MAY 1962 EDITION GSA FPMR (41 CFR) 101-11.6 UNITED STATES GOVERNMENT

# emorandum

Addressees listed below TO

OPTIONAL FORM NO. 10

File AGS

NASA-Manned Spacecraft Center Houston, Texas

## DATE: JAN 17 1968

EG/Chief, Guidance and Control Division FROM •

In reply refer to: EG43-53-68-66

Abort Guidance System Flight Program 2 Customer Acceptance Readiness SUBJECT: Review (CARR)

> The Customer Acceptance Readiness Review (CARR) for the unmanned IM-2 AGS flight program will be conducted at 9:30 AM, February 1, 1968, in Building 2, Room 716.

The chairman of the CARR will be the Chief of the Guidance and Control Division. Each Division Chief addressee is requested to serve as a member of the CARR board or designate a representative from his division.

"Copy to" addressees or their representatives are invited to attend and offer comments if desired.

TRW will present the following agenda:

a. AGS applications on the unmanned IM-2 mission.

b. Equation modifications since acceptance of the Design Mission Computer Program (incorporation of approved software change proposals into the DMCP).

c. Verification testing (test plan and results).

d. Mission and hardware dependent constants generation.

e. Downlink format and utilization for post-flight analysis.

f. MSC determination of the acceptability of the program for the IM-2 mission.

g. Application of the basic flight program (less the special-purpose unmanned modification) to future manned missions.

The enclosed AGS final report on FP-2 is forwarded for review. Any comments which may affect the TRW presentation or acceptance of the program by MSC should be submitted to this division by January 29, 1968.

Robert A. Gardiner

Enclosure

Buy U.S. Savings Bonds Regularly on the Payroll Savings Plan

LM AGS GUIDANCE SOFTWARE FINAL DESIGN REPORT FLIGHT PROGRAM NO. 2 (UNMANNED B MISSION ONLY)

11.0 8

Contract No. NAS 9-4810 TRW No. 05952-6191-T000

5 January 1968

Approved:

T. W. Layton, Chairman LM AGS Guidance Software Review Board

Approved:

N. W. Trembath, Manager LM AGS Project Office

#### 1. INTRODUCTION

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This Design Report documents the final design review of the LM AGS Flight Program No. 2 (FP2), as specially modified for the Unmanned LM 2 B Mission. The documents associated with this review are included as the following attachments to this report:

Attachment A.- TRW Memo 7332.9-32, "Flight Program 2, Revision C, Description Document," dated 15 December 1967

Attachment B.- TRW Memo 7321.7-176, "Verification Test Plan for Flight Program 2 Unmanned Modification," dated 4 December 1967

Attachment C.- TRW Memo 7332.9-33, "Verification Test Results for Flight Program 2, Bevision C," dated 26 December 1967.

TRW has completed the review of Flight Program 2 and the associated documents, and has determined that the tests defined in Attachment B. have been satisfactorily completed. Therefore, the LM AGS Flight Program 2 has been verified and is approved for release for the Unmanned IM 2 B Mission application only. The final verified Flight Program 2, Revision C, in the form of card decks, BTME tape and listing, designated FP2-SO3C, was delivered as scheduled on 20 December 1967 to MSC and GAEC under Reference 1.

The final version of FP2 has evolved in several steps. It has originated from the approved DMCP issued in April 1967, which was further modified by selected, approved Software Change Proposals from SCP 6 through 27, and was modified uniquely for the unmanned B mission application by SCP 31. It should be noted that the changes from the DMCP resulting from the incorporation of SCP's 6 through 27 have not been verified to perform satisfactorily on other than the unmanned B mission application.

#### 2. PROGRAM APPLICATION

Since the unmanned modifications to the FP2 program has used certain locations in the scratchpad memory normally used by the CSI, CDH and TPI guidance routines, these routines are not operable in this program. Also, the guidance steering routine has been modified so that only attitude hold can be commanded, which prohibits the normal operation of the orbit insertion routine. Therefore, no attempt should be made to apply the FP2 SO3C program to any other application than that intended for the unmanned B mission.

If a "simflight" test is required as part of the LM2 prelaunch operations, the "simflight" test using the DMCP program should be used.

When the AGS operation is initiated several days before launch, the appropriate switch settings should be made to place the AGS in Follow-up and Attitude Hold. The IM closeout procedures should be modified accordingly.

