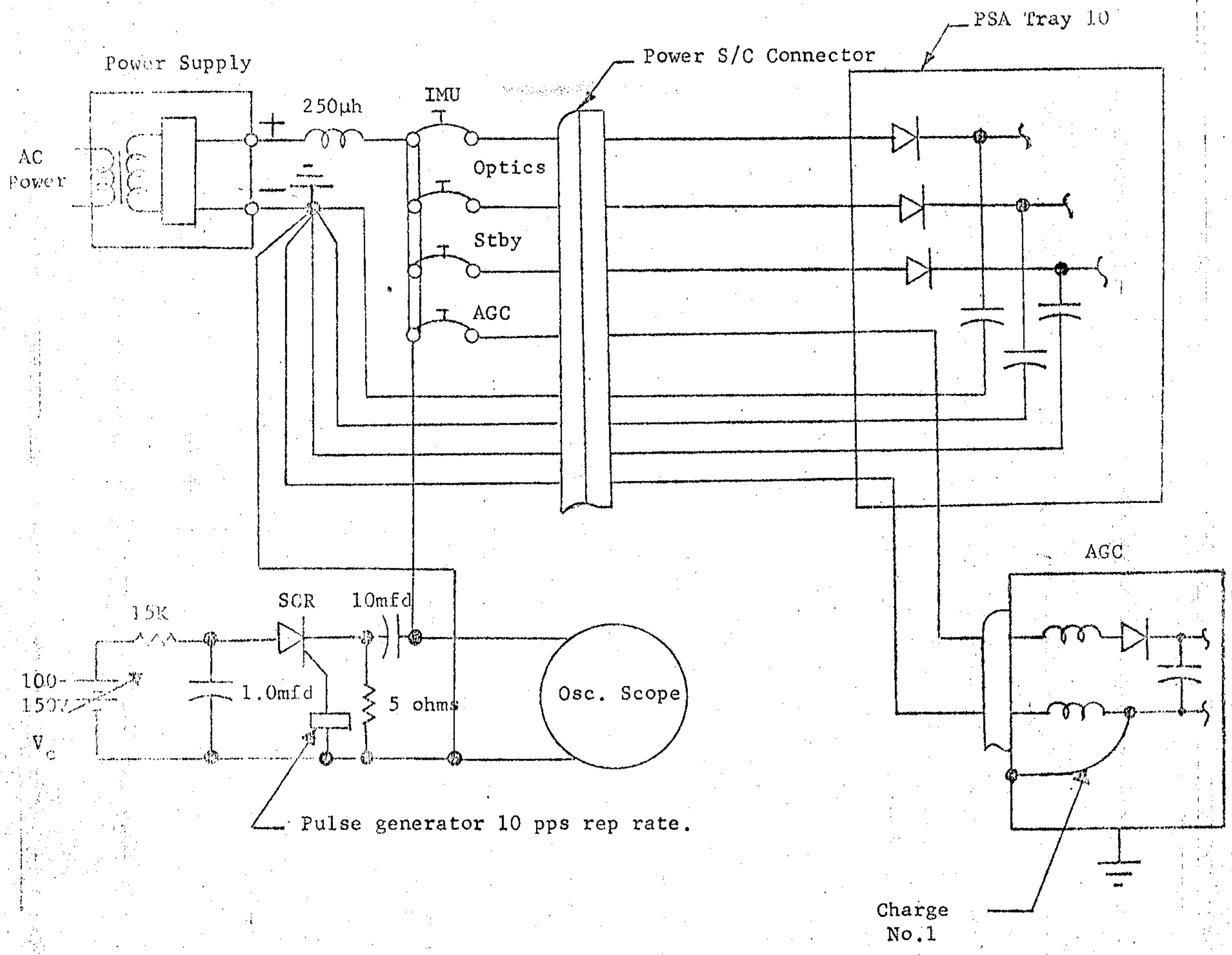

Fig. 1. Powerline Transient Test Setup.

Notes

1. Use circuit as shown to generate positive transients. Adjust V_c until peak amplitude across terminals a and b are 50 volts open circuit.

