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Flight 501 Memo #10

TO: Distribution
FROM: Jay Sampson
DATE: 26 October 1966
SUBJECT: Summary of Results of AS-501 Digital Simulations.

The following is a description and short summary of verification runs that qualified the AS-501 flight program. Since all the runs were not made using the final revision of SOLARIUM, a revision number is included for each run. Not included wherein are the Time-Line Summaries and Special (Boost Monitor, Attitude Maneuver, SPS Burn, Entry) Summaries. These will be available in a forthcoming E- or R- Document.

RUN NO.	DESCRIPTION	OBJECTIVE	REMARKS	RESULTS	REVISION
1A	NOMINAL MISSION PROFILE.	PROVIDE REFERENCE CASE FOR COMPARISON WITH OTHER RUNS.	FROM GRR TO SPLASH.	AGC NAVIGATION ERRORS WERE ACCUMULATED DURING ORBITAL COAST. THE COLD SOAK APOGEE WAS 9905 N.M. AND PERIGEE WAS -50 N.M. AT 400,000 FT. VELOCITY AND VELOCITY ERROR WERE 36309 AND 546 F/S RESPECTIVELY. GAMMA AND GAMMA ERROR WERE -7.11 AND 0.76 DEG. THE MAX G PULLED DURING ENTRY WAS 07.9 AND SPLASH WAS SHORT BY 89.4 N.M. AT SPLASH AGC POSITION AND VELOCITY ERROR WERE 526,303 FT AND 735 F/S.	54
1B	3-SIGMA ERROR RUN FROM PRELAUNCH TO SPLASH WITH NO UPDATES.	PROVIDE ERROR ANALYSIS.	600 SECS. OF PRELAUNCH. THE IMU ERRORS FOR THIS RUN WERE GENERATED BY COMBINING THE MEASURED VALUES AS OF 9/23/66 WITH THE ESTIMATED 3-SIGMA UNCERTAINTIES AS FOLLOWS-	AT S4B SEPARATION, THE AGC POSITION WAS IN ERROR BY 413,000 FT AND VELOCITY BY 316 FT/SEC. AT SPS1 CUT-OFF, THE VELOCITY-TO-BE-GAINED WAS STILL 121 FT/SEC. WHEN THE AGC THOUGHT THAT TFF = TFFMIN = 720 SEC, THE ACTUAL TFF WAS 48 SEC. AS A RESULT THE RUN WAS ABORTED WHEN THE SPS ENGINE IGNITED WITHIN THE ATMOSPHERE. THE APOGEE ACHIEVED DURING THE COLD SOAK PHASE WAS 9547 N.M. THE PERIGEE WAS -73.5 N.M.	51, WITH PATCHES TO UPDATE TARGET VECTORS AT LIFT-OFF CORRECTLY. (EQUIVALENT TO REV. 52)

	MEASURED	NBD MERU	ADIA MERU/G	ADSRA MERU/G	PBIAS CM/S/S	PIPA S.F. PPM
	X	-5.5	-7.5	-1.5	.42	-332
	Y	-3.0	0.8	-6.5	-.48	-219
	Z	4.9	4.8	1.8	-.18	-142
	UNCERTAINTIES					
	X	1.8	7.5	1.8	.30	150
	Y	1.8	7.5	1.8	.30	150
	Z	1.8	1.1	1.8	.30	150
	COMBINED					
	X	-2.7	0.0	0.3	.12	-482
	Y	-4.8	8.3	-8.3	-.78	- 69
	Z	6.7	3.7	0.0	-.48	-292

THE MEASURED BIAS VALUES WERE USED IN THE AGC INERTIAL COMPENSATION ROUTINES.