The downlink recorded from the AGS should be processed in the normal manner (see the latest telemetry listing, Reference 2) and recorded on tape for subsequent data reduction by TRW, even though the meaning of certain quantities has been modified for the unmanned mission from that described in SCP 27 (as stated in SCP 31). A revised telemetry list, specifically limited to the LM 2 B mission application will be issued under separate cover by 31 January 1968.

#### 3. PROGRAM SPECIFICATIONS

The requirements for the FP2 program are defined by a combination of the following documents:

- a. Interface Requirements The interface requirements for FP2 are defined by the IM AGS Performance and Interface Specification (Reference 3) as interpreted by the DMCP Program Specification (Reference 4).
- b. Functional Requirements The functional requirements for FP2 are defined by the DMCP Program Specification (Reference 4) and the MSC approved SCP's 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 18, 19, 20, 21, 22, and 27 as modified for unmanned operation by SCP 31.
- c. Performance Requirements No performance requirements have been specified for FP2.
- d. Vehicle Characteristics Although no vehicle characteristics are employed in the unmanned mission program operation, the vehicle related constants contained in the program are those of the AGS P and I Spec (Reference 3).
- e. Mission Characteristics The mission characteristics in the form of time line data, initial condition state vector and LM powered flight time periods are based on the Mission AS-206 Spacecraft Operational Trajectory of April 1967 (Reference 5).
- f. Unmanned Mission Modifications Summary The requirements for this special purpose program modification can be summarized as follows:
  - Provide Attitude Hold and Engine Off commands to the spacecraft if control is switched to the AGS by the IM Mission Programmer
  - Revise the downlink telemetry list to enhance the value
    of the AGS downlink data prior to launch and during the
    mission for the purpose of postflight analysis of the AGS

o Utilize the baseline DMCP version of the flight program as modified by the approved SCP's for Flight Program 2 and subsequent programs to the extent possible.

05952-6191-T000 Page 4

#### 4. PROGRAM DOCUMENTATION

Since the special purpose version of the AGS flight program was conceived primarily to enhance the value of the AGS downlink, while causing minimum impact on the continued development of AGS software, MSC has indicated that the testing can be limited to those portions of the program to be exercised in this mission and that the documentation can be informal (see Reference 6). However, to aid in the correlation of the existing documentation with that normally planned for AGS flight programs, the following discussion is provided.

a. Equation Description

The Flight Program 2, Revision C, Description Document (Attachment A.) modifies the DMCP Programmed Equations Document (Reference 7) and replaces SCP's 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 18, 19, 20, 21, 22, 27 and 31 as the definition of the programmed equations for FP2 SO3C. The specific configuration of the program and stored constants are contained in the FP2 SO3C program listing delivered with the program tape and card decks under Reference 1.

#### b. Verification Test Plans

The final version of FP2, Revision C, has been tested in accordance with the unmanned mission modification test plan, Attachment B. However, the previous version of FP2, Revision B, has successfully passed the program checkout testing defined as Part 1 of the FP2 Verification Test Plan, Reference 8. The review of Reference 8 at the FP2 FACI resulted in the added cases described in Reference 9. However, the tests defined in Parts 2 and 3 of the FP2 Verification Test Plan and the added cases requested at the FP2 FACI were not accomplished on the final FP2. This was consistent with MSC direction (Reference 6) as these tests are no longer appropriate for the unmanned B mission modification of the AGS program.

#### c. Verification Test Results Summary

The test results of the final program configuration for FP2 are documented in Attachment C. of this design report. The results of the program checkout performed on the Revision B to the program have not been documented, but were successfully completed before the release of the preliminary, unverified FP2 SO3B program transmitted to MSC and GAEC under Reference 10.

#### d. Revision to AGS Operating Manual

A preliminary revised Operating Manual for FP2 SO3B (Reference 11) was issued to indicate the changes in operating procedures due to the approved modifications to DMCP. This document does not reflect the unmanned mission modifications of SCP 31 and hence, does not apply to the final verified FP2 program. There are no plans to issue a final operating manual for the final FP2 program due to the unmanned nature of the mission.

#### e. Performance Analysis Report

Because of the limited AGS application planned for the unmanned B mission, no mission related performance criteria or performance analyses have been specified. The AGS hardware to be used, however, is required to meet the performance criteria of the lunar mission as a criteria of the compatibility test plan.

