

Sampson

Massachusetts Institute of Technology
Instrumentation Laboratory
Cambridge, Massachusetts

Flight 501 Memo # 8

FROM: J. A. Sampson (AC Electronics Resident Engineer)

DATE: 7 October 1966

SUBJECT: Programming Changes from AS-202 to AS-501

A. Prelaunch Alignment

The erasable word WTRWD has been deleted by request because it was a prelaunch erasable load that changed during the course of prelaunch alignment.

The fixed constant WIE has been doubled because of the new RN scaling.

B. Guidance Reference Release

ΔT for IMU COMPENSATION, which was 1/2 seconds for Prelaunch Alignment, is changed to 2 seconds at GRR for the Mission Control Program (SERVICER), which is called every 2 seconds after GRR. Since ΔT for SERVICER is set to 2 seconds at the end of SERVICER, in 202 the first SERVICER after GRR used an IMU COMPENSATION ΔT of 1/2 second.

C. Lift-Off

Lift-Off has been rewritten like 204 to zero the AGC Clock, at NASA's request. To be more exact, the AGC clock is set to 2 seconds at 2 seconds after Lift-Off because of all the activity at Lift-Off.

D. Boost Monitor

The Boost Monitor Program has been rewritten like the new one in 204 to incorporate both roll and pitch monitor in the same job; the 204 scheme produced some very accurate results. Since in 501 boost roll and pitch begin at different times and the platform alignment is different, the 204 program had to be modified slightly.

D. Boost Monitor (Continued)

It should be noted that the Boost Monitor Program runs as a continuous job (except for interrupts) because execution times equal cycle time.

E. Tumble Monitor

Major Mode 14 is set only at the beginning rather than every one second during tumble monitor, because it would interfere with the Pre-TLI update (Major Mode 27). Also the first time thru Tumble Monitor the buffer that holds the previous CDU sample is initialized to the present CDU setting so that TUMBLE Flag is not set the first time through.

F. Pre-TLI Update

This update is intended to correct the Navigation Program while it is running, and thus must be incorporated differently than the Cold Soak update. In 501 a time is sent along with the corrected position and velocity which represents the time at which the Navigation Program should incorporate the new position and velocity. If this time represents a past time, the update will not be incorporated and Program Alarm 01411 will be displayed. As an extra precaution, UPDATE Flag is reset at S4B Separation and before the Abort Signal is tested so as not to incorporate an update which represents a time in Major Mode 14, but after Separation. The update should be in ECI coordinates with position scaled 2^{26} meters and velocity 2^7 m/centiseconds.

G. Receipt of the Ground Abort Signal

In 501 a new flag, ABORTSIG, is set rather than setting the Burn Switch to ABORT. This was necessitated because a Tumble Arrest Burn might later set the Burn Switch to ARRST and would have no way of knowing whether to do a nominal or abort burn after the tumbling has been arrested. Note that since entry chooses the Atlantic Target if ABORTSIG is set, the Abort Signal could be sent anytime after 1.7 seconds after S4B Separation to force the Mission Control Program to do the nominal mission, but choose the Atlantic Target Point for entry.

H. S4B Separation Logic

1. Nominal Separation

If there is no tumbling and the abort signal is not received within 1.7 seconds after the separation signal is received by the AGC, the +X Translation signal is removed 10 seconds after the separation signal is received, the maneuver to SPS1 Burn attitude is initiated after +X Translation is removed, and the SPS engine is ignited 100 seconds after the separation signal is received.

2. Separation with Tumbling, no Abort

The Tumble Arrest Burn is performed as in 202, and after tumbling has been arrested and if the abort signal has not been received, +X Translation is removed, the maneuver to SPS1 Burn attitude is initiated, and the SPS engine is ignited 94.3 seconds after Tumbling has been arrested.

3. Separation with Abort, no Tumbling

Exactly the same as in 202, except that engine ignition occurs 6 seconds after separation instead of 3 seconds.

4. Separation with Abort and Tumbling

The same as the Tumbling only case in 202, i. e., the Tumbling is arrested and the abort burn is initiated as soon as the spacecraft has been maneuvered to the abort burn attitude.

I. Maneuvers to Burn Attitude

Maneuvers are started over again from the beginning if a restart should occur. If the maneuver to either the SPS1 or SPS2 Burn attitude is not complete when ignition occurs, that maneuver is terminated because of common erasable usage between the maneuver and steering programs.

