

BELLCOMM. INC.

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

SUBJECT: LM Weight Status
Case 310

DATE: February 16, 1968

FROM: J. L. Marshall, Jr.

ABSTRACT

At the LM Program Management Review on January 31, 1968, GAEC presented a confusing and misleading LM weight status. This memorandum explains the basis for the values presented by GAEC and shows that the presentation should have indicated a 500-pound positive margin rather than a negative 400-pound margin, relative to the "maximum flyable weight". GAEC's point that the LM weight is growing rapidly has already been recognized by the Apollo Program Office. This growth is the reason for the approval of recent specification changes.

(NASA-CR-93609) LM WEIGHT STATUS, CASE 310
(Bellcomm, Inc.) 9 P

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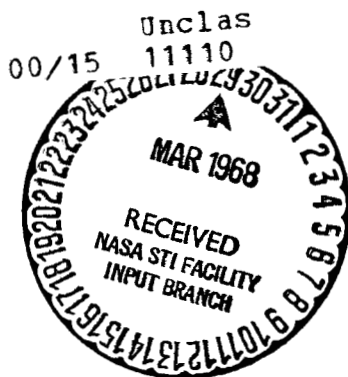
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MEMORANDUM FOR FILEINTRODUCTION

At the LM Program Management Review on January 31, 1968, GAEC presented a number of charts on the LM weight status, including the one attached as Figure 1. Dr. Mueller, among others, expressed considerable concern over two conclusions drawn from this chart: (1) the LM weight increased 470 pounds from November 1 to January 1, and (2) the LM, as of January 1, was 437 pounds over the "maximum flyable weight". No explanation was available at the meeting as to why these numbers differ from values previously presented by MSC. The intent of this memorandum is to explain the basis for these values and to clarify the confusion that resulted from the GAEC presentation.

A brief explanation of the problem was given to General Phillips at the February 2 Apollo Program Office review. Subsequently, on February 7 R. L. Wagner and the author attended a briefing on this subject by MSC to G. M. Low. Part of the material in this memorandum is based on that briefing.

CURRENT ANTICIPATED WEIGHTS

The "current anticipated weights" can be derived from the GAEC weight reports* as shown below.

	<u>November 1</u>	<u>January 1</u>
Current Separation Weight	32480.5	32967.8
Pending Changes-Category I	195.2	176.8
Category II	279.1	348.3
Category III	43.2	---
	<hr/>	<hr/>
Current Anticipated Weight	32998.0	33492.9

*GAEC LM Monthly Mass Property Status Reports for November, 1967 and January, 1968, LSR-490-50 and LSR-490-52.

The November 1 value is based on LM-4 weights, while the January 1 value is comprised of the LM-4 current weight plus LM-6 pending changes. (The GAEC report does not give the current LM-6 weight.) The 25.9 pound difference between the December 1 value derived here and the 33,467 pounds shown by GAEC at the Program Management Review is due to this combination of LM-4 and LM-6 data. It should be noted that the MSC weight reports use LM-5 as the operational spacecraft for the lunar mission.

These current anticipated weights were calculated by GAEC using the ΔV budget and minimum I_{sp} that were in effect prior to the changes that were approved in December. The former and current values are shown below.

	<u>Former</u>	<u>Current</u>
Descent ΔV Budget (fps)	7332	7180
Ascent ΔV Budget (fps)	6150	6060
Minimum Descent Integrated Average I_{sp} (sec)	296.4	299.4
DPS Usable Propellant Capacity(lb)	17,360	17,510

Two other relevant facts are as follows:

1. The current weight given in the January 1 GAEC report includes 127 pounds more descent propellant than the tank capacity, and it is clear that this capacity was further exceeded by the addition of the pending changes.
2. Some of the pending changes are quite soft, e.g., one change was reported as 4.3 to 127.7 pounds. In this case, GAEC used the larger value.

MAXIMUM FLYABLE WEIGHT

The maximum flyable weight is the maximum allowable LM weight at separation based on the amount of weight that can be landed with full descent propellant tanks and a given descent ΔV budget and I_{sp} . Figure 2 summarizes the maximum flyable weight and the current anticipated weight for several combinations of ΔV and I_{sp} . These numbers were calculated

using the rocket equation, an integrated average I_{sp} , and the conservative assumption that expendables consumed during descent were carried all the way to the surface. This agrees with the approach used by MSC in developing their "limit weights".* The anticipated weights are based on GAEC's January 1 anticipated inert weights (shown in Figure 4).

GAEC presented a maximum flyable weight of 33,030 pounds. Figure 3 summarizes the assumptions used in GAEC's calculation and those used to obtain the MSC limit weights. Although GAEC used the current ΔV budget, they used a more pessimistic I_{sp} and usable propellant capacity. As was shown in Figure 2, use of the current data yields a positive margin of over 500 pounds as opposed to GAEC's presentation of a negative margin of over 400 pounds.