The only mission related AGS performance parameter, associated with the use of the AGS in the unmanned B mission, is that of attitude hold accuracy. The accuracy of the AGS commanded vehicle attitude in Attitude Hold is for all practical considerations limited by the gyro fixed drift error in coasting flight multiplied by the elapsed time from the initiation of Attitude Hold. The latest 3: 18-day stability value for gyro fixed drift is .80 deg per hour (Reference 12). Since the B mission is currently "open ended", this means that the AGS can be expected to maintain the initial spacecraft attitude to within less than 19 deg/day after the initiation of AGS Attitude Hold. No dynamic drift rate due to limit cycling or vibration from RCS jet firings has been estimated for coasting flight.

The AGS postflight analysis is greatly facilitated if the relative error between the AGS orientation and the PGNCS IMU is kept small. By programming an AGS to PGNCS alignment/calibration four times during the IM flight operations, this error is reduced to the initial relative alignment uncertainty of about 10 min some time before each burn. This error is mainly attributed to the navigation base mounting surface errors which are not compensated for in the AGS flight program. Between these alignments the relative orientation error will grow due to gyro fixed drift and dynamic and mass unbalance drifts during powered flight.

#### 5. PROGRAM CONSTANTS UPDATING

A complete tabulation of the program constants assembled into FP2 SO3C is contained in the program listing (Reference 1). The significant mission dependent constants are contained in the equation description document (Attachment A.). The requirements for flight program constants tapes for FP2 are a function of the prelaunch procedures planned for LM2 which are not currently defined. Since the AGS hardware compensation constants delivered with the program reflect nominal accelerometer and gyro scale factors and zero mean values of other errors, it would be desirable to update these constants in FP2 before launch.

The new procedure for generating a program constants listing is currently being developed. When the technique is verified, a constants listing in the new format will be provided to MSC based on the released Flight Program 2. However, MSC is requested to review the mission constants delivered with the program (see Attachment A. or the program listing) to determine their suitability and determine the requirements for LM2 constants tapes at least 10 weeks prior to launch and two weeks prior to the need for an EPC input constants tape. The results of the bench calibration of the AGS performed at KSC should also be provided to TRW at least two weeks before the EPC constants tapes are required.

#### REFERENCES

- 1. THW Letter No. 1330.4-6445, (Transmittal of FP2 SO3C Program Listing, Compressed and Absolute Deck and Program Description Document to MSC and GAEC), dated 20 December 1967
- TRW Memo No. 7332.3-752, "AGS Digital Downlink Characteristics", dated 8 September 1967
- 3. GAEC Spec. No. LSP-500-1, "Abort Guidance Section Software GFE Performance and Interface Specification", dated 14 August 1966, as revised by: TRW Letter No. 7001.16-1192, "Review of Proposed Changes to the IM AGS P and I Spec", dated 13 December 1967
- 4. TRW Report No. 05952-6146-T000, "IM AGS Revised Computer Program Specification, Design Mission Computer Program", dated April 1967
- 5. TRW Report No. 05952-H174-R0-00, "Apollo Mission AS-206 Spacecraft Operational Trajectory, dated 1 April 1967
- 6. MSC TWX No. EG43-820-67-3032, (Approval of IM AGS Software Change Proposal No. 31), received 8 December 1967
- 7. TRW Report No. 05952-6147-T000, "LM AGS Programmed Equations Document, Design Mission Computer Program", Revision A, dated April 1967
- 8. TRW Report No. 05952-6143-T004, "IM AGS Program Verification Test Plan, Flight Program 2", dated 22 September 1967
- 9. TRW Memo No. 7221.7-158, "Additional FP No. 2 Verification Test Cases", dated 28 September 1967
- 10. TRW Letter No. 1330.4-6441, (Transmittal of FP2 SO3B Compressed and Absolute Card Decks, Listing and BTME Tape to MSC and GAEC), dated 22 November 1967
- 11. TRW Report No. 05952-6188-T000, "Preliminary LM/AGS Operating Manual, Flight Program 2", dated November 1967
- 12. TRW TWX No. 7001.16-1173, "LM AGS Performance Capability with 18-day Gyro Stability", dated 27 November 1967

# TRW SYSTEMS

INTEROFFICE CORRESPONDENCE

7332.9-32 (Revision)

TO	Distribution	CC:	DATE: 15 December 1967

Flight Program 2, Revision C SUBJECT: Description Document

FROM: H. G. King ROOM 9010 EXT 66521 BLDG STS

(1)05952-6147-T000, Revision A, LM AGS Programmed References: Equations Document Design Mission Computer Program, dated April 1967.

