APOLLO

GUIDANCE AND NAVIGATION

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C W S

This revision replaces the earlier edition

E-1142(REV. A)

WEIGHT AND BALANCE REPORT

(UNCLASSIFIED TITLE)

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MIT INSTRUMENTATION LABORATORY

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ABSTRACT

Report E-1142 Rev. 1 presents estimates of total weights in planned APOLLO Guidance and Navigation subassemblies. The estimate is to be revised periodically.

The balance portion of the required report is to be part of subsequent editions as soon as space allocation and form factor are firm enough to make an estimate of c. g. location meaningful. However, the general locations of the subassemblies within the spacecraft are identified to give a first estimate for balance studies.

Introduction

This revision to E-1142 is submitted in compliance with the documentation requirement for weight and balance data.

At this stage of Guidance and Navigation System design, equipment is not yet clearly enough determined in form factor to make estimates of c. g. location meaningful. Thus only weight estimates are given herein with their general spacecraft location. Future revisions will update the weight estimates and add balance and volume estimates.

Weight Estimate Summary

Table 3 tabulates the current weight estimate according to subassemblies and equipment location. Also shown on this table is a comparison with previous weight estimates given in MIT Report R-339 and the first edition of E-1142.

The subassemblies in Table 3 are identified in more descriptive detail in Table 1.

The subassemblies in Table 3 are compared on a descriptive basis with the earlier weight estimate reports in Table 2.

Table 3 does not include weight provision for spares on any of the hardware. Spares provisioning is anticipated to meet reliability goals.

Detail of Weight Growth

Table 3 shows a growth of about 130 pounds from the original estimate in September 1961. An item by item comparison shows good comparison except in the following areas .

The display and controls weight at the main navigation station have grown mainly due to more accurate identity of devices and better estimates such as including the weight of the display panel itself. Latest packaging considerations have caused the computer display to be remote from the computer proper causing penalties in structure and buffering amounting to several pounds.

The original concept in R-339 considered the IMU and optics

to be mounted on a common rigid part of spacecraft structure. The current location of these equipments in the lower bay area on the hot side of the spacecraft means a more elaborate navigation base with provision for deploying and retracting the optical devices to get adequate field of view through the thick heat shield material in this local area.

The computer has grown considerably in weight but also has grown considerably in capacity in the memory and input-output. Other causes for weight increase can be attributed to the module replacement concept and a more realistic appreciation for structure. Power estimates for the computer running at full capacity are still very small (about 30 watts) which results in a corresponding considerable reduction in spacecraft power supply weight, an advantage which does not reflect in the figures given.

All of the display on the main panel is redundant with that at the lower equipment bay and therefore is just added weight not considered before. This is an added penalty for moving the navigation station to the lower bay area. This repeat display of certain variables is necessary for periods when the astronauts are necessarily in their couches.

If one makes allowance for the earlier concept of using spacecraft structure instead of the deployable optics navigation base made necessary because of the thick heat shield material and if the redundant display caused by main navigation station relocation is considered, then the figure of 399 pounds of Table 3 could be reduced. Thus using earlier philosophy and location a figure for total weight of about 335 pounds would result.

Future Weight Expansion

Every effort will be made to keep weight reasonable and decrease weight where possible. However, future revisions to this report will reflect additions not included in Table 3 such as the optics eyepieces, the sextant optical bridge, the cabling in the lower equipment bay, and the navigation display on the main panel. Moreover, additions will be necessary to recognize provision for necessary spares.