2. Reverse leads to terminals a and b to generate negative transients.

3. Negative return at power supply must tie to structure ground at ground stud on G&N fixture to simulate S/C grounding.

Method of Test

a. Apply power to G&N and connect transient generator as shown in Fig. 1.

b. Command AGC to perform self-test diagnostic routine and display results on DSKY.

c. Allow five minutes for each polarity transient. If no AGC failure is incurred, the AGC will be deemed not susceptible to the applied transient.

d. Repeat step (b) and (c) above except the AGC will be commanded to perform orbital integration.

Note

The above tests have been performed on the AGC in the Digital Development Laboratory and change #1 does indeed result in drastically reduced susceptibility and the ± 50V transient test can be passed successfully. The test has not been performed in a system configuration in which the powerlines are not well isolated from signal lines as in the test run to date. If the AGC fails to pass the transient test in a system configuration, then the probem would not lie in the realm of powerline susceptibility but would have to be approached from a different point of view.

2. Simulated Static Discharge Tests

The G&N system will be evaluated for the effects of spark discharges in the vicinity of the holding fixture to determine the relative improvement affected by changes #2, 3, and 4. Improvement noted here can be expected to have similar effect in the spacecraft configuration. The method of test will be as follows:

1. Disconnect all external cables from the G&N. This includes cables from CTS, GSE, etc. The IMU must be mounted in the holding fixture and not located remote from the fixture. The shielded G&N harness will be employed during this test.

