[redacted]

CONTRACT REQUIREMENTS	CONTRACT ITEM	MODEL	CONTRACT NO.	DATE
Exhibit E Para. 5.1	4	LEM	NAS-9-1100	15 Jan.'63

Type II - Documentation

PRIMARY # 304

[redacted]

REPORT

NO. LED-340-2

DATE: 19 June 1963

EQUIPMENT ITEM LOCATION RATIONALE FOR THE ASCENT VEHICLE [redacted]

CODE 26512

R. Seebol

PREPARED BY:

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CHECKED BY:

R. M. Carbee/J. M. Rigsby

APPROVED BY:

REVISIONS

DATE	REV. BY	REVISIONS & ADDED PAGES	REMARKS

[redacted]

[redacted]

AVAILABLE TO NASA HEADQUARTERS ONLY

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Abstract

1. This report has been prepared in fulfillment of Exhibit E of contract NAS-9-1100 and item one and two of Reference 1.

1.1 The purpose of this report is to establish a justification for locating equipment in either the inside or outside equipment bay of the ascent vehicle (reference 1). Many factors were proposed and digested as bases for such a determination by many people. The result of a discriminate analysis follows.

2.0 Summary: Factors were considered that influenced the location of equipment relative to the inside or outside equipment bays of the ascent vehicle. Examination and classification reduced the factors to those that do or do not have material bearing. Neuter factors are investigated first and catalogued. Subsequently, the minimum basic factors; i.e. weight and balance, acoustical operating level, interchangeability, lines runs and in-flight maintenance prelaunch complex considerations, were established as determining criteria.

2.1 The following rationale is based upon the present state of knowledge available and will be subject to revision.

3.0 References:

**(1) LEM-IOM-62-47H (18 Dec.'62); Technical Data Review; C. W. Rathke
(2) LED-520-1 (15 May '63); Design Criteria and Environments - LEM; A. Shreeves
(3) Space Materials Handbook (Jan. '62); LMSC
(4) LMO-520-34 (6 May '63); LEM Lunar Landing Shock Response; E. Pasyanos/A. MacKenzie
(5) Proposal for Lunar Excursion Module (4 Sept. '62)
**(6) Exhibit B (Contract NAS-9-1100; 20 Dec.'62)
*(7) LMO-340-16-004 (29 May '63); Visit to AMR; F. DeRespinis/J. Uradnisheck
**(8) LMO-610-10 (26 April '63); AMR Prelaunch Checkout Plan for LEM, D. Carew
*(9) LMO-340-18-004 (5 June '63); Equipment Location - Ground Rules; R. L. Stone
*(10) LMO-550-49 (10 June '63); Weight considerations as a function of LEM Equipment Failure - Detection Capability; K. Moran
*(11) LMO-250-34 (13 May '63); Ground Rules for IFTS and In-Flight Maintenance or Repair Provisions; T. J. Kelly

* Enclosures of the entire reference is included herein at end of the report.

** Excerpts of these references is included herein at the end of the report.

4.0 The location of equipment inside or outside the crew compartment pressure vessel is unaffected by the following considerations:

1) Mechanical shock
2) Vibration
3) Meteoroid impact
4) Acceleration & gravity
5) Radiation
6) High vacuum
7) Temperature
8) Common usage (cost item)
9) Life support equipment (limited)
10) Reliability
11) Magnetic field

A brief examination of each of the above considerations will be made to establish the reasoning for their elimination.

4.1 Mechanical shock

The effect on equipment from mechanical shock originating outside the LEM will be essentially the same regardless of the bay in which it was located. Such shocks are expected to occur as a result of earth launch, propulsion starts and stops of modules other than the LEM, lunar landing and rendezvous docking. Any anticipated mechanical shock produced on the LEM would be insufficient to adversely affect equipment regardless of which equipment bay it may be located. Neglecting catastrophic explosions as irrelavent here, internal mechanical shock is interpreted as conforming to paragraph 3.4.3.3 of reference 2.

4.2 Vibration

It is estimated that the worst case of vibration may be the result of earth launch followed by powered thrust of the other stages including LEM. (Chapter 3 of reference 3). Until the detail structure is known, and probably even then, the range of vibration that would be experienced in both bays could be considered essentially the same (reference 4).

4.3 Meteoroid impact

Meteoroid impact protection, in the form of a double wall covering both bays, is presently being considered by Vehicle Design. The shielding should be sufficient to meet the requirements of reliability specified in paragraph 1.2.9.1 of reference 5. A formula for determining the level of protection afforded by the shielding has been established in paragraph 4.2.2 of reference 2. Selective location of critical equipment could provide supplemental protection by interposing of other equipment. Additional data and background is obtainable from Chapter 8 of reference 3; and from Meteoroid Design Criteria for LEM by L. G. St Leger of MSC (March 1963) for sporadic meteoroids.