For the burns a heads-down roll attitude is maintained during SPS1 and a heads-up during SPS2.

In 202 only the pitch/yaw maneuver to the initial SPS1 burn attitude was performed due to the short time between separation and SPS1 ignition. In 501 the whole pitch/yaw and roll maneuver sequence is performed.

J. Yaw Steering for Nominal Burns

Instead of defining the burn plane by ($\overline{RN^* RTPACIFC}$) as in 202, it is defined by ($\overline{RN^* VIGNTION}$) in 501. For SPS1 burn, $\overline{VIGNTION}$ represents \overline{VN} at the start of the maneuver to SPS1 burn attitude, or 90 seconds before ignition. For SPS2 burn, $\overline{VIGNTION}$ represents the velocity at ignition computed by orbital integration after SPS1 cut-off. If a re-maneuver to SPS2 burn attitude is performed, $\overline{VIGNTION}$ represents \overline{VN} at the beginning of the re-maneuver, 2 minutes before ignition.

K. Nominal Post SPS1

The Vertical Erection Initialization has been replaced by a Cold Soak Initialization which orientates the spacecraft to 3 specified erasable IMU gimbal angles.

After the desired Cold Soak attitude has been achieved, Orbital Integration is performed to determine the position and velocity 23 minutes before the spacecraft's free-fall trajectory intersects 400,000 feet altitude, the desired spacecraft attitude for SPS2 burn is computed, and the Navigation program is terminated. Since the Cold Soak gimbal angles can be maintained by the attitude control loop, the AGC idles during the entire coast phase, except for the first FDAI Align 300 seconds after SPS1 burn cut-off and the Pre-SPS2 state vector and TFFMIN updates. At SPS1 cut-off, TFF2 Flag is set to enable the TFF : TFFMIN comparison for SPS2 Ignition logic.

L. Orbital Integration Rescaling and Changes

Orbital Integration has been rescaled to handle higher altitudes. For 501 \overline{RRECT} is scaled 2^{16} km or 32,000 n. m. and \overline{VRECT} is scaled the same as in 202.

M. Rescale Navigation Program (AVERAGE G INTEGRATOR)

The Navigation Program was rescaled to higher altitudes during the Mission Control Program. \overline{RN} is now scaled to 2^{25} meters; \overline{VN} retains the 202 scaling of 2^7 meters/centiseconds.

N. Cold Soak TFFMIN and State Vector Update

The Cold Soak state vector update should be sent up in the same format as the PRE-TLI update; i. e., in ECI coordinates with position scaled 2^{26} meters and velocity 2^7 m/centiseconds. The UPDATE Flag is used for the two VERB 76 state vector updates, and VERI Flag

N. Cold Soak TFFMIN and State Vector Update (Continued)

is inverted after every successfully accepted update. Note that TFFMIN must be sent up before the state vector because once the UPDATE Flag is set, no other updates are accepted until it has been knocked down (or the update is incorporated).

O. SPS2 Ignition Sequence

Instead of scheduling the end of coast phase on a fixed-time basis from SPS1 cut-off, at SPS1 cut-off the end of coast phase is scheduled 25 minutes before the spacecraft's free-fall trajectory intersects as altitude of 400,000 feet. At the end of coast phase another FDAI Align is performed and the PRE-SPS2 state vector update is incorporated. 2 minutes later the Navigation Program is restarted, the spacecraft is maneuvered to SPS2 burn attitude, and the AGC idles, zeroing the PIPA's for the Navigation Program, until SPS2 ignition is scheduled.

When the freefall time to 400,000 feet (TFF) equals TFFMIN, the AGC stops zeroing PIPA bias and schedules SPS2 ignition 2 minutes later.

P. SPS3 and SPS4 Burns

The logic for these two burns has been by-passed in the 501 Program.

Q. ΔV Monitor and VG Alarm

After engine ignition ΔV can be less than ΔV_{\min} for 20 seconds before a shutdown sequence is initiated.

If a ΔV or VG Alarm occurs during SPS1 burn, the engine will be shut off immediately and the Post SPS1 sequence will be initiated as after a nominal SPS1 cut-off.

As in 202, a ΔV or VG Alarm during SPS2 Burn will initiate a shutdown sequence.