RUN NO.	DESCRIPTION	OBJECTIVE	REMARKS	RESULTS	REVISION
1C	3-SIGMA ERROR RUN FROM PRELAUNCH TO SPLASH WITH UPDATE IN ORBIT ONLY.	VERIFY AGC ABILITY TO INCORPORATE STATE VECTOR UPDATE INTO ITS NAVIGATION PROGRAM AND PROVIDE COMPARISON WITH RUN 1B.	600 SECS OF PRELAUNCH. THE UPDATE POINT IS 292 SECS BEFORE THE TLI BURN, OR ABOUT 11,203 SECS AFTER L/O. UPDATE POINT DATA IS TAKEN FROM THE ACTUAL POSITION AND VELOCITY IN RUN 1B. THIS RUN IS OTHERWISE A REPEAT OF RUN 1B, WITH THE SAME BIASES AND INITIAL CONDITIONS, ETC.	THE AGC POSITION AND VELOCITY ERRORS BEFORE THE ORBITAL UPDATE WERE 550,000 FT AND 448 F/S. THE POSITION AND VELOCITY ERRORS AFTER THE UPDATE WERE 2069 FT AND 3.32 FT/SEC. AT TTEMIN THE AGC TFF ERROR WAS 03 SECS. AT 400,000 FT THE VELOCITY AND VELOCITY ERRORS WERE 36,333 AND 68 FT/SEC AND GAMMA AND GAMMA ERROR WERE -7.32 AND 0.05 DEG. MAX G DURING ENTRY WAS 8.4 AND R-TO-GO AT SPLASH WAS 15 N.M. FINAL POSITION AND VELOCITY ERROR WERE 116,934 FT AND 249.4 FT/SEC. THE COLD SOAK APOGEE WAS 9887 N.M., AND THE PERIGEE WAS -52 N.M.	54
1D	3-SIGMA ERROR RUN FROM PRELAUNCH TO SPLASH WITH COLD SOAK UPDATE ONLY.	DEMONSTRATE EFFECT OF 2ND UPDATE ON RUN 1B.	ROLLBACK OF RUN 1B FROM 28,778 SECONDS AFTER L/O, WITH AN UPDATED STATE VECTOR PATCHED INTO THE STBUFF BUFFER AND UPDATE FLAG PATCHED UP. THE UPDATE POINT DATA IS TAKEN FROM THE ACTUAL POSITION AND VELOCITY IN RUN 1B.	THE AGC POSITION AND VELOCITY ERRORS BEFORE THE COLD SOAK UPDATE WERE 15,299,202 FT AND 8512 FT/SEC, AND AFTER THE UPDATE 1754 FT AND 4.40 FT/SEC. AS SOON AS THE UPDATE WAS INCORPORATED, THE AGC TFF WAS 687 SECS, SO SPS2 IGNITION WAS SCHEDULED IN 2 MIN. AT 400,000 FT THE VELOCITY WAS 36,333 F/S, GAMMA WAS -7.23 DEG. AND VELOCITY AND GAMMA ERROR WERE 24.8 FT/SEC AND 0.03 DEG. A MAX 8.1 G WAS PULLED DURING ENTRY AND AT SPLASH THE MISS WAS 26.7 N.M. THE POSITION AND VELOCITY ERROR AT SPLASH WERE 126,675 FT AND 304 FT/SEC.	51, WITH PATCHES TO UPDATE TARGET VECTORS AT LIFT-OFF CORRECTLY, YAW STEER, AND STATE VECTOR UPDATE LOADED INTO STBUFF BUFFER. (EQUIVALENT TO REV 53)