Figure 4 is a summary of weights reported since MSC's December 12 weight and performance definition. For ease in comparison, all propellant calculations were based on the currently approved performance values and the method outlined above (and used by MSC, with the exception that the descent propellant tanks were loaded to meet the ΔV budget, not to capacity).

CONCLUSIONS

The rapid LM weight growth indicated by GAEC is a very real, but not new, problem. Figure 4 indicates (from MSC data) that the LM weight has grown 250 pounds from the December 12 baseline report, with pending changes of over 200 pounds. In addition, if several weight reducing changes (e.g., welding propellant tank covers) cannot be made effective until LM-6, as GAEC asserts, the MSC values (based on LM-5) will increase further.

However, GAEC's point that the current anticipated LM weight exceeds the maximum flyable weight is not correct. Their maximum flyable weight assumed the former minimum I_{sp} and less descent propellant than the usable DPS capacity, while their anticipated weight was based on the former I_{sp} and ΔV budget. The comparison was invalid on two counts: (1) the two numbers being compared were based on different assumptions, and (2) neither number used the baseline performance data presented by MSC on December 12 and approved by the Apollo Program Office.

*Apollo Spacecraft Weight and Mission Performance Definition, MSC, December 12, 1967.

Using the latter data and GAEC's January 1 inert weights yields a margin of about 500 pounds.

2013-JLM-wcs

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Attachments
Figures (4)

Copy to

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WEIGHT STATUS
LUNAR MISSION LM

	<u>1 November</u>	<u>1 January</u>
<u>Design Specification Weights</u>		
Separation	32,518	32,518
<u>Maximum Flyable Weight (1)</u>		
Separation		33,030
<u>Current Anticipated Weight</u>		
Separation	32,997	33,467 (2)

Notes: (1) Using ΔV budgets from CCA-888, current engine Isp's, and relaxing Earth Launch structural factor of safety, full Descent and RCS Tanks.

(2) Including 183 lb for anticipated changes shown on next page.

FIGURE 2

EFFECT OF ΔV BUDGET AND DESCENT I_{SP} ON LM WEIGHTS

ΔV \ Descent I_{sp}	FORMER 296.4	CURRENT 299.4
FORMER		
7332 DESCENT	32,640	32,860
6150 ASCENT	33,774	33,515
	<u>-1,134</u>	<u>- 655</u>
CURRENT		
7180 DESCENT	33,100	33,322
6060 ASCENT	33,031	32,782
	<u>+ 69</u>	<u>+ 540</u>

KEY:

LIMIT
- ANTICIPATED
<u>MARGIN</u>

NOTES:

1. Separation weights are shown. Earth launch weights are 428 pounds less.
2. Limit weights (maximum flyable weights) are based on a descent tank capacity of 17,510 pounds.
3. Anticipated weights are based on GAEC 1/1/68 inert weights, including all pending changes.

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FIGURE 3

LM LIMIT WEIGHT DIFFERENCES

	GAEC	MSC	MSC-GAEC Δ Weight
Descent Integrated Average I_{sp} (sec)	296.4	299.4	+22?
Descent ΔV (fps)	7,180	7,180	--
DPS Usable Propellant (lb)	17,441	17,510	+130
Other Differences			- 60
Touchdown Abort vs. Nominal	Nominal	TD Abort	
Expendables Carried to Surface	No	Yes	
RCS Propellant Budget			
Limit Weight (Separation)	33,030	33,322	+292

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FIGURE 4

LM WEIGHT SUMMARY

	GAEC 1/1/68	MSC 12/12/67	MAS* 1/1/68	MSC 2/2/68
<u>Ascent Inert Weight (less RCS)</u>				
Current	4808	4813	4777	4844
Δ , LM-4 to LM-5	+10		--	--
	<u>4818</u>		<u>4777</u>	<u>4844</u>
Pending Changes	+22**		+85	+25
	<u>+29***</u>		<u> </u>	<u> </u>
Anticipated	4869		4862	4869
<u>Descent Inert Weight</u>				
Current	4707	4650	4680	4712
MSC Addition Error	--		--	- 6
	<u>4707</u>		<u>4680</u>	<u>4706</u>
Δ , LM-4 to LM-5	+ 5		--	--
	<u>4712</u>		<u>4680</u>	<u>4706</u>
Pending Changes	+52**		+90	+70
	<u>- 4***</u>		<u> </u>	<u> </u>
Anticipated	4760		4770	4776
<u>LM Separation Weight</u>				
Current	32481	32331	32255	32583
Anticipated	32782		32776	32816

*Based on MSC status as of 12/29/67, plus pending changes to adjust to MSC status as of 1/19/68.

**GAEC Category I

***GAEC Category II