BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Apollo Spacecraft Acoustical Environment - Case 320

DATE: October 2, 1967

FROM: T. A. Bottomley, Jr.
R. K. Chen
R. D. Raymond

ABSTRACT

The current effort for assessing the Apollo spacecraft acoustic environment is reviewed. The analytical results obtained by MSC and the flight test result from the AS-202 mission are summarized briefly. The proposed plan for collecting additional data on the AS-501 mission and the desirable data collection periods are outlined. The decision to provide the instrumentation for making noise measurements on AS-502, instead of AS-501, is noted.

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MEMORANDUM FOR FILE

I. INTRODUCTION

The status of the current effort to assess the Apollo spacecraft acoustical environment is reviewed in this memorandum. An overall analysis, with particular emphasis on the "Apollo launch noise", was made by MSC over a year ago (prior to the AS-202 mission).

The Apollo spacecraft acoustical noise environment of interest is given in Sec. II. The results of the analysis made by MSC are reviewed briefly in Sec. III, and compared with the flight results obtained from the AS-202 mission which is described in Sec. IV. The current plan for collecting similar data for the AS-502 mission is described in Sec. V which also contains recommendations for the particular periods of interest for data collection during the mission.

II. APOLLO SPACECRAFT ACOUSTICAL ENVIRONMENT OF INTEREST

There are three major areas where the Apollo spacecraft acoustical environment could have an impact. These are (1) the physiological area, (2) communications, and (3) equipment (vibration).

The sources of the acoustical noise are propulsion devices, aerodynamic effects, and on-board equipment. Typical of the latter are fans, inverters, gyros, pumps, and valve orifices.

For the purpose of data collecting, the following phases of an Apollo mission would be of interest.

(1) CM during boost phase - suited crew,

(2) CM during coast phase - suited crew,

(3) CM during coast phase - in shirt sleeves

(4) CM during RCS and SPS burns - suited crew,

(5) CM entry phase - suited crew,

(6) LM descent phase - suited crew,

(7) LM lunar stay phase - suited crew but with helmet off,

(8) LM ascent phase - suited crew, and

(9) EVA activity - suited using the PLSS.

Both crew compartment and suit circuit levels should be measured.

III. Recently Published Data "Appraisal of Apollo Launch Noise"

An article authored by Mr. B. O. French, formerly of the Crew System Division at MSC, appeared in the July 1967 issue of Aerospace Medicine. Although the article was published recently, the work on which it is based is more than one year old since Mr. French has been on leave from MSC for more than a year. The background information contained in the article was reviewed previously* after discussions with Mr. French. The new information in the article is from the results of an Air Force study of the effects of low frequency noise on man.

It should be noted that the noise environment discussed in the article does not distinguish between the Saturn IB and Saturn V launch vehicles. In addition, the data presented are extrapolations of data collected from a small number of Saturn I boiler plate ground tests and flights, and wind tunnel tests (scale model). Recorded data from Saturn IB flights, in particular the AS-202 mission, were not incorporated into the article. A comparison between the data presented in the article and the flight data collected on AS-202 indicates that the agreement is relatively poor. In general, Mr. French's prediction of the crew compartment noise levels is consistently on the high side by one order of magnitude (i.e., 10 db).

The estimates are, at best, a prediction based on a model which only approximates the Saturn V configuration. In order to prove the accuracy of the model, additional flight test data are needed.

IV. AS-202 FLIGHT TEST DATA

Two microphones were used on the AS-202 mission to collect acoustical noise data in the CM cabin. A brief summary report of the test results is given in the AS-202 post flight summary report (pp. 7-369 to 7-377). The recording periods are shown in the

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*T. A. Bottomley, Jr. and R. K. Chen, "Trip Report - Acoustical Environment of Apollo Spacecraft", Bellcomm Memorandum for File, April 29, 1966.

attached table (table 2.0-1). Comparing the data recording periods during the AS-202 mission with the desired periods given above, the following data are lacking:

(1) CM ECS suit circuit data,

(2) LM related data, and

(3) PLSS data.

It should also be noted that only selected data are presented in the AS-202 report; that is, emphasis was placed mainly on the boost phase results.

Mr. Frank Rotramel of MSC/IESD provided the following information concerning the instrumentation of the AS-202 test flight. This was not described in the summary report.