- (2)LM AGS Software Change Proposals 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 18, 19, 20, 21, 22 and 27.
- (3)05952-6188-T000, Preliminary LM AGS Operating Manual Flight Program 2, dated November 1967.
- (4)LM AGS Software Change Proposal 31.

Flight Program 2, Revision C, has been developed for the unmanned LM 2 mission. This program evolved in two steps from the baseline DMCP, Reference (1). Flight Program 2, Revision B, incorporated all of the Software Change Proposals listed as Reference (2) in accordance with MSC TWX EG43-515-67-770. Revision C incorporates the unmanned mission modifications of Reference (4) in accordance with MSC TWX EG43-820-67-3032. The following is a brief resume of the changes made as a result of the SCP's which have been incorporated:

Software Change No.	Description
6	Delete redundant reset of ullage counter
7	Remove establishing particular value of
	V <sub>dX</sub> , V <sub>dY</sub> , V <sub>dZ</sub>
8	Delete $\Delta r_0$ and $T_{c0}$ and replace $\Delta r_0$ on telemetry list with $\Delta r$ and make $\Delta r$ and $T_c$
	available for DEDA display.
9	Input tangent of the desired line-of-sight angle rather than the desired line-of-sight angle.
10	Remove the time sharing of q

<sup>†</sup>This document has been revised from the preliminary version by a sign correction to Ve in Table I and corrections to Figures 3.39, 3.9, 3.2, 3.8, 3.18, 3.25, 3.28 and 3.35.

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7332.9-32

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11	Delete the automatic exit from lunar align when the abort stage discrete $(\beta_5)$ is set.
12	Simplification of $S_{14}$ logic in Branch 50.
13	Substitution of $-\underline{W}_{b} \cdot \underline{Z}_{b}$ for $-\underline{W}_{c} \cdot \underline{Z}_{b} - J^{4}$ in $\underline{E}_{X}$ computation during guidance steering.
14	Correct DEDA "CLR" error problem.
16	Delete abort and abort stage from the steering loops.
18	Implement capability to perform CDH at first, second, or third apsidal crossing.
19	Compute out-of-plane position and velocity at all times.
20	Implement capability of out-of-plane maneuvers at CSI and CDH.
21	Generate a node 90 <sup>0</sup> from TPI.
22	DEDA read out of h and $\Delta$ r in nautical miles.
27	Delete $V_{yb}$ , $y_f$ from telemetry list, add $V_{dY}$ , $V_{dZ}$ and time share $S_{10}$ and engine on/off flag, $V_{p0}$ and $V_T$ , and $\Delta r$ and $q_1$ .
31	Modification for unmanned LM 2 (see description below).

The attached flow charts 3.1 to 3.40 show the modifications to the guidance equations of DMCP which incorporated the SCP's exclusive of the unmanned mission modifications. Reference (3) describes the capabilities of Flight Program 2, Revision B. Figures A.1 and A.2 show the routines inserted as a result of SCP 31.

Figure A.l shows the changes made to incorporate the computed attitude errors and the gyro and accelerometer biases onto the AGS downlink. The attitude errors will appear as words 37, 39 and 46 in place of unused guidance quantities (the AGS will always be in the orbit insertion guidance mode). The gyro biases replace the computed CSM velocity vector and the accelerometer biases replace the guidance desired pointing direction vector (words 32 - 34 and 40 - 42). Figure A.2 shows the logic which incorporates the following:

- (1) At liftoff (when sensed acceleration exceeds 38 ft./sec.<sup>2</sup> for a two second period) a flag (\$79) is set and a counter is initiated. At a time of 1138 seconds after liftoff is sensed, AGS time will be initialized at its negative maximum, navigation of the CSM and LM will be initialized with nominal state vectors (see Table 1 for the respective values), and a PGNCS to AGS alignment will be performed. The navigation initialization is accomplished by setting the downlink data received flag to 1. The necessary ephemeris data is preset into the downlink input cells by the program.
- (2) At four subsequent times during the mission an inflight gyro and accelerometer calibrate will be performed, (see Table 2 for the times). Based upon the LM 1 mission profile a calibration will be performed prior to each of the three burn maneuvers plus one calibration after the last burn (2nd APS burn) by setting  $S_{00} = 3$  and  $\delta_6 = 1$  when the absolute time is equal to one of the four preset times. Since the normal  $S_{00} = 6$  DEDA entry is bypassed, the logic of Branch 50 was altered from that shown on Figure 3.36. The modification consisted of changing the exit from the block which sets  $S_{00} = 6$  and  $\delta_6 = 0$  to the block labeled MABEE instead of EXECA.

