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APOLLO

GUIDANCE AND NAVIGATION

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Average Power Profiles For Apollo
Guidance and Navigation In The Command
Module and Lunar Excursion Module (U)

by

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AVERAGE POWER PROFILES FOR APOLLO
GUIDANCE AND NAVIGATION IN THE COMMAND
MODULE AND LUNAR EXCURSION MODULE

The accompanying tables summarize the average power and energy as a function of time and Apollo mission phase for the Block 2 Command Module and Lunar Excursion Module Guidance and Navigation equipments as defined in the G&N System Status Report.*

The values reported are center value (average) estimates. They are the latest expected values and should not be taken as "not to exceed" extremes.

Transient peaks of power occur at higher levels during turn-on and slewing operations. These are not included but are estimated to consume negligible energy. Data on these peaks will be published soon.

All power and energy numbers are those drawn from the spacecraft's primary supplies assumed exactly at the nominal 28 volt level.

Two charts are given each for the Command Module and Lunar Excursion Module Guidance and Navigation Systems.

A. Power Profile

This is a tabular listing of average power against time. The column entitled mission phase contains the various phases of the nominal mission time line identified below. The mission event column denotes a particular occurrence at each listed time. For convenience, elapsed time is recorded in both hours and minutes. Associated

* MIT/IL Report E-1142, Rev. 18, March 15, 1964 (Confidential)

with each activity (or group of recurrent activities) is a beginning and an ending time. The "X" in columns 1 through 7 marks the AGE equipment in operation during each activity. Column 8 is the power level for the operating mode of the G&N activity. Columns 9 and 10 are self-explanatory.

B. Power and Energy Summary

This summarizes power and energy as a function of G&N activity and equipment identification.

The column labeled "G&N Activity" describes the operation configuration of the G&N system in words and gives associated power and total time in each configuration. The first row identifies the operating elements of the G&N system as selected by the "on-off" switches. Numbers at the intersections are total average energy consumption in kilowatt hours.

Command Module G&N

Table I is a chronological power profile and mission time-line for the Block 2 Guidance and Navigation equipment in the Apollo Command Module.

Table II is a power and energy summary of the data in Table I.

The mission time-line upon which these tables are based is a "14-day" mission listed in the enclosure to North American Aviation, Inc. , letter 64MA3540, dated March 12, 1964, submitted to MIT as the required electrical power design mission.

The operating details of the G&N system throughout the Command Module mission were based upon the following:

- (1) Alignment of IMU: Considering expected platform coarse-alignment and fine-alignment times and the time required to acquire and "mark" the necessary

alignment stars, the time of fifteen (15) minutes for alignment of the platform in midcourse was established. Similar considerations were employed to define the alignment updating time interval of five (5) minutes.

- (2) Optical Measurements: The time required for mid-course star-landmark measurements (Sextant) was defined to require ten (10) minutes. The time available for telescope tracking was assumed to be the time that the landmark was visible, i. e., nearly horizon to horizon passage. This was calculated to be five (5) minutes for Earth Orbit and thirteen (13) minutes for Lunar Orbit. The number and frequency of optical measurements were based upon guidelines established by the Space Guidance Analysis Division.
- (3) Second Computer Update: Since the Block II G&N System has two computers, a time of one (1) minute was available to update the second computer after each sextant sighting, landmark tracking, and star occultation. For similar considerations the second computer was turned on for an additional fifteen (15) minutes prior to each major maneuver and throughout the maneuver to provide emergency backup. The major maneuvers are defined as ascent, translunar injection, lunar orbit injection, transearth injection, and entry.
- (4) ΔV Corrections: A time of fifteen (15) minutes was established for the time necessary to accomplish and confirm each of the three ΔV corrections during transearth and translunar operations.
- (5) IMU Operation: The IMU is in operation from pre-launch until after the first midcourse correction. It is then off during periods of free-fall in order to conserve energy.

Lunar Excursion Module G&N

Table III is a chronological power profile and mission timeline for the Guidance and Navigation equipment in the Apollo Lunar Excursion Module.

Table IV is a power and energy summary of the data in Table III.

The mission timeline upon which these tables are based is that listed in the preliminary LEM Interface Control Document ICD LIS-390-2 submitted from Grumman Aircraft Engineering Corporation to MIT as the required electrical load analysis form. (The incompatibilities between this LEM mission and the former one for the command module are recognized.)

The operating details of the LEM G&N system during the LEM mission are based upon considerations similar to those for the CM G&N equipment.