(1) The microphones used did not have omni-directional characteristics; the principal axes of the microphones were pointed towards the apex of the CM.

(2) The design of the microphones provides for decoupling the sensors from the mechanical mounting arrangement.

(3) The microphones were turned on all the time during the entire flight, however, the recorder was turned on and off by the programmer.

(4) The onboard data storage recorder was used. Since this recorder has multiple tracks, other data were recorded at the same time. Therefore, the freedom of selecting the desired recording periods for the acoustical data was limited by the time periods of interest to other users of the machine.

V. SATURN V ACOUSTICAL ENVIRONMENT

The acoustical noise environment in the CM is expected to be different for missions in the AS-500 series as compared to the AS-202 mission. The principal differences would occur during the following phases of the mission:

(1) Boost phase - Saturn V launch vehicles will be used instead of the up-rated Saturn 1 launch vehicles.

(2) A second burn of the S-IVB stage will occur during missions in the AS-500 series. The acoustical noise for the S-IVB second burn may be different from that of the S-IVB first burn because of the change in mechanical environment (e.g., mass distribution with partially empty tank).

(3) Reentry phase - The CM will experience higher dynamic pressure during the reentry phase of AS-501 and AS-502 test missions and subsequent lunar missions. The initial reentry velocity will be 36,000 ft/sec instead of 27,000 ft/sec for the AS-202 mission.

One particular reason for the need to know the acoustical environment of spacecraft that are launched on Saturn V vehicles was given by Mr. D. Hudson of the Flight Crew Support Division (FCSD) at MSC. He would like configuration of existing Saturn V predictions by obtaining flight data. These data would then be used in simulation training of the astronauts. His argument seems based largely on uncertainties regarding the dynamic range and response of the onboard sensors used in the AS-202 mission.

A set of acoustical test equipment, in kit form, has been designed to be carried on either AS-501 or AS-502 test missions. Because of the schedule restriction on the AS-501 mission, it has been decided that the test equipment will be installed in CSM spacecraft 020, which is assigned to the AS-502 mission at present. The following information concerning the acoustical test was obtained from Mr. Rotramel and Mr. W. T. Sleeman of KSC:

(1) The same type of instrumentation used on the AS-202 flight with the exception of the high range microphone, has been provided in the kit.

(2) Instead of the crystal microphone made by Gulton Industries, a dynamic type microphone made by LTV is provided as the high range microphone. This microphone is similar in design to the low range microphone.

(3) The measurement numbers assigned to the test are (a) CK0324, covering sound pressure range from 70-110 dB of the low range microphone, and (b) CK0334, covering sound pressure range of 100-140 dB of the high range microphone.

(4) The detail description of the test is given in NAA Drawing No. B16-880303.

(5) The capacity of the recording tape is approximately 30 minutes. The present planning is to record the acoustical measurements between T-3 hrs. and T-0 via an A2A cable hardwired between the CM and the Manned Spacecraft Operations Building (MSOB). The exact recording periods during the flight are not known. The attached Table 3-1 shows the recording periods that were planned for the AS-501 mission, also shown on the

table are the recording periods desired by the authors which would remain the same by the "event" count.

T. A. Bottomley, Jr.

R. K. Chen

R. D. Raymond

2031-TAB
2034-RKC-dlb
2031-RDR

Attachment
(Table)