2. The AGC will be commanded to perform the self-test diagnostic in routine via the DSKY.

3. The spark generating apparatus depicted in Fig. 2 will be setup as described on the next page.

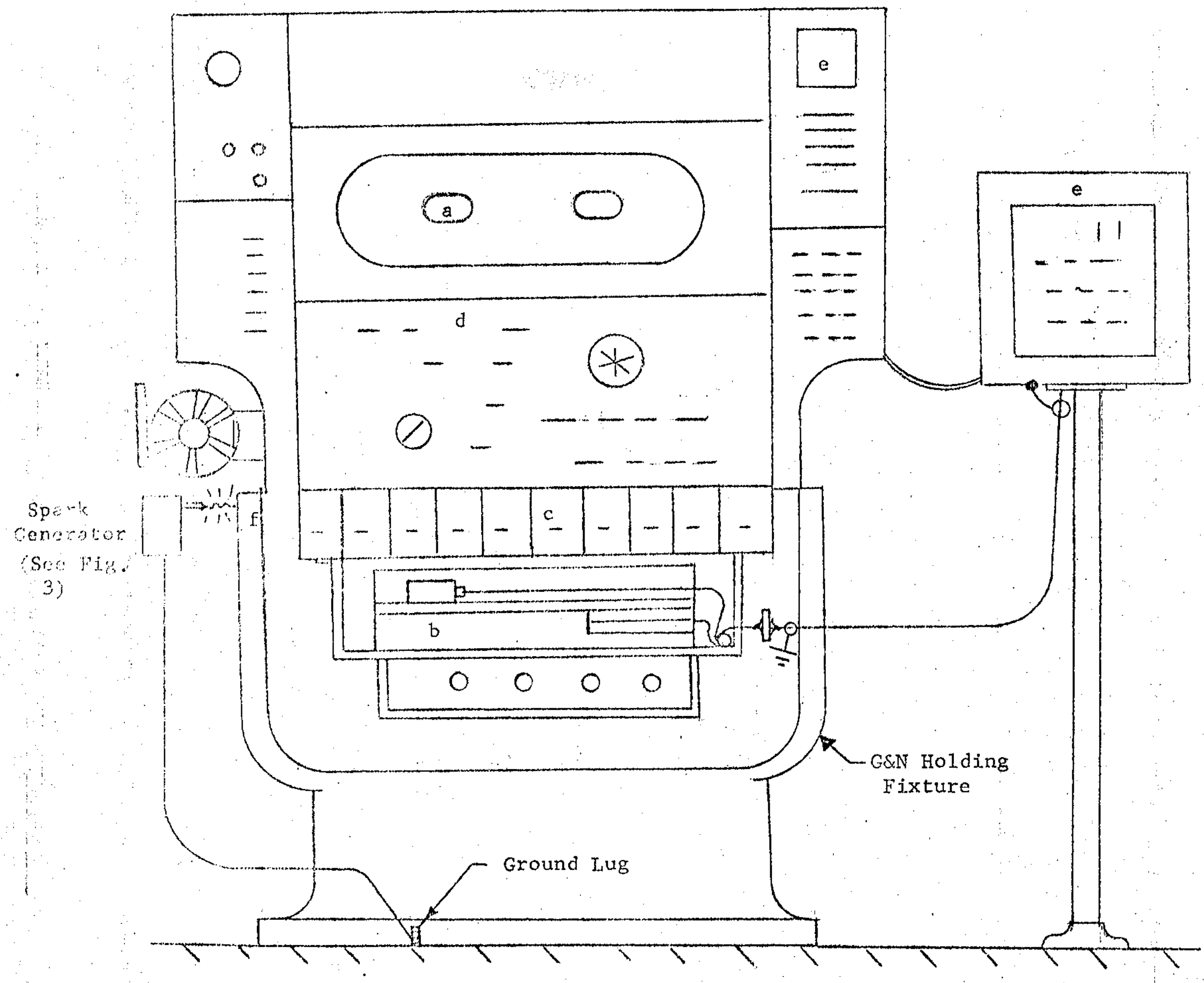

Fig. 2. Simulated Static Discharge Test.

5. The low side of the spark generator will be connected to the system ground lug to provide a ground return for the discharge. The connection will be a clip lead 4-6 feet long.

6. The high voltage terminal of the step up transformer will be brought in the vicinity of preselected test points on the holding fixture to within 0.2". A spark discharge will ensue at a rate of approximately 2 pps. The generator will be kept on for approximately one

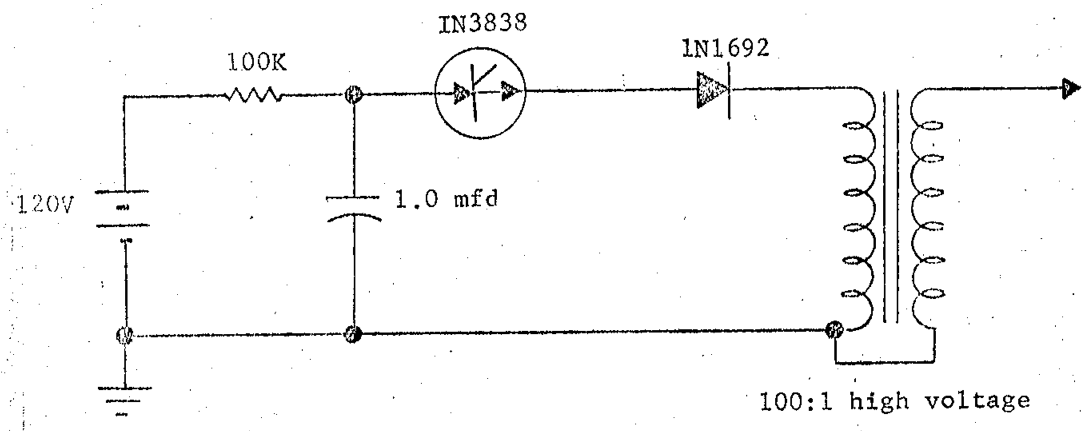

Fig. 3. Spark Generator Schematic.

minute. If no AGC malfunction is incurred, the AGC will be deemed not susceptible to statis discharge at that point and the next point will be selected. The test will proceed until all selected points have been tested.

7. List of selected test points.

   a. Optics eye piece and panel.

   b. AGC case (front and back).

   c. PSA trays (1 through 10 inclusive).

   d. IMU control panel (anywhere on panel including switches, knobs, screws etc.

   e. DSKY panels (front only).

   f. Holding fixture at several points likely to be touched during system operation.