RUN NO.	DESCRIPTION	OBJECTIVE	REMARKS	RESULTS	REVISION
1D-1	3-SIGMA ERROR RUN FROM PRELAUNCH TO SPLASH WITH BOTH UPDATES.	DEMONSTRATE EFFECT OF BOTH UPDATES ON RUN 1B, AND 2ND UPDATE ON RUN 1D.	ROLLBACK OF RUN 1C FROM 27,542 SECONDS AFTER L/O, WITH THE COLD SOAK UPDATE ENABLED. THE UPDATE POINT DATA WAS TAKEN FROM THE ACTUAL POSITION AND VELOCITY IN RUN 1C.	THE AGC POSITION AND VELOCITY ERRORS BEFORE THE COLD SOAK UPDATE WERE 30,336 FT AND 14 FT/SEC, AND AFTER THE UPDATE 4231 FT AND 3.70 FT/SEC. AT 400,000 FT THE VELOCITY WAS 36,337 FT/SEC, GAMMA -7.17 DEG, AND VELOCITY AND GAMMA ERRORS WERE 25.2 FT/SEC AND 0.03 DEG. A MAX 8.2 G WAS PULLED DURING ENTRY AND AT SPLASH THE MISS WAS 11.2 N.M. THE POSITION AND VELOCITY ERRORS AT SPLASH WERE 93,284 FT AND 294 F/SEC.	54
1E	NOMINAL PROFILE FROM S4B SEPARATION WITH AGC RE-STARTS.	DEMONSTRATE MINIMAL EFFECT OF RESTARTS ON PERFORMANCE.	S4B SEPARATION TO SPLASH THE AGC PROGRAM IS FORCED TO RESTART EVERY 7.62 SECS FROM S4B SEP, EXCEPT DURING MODES 22 (ORBITAL INTEGRATION) AND 24 (COAST). RANDOM RESTARTS WERE TESTED DURING THESE TWO MODES IN EARLIER RUNS.	MINIMAL EFFECT ON MISSION. MANEUVERS TO VARIOUS ATTITUDES WERE COMPLETED IN TIME. THE 2ND FDAI ALIGN WAS ON FOR OVER 100 SECS BE-CAUSE THE 10 SEC TASK TO REMOVE THE DISCRETE IS NOT RESTARTABLE. ANOTHER TASK 2 MIN. LATER TURNS FDAI OFF AS A BACKUP.	50
1F	NOMINAL RUN FROM PRE-LAUNCH INTO BOOST (MAJOR MODE 14) WITH AGC RE-STARTS.	DEMONSTRATE MINIMAL EFFECT OF RESTARTS ON PERFORMANCE.	10 MINUTES OF PRELAUNCH INTO BOOST. THE AGC PROGRAM IS FORCED TO RESTART EVERY 4.74 SECS. FROM THE END OF OPTI-CAL VERIFICATION (18 SECONDS BEFORE L/O) UNTIL 400 SECS INTO BOOST. RESTARTS OCCURRED BETWEEN GRR AND L/O AND BETWEEN L/O AND AGC CLOCK ZERO (L/O + 2 SEC)	THE ONLY EFFECTS OF RE-STARTS ON THE BOOST MONITOR PROGRAM WERE THAT THE MAX ROLL ERROR WAS 0.73 DEG IN COMPARI-SON WITH 0.27 DEG IN A RUN WITHOUT RESTARTS, AND SOME OF THE EVENTS WERE 2 OR 3 TENTHS OF A SECOND LATE.	51