7332.9-32 Page -4-

LM r <sub>L</sub>		-4159440 -16587900 -12974400 -262142	ft. sec	$\underline{V}_{L} = \begin{pmatrix} 23335\\ 2222.5\\ -10450.2 \end{pmatrix}$ fps.
CSM <u>r</u> e t <sub>e</sub>	-	-9539600 9277400 17527800 -262142	ft. sec	$\underline{\underline{V}}_{e} = \begin{pmatrix} -22757 \\ -6530 \\ -8935 \end{pmatrix} \text{ fps.}$

TABLE 1. Post Boost Initialization Values

7332.9-32 Page -5-

	Symbol	Location	Value and Units	DEDA Quantization	Description
	TICAL	300	-251,882 sec	.l min	Time of 1st Calibrate, +10260 sec after initialization
a	T2CAL	301	-247,982 sec	.l min	Time of 2nd Calibrate, +14160 sec after initialization
	T3CAL	302	-243,302 sec	.l min	Time of 3rd Calibrate, +18840 sec after initialization
	T4CAL	303	-230,882 sec	.l min	Time of 4th Calibrate, +31260 sec after initialization
	4K36	774	38 fps	*	Constant used to sense lift-off
	4K37	775	569 counts	*	Constant time delay from lift-off to initialization
	DEL79	777		*	Lift-off flag
	DEL80	776		*	Post initialize flag
	1K35	634**	.25 fps	octal	Navigation sensed velocity threshold
	2J	605****	.5004	octal	Tangent of desired TPI LOS
	WBX	514***		octal	Unit vector for
	WBY	515***		octal	Bardance presiming
	WBZ	516***		octal	

TABLE 2. Revised Constants or Variables

\* These quantities not available via DEDA.

\*\* Value has changed.

Location has changed.

When FP2, Revision C, is loaded into the AEA, the LM position and velocity is initially:

$$\underline{\mathbf{r}} = \begin{pmatrix} 20,926,000 \\ 0 \\ 0 \end{pmatrix} \text{ ft. }, \quad \underline{\underline{V}} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \text{ fps,}$$

and the CSM epoch position and velocity is:

$$\underline{\underline{V}}_{e} = \begin{pmatrix} -9,539,600\\ 9,277,400\\ 17,527,800 \end{pmatrix} \text{ft.}, \quad \underline{\underline{V}}_{e} = \begin{pmatrix} -22,757\\ -6,530\\ -8,935 \end{pmatrix} \text{fps,}$$

with an epoch of -262,142. These values are loaded into the AEA to preclude unnecessary overflows during computer operation.

The modification incorporated invalidates the use of Flight Program 2, Revision C, for anything but the actual B mission. If a Flight Program 2 is required for any simulation or other testing, the previously delivered, unverified Flight Program 2, Revision B, should be used.

H. G. King, Section Head Space and Missile Systems Software

Approved:

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H. B. Grossman, Department Manager Data Processing Systems

Attachments



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Figure 3.1. AGS Total Software System Block Diagram

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Figure 3.2. Start of 20 msec Computations, Input Data



Figure 3. 3. Gyro Compensation











Figure 3.6. Processing of PGNCS Angles, Body Axis Align Computations



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Figure 3.7. 40 msec Attitude Error Computations

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Figure 3.8. Engine Discrete Logic; Direction Cosine Normality and Orthogonality Computations



Figure 3.9. Lunar Align Computations



Figure 3.10. FDAI Computations



Figure 3.11. LM Initialization, Branch ICl



END OF INITIALIZATION





Figure 3.13. Navigation Update Equations, Branch 1



Figure 3.14. Computation of CSM Orbit Parameters from Ephemeris Data, Branch 2



Figure 3.15. Prediction of Present CSM Position and Velocity, Branch 3



Figure 3.16. Total Velocity, Range and Range Rate



Figure 3.17. Radar Filter



Figure 3.18. LM Orbit Parameters



Figure 3. 19. Guidance Selection Logic



Figure 3. 20. CSI, CDH-Setup





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Figure 3.22.  $CSI/CDH - T_A$  Computation