Note

It is our opinion that this test closely simulates actual static discharges that occur in the Systems Test Laboratory

D. EMI INVESTIGATIONS ON BP14

Reference (c) establishes the requirement for monitoring the effects of EMI during system AGE-8 tests with BP14. While said tests may provide data relevant to AGC/EMI investigations the environment is still not a true S/C enviornment and will not completely confirm the S/C caused EMI effect..

The test procedures established by Reference (b) are the minimum required for evaluation of EMI effects on the G&N system. It is highly recommended these tests be accomplished in conjunction with system integration testing on BP14 and the first S/C.

In addition, MIT/IL recommends the implementation of the powerline transient test and the simulated static discharge test on BP14 to verify the effectiveness of the modifications noted previously. The powerline transient test can be implemented easily since it is a straight forward and highly controlled test. The transient generator is available at NAA and the test can be carried out by NAA EMI personnel responsible for BP14 compatability. It is recommended that the circuit breaker panel in the S/C be used as the point of injection for the transient to simplify the test. If NAA EMI personnel so desire, the G&N circuit breakers can be pulled to allow testing of the AGC only.

It is also recommended that a simulated static discharge test such as the one outlined above be implemented into the system integration tests. This test can be carried out via MIT/IL personnel or by the NAA EMI group. The manner of test should be similar to that which is being carried out by MIT/IL in the Systems Test Laboratory. The test points to be selected would include the G&N panel, AGC cover panel, and anywhere in the S/C cabin likely to incur a static discharge. Failure to pass this test will indicate that the shielding in the spacecraft is inadequate and a course of action decided. Since there is no concrete evidence available that the astronaut will not generate and cause static discharges during flight (especially during low humidity, low pressure conditions) due to the nylon suit he will wear, there would be reason to pursue this problem further.

[illegible]

CHANGE REQUIRED	DRAWINGS EFFECTED	AGE-5 MIT TESTS	[illegible]	BP-14 TESTS NOTE 1	S/C TESTS NOTE 1	R E M A R K S
OVDC to Case Ground.	1003819-011 Power Switch Assembly.	Preliminary Test completed June. Power Switch Modules modified in-house.		New power switch required from Raytheon to support EMI test plan. If not available, AGC 108 power switch modules can be modified.		
Add filter condensers to Standby Switch.	1003212 EMI Capacitor Mod. Assy.	Assy. under construction. Start Tests 8-23-65		Note 2	Note 2	
*Change grounding shields, add filters to "Y" harness.	AGC/PSA/S/C Wiring harness. 1004866 (100 Ser.) "Unassigned" (50 Ser.)	*Harness (50 Ser.) under construction (Est. Start Test 8-27-65)		Note 2	Note 2	*New Component [illegible] Pin Malco Connector [illegible] designed at Raytheon [illegible] to build one in house [illegible] AGE 5 tests
*Addition of AGC failure indications.	1003217 G & N Failure Detect Assy.	Assy. under construction (Est. Start Test 8-27-65)		Note 2	Note 2	*This change must [illegible] coordinated with the new "Y" harness installation due to wiring configuration
Wrap harnesses with 520-100 EMI/RFI tape.	1015056 (50 Ser.) 1015086 (100 Ser.) AGC Harness & PSA End Conn.		In preparation. (ACED)	Note 3	Note 3	

Note:
1. Test plan to be reviewed by NASA and tests scheduled at earliest possible time.
2. MIT will supply new assemblies for EMI tests at NAA. EMI Retrofit Kit will be available [illegible] 1965
3. NASA to direct ACED to provide new harness.

Instrumentation Laboratory
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Apollo Project Memo No: 1318

To: Distribution

From: Ain Laats

Subject: G & N Operations During Integrated Systems Tests in the Spacecraft

Date: 15 July 1965

Introduction:

The intent of this memorandum is to publish MIT proposals for operation and monitoring of the G & N system during integrated spacecraft tests such as Electromagnetic Interference tests, Electromagnetic Susceptibility tests and Electromagnetic compatibility tests.