RUN NO.	DESCRIPTION	OBJECTIVE	REMARKS	RESULTS	REVISION
1G	EARLIEST POSSIBLE TUMBLE ABORT BURN TO ATLANTIC TARGET.	CHECK UPLINK ABORT AND 202 ABORT PROGRAM. CHECK TUMBLE ABORT SEPARATION LOGIC.	UPLINK ABORT AT 502 SEC. SEPARATION AT 508 SEC. THIS IS THE EARLIEST AFTER LIFT-OFF AT WHICH AN ABORT BURN CAN BE MADE. AN EARLIER ABORT BURN WOULD BE TERMINATED BY THE 200 SEC. TFF INTERRUPT.	THE 202 ABORT PROGRAM AND CONSTANTS SEEMED TO WORK WELL FOR THE 501 BOOST TRAJECTORY. THE DESIRED SPLASH POINT WAS ACHIEVED WITHIN 1 N.M. THE ABORT BURN LASTED 183 SECS.	50
1H	SEPARATION JUST AFTER INJECTION INTO PARKING ORBIT (WITH TUMBLING) TO SPLASH.	CHECK THAT THE SPS1 BURN CAN PERFORM THE TRANS-LUNAR INJECTION AND THAT THE MISSION OBJECTIVES CAN BE ACCOMPLISHED. CHECK NOMINAL SPS1 BURN FOLLOWING A TUMBLE ARREST LOGIC.	S4B SEPARATION OCCURS AT L/O + 695 SECS (JUST AFTER 1ST S4B BURN CUT-OFF) WITH A +6 DEG/SEC YAW RATE. THE AGC USED A 280,000 FT FREE-FALL REFERENCE ALTITUDE THROUGHOUT THE FLIGHT BECAUSE REFSWTCH WAS NEGATIVE.	AFTER TUMBLING WAS ARRESTED, THE SPS1 BURN LASTED 420 SECS. TO ACHIEVE THE DESIRED P AND E. USABLE SPS FUEL WAS DEPLETED 20 SECS. INTO THE SPS2 BURN, WHICH RESULTED IN A DELV ALARM AND A SHUT-DOWN SEQUENCE. BECAUSE ENTRY WAS TWO ORBITS EARLY AND THE SHORT SPS2 BURN, A MAX 15.5 G, -8.85 GAMMA STEEP ENTRY WITH NO SKIP-OUT RESULTED. THE SPLASH POINT WAS OVER-SHOT BY 330 N.M.	50
1I	502 NOMINAL MISSION PROFILE.	PROVIDE REFERENCE MISSION.	FROM S4B SEPARATION TO SPLASH WITH 501 DYNAMICS.	SEP OCCURRED 11.899 SECS AFTER L/O. SPS1 BURN LASTED 276 SECS. SPS2 BURN LASTED 186 SECS. COLD SOAK APOGEE WAS 9000 N.M., AND PERIGEE WAS -55 N.M. AT 400,000 FT THE VELOCITY WAS 36,330 FT/SEC AND GAMMA WAS -7.19 DEG. SPLASH MISS WAS 0.3 N.M. THE MAX G PULLED DURING ENTRY WAS 8.3.	54