Figure 3.24. CSI/CDH - CSM at CDH











Figure 3.27. Guidance Law



Figure 3.28. Pitch and Yaw Steering Equations Velocity-to-be-Gained Equations















Figure 3.32. Prediction of Transfer Orbit Vectors and Central Angle Sine and Cosine











Figure 3.35. Total Velocity



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1.8

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A=42



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Figure 3. 37. Branch Control



Figure 3. 38. Orbit Parameters and Ellipse Prediction Subroutines



Figure 3. 39. Gravity and CSM Orbit Parameters Recovery Subroutines



Figure 3.40. Display Routine: Altitude, Altitude Rate and Lateral Velocity











#### INTEROFFICE CORRESPONDENCE

7221.7-176

TO Distribution

CC

DATE: 4 December 1967

SUBJECT Verification Test Plan for Flight Program 2 Unmanned Modification FROM: R.L. Eshbaugh BLDG STN MAIL ST A. 7087 EXT. 67996

#### INTRODUCTION

A minimal verification of Flight Program 2, Revision C is required for the Unmanned B Mission. This verification testing will consist of an ICS run to verify the logic modification to Flight Program 2 which is unverified. The logic modification provides for sensing lift-off, initializing the flight program in orbit, and requesting four inflight calibrations. This modification is discussed in SCP No. 31, dated 1 November 1967.

#### TEST OBJECTIVES

The objectives of this verification test are to demonstrate that the logic in the unmanned modification will provide the proper discretes and that this modification does not interfere with the initialization, telemetry, or calibration functions required to enable reasonable post flight analysis.

#### TEST CRITERIA

(a) The unmanned modification shall provide a lift-off discrete, an initialization, and four inflight calibrations at the requested test times.

(b) The initialization and calibration routines shall perform with the same accuracy as found during DMCP verification testing where applicable. TEST CASES

The following tabulation describes an ICS test case which simulates the AS-206 operations trajectory in the number and type of maneuvers. The entire mission has been condensed to seven minutes mission time. The LM state is initialized such that it will overflow prior to lift-off. Absolute time will overflow during boost. The AGS is initialized with the CES follow-up and automatic discretes present. The first three calibrations are shortened to 6 sec by setting the gyro calibrate time constant  $1K_{30} = 3$ . Every cycle printout at selected intervals will show telemetry.

Time		Gyro Outputs		Accelerometer Outputs				
(sec)	Δαχ	Δαγ	Δα	$\Delta \mathbf{V}_{\mathbf{x}}$	ΔV <sub>y</sub>	ΔV <sub>z</sub>	Other Inputs to	Remarks
	°/sec	°/sec	°/sec	ft/sec <sup>2</sup>	ft/sec <sup>2</sup>	$ft/sec^2$	Filght Hogram	
0	.003	.003	0	32.2	0	0		
10	0	0	0	39.	1.	1.		SIB lift-off
14	10.	10.	10.	max*	80.	-80.		SIB boost
18	0	0	0	0	0	0		SIB staging
22	1.	1.	1.	20.	1.	1.		SIVB boost
26	0	0	0	0	0	0		
27.5		_			x			Request FP2 Initialization
32	0	0	0	0.4	0	0		RCS thrust for separation
36	0	0	0	0	0	0		
39.5								Request 1st Calib.
50	0	0	0	10.	0	0	<sup>a</sup> <sub>1</sub> = 1	lst DPS burn
54	0	0	0	0	0	0	P <sub>1</sub> = 0	
57.5							-	Request 2nd Calib.
68	0	0	0	15.	0.1	0.1	e <sub>1</sub> = 1	2nd DPS burn
72	- A						$B_1 = 0, B_2 = 1$	Stage, 1st APS burn
76	0	0	0	0	0	0	°2 = 0	
79.5								Request 3rd Calib.
90	0.1	0.1	0.1	20.	0	0	P <sub>2</sub> = 1	2nd APS burn
98	0	0	0	0	0	0	P <sub>2</sub> = 0	
100	.001	.001	.001	.01	.01	.01	$K_{30}^1 = 150$	Request 4th Calib.
410	1.	1.	1.	0	0	0		
412	Sec. 1	L. 15	1.2. 20	1.0	a 57. 54		° <sub>3</sub> = 0	Attitude Hold
420	End of	Run						

\* max = 29 pulses x 0.003125 fps/pulse x 1000 cy/sec = 90.625 ft/sec<sup>2</sup>.