TABLE I (cont) BLOCK 2 COMMAND MODULE G&N POWER PROFILE

Mission Phase	Mission Event	Minutes		G&N Activity	1 One AGC Operate 1200 watts	2 Two AGC Operate 2100 watts	3 AGC Standby 20.0 watts	4 IMU Operate 285.2 watts	5 IMU Standby 58.5 watts	6 D/C Operate 366 watts	7 Office Operate 1307 watts	8 Waits	9 Hours in Operation	10 Kilowatt Hours Consumed	
		Hours	From Launch												
Trans-lunar Coast	Complete ΔV_1	1340	22.33	Inactivity & Monitor 97.18% of the time			X		X			78.5	78.06	6.1277	
				11 Sextant Sightings 2.28% of the time					X				348.8	1.83	0.6383
			11 Computer Updates 0.22% of the time			X							268.5	0.18	0.0491
			1 Alignment 0.31% of the time		X			X					575.5	0.25	0.1439
			ΔV_2		X								405.2	0.25	0.1013
			Inactivity & Monitor 93.58% of the time				X						78.5	16.92	1.3282
			5 Sextant Sighting 4.59% of the time		X				X				348.8	0.83	0.2895
			5 Computer Updates 0.44% of the time			X				X			268.5	0.08	0.0215
			1 Alignment 1.38% of the time		X				X				575.5	0.25	0.1439
			Inactivity & Monitor 68.46% of the time				X						305.2	1.78	0.5433
			4 Sextant Sightings 25.77% of the time		X				X				575.5	0.67	0.3856
			4 Computer Updates 2.69% of the time			X							495.2	0.07	0.0347
			1 Alignment 3.07% of the time		X				X				575.5	0.08	0.0460
			ΔV_3		X				X				405.2	0.20	0.0810
			Inactivity & Monitor					X	X				305.2	0.13	0.0397
		3 Sextant Sightings 66.66% of the time		X				X				575.5	0.50	0.2878	
		3 Computer Updates 6.66% of the time			X			X				495.2	0.05	0.0248	

TABLE I (cont) BLOCK 2 COMMAND MODULE G&N POWER PROFILE

Mission Phase	Mission Event	Minutes	Hours from Launch	G&N Activity	1	2	3	4	5	6	7	8	9	10
					AGC Operate 1200 watts	Two AGC Operate 2100 watts	AGC Standby 20.0 watts	IMU Operate 283.2 watts	IMU Standby 84.5 watts	D/C Operate 346 watts	Optics Operate 130.7 watts	Watts	Hours In Operation	Kilowatt Hours Consumed
	Complete IMU Alignment	7805	130.08											
	Start Landmark Tracking	7810	130.17	Inactivity & Monitor			X					305.2	0.09	0.0275
	Finish Landmark Tracking	7823	130.38	1 Landmark Tracking	X			X		X		575.5	0.21	0.1209
Lunar Orbit Coast	Complete AGC Update	7824	130.39	1 Computer Update		X		X				495.2	0.01	0.0050
	Begin IMU Alignment	7832	130.53	Inactivity & Monitor	X			X				405.2	0.14	0.0567
	Complete IMU Alignment	7842	130.69	2 Alignments	X			X		X		575.5	0.16	0.0921
Injection into Equal Period Orbit	Begin LEM Injection to Equal Period Orbit	7872	131.20	LEM Checkout & Separate from C.M.	X			X				405.2	0.51	0.2067
	Begin Transfer to 50,000 feet	7872.6	131.21	Injection into Equal Period Orbit	X			X				405.2	0.01	0.0040
	Begin Equal Period Orbit Stay	7902	131.70	Radar Track of LEM During Transfer to 50,000 feet	X			X		X		575.5	0.49	0.2820
Equal Period Orbit Stay				Inactivity & Monitor 59.05% of the time	X			X				405.2	1.37	0.5551
				3 Landmark Trackings 28.02% of the time	X			X		X		575.5	0.65	0.3741
				3 Computer Updates 2.15% of the time		X		X				495.2	0.05	0.0248
Perilune Retro (50,000 to 10,000 feet)	Begin Perilune Retro	8041	134.02	3 Alignments 10.77% of the time	X			X		X		575.5	0.25	0.1439
	Begin Hover, Translation & Touchdown	8046.6	134.11	Perilune Retro	X			X				405.2	0.09	0.0365
	Begin LEM Lunar Surface Stay	8049	134.15	Hover, Translation & Touchdown	X			X				405.2	0.04	0.0162
LEM Lunar Surface Stay				Inactivity & Monitor 88.44% of the time	X			X				405.2	32.92	13.3392
				2 Alignments 1.56% of the time	X			X		X		575.5	0.50	0.2877
				Lunar Ascent to Circular Orbit at 50,000 feet	X			X		X		405.2	0.07	0.0284
Lunar Ascent to Circular Orbit at 50,000 feet	Start Landmark Tracking	10058.4	167.64											