RUN NO.	DESCRIPTION	OBJECTIVE	REMARKS	RESULTS	REVISION
2A-1	ENTRY WITH LOW FLIGHT PATH ANGLE (-6.76 DEG) AND LOW L/D (.3)	CHECK OUT ENTRY STEERING UNDER 3-SIGMA DISPERSION IN GAMMA PLUS EXTREME CONSTANT L/D VARIATION.	FROM START OF ENTRY (ALT. OF 400,000 FT) TO MACH = 0.5 APPROX. THE AGC WAS INITIALIZED AT A NOMINAL GAMMA OF -7.12 DEG. AND THE ENVIRONMENT AT A GAMMA OF -6.76 DEG. THE DYNAMICS SIMULATION WAS PERTURBED TO USE AN L/D OF 0.3.	ENTRY OVERSHOT THE TARGET BY 139 N.M.. THE LATERAL MISS WAS 26.4 N.M. AND A MAX OF 7.3 G WERE PULLED.	54
2A-2	ENTRY WITH HIGH FLIGHT PATH ANGLE (-7.50 DEG) AND LOW L/D (.3)	CHECK OUT ENTRY STEERING UNDER 3-SIGMA DISPERSION IN GAMMA PLUS EXTREME CONSTANT L/D VARIATION.	FROM START OF ENTRY (ALT. OF 400,000 FT) TO MACH = 0.5 APPROX. THE AGC WAS INITIALIZED AT A NOMINAL GAMMA OF -7.12 DEG. AND THE ENVIRONMENT AT A GAMMA OF -7.50 DEG. THE DYNAMICS SIMULATION WAS PERTURBED TO USE AN L/D OF 0.3.	ENTRY WAS SHORT OF THE TARGET BY 361 N.M. THE LATERAL MISS WAS 19.6 N.M. AND A MAX OF 10.9 G WERE PULLED.	54
2A-3	ENTRY WITH LOW FLIGHT PATH ANGLE (-6.76 DEG) AND HIGH L/D (.43)	CHECK OUT ENTRY STEERING UNDER 3-SIGMA DISPERSION IN GAMMA PLUS EXTREME CONSTANT L/D VARIATION.	FROM START OF ENTRY (ALT. OF 400,000 FT) TO MACH = 0.5 APPROX. THE AGC WAS INITIALIZED AT A NOMINAL GAMMA OF -7.12 DEG. AND THE ENVIRONMENT AT A GAMMA OF -6.76 DEG. THE DYNAMICS SIMULATION WAS PERTURBED TO USE AN L/D OF 0.43.	ENTRY WAS SHORT OF THE TARGET BY 19.8 N.M. THE LATERAL MISS WAS 17.7 N.M. AND A MAX OF 5.9 G WERE PULLED.	54
2A-4	SHALLOW ENTRY (LOW FLIGHT PATH ANGLE OF -5.5 DEG.)	CHECK OUT ENTRY STEERING FOR A SHALLOW, LIFT-DOWN ENTRY.	FROM START OF ENTRY (ALT. OF 400,000 FT) TO MACH = 0.5 APPROX. BOTH THE AGC AND ENVIRONMENT WERE INITIALIZED FOR A GAMMA OF -5.5 DEG.	ENTRY SPLASH WAS WITHIN 1 NAUTICAL MILE OF THE DESIRED TARGET IN BOTH LATERAL AND CROSS RANGE. A MAXIMUM OF 3.9 G WAS PULLED.	54

RUN NO.	DESCRIPTION	OBJECTIVE	REMARKS	RESULTS	REVISION
2A-5	ENTRY WITH LOW FLIGHT PATH ANGLE (-6.97 DEG) AND LOW L/D (.3)	CHECK OUT ENTRY STEERING UNDER 3-SIGMA DISPERSION IN GAMMA PLUS EXTREME CONSTANT L/D VARIATION.	FROM START OF ENTRY (ALT. OF 400,000 FT) TO MACH = 0.5 APPROX. THE AGC WAS INITIALIZED AT A NOMINAL GAMMA OF -7.12 DEG. AND THE ENVIRONMENT AT A GAMMA OF -6.97 DEG. THE DYNAMICS SIMULATION WAS PERTURBED TO USE AN L/D OF 0.3.	ENTRY OVERSHOT THE TARGET BY 54.6 N.M. THE LATERAL MISS WAS 35.6 N.M. AND A MAX OF 10.3 G WERE PULLED.	54