TABLE 2.0-I.- MISSION EVENTS AS-202

Event	Range time, sec		Difference, (actual minus nominal), sec	
	Nominal	Actual		
Range zero 17:15:32 G.m.t.				
First motion	0.5	0.7	0.2	
Lift-off	0.7	0.9	0.2	Recorded
OECO	144.6	143.5	-1.1	
S-IB/S-IVB separation	145.2	144.2	-1.0	
S-IVB ignition	146.7	145.6	-1.1	
LES jettison	170.7	170.5	-0.2	
S-IVB cutoff	602.3	588.5	-13.8	
RCS direct ullage on	610.8	597.0	-13.8	
S-IVB/CSM separation	612.5	598.7	-13.8	
+X translation on	613.3	600.0	-13.3	
Start maneuver for first SPS burn	616.0	603.6	-12.4	Recorded
SPS on (first burn)	623.3	609.7	-13.6	
SPS off (first burn)	841.1	825.6	-15.5	
Start maneuver to local vertical	848.9	837.1	-11.8	
Apogee	2478.0	2474.0	-4.0	
+X translation on	3941.6	3926.1	-15.5	
SPS on (second burn)	3971.6	3956.1	-15.5	
SPS off (second burn)	4061.2	4044.5	-16.7	
SPS on (third burn)	4071.2	4054.5	-16.7	
SPS off (third burn)	4074.2	4057.5	-16.7	
SPS on (fourth burn)	4084.2	4067.5	-16.7	
SPS off (fourth burn)	4087.2	4070.5	-16.7	
Start maneuver to CM/SM separation attitude	4203.2	4188.2	-15.0	Recorded
CM/SM separation	4273.4	4264.0	-9.4	
Start maneuver to entry attitude	4280.8	4272.2	-8.6	
Entry	4358.4	4348.0	-10.4	
Begin blackout	4418.7	4416.0	-2.7	
0.05g	4435.1	4426.9	-8.2	
End blackout	5010.8	5008.0	-2.8	
Forward heat shield jettison	5196.1	5218.3	22.2	
Drogue parachute deployment	5197.1	5219.9	22.8	
Main parachute deployment	5247.8	5268.2	20.4	
Splashdown	5574.7	5582.2	7.5	

Table 3-1. AS-502 Mission/Discrete Events Summary

	Event	Time From Lift-off (hr:min:sec)	
	Saturn V Ascent to Orbit		
RECORDED	Liftoff	00:00:00.00	RECORDING DESIRED
	S-IC Inboard Engine Cut-off	00:02:25.51	
	S-IC Outboard Engine Cut-off	00:02:30.10	
	S-II Engine Ignition	00:02:31.40	
	S-IC Interstage Jettison	00:03:01.95	
	LES Jettison	00:03:05.95	
	S-II Engine Cut-off	00:08:37.48	
	S-IVB Engine Ignition	00:08:37.98	
	S-IVB Engine Cut-off	00:11:10.13	
	Earth Parking Orbit		
	Start Earth Parking Orbit	00:11:10.13	
	Start Second Orbit Revolution	01:38:34.80	
	Start S-IVB Attitude Orientation and Preignition Sequence	03:06:07.00	
	Second S-IVB Burn		
	S-IVB Engine Ignition	03:11:44.20	RECORDING DESIRED
	S-IVB Engine Cut-off	03:16:54.91	
	Coast to First SPS Burn		
	Begin Reorientation to Cold Soak Attitude	03:16:54.91	
	End of Reorientation to Cold Soak Attitude	03:19:59.23	
	CSM/S-IVB Separation	03:26:56.61	
	Begin Reorientation to First SPS Ignition Attitude	03:27:04.91	
	End of Reorientation to First SPS Ignition Attitude	03:27:30.84	
	First SPS Burn		
	SPS Engine Ignition	03:28:34.91	
	SPS Engine Cut-off	03:28:58.84	
	Earth Intersection Coast		
	Begin Reorientation to Cold Soak Attitude	03:28:59.68	
	End of Reorientation to Cold Soak Attitude	03:29:25.61	
	Apogee	05:48:42.67	
	Begin Reorientation to Second SPS Ignition Attitude	08:01:09.29	
	End of Reorientation to Second SPS Ignition Attitude	08:01:40.96	
	RCS Thrusters On	08:14:08.57	
	Second SPS Burn		
	Second SPS Engine Ignition	08:14:38.57	RECORDING DESIRED
	Second SPS Engine Cut-off	08:19:03.99	
	Begin Reorientation to CM/SM Separation Attitude	08:19:45.19	
	End of Attitude Orientation, Coast to CM/SM Separation	08:19:59.53	
	CM/SM Separation	08:21:40.09	
RECORDED	Start CM Attitude Orientation for Entry	08:21:45.09	
	End of Attitude Orientation, Coast to Entry	08:22:03.01	
	Atmospheric Entry		
	400,000-Ft Altitude	08:23:05.06	
	Enter Communications Blackout	08:23:31.06	
	Exit Communications Blackout	08:25:19.06	
	Drogue Parachute Deployment	08:37:29.45	RECORDING OPTIONAL
	Main Parachute Deployment	08:38:19.46	
	CM Splash	08:43:30.17	

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