TABLE I (cont) BLOCK 2 COMMAND MODULE G&N POWER PROFILE

Mission Phase	Mission Event	Time From Launch		G&N Activity	1	2	3	4	5	6	7	8	9	10
		Minutes	Hours		One AGC Operate Two AGC Operate	210 watts Operate AGC Standby	200 watts Operate AGC Standby	285.3 watts Operate IMU Standby	58.5 watts Operate IMU Standby	306 watts Operate D/C	130.7 watts Operate Office	Watts	Hours in Operation	Kilowatt Hours Consumed
Ascent Transfer to 80 n. m.	Begin Ascent Transfer to 80 n. m.	10058.4	167.64		X			X				405.2		0.0446
	Start Landmark Tracking	10065.0	167.75	Inactivity & Monitor										
	Finish Landmark Tracking	10078	167.96	1 Landmark Tracking	X			X	X		X	575.5		0.1208
	Complete AGC Update	10079	167.97	1 Computer Update		X		X				495.2		0.0050
	Begin Period of LEM Trackings	10152	169.20	Inactivity & Monitor	X			X				405.2	1.23	0.4984
Rendezvous, Docking, & Crew Transfer				Inactivity & Monitor 87.30% of the time	X			X				405.2	8.73	3.5374
				4 LEM Trackings 8.70% of the time	X			X		X	X	575.5	0.87	0.5007
				4 Computer Updates 0.70% of the time		X		X				495.2	0.07	0.0347
				4 Alignments 3.30% of the time	X			X			X	575.5	0.33	0.1899
				2 Once Per Orbit Star Occultation Sightings 32.76% of the time	X				X			178.5	1.72	0.3070
Lunar Orbit Coast	LEM Docking	10752	179.20	2 Computer Updates 0.57% of the time		X			X			268.5	0.03	0.008
				Inactivity & Monitor 66.67% of the time			X					78.5	3.50	0.2748
	Start First Alignment After Star Occultation Sightings	11067	184.45	2 Alignments 18.85% of the time	X			X		X	X	575.5	0.33	0.1899
				Inactivity & Monitor 81.14% of the time	X			X				405.2	1.42	0.5754
	Start Landmark Tracking	11172	186.20	1 Landmark Tracking	X			X		X	X	575.5	0.21	0.1209
	Finish Landmark Tracking	11185	186.41	1 Computer Update		X		X				495.2	0.01	0.0050
	Complete AGC Update	11186	186.42	Inactivity & Monitor	X			X				405.2	0.69	0.2796
	Begin Last IMU Alignment Before Trans-earth Injection	11227	187.11	1 Alignment	X						X			
	Complete IMU Alignment	11232	187.19		X			X			X	575.5	0.08	0.0460

TABLE I (cont) BLOCK 2 COMMAND MODULE G&N POWER PROFILE

Mission Phase	Mission Event	Time From Launch		G&N Activity	Power Profile																			
		Minutes	Hours		1 1200 Operate AGC	2 2100 Operate AGC	3 200 Operate AGC	4 283.2 Operate IMU	5 58.5 Standby IMU	6 39.6 Operate D/C	7 190.7 Operate Optics	8 Watts	9 Hours in Operation	10 Kilowatt Hours Consumed										
Lunar Orbit Coast	Complete IMU Alignment	11232	187.19	Inactivity & Monitor	X			X																
	Start Last AGC Update Before Trans-earth Injection	11235.6	187.26	Computer Update		X		X																
Trans-earth Injection	Begin Trans-earth Injection	11250.6	187.51	Trans-earth Injection		X																		
	Begin Trans-earth Coast to 400,000 feet	11253	187.55	Trans-earth Coast	X				X															
Begin Trans-earth Coast to 400,000 feet	Start 1st Sextant Sighting After Trans-earth Injection	11324	188.73	9 Sextant Sightings 9.33% of the time	X				X															
				8 Computer Updates 0.93% of the time		X				X														
Trans-earth Coast to 400,000 feet				Inactivity & Monitor 88.17% of the time			X																	
				1 Alignment 1.55% of the time	X					X														
Trans-earth Coast to 400,000 feet	Complete IMU Alignment	12280	204.80	ΔV_1	X				X															
	Complete ΔV_1	12303	205.05	Inactivity & Monitor 96.48% of the time			X																	
				8 Sextant Sightings 2.73% of the time	X																			
				8 Computer Updates 0.27% of the time			X																	
				1 Alignment 0.51% of the time	X																			
				ΔV_2	X					X														
				Inactivity & Monitor 95.84% of the time			X																	
				10 Sextant Sightings 3.33% of the time	X																			
				10 Computer Updates 0.32% of the time			X																	