Test Philosophy:

The proposed tests are based on selected areas of the G & N chosen as sensitive to electromagnetic energy capable of interfering with other systems. The test was devised to insure that most of the sensitive areas are included either in measurement or monitoring and that most of the G & N operations capable of producing interference are performed.

The following areas are considered EMI sensitive in the G&N system:

1. Pulse Interfaces
   a. CDUs to AGC
   b. PIPAs to AGC
   c. AGC timing to PSA
   d. AGC drive to CDU and IMU

Enclosure 1.

2. Power Supplies
    a. 800 cps 1% (resolver excitation)
    b. 3200 cps 1 % (inertial components)
    c. 800 cps 5 % (wheel voltage)
    d. 120 VDC (DC loops)
3. Servo Loop Stability
    a. Gimbal stabilization loops
    b. PIPA loops
    c. CDU position loops
    d. Optics command and position loops
4. AGC

The following areas are considered to be sources of possible electromagnetic interference.

1. AGC
2. Temperature control system
3. Relays and switches
4. Failure indicator circuit
5. Motor and tachometer operations
6. Saturable reactors in light dimming circuits

Test Description:

The proposed testing is first described for a general case. Any deviation from the general procedure due to the nature of the EM test being conducted (i.e. EMI, EMC, EMS) will be considered separately.

1. Monitoring

Analog recorder monitoring is considered most desireable for the power supplies and servoes. Transient effects from which the system recovers with no ill effects are not of interest. The following signals are to be monitored:

a.	800 cps 1% ISS	(1201)
b.	800 cps 1% OSS	(1211)
c.	3200 cps 1 % (Feedback)	(1301)
d.	120 VDC PIP	(1000)
e.	120 VDC IRIG	(1010)
f.	XPIP S. G. OUT IN PHASE	(2001)
g.	YPIP S.G. OUT IN PHASE	(2021)
h.	Z PIP S.G. OUT IN PHASE	(2041)
k.	IG A Servo error	(2117)
l.	MGA Servo error	(2147)
m.	OGA Servo error	(2177)
n.	Trun CDU 16 X Res Error	(3101)
o.	Shaft CDU 16 X Res Error	(3111)
p.	IGA CDU 16 X Res Error	(2204)
q.	MGA CDU 16 X Res Error	(2234)
r.	OGA CDU 16 X Res Error	(2264)
s.	CRT reproduction of DSKY displays	

2. System Operation

The system operation selected for the testing consists of closed loop operations exercising the AGC interfaces, AGC self tests and monitoring of system inertial component performance.

Two options are suggested. First, an operational test for the one time quick check of G & N operation, and second, continuous G & N operation for long period testing where correlation of time, events, and G & N performance is desired.

The test procedures are written for a Block I, Series 100 system with ground test program assembly.

A. Operational Test

The G & N operational test is a semi-automatic sequence which exercises all system modes and measures inertial component performance. It is designed to be used as a quick check of system operation. Correlation of events and time is not readily available. The test requires approximately 30 minutes.

PROCEDURE	DESCRIPTION
1. Establish that G & N system power has been applied per applicable procedure.	1. N/A
2. Using ACE control of AGC DSKY (or AGC DSKY) perform the following keyboard operations. (Note: V will be used throughout as abbreviation for VERB, N for NOUN and E for ENTER)	2.
a. V 36 E	a. Initialize AGC
b. V 21NO1 E 1762 E 77777 E V 21 N 26 E 02000 E V 2 0 N 01 14042 E Self test failure will result in PROGRAM ALARM and the following DSKY DISPLAY V01 N 31 01202	b. This sequence initializes the AGC and starts the AGC self check. AGC self check automatically checks AGC instructions and eraseable memory. The program is described in detail in MIT DDG Report # 6.