RUN NO.	DESCRIPTION	OBJECTIVE	REMARKS	RESULTS	REVISION
2B	NOMINAL RUN FROM S4B SEPARATION TO SPLASH, WITH SPS1 BURN INHIBITED	DEMONSTRATE EFFECT OF NO SPS1 BURN ON MISSION PROFILE.	S4B SEPARATION OCCURS AT L/O + 12,430 SECS. SPS1 BURN IS INHIBITED VIA AN ENGINE FAILURE, CAUSING A DELTA V ALARM. 20 SECONDS LATER, THE SPS1 CUT-OFF LOGIC IS ENTERED JUST AS IF THE SPS1 CUT-OFF CONDITIONS WERE MET.	AS A RESULT OF NOT PERFORMING THE 1ST BURN, THE APOGEE WAS LOWER (8987 VS. 9887 N.M.), THE 2ND BURN LASTED LONGER (289 VS 262 SEC), AND ENTRY WAS VERY MUCH THE SAME AS RUN 1D-1.	51
2D	LATEST POSSIBLE ABORT TO THE ATLANTIC TARGET.	CHECK UPLINK ABORT AND 202 ABORT PROGRAM.	UPLINK ABORT AT 593 SEC. SEPARATION AT 610 SEC. THIS IS THE LATEST AFTER LIFT-OFF AT WHICH AN ABORT CAN BE MADE TO THE ATLANTIC SPLASH POINT.	ABORT BURN LASTED ONLY 7 SEC BECAUSE ABORT WAS SO LATE. THE DESIRED SPLASH POINT WAS ACHIEVED TO WITHIN 1 N.M.	50
2E	NOMINAL PROFILE FROM PRELAUNCH INTO BOOST WITH NO GRR OR L/O RECEIVED BY AGC. UPLINK BACK UP BY V 75 E 2 E AT L/O + 15.27 SECS.	DEMONSTRATE THAT BOTH GRR AND L/O ARE BACKED UP BY UPLINK COMMAND.	FROM 10 MINUTES OF PRELAUNCH TO L/O + 545 SECS. THE UPLINKED LIFTOFF BACK UP ZEROS THE AGC CLOCK AT 15.27 SECS AND INITIATES THE BOOST MONITOR SEQUENCE 15.27 SECONDS LATE. THE AVERAGE G ROUTINE IS IN ERROR THROUGH MISSING ABOUT 15 SECS OF THRUST DELTA V, AND THE TARGETS ARE IN ERROR BY 15 SECS OF EARTH ROTATION.	THE PRELAUNCH PROGRAM RELEASED THE PLATFORM AT 15.36 SECS AND STARTED THE AVERAGE G ROUTINE. THE MAXIMUM POLL MONITOR ERROR WAS 14.6 DEGS AND MAXIMUM PITCH MONITOR ERROR WAS 11.4 DEG. AT AGC LIFT-OFF. THE POSITION ERROR WAS 2302 FT AND VELOCITY ERROR WAS 147.8 FT/SEC.	54

RUN NO.	DESCRIPTION	OBJECTIVE	REMARKS	RESULTS	REVISION
2F	DE-ORBIT JUST AFTER S4B SEPARATION IN ORBIT.	DEMONSTRATE CAPABILITY OF MISSION CONTROL PROGRAM LOGIC TO RETURN TO EARTH SHORTLY AFTER A SEPARATION IN ORBIT.	S4B SEPARATION OCCURS AT L/O + 695 (JUST AFTER 1ST S4B BURN CUT-OFF). SPS1 BURN IS INHIBITED VIA AN ENGINE FAILURE (GROUND CUT-OFF), CAUSING A DELTA V ALARM. 20 SECS LATER, THE SPS1 CUT-OFF LOGIC IS ENTERED. SINCE TEENOM CONTAINS 30 MIN AND A DE-ORBIT P AND E ARE USED INSTEAD OF THE NOMINAL SPS2 P AND E. SPS2 BURN PERFORMS THE DE-ORBIT.	SPS2 IGNITION OCCURRED 9 MINUTES AFTER SPS1 DELTA V CUT-OFF. THE BURN LASTED 74 SECS. THE ENTRY MISS WAS 8600 N.M. (AFRICA).	54
2G	ABORT BURN TO THE CORRECT ATLANTIC TARGET.	CHECK UPLINK ABORT AND 202 ABORT PROGRAM. VERIFY THAT THE ABORT KEYCODE CAN BE RECEIVED WITHIN 1.7 SECS AFTER SEPARATION.	SEPARATION AT 552 SEC. UPLINK ABORT LATER.	THE 202 ABORT PROGRAM AND CONSTANTS SEEMED TO WORK WELL FOR THE 501 BOOST TRAJECTORY. THE DESIRED SPLASH POINT WAS ACHIEVED WITHIN 1 N.M. THE ABORT BURN LASTED 78 SECS.	54