TABLE II BLOCK 2 COMMAND MODULE G&N POWER AND ENERGY SUMMARY

		SUMMARY OF BLOCK II COMMAND MODULE ENERGY CONSUMPTION (Kilowatt Hours)							
Operating Mode	G&N ACTIVITY	1	2	3	4	5	6	7	TOTAL
		AGC Operate 190 watts 78.47 hours	AGC Operate 210 watts 79.70 hours	AGC Standby 20 watts 225.40 hours	MID Operate 285.2 watts 79.47 hours	MID Standby 28.3 watts 228.10 hours	D/C Operate 39.8 watts 19.83 hours	Offices 150.7 watts 19.83 hours	
A	Accomplish & confirm course corrections Inactivity & Monitor 405.2 watts 55.72 hrs.	6.686	-----	-----	15.891	-----	-----	-----	22.577
B	Alignments Landmark Trackings SNT Sightings 575.5 watts 12.69 hrs.	1.523	-----	-----	3.619	-----	0.503	1.658	7.503
C	Star Occultation Sightings 178.5 watts 2.90 hrs.	0.348	-----	-----	-----	0.170	-----	-----	0.518
D	SNT Sightings (Midcourse) 348.8 watts 7.16 hrs.	0.859	-----	-----	-----	0.418	0.283	0.936	2.496
E	Inactivity & Monitor 78.5 watts 217.31 hrs.	-----	-----	4.346	-----	12.713	-----	-----	17.059
F	Inactivity & Monitor 305.2 watts 8.09 hrs.	-----	-----	0.162	2.307	-----	-----	-----	2.469
G	Computer Updates Major Maneuvers 495.2 watts 2.97 hrs.	-----	0.624	-----	0.847	-----	-----	-----	1.471
H	Computer Updates 268.5 watts 0.73 hrs.	-----	0.153	-----	-----	0.043	-----	-----	0.196
	TOTAL 308.30 hours	9.416	0.777	4.508	22.664	13.344	0.786	2.594	54.089

TABLE III LUNAR EXCURSION MODULE G&N POWER PROFILE

Mission Phase	Time From Launch		LEM G&N Activity	1	2	3	4	5	6	7	8	9	10
	Minutes	Hours		AGC Off 0.0 waits	AGC Operate 105.0 waits	AGC Standby 10.0 waits	IMU Operate 297.3 waits	IMU Standby 59.3 waits	Two Radar Operate 25.4 waits	OMT (A.O.C.T.) Negligible	Waits	Hours Operation	Hours Contained
Pre-launch (countdown)	-300	-5	Inactivity	X				X			58.5	5.00	0.293
Launch and Earth Ascent	0	0	Inactivity	X				X			58.5	0.20	0.012
Earth Orbit	12	0.20	Inactivity	X				X			58.5	3.00	0.176
Translunar Insertion & Initial Coast	192	3.20	Inactivity	X				X			58.5	0.58	0.034
C.S.M. Transposition	227	3.78	Inactivity	X				X			58.5	0.50	0.029
Jettison S IVB	257	4.28	Inactivity	X				X			58.5	0.34	0.020
LEM Translunar Checkout	277	4.62	G&N Checkout		X		X		X	Negligible	427.7	1.00	0.428
Continue Translunar Trio	337	5.62	Inactivity	X				X			58.5	76.66	4.484
Insert Into Lunar Orbit	4937	82.28	Inactivity	X				X			58.5	0.10	0.006
1/2 Lunar Orbit	4943	82.38	Inactivity	X				X			58.5	1.02	0.060
LEM Checkout	5004	83.40	G&N Checkout and Initial IMU Alignment		X		X		X	Negligible	427.7	1.02	0.436
Continue Lunar Orbit	5065	84.42			X		X		X	Negligible	427.7	0.41	0.175
Separate - 100 feet	5090	84.83			X		X		X		427.7	0.02	0.009
Orient LEM	5091.3	84.85	Final IMU Alignment		X		X		X	Negligible	427.7	0.15	0.064
Insert Into Synchronous Orbit	5100	85.00	Descent Injection Guidance		X		X		X		4.277	0.01	0.004
Coast in Synchronous Orbit	5100.5	85.01	Inactivity		X		X		X	Negligible	427.7	2.04	0.873
Coast to Pericynthion	5223.1	87.05	Re-align IMU		X		X		X	Negligible	427.7	0.49	0.210
	5252.5	87.54											