R. Restarts

The restart discrepancies in 202 have been corrected and restart protection for all new 501 logic has been incorporated. The 202 discrepancies corrected were in Orbital Integration, Roll Job, AGC Self-Check, Entry, and Back-up Discrete sections.

S. Cross Product Steering

The logic to terminate SPS2 burn 6 seconds early has been eliminated.

T. CALCMANU Package

The Routine to compute the spacecraft maneuver sequence has been modified from 202 to make it more optimum.

U. New Re-entry Package

The new entry program is as described in R-532 and R-537 including the supplementary changes in Appendix J of R-532 except:

1. The .05G discrete is sent in the INITROLL phase when the G level exceeds .05.
2. The .05G discrete is removed in the KEP2 phase when the G level drops below .05 and is sent whenever it exceeds it.
3. A roll bias term is added so that the roll command angle ROLLC is the angle about the Relative Velocity Vector measured from lift-up position. This is the same as in 204 entry.
4. An Entry display has been added during Major Modes 63 through 67. It is updated every two seconds and displays in R1 Time from L/O (XXX.XX secs), in R2 velocity that must be multiplied by 3.14 to give ft/sec, and in R3 Estimated Range to Target which must be multiplied by 1.32 to give nautical miles.

V. SXT-On Switch Fixes

All portions of the 501 program that test bit 13 of WASOPSET to see if the SXT-ON switch is set have been modified to assume it is on in light of the wiring changes in Blocks 50 and 100.

W. Down-Telemetry

Changes were made in the Down-Telemetry list to reflect changes made in the Update Programs. Also, no more than 3 TMMARKERS will be sent down per 50 word downlist.

X. New TFF Package

The 204 TFF package was incorporated into 501 because it is more accurate than the approximate algorithm used in 202. The new TFF package assumes elliptical orbits, and the calculations become very inaccurate as the eccentricity of .9992 and nearly escape velocity during SPS2 burn, the calculations become inaccurate.

X. (Continued)

After trying to modify the TFF package by increasing the accuracy of the existing equations near parabolic conditions, it was found that additional problems arose and the results were still not accurate. The approach decided upon was a set of perturbed parabolic equations for TFF. These equations are accurate to 1% for eccentricities ranging from .8 to 1.2 and their simplicity and accuracy lend themselves well to the application.

The equations are used for eccentricities greater than .8, a semimajor axis greater than 50×10^6 feet; a provision for 502 application has been included to set TFF equal to orbital period if the above conditions exist and the spacecraft is on the outbound leg of the trajectory.

For eccentricities less than .8, the 204 TFF package is used.

Y. DSKY Fixes

1. Double Entries

A second keycode will not be accepted within 120 ms after the first or until the first has been processed.

2. Clear Key

No longer will it be possible to change the VERB by entering too many CLEAR's.

3. Multiple Sign Keys

A change was made to allow only the first of consecutive "x" / "-" characters.

Z. New 501 Flags

1. VERIFLAG is **equivalenced** to HIND2SW (Entry) and is inverted every time an update has been successfully completed.
2. ABORTSIG has replaced MIDFLAG and is set when the ground abort is received instead of setting the burn switch to ABORT.
3. TFF2FLAG has replaced MOONFLAG and is set to enable the TFF : TFFMIN comparison for SPS2 Ignition time logic.
4. BIASFLAG has replaced FIRSTFLAG and is set to enable **SERVICER** to Zero DELV before going to CALCRVG. This is done between the time the Navigation Program is restarted and TFF falls below TFFMIN for the first time.
5. VERTFLAG has been renamed SOAKFLAG.

AA. New 501 Erasables

1. UPTIME - holds time from L/O to incorporate new position and velocity into Navigation Program (PRE-TLI update)
2. ANGLEX, Y, Z - Cold Soak desired IMU gimbal angles
3. TFFMIN - holds time to schedule SPS2 ignition (updateable)
4. 1/RLLRTE - Roll rate during boost monitor
5. MAXROLL - Final roll angle during boost
6. CGY - c. g. rotation about Y S/C axis
7. CGZ - c. g. rotation about Z S/C axis
8. ATDT - Integrated Initial Thrust Acceleration Magnitude
9. TFFNOM - Nominal TFF to be used if TFF is uncomputable after SPS1 cut-off
10. S2SWITCH - Re-maneuver to SPS2 burn attitude 2 minutes before ignition if negative
11. REFSWITCH - Use 280,000 ft. as a Free-Fall reference altitude if negative
12. REDOSPS1 - Redo SPS1 burn when SPS2 burn is scheduled if negative
13. ECC - The TFF program dumps 1/2 e here when $e > .8$ for simulation editing purposes. This register is not used in the mission.