4.4 Acceleration and gravity

Gravity and other linear accelerations will produce identical effect on equipment located in either equipment bay. Angular accelerations are not expected to be of any real significance. The resultant

4.4 (Continued)

translational acceleration due to the combined effect of translational and rotational acceleration of the vehicle is not expected to reach the limit of the shock loading envelope as defined by paragraph 3.3.3.4.2 of reference 2.

4.5 Radiation

Radiation protection will be minimal for both equipment bays (paragraph 1.2.9.2 of reference 5 and paragraph 4.3.5 of reference 6). The double wall construction for micrometeorite protection (paragraph 4.3) covering both the pressure vessel and the outside equipment bay affords the radiation protection conforming with the above reference 5. However, since semi-conductors are more susceptible to radiation, units containing transistors should be located, if possible, so that other equipment may be counted upon for a further measure of protection (chapter 15, paragraph 1.1.1 of reference 4)

4.6 High vacuum

High vacuum considerations can be, virtually, eliminated because of the contractual requirement that the equipment conform to paragraph 2.2.4.2.2 of reference 6. Sealed units exposed to a small number of pressure drop cycles, will be expected to remain unaffected by them.

4.7 Temperature

The temperature range in both the inside and outside equipment bays will be essentially the same (paragraph 3.3.2.1 and 3.3.3.1 of reference 2).

4.8 Common usage

Common usage as a cost of procurement factor is not applicable here. When, and if, common usage is to connote physical conformity for the purpose of interchangeability with CM components, then it shall be considered under interchangeability (paragraph 5.4).

4.9 Life support equipment

Life support equipment, per se, could be located in either bay. It is only when in-flight accessibility is coupled with it, that life support items are restricted in location. When it occurs, the equipment location must be judged on in-flight accessibility (paragraph 5.5).

4.10 Reliability

An estimation of the over-all reliability of an item, per se, is that it would not be materially affected by location in either bay. External factors such as maintenance, redundancy and/or replaceability would improve the reliability but will be examined separately. Temperature range (paragraph 4.7), vacuum operation (paragraph 4.6), radiation

4.19 (Continued)

protection (paragraph 4.5) and meteoroid protection (paragraph 4.3) appear to be more or less equalized as far as preferential attraction to one site or another. Incremental time exposure to extreme temperature and vacuum may be a minor degree of hardship, but so is cyclic pressurization and temperature fluctuation. Water vapor presence also may create some problems.

4.11 Magnetic field

Magnetic fields originating from sources external to the LEM, will have no bearing on the location of the equipment. No magnetic shielding of the vehicle is planned as such, and whatever value may be accrued from the metallic outer walls is expected to be sufficient. Magnetic fields produced within the LEM are a potential source of communication interference and garbled signals to other equipment and/or systems. Electrical/electronic cables, equipment and operating apparatus will require a limitation of transmittable EMI. This may have to be accomplished through use of shielding and filters which are weighty. Thus, length of cable runs should be as short as possible consistent with design practices and maintenance requirements. Cable connectors will be required, but should be limited to essential areas. Use of welded, wire wrapped or crimped connections are to be considered wherever possible because of weight and reliability. (reference 7).

5.0 Influencing considerations

Weight and complexity and trade-off items which must be considered when evaluating location of equipment, with respect to inside or outside equipment bays. The size of the crew compartment pressure vessel equipment tunnel is a function of the equipment it must accommodate. Growth to accommodate more equipment inside the pressure vessel, will increase the overall weight of the LEM by creating more pressure vessel surface area. This may be attributed to two predominant reasons. Packing density will be low because of aisle space required and volume losses due to the cylindrical shape of the tunnel.

The considerations influencing the location of equipment are:

1) Prelaunch complex considerations
2) Weight and balance
3) Acoustical operating level
4) Interchangeability
5) In-flight maintenance
6) Line runs

5.1 Prelaunch complex considerations

For the purpose of this report, the following phases will be considered as prelaunch complex considerations (reference 8).

1. Acceptance tests at GAEC
2. Acceptance and functional tests at launch facility

   a. Integrated tests
   b. Assembly tests
   c. Launch pad tests

During this period which may cover the major portion of a year for any given vehicle, equipment will be installed, tested, accepted or rejected by performance, modified, retested, etc., etc. The freedom to do these things are predicted upon maximum accessibility without prejudicing the structure or other subsystems (reference 9).