TABLE III (cont) LUNAR EXCURSION MODULE G&N POWER PROFILE

Mission Phase	Minutes	Hours	LEM G&N Activity	1	2	3	4	5	6	7	8	9	10
	Time from Launch			AGC Off 0.0 watts	AGC Operate 103.0 watts	AGC Standby 10.0 watts	IMU Operate 297.3 watts	IMU Standby 58.5 watts	Radar Operate 25.4 watts	OMC (A.O.T.) Negligible	Watts	Hours Operation	Kilowatt Hours Consumed
Retro from Pericynthion	5252.5	87.54		X	X		X		X		427.7	0.07	0.030
Final Powered Descent	5256.3	87.61	Landing Guidance	X	X		X		X	Negligible	427.7	0.03	0.013
Hover to Touchdown	5258.5	87.64		X			X		X	Negligible	427.7	0.04	0.017
Post Landing & Pre-launch Checkout	5260.5	87.68		X			X		X	Negligible	427.7	1.25	0.535
One Man Explore	5335.5	88.93	G&N Checkout			X					68.5	4.00	0.274
Report	5575.5	92.93	Inactivity			X					68.5	6.00	0.411
One Man Explore	5935.5	98.93	Inactivity			X					68.5	4.00	0.274
Report	6175.5	102.93	Inactivity			X					68.5	6.05	0.414
Pre-launch Preparation	6538.8	108.98	IMU Alignment		X		X		X	Negligible	427.7	1.67	0.714
Powered Ascent	6638.8	110.65	Ascent Guidance		X		X		X		427.7	0.10	0.043
Orbit Contingency	6644.8	110.75	Inactivity		X		X		X	Negligible	427.7	0.50	0.214
Orbit Contingency	6674.8	111.25	Inactivity			X					68.5	15.70	1.075
Orbit Contingency	7616.8	126.95	Midcourse Measurement		X		X		X	Negligible	427.7	1.5	0.642
Inject Into Transfer Orbit	7706.8	128.45	Transfer Orbit Guidance		X		X		X		427.7	0.00 ⁺	0.000 ⁺
Coast in Transfer Orbit	7706.9	128.45	Midcourse Measurements & Corrections		X		X		X	Negligible	427.7	0.97	0.415
Rendezvous From 20 N. Miles	7764.9	129.42	Rendezvous Guidance		X		X		X	Negligible	427.7	0.40	0.171
Dock	7788.9	129.82	Monitor		X		X		X	Negligible	427.7	0.25	0.107
Crew Transfer	7803.9	130.07	Inactivity								0.0	0.33	0.000
	7823.9	130.40											

TABLE IV LUNAR EXCURSION MODULE G&N POWER AND ENERGY SUMMARY

Mode	LEM G&N Activity	Summary of Lunar Excursion Module Energy Consumption in Kilowatt Hours							Total
		1 AGC Off 0.0 watts	2 AGC Operate 103.0 watts 11.91 hours	3 AGC Standby 10.0 watts 35.75 hours	4 IMU Operate 297.3 watts 11.91 hours	5 IMU Standby 58.5 watts 123.15 hours	6 Two Radar CDU Operate 25.4 watts 11.91 hours	7 (A.O.T.) Negligible Operate 27.43 hours	
I	Inactivity 87.40 hours 58.5 watts	0.000	—	—	—	5.113	—	—	5.113
II	Inactivity Alignment Midcourse Measurements 11.72 hours 427.7 watts	—	1.231	—	3.484	—	0.298	Negligible	5.013
III	Guidance During Major Event 0.20 hours 427.7 watts	—	0.021	—	0.059	—	0.005	—	0.085
IV	Inactivity 20.05 hours 68.5 watts	—	—	0.20	—	1.173	—	—	1.373
V	Inactivity 15.70 hours 68.5 watts	—	—	0.157	—	0.918	—	Negligible	1.075
	Total	0.000	1.252	0.357	3.543	7.204	0.303	Negligible	12.659

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