BB. Changes in VERB Codes

V71: TFFMIN Update

V72: Abort

V77: Lift-off Time Update

CC. Changes in Major Modes

21 - Maneuver to Cold Soak Attitude

22 - Hold Attitude During Orbital Integration

26 - Hold SPS2 Burn Attitude and Wait for TFF : TFFMIN

DD. Shutdown Sequence

The first Shutdown will occur at TFF = 200 seconds instead of 160 seconds in 202. The second shutdown will still occur at TFF = 95 seconds.

EE. CDUDRIVE Conflict

The conflict in 202 between Roll Job and Steer Law, both wanting to drive the ICDU's at the same time, was eliminated.

FF. IMU COMPENSATION

This program was changed to complement the sign of the erasable PIPA Scale Factor in light of what was found on 202.

GG. Off-Nominal Mission Logic

1. Uncomputable TFF after SPS1 Cut-off

If TFF is uncomputable due to a trajectory that will not intersect 400,000 ft, TFFNOM will be used to compute the time orbital integration will integrate over and the time until the end of coast phase. If TFFNOM is used instead of TFF, TFF2 Flag will not be set after SPS1 cut-off so as not to enable the TFF : TFFMIN comparison for SPS2 Ignition logic. Instead, at TFFNOM - 23 minutes, when TFF2 Flag is not set the maneuver sequence to SPS2 burn attitude is recomputed, the maneuver is initiated, and the SPS2 ignition is scheduled a fixed time 2 minutes later. Thus, when TFF is not computable after SPS1 cut-off, the end of coast phase and SPS2 burn is scheduled on a fixed time basis.

2. Uncomputable TFF at End of Coast Phase

If TFF was computable after SPS1 cut-off and TFF2 Flag was set, but after the Cold Soak update TFF is not computable at the end of coast phase, TFF2 Flag is knocked down. Two minutes later the maneuver sequence to SPS2 burn attitude is recomputed, the maneuver is initiated, and SPS2 ignition is scheduled a fixed time 2 minutes later.

3. TFF at SPS1 cut-off less than 25 Minutes

If TFF is less than 25 minutes, the cold soak maneuver is cancelled, the Navigation Program is not terminated, the maneuver sequence to SPS2 burn attitude is computed, initiated, and the TFF2 Flag is set to enable the TFF : TFFMIN comparison for SPS2 ignition logic.

GG. (Continued)4. Re-schedule SPS1 Burn

If for some reason the first burn sequence is to be repeated at SPS2 ignition time, REDOSPS1 should be set negative. This could be used if after a S4B separation in orbit, the SPS1 burn could not do the TLI. After the Mission Control Program sequences through the Post SPS1 and SPS2 Ignition Sequence logic, REDOSPS1 is checked. If it is negative, the burn switch is set to SPS1 and everything from SPS1 ignition on will be repeated. If REDOSPS1 is positive, the nominal SPS2 burn will be performed.

5. Re-entry from Orbit

If during the nominal parking orbit coast it is desirable to bring the spacecraft back in a hurry, a S4B separation sequence could be initiated from the ground, and if TFFNOM contained 30 minutes, and if the SPS1 burn is inhibited, SPS2 ignition will occur 9 minutes later. Since the 400,000 ft 200 second TFF interrupt will terminate the burn before de-orbit, REFSWITCH should be set negative to use a 280,000 ft TFF reference altitude and the valve for p and/or e^2 should be changed to de-orbit before the 280,000 ft 200 second TFF interrupt.

HH. Miscellaneous

1. The +X Translation discrete is removed whenever the engine is shut-off, independent of the burn.
2. CALCG no longer has to be preloaded with the CADR of CALCGEAR. The Navigation Program now unconditionally transfers control to CALCGEAR for GRAVITY.
3. The key code is no longer loaded in TAVEGON for downlink transmission during Prelaunch Major Modes.