5.2 Weight and balance

Stability of the LEM requires, within prescribed tolerances, that the CG be aligned with the thrust axis. This tends to limit the location of equipment in so far as it will cause misalignment of the CG. In order to circumvent this problem, to a degree, the equipment should be, if possible, so located as to balance out at the CG of the entire LEM. This is definitely preferable to correcting CG misalignment than by the use of ballast. Consumable supplies or equipment should be located as close to the CG as possible to minimize in-flight shifting of the CG as the consumables are expended. An indication of weight growth that could be prohibitive can be gleaned from reference 10.

5.3 Acoustical operating level

For the purpose of this report, the acoustical requirement concerns the noise level experienced by the astronauts (paragraph 2.4.4.7 and figure 7 of reference 6) in the cabin. An overall chart of the respective noise levels of all the equipment operating on the LEM will show what level of noise each piece of equipment produces in the cabin area. These then will be examined for combined noise levels corresponding to concurrently operating equipment. A chart listing the sound pressure levels at different frequencies has been included as Appendix II.*

5.4 Interchangeability

Interchangeability of LEM units or modules with identical items in the CM may provide for greater reliability, but it does produce some difficult problems. Should any equipment be required to conform to this consideration, it would be necessary to mount the unit in the inside equipment bay.

* At the present issue, the material for inclusion in the chart has not been correlated and will be forthcoming at the next revision.

Code 20512 Eng-23A

5.5 In-flight maintenance

In-flight maintenance and in-flight accessibility are essentially the same type of requirement. These may be subdivided three ways. First, removal, and/or replacement of modules or items. Second, in place adjustment of the equipment. Third, the transfer of consumable supplies from storage areas as they become needed (reference 11). When any of these requirements are to be accomplished, then the item must be located inside the crew compartment pressure vessel. (reference 9).

5.6 Line runs

The length of cables and piping represents another trade-off. Light weight installations of equipment in a system are valueless (weightwise) if the ensuing runs more than offset the weight advantage. Each time piping or mechanical means must penetrate the pressure vessel shell, it represents a weight penalty in structure and sealing. The reliability of the pressure vessel itself is further attenuated by each penetration of the shell. The above holds true for electrical/electronic cables which, if long, will produce more EMI. (Paragraph 4.11). The fluid mass in the case of piping and power requirements in the case of cables will increase as the runs grow longer.

APPENDIX I

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

LEM Inter-Office Memorandum

18 December 1962
LEM-IOM-62-47H

From: C. W. Rathke

To: Grumman Negotiation Management Team; LEM Distribution List "A" LEM Distribution List "B"

Subject: TECHNICAL DATA REVIEW.

Discussions were held with Mr. C. W. Mathews, with regard to priority efforts during the early stages of the LEM design period; i.e., the first three (3) or four (4) months. The priority list was divided into three (3) categories: Configurations, Systems, and Mission Plans and Test Programs. The Mathews list was compared with our individual system and subsystem engineering work statements, and the following items were agreed upon and action dates as noted:

CONFIGURATION

[illegible] Establish changes in cabin size and shape, crew [illegible] cabin-located equipment. The cabin is considered [illegible] Grumman should set up a study to develop [illegible] justify the location of equipment items inside or outside the cabin.

[illegible] Establish the arrangement of equipment, tanks and [illegible] for [illegible] center of gravity control. This must be [illegible] in coordination with item 1 above.

The [illegible] vehicle configuration freeze, three (3) months after go-ahead, will satisfy the [illegible] requirements for these two (2) items. This does include, however, a satisfactory resolution of the center of gravity problem.

[illegible] Analyze the "fire in the hole" problem, establish venting [illegible]. ASC has an empirical rule that the descent engine injector should be no less than one-half bell diameter from the end of the descent engine. North American has studied this problem in regard to service module aborts and we should consult with them. A preliminary evaluation of the magnitude of this problem is required two (2) months after go-ahead.

[illegible] Establish rationale for propulsion tank size, number and [illegible]. A trade-off study (parametric) is required here. Owen [illegible]'s group in ASC has done some of this and are continuing. ASC appears to favor four (4) cylindrical tank arrangement in the descent stage, but they are willing to discuss it. A tank total capacity trade-off study is required in one (1) month from go-ahead. This study need not include such secondary considerations as number, shape, arrangement of tanks, center of gravity, etc.

Excerpts from Exhibit B of NAS-9-1100

2.2.4.2.2 Lunar Excursion Module - Equipment which is normally operated in the pressurized cabin environment shall be designed to function for a minimum of two days in vacuum without failure. Time period in vacuum prior to operation shall be a minimum of 4 days.

4.3.7.1 System Requirements - The Environmental Control System shall provide an unpressurized space suit environment, provisions for space suits, thermal control of all Lunar Excursion Module Equipment where needed, and provisions for recharging the portable life support system. It will allow the crew to open their face plates and remove their gloves during normal operations. In the event of decompression, the crew shall close their face plates, don their gloves and continue operations unimpeded. The Environmental Control System shall meet the requirements imposed by egress and ingress. The following conditions shall be provided by the environmental control system.