PROCEDURE	DESCRIPTION
c. V 21N 26 E 04000 E V 20 N 01 E 15233 E Visual monitor required.	c. AGC will exercise all DSKY displays under program control. The program is described in detail in MIT/IL STG Memo No. 377.
d. V 21 N 26 E 04000 E V 20 N 01 E 15120 E Test failure will result in PROGRAM ALARM and the following DSKY display: V 01 N 31 01103	d. AGC will exercise all relays under AGC control. The program is described in detail in MIT STG Memo No. 376.
2. Manually switch OPTICS MODE SWITCH to ZERO OPTICS. Wait for ZERO ENCODER condition indication to go out.	2. Optics subsystem test initialization.
3. Manually switch OPTICS MODE SWITCH to MANUAL and then to COMPUTER.	3. Optics subsystem turned over to AGC control.
4. a. Perform the following AGC keyboard operations. V 21 N 01 E 744 E 4 0 0 0 0 E V 41 N 55 E WAIT FOR V 21 N 57 FLASHING Then do + 27000 E + 45000 E	4. This sequence drives the optics shaft to + 270^{o} and trunnion to + 45^{o} and holds these angles in a closed loop through the CDU's. This will check the optics CDU pulse interfaces.

PROCEDURE	DESCRIPTION
4.b. An alternate optics test may be used providing GSE is available to provide a star image for the star tracker. V 21 N 01 E 7 4 4 E 40000 E V 41 N 55 E WAIT FOR V 21 N 57 FLASHING DO + XXX.XX (Optics angle required to + XX.XX acquire the star image) WAIT until OPTICS reach commanded angles V 21 N 01 E 7 4 4 E 40003 E	4. This test will exercise the star tracker mode of optics operation. CDU - AGC pulse interface can only be checked by monitoring the DSKY display of CDU angles.
5. Perform the following AGC keyboard operations. V 21 N 26 E 04000 E V 2 0 N 01 E 55711 E Wait approximately 10 minutes. DSKY will display local gravity ± 1% and cosine of local latitude angle ± 5 %.	5. This starts a self check of the inertial subsystem with AGC. This program is described in detail in MIT/IL STG Memo No. 358. The program will establish operation of the ISS - AGC interfaces and measure performance of the inertial components.

PROCEDURE	DESCRIPTION
6. Terminate test by doing V 36 E. Test may be conducted repeatedly.	

B. Continuous G & N Monitor

The following procedure will allow continuous monitoring of G & N performance.

PROCEDURE	DESCRIPTION
1. Repeat Steps 1 through 3 of the previously described operational check.	1. AGC and optics operations are identical.
2. Perform the following AGC keyboard operations: V 21 N 01 E 1 7 6 2 E 7 7 7 7 6 E	2. This procedure re-initializes AGC Self Check.
3. Perform the initialization procedure for the G & N post-installation gyro compassing test (JDC 10322). The gyro compass test will normally be run for 5 hours. For this application, after one hour perform the following AGC keyboard operation: V 37 E 03 E	3. The initialization procedure is complex and is described in detail in STG Memo No. 347; JDC 10322. The mode of operation is changed from gyro compass to a vertical erection mode one hour after start.
4. Perform the following AGC keyboard operations: V 21 N 26 E 02000 E V 20 N 01 14042 E	4. This will reinitialize and start AGC Self Check which was interrupted by the gyro compass initialization.

PROCEDURE	DESCRIPTION
5. Perform steps 2, 3, 4. a or 4. b of the previously described operational check.	5. This will provide optics subsystem operation monitoring.
6. Perform the following AGC keyboard operations: V 15 N 01 E 00235 E Record contents of R1 and R3 every 15 minutes correlating time of DSKY reading with analog records.	6. The performance of the G & N system will be monitored by observing the gyro torquing current required to maintain vertical erection on two axes and by monitoring accelerometer output rates. The analog recorder monitoring and DSKY monitoring will provide enough information to derive the performance of the inertial system.

3. SPECIAL TESTS

A. Electromagnetic Susceptibility Testing

The G & N system should be operated per procedure 2A (operational check) during susceptibility testing not involving transients. The G & N system should be operated per procedure 2 B during susceptibility testing involving transients (RCS jets, etc.)

B. Electromagnetic Interference Testing

For interference testing, the procedure 2 A (operational check) is more applicable.

C. Electromagnetic Compatibility Testing

The choice of procedures depends on length of test. For short term tests, procedure 2 A is recommended and for long term tests, procedure 2 B is recommended.

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