Table 1. Identity of Equipment Reported

CDU:	Coupling Display Units; three units used as angle data interface among the IMU, AGC, and spacecraft autopilot.
IMU:	Inertial Measurement Unit; gimbal assembly, inertial components, data transducers, support structure, etc.
D&C/NAV:	Display and Control, Navigation; meters, switches, lights, etc. except as reported elsewhere. Weight includes display panel in lower equipment bay but does not include wire, clock, or optics controller gear train. The display clock is not considered part of G&N equipment even though it appears above the G&N display panel.
D&C/AGC:	Display and Control, Computer; letter and number readout, keyboard, control relays, and support structure.
M&VD:	Map and Visual Display; film viewer for display of maps, charts, procedures, etc.
NVB:	Navigation Base; rigid structure to tie together the IMU, SXT, and SCT; includes mechanism for deploying and retracting optics; bellows, and bellows frame.
SCT:	Scanning Telescope; single line-of-sight wide field two degree of freedom telescope, drives, etc. This report does not include weight of eyepiece because position of Navigator is not yet determined.
SXT:	Sextant; two line-of-sight narrow field three degree of freedom sextant, drives, etc. This report does not include weight of eyepiece nor weight of optical bridge for precision optical angle readout.
AGC:	Apollo Guidance Computer; complete computer except display and keyboard including all structure and mounting rails.
PSA:	Power Servo Assembly; IMU, SCT, and SXT servos, power supplies, and miscellaneous electronics. Does not include cold plate which is assumed part of spacecraft structure.
RAD:	Radar; complete radar, tracking radar, doppler radar, and/or altimeter necessary for earth orbit rendezvous and lunar landing.
JBX:	Junction Box; electrical interconnection center among subassemblies in lower equipment bay.
CBL:	Cabling; intra subassembly cabling in lower equipment bay. Inter equipment cabling from lower equipment bay to other assemblies is assumed a spacecraft responsibility.

Table 2. Equipment Comparison With Previous Reports

Current Descriptive Title	Report Number and Short Form Code Used		
	R-339	E-1142	E-1142 Rev.1
Coupling Display Units	(1)	CDU	CDU
Inertial Measurement Unit	IMU	IMU	IMU
Display and Controls, Navigation	DCU	D&C	D&C/NAV
Display and Controls, Computer	DCU	D&C	D&C/AGC
Map and Visual Display	(2)	M&VD	M&VD
Navigation Base	(3)	—	NVB
Scanning Telescope	OMU[4]	Scanner	SCT
Sextant	OMU[4]	SXT	SXT
Apollo Guidance Computer	Computer	AGC	AGC
Power Servo Assembly	Electronics	PSA	PSA
Radar	RDMU[5]	FAE[6]	RAD
Junction Box	Cabling	(7)	JBX
Cabling	Cabling	(7)	CBL
Miscellaneous	SFA & AMW[8]	(7)	—

Notes:

1. Stepping Motors for Autopilot Commands
2. Chart Book and Star Catalog
3. Not considered part of Guidance & Navigation Equipment
4. Optical Measurement Unit
5. Range and Drift Measurement Unit
6. Final Approach Equipment
7. Sun Finder and Miscellaneous Cabling
8. Sun Finder Assembly and Angular Momentum Wheel

Table 3. Locations and Weights Showing Comparison With Previous Reports

For this report read last column →

Subassemblies / Date of Report		R-339 Sept. 61	E-1142 Mar. 62	E-1142 (Rev.1) June 62
Lower Equipment Bay-Forward:				
	CDU	5.2	66	6
	IMU	60		60
	D&C/AGC	26		15
	D&C/NAV			39.5
	M&VD	5.2	83	8.5
	SCT	32.5		7.5
	SXT			26.5
	NVB	See Note (1)	(2)	45.8
	CBL	—	See Note (3)	See Note (4)
Lower Equipment Bay-Middle:				
	AGC	39	100	100
	PSA	39	20	24
	JBX	13	11	11
Main Panel:				
	D&C/AGC	—	—	15
	D&C/NAV	—	—	See Note (5)
Service Module:				
	RAD	32.5	40(6)	40(6)
Miscellaneous:	AMW	13	—	—
	Totals	270	320	398.8
		Pounds weight at lg		

Notes:

1. Navigation Base was assumed part of the spacecraft structure.
2. Navigation Base did not include deployable feature of optics.
3. Was included with sun finder assembly in value shown under JBX.
4. Weight not yet determined.
5. Weight cannot be determined until main panel G & N display items are accurately identified.
6. Estimated range of possible values from 10 to 70 pounds.