Note: All inputs (gyro, accelerometer and others) are input at the time specified and remain constant until altered by another entry at a later time.

B-2

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Attachment B

7221.7-176 Page -2-

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7221.7-176 Page -3-

Submitted by: R.L. Eshbaugh

Approved by:

T.S. Bettwy, Section Head IM G&N Section

P.D. Joseph, Manager

System Analysis & Software Department

Attachment B

RLE/ns Distribution: LM G&N Section

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J.L. Thomas

## RW SYSTEMS

INTEROFFICE CORRESPONDENCE

CC

7332.9-33

TO

Distribution

DATE: 26 December 1967

SUBJECT: Verification Test Results for Flight Program 2, Revision C

FROM: H. G. King BLDG STS ROOM 9010 EXT 66521

(1)05952-6143-T004. LM AGS Program Verification Test References: Plan, Flight Program 2, dated 22 September 1967.

- (2)IM AGS SCP 31, Modifications for Unmanned IM 2, dated 1 December 1967.
- (3)7221.7-176, Verification Test Plan for Flight Program 2 Unmanned Modification, dated 4 December 1967.
- (4)7332.9-32, Flight Program 2, Revision C Description Document, dated 15 December 1967.

Flight Program 2, Revision C, (IM FP2 SO3C) has been successfully verified by means of the ICS test case described in Reference (3) and the additional tests described below. The program was developed from the previously delivered Preliminary Flight Program 2, Revision B, and incorporates modifications for an unmanned mission (References (2) and (4)). Revision B, which incorporated various modifications from the baseline DMCP, underwent extensive ICS testing in accordance with Part I of Reference (1) prior to its release as a preliminary unverified program.

The purpose of the testing reported herein was to demonstrate that the logic of the unmanned modifications provides the proper discretes, performs an initialization at a prescribed time after sensing liftoff, performs in-flight calibration at four prescribed times after initialization, issues the proper engine discretes, issues zero or attitude hold error signals depending upon the state of the follow-up discrete and provides the proper telemetry outputs.

The attached table lists the ICS test inputs and event times which simulate the AS-206 operations trajectory in the number and type of maneuvers. The entire mission has been condensed to seven minutes mission time to reduce the simulation time. The LM state is initialized such that it will overflow prior to lift-off. Absolute time will overflow during boost. The AGS is initialized with the CES follow-up and automatic discretes present. The first three calibrations are shortened to 6 sec by setting the gyro calibrate time constant 1K30 = 3.

Output consisted of normal ICS printout every two seconds throughout the run, plus printout every 20 milliseconds for 7 two second periods for the purpose of evaluating telemetry output.

Following is a tabulation of points of interest:

- For the first 10 seconds the program functioned in a one-g environment. Numerous overflows were detected due to the initial values set in for IM and CSM ephemeris. These overflows included the following parameters:
  - a. Total position magnitude,r, which in turn caused all three components of  $\underline{U}_1$  to overflow. This effects gravity and various navigation functions.
  - b. CSM prediction time.
  - c. Range rate.
  - d. Various LM orbit parameters.
  - e. Steering computations.

The overflows did not in any way affect the unmanned mission logic or have any other adverse effect.

2. At cycle 501 (10 seconds) the sensed acceleration was increased to 39 ft/sec<sup>2</sup> to simulate liftoff. At cycle 604 (Branch 1) the computed acceleration exceeds 38 and the liftoff flag was set to 1. At cycle 704 the liftoff counter started incrementing. At 701 cycles high turning rates and accelerations were input to simulate a boost environment. Various navigation overflows continued to occur and absolute time overflowed without affecting program operation. The liftoff counter was incremented by 1 each two seconds until cycle 1404. For this run, the constant which controls the delay between the sensing of liftoff and the time of initialization, was set for 16 seconds.

- 3. At cycle 1404 the flag which indicates the post boost initialize point was set to 1 and  $S_{00}$  to 3. At cycle 1405 the PGNCS to AGS alignment was accomplished and at cycle 1502 (Branch 50)  $S_{00}$  was set back to 0. During the next two second cycle the pseudo downlink navigation initialize was accomplished. From that point on no illegal overflows were detected.
- 4. At cycles 2004, 2904, and 4004 inflight calibrates were initiated. These corresponded to the calibrate times specified for this case. For each of these, zero gyro and accelerometer inputs were used and the calibrate duration was reduced to 6 seconds. At the above mentioned cycles  $S_{00}$  was set equal to 3 and  $S_6$  was set equal to 1. At the following Branch 50 cycle  $S_{00}$  was set to 6 and after 6 seconds  $S_{00}$  was reset to 0.
- 5. Input discretes were set at various points, as shown in the table, to test the engine and staging logic of the program. In all cases the engine command and its telemetry word followed the input engine discretes.
- 6. At cycle 5004 a full length inflight calibrate was initiated. Gyro inputs and accelerometer inputs were provided and the biases obtained as below:

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- 7. At cycle 20600 the follow-up discrete was removed. At that time the attitude hold mode was entered. The attitude error signals which had been zero throughout the run, due to the combination of the follow-up and automatic discretes being present and  $S_{00}^{=0}$ , were subsequently computed to hold the vehicle attitude constant.
- 8. Telemetry was verified over 7 two second periods distributed throughout the run. The new telemetry functions for the unmanned mission were output correctly. All other outputs also functioned properly. One point of interest is that the attitude errors output on telemetry are quantized at 2<sup>-15</sup> and occasionally will have a bit or two when the CES output attitude errors, which are quanitzed at a higher value, are zero.
- 9. The DEDA processing routine was checked by calling for DEDA readouts or entries during the verification test case. Included was continuous DEDA readout of the y-gyro bias during the final calibrate. All processing was correctly executed.

An additional test case was made in order to verify the logic of the program with the correct values of constants included. This was performed by initially setting the boost delay counter to a high value in order to reduce the delay time. Absolute time was then periodically jumped to the prescribed calibrate times. The initialization, navigation values and calibrate decisions were all correct.

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Approved:

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jfp

Attachment

Cycle		Gyro Outputs Accelercmeter Outputs							
	Δα	Δα	$\Delta_{\alpha_{z}}$	$\Delta V_{\rm x}$	$\Delta V_{\rm v}$	ΔV <sub>z</sub>	Other Inputs to	Remarks	
	0/202	10/000	0/500	f+/s22	f+/se2	ft/sec <sup>2</sup>	Flight Program		
1	.003	.003	0	32.2	0	0			
501	0	0	0	30	and the second	1.		STB lift-off	
701	10	10	10	20.6	20	-80		STB boost	
101	10.	10.	10.	-0.0	00.	-00.		SID storing	
901	0	0	0	0	0	0		SIB staging	
1101	1.	1.	1.	20.	1.	1.		SIVB boost	
1301	0	0	0	0	0	0			
1404								Initialization	
1601	0	0	0	0.4	0	0		RCS thrust for	
1801	0	0	0	0	0	0		separation	
2004								Request 1st Calib.	
2501	0	0	0	10.	0	0	6 = 1	lst DPS burn	
2701			0	<u>.</u>	0	0			
2701	U	U	0	U	U	0	p <sub>1</sub> = 0	Devent Ord Ord 1	
2904		<u> </u>			<u> </u>			Request 2nd Galib.	
3401	0	0	0	15.	0.1	0.1	β <sub>1</sub> = 1	2nd DPS burn	
3601							$\beta_1 = 0, \beta_2 = 1$	Stage, 1st APS burn	
3801	0	0	О	0	0	0	$\beta_2 = 0$		
4004	7							Request 3rd Calib.	
4501	0.1	0.1	0.1	20.	0	0	$\beta_2 = 1$	2nd APS burn	
4901	0	0	. 0	0	0	0	$\beta_0^2 = 0$		
5004	.001	.002	.0005	.01	.02	.015	$k_{10}^2 = 150$	Request 4th Calir.	
20500	1.	1.	1.	0	0	0	0		
20600	4 1 3	18 8 <b>1</b> 1 1					$\beta_{0} = 0$	Attitude Hold	
21000	Frd of	Dun					-3		
21000									

Table 1 Verification Test Inputs

Note: All inputs (gyrc, accelerometer and others) are input at the time specified and remain constant until altered by another entry at a later time.

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