Total Cabin Pressure (O_2) 5 $\pm$ 0.2 psia

Relative Humidity 40-70%

Carbon Dioxide Partial 7.6 mm Hg

Pressure (Maximum)

Temperature $75^{\circ} \pm 5^{\circ}$ F

In the event of _ _ _ _ _ _ _ .

2.4.4.7 Noise - The noise nonstressed limit shall be 80 db over all and 55 db in 600 cps to 4800 cps range. The stressed limit shall be the maximum noise level which will permit communications with the ground and between crew members of all times. The emergency limit is presented in figure 7.

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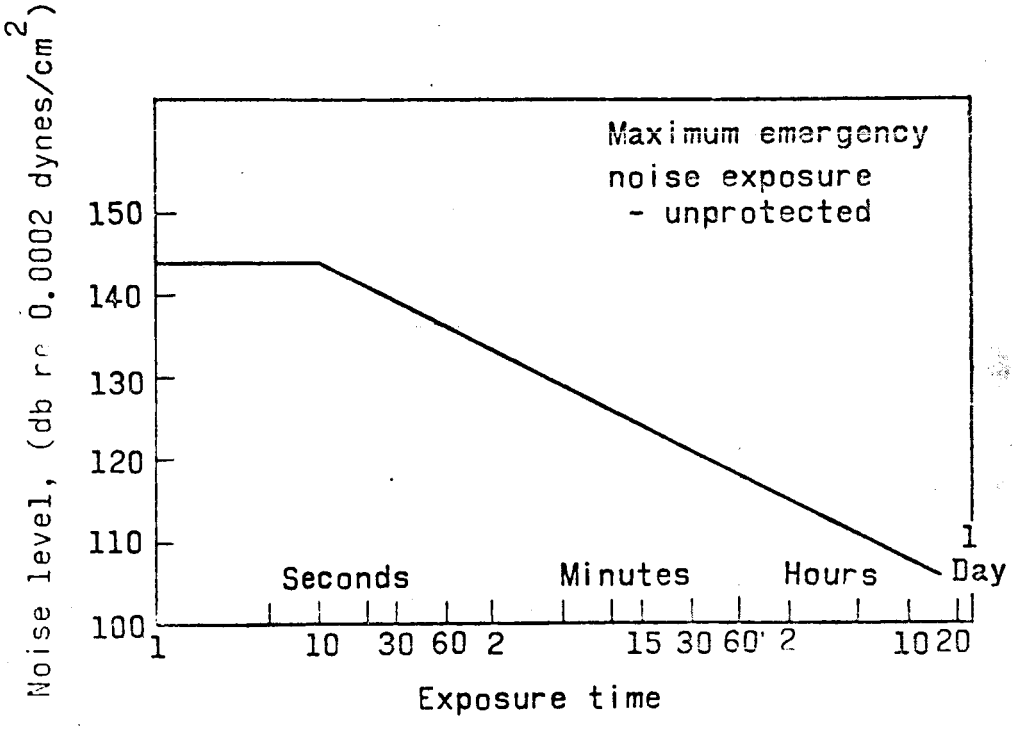

Figure 7.- Noise tolerance, emergency limit.

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

LEM ENGINEERING MEMORANDUM

LMO-340-16
004

29 May 1963

From: F. DeRespinis, J. Uradnisheck

To: LEM Distribution List "D" and "E"

Subject: VISIT TO NASA-MSC-AMR OPS - CAPE CANAVERAL ON MAY 23 AND 24, 1963.

Reference: Memo; LTM-340-7, LTM-340-9, LTM-340-12
TWX; LTX-340-3

Personnel present at meeting:
AMR Mechanical Systems Branch

Mechanical Systems

Jim C. Kirkpatrick, Reaction Control System
Al Branscomb
Jim Hiers, Environmental Control System
Mort Schler, Fuel Cells

Vehicle Integration

John Janokaitis

Electrical Systems

Ted Sasseen

Grumman Aircraft Engineering Corporation

Frank DeRespinis, Vehicle Design Integration
J. Uradnisheck, Crew Provisions
L. J. Cervellino, Resident Engineer, AMR

Summary:

The purpose of this visit was to discuss the equipment location in the LEM and its contribution to launch site checkout and maintenance. The complete agenda is included in LTX-340-3.

The outstanding requirement of the AMR personnel is that all equipment be independently accessible for checkout and for possible removal while the LEM is assembled with the CM to the booster. The proposed equipment arrangements shown on LSK-340-107 and 1032 were favorably received in that they illustrate the accessibility of all pieces without the necessity of removing another unit. Test points must be accessible not only on the electronic equipment but also on all plumbing lines. The personnel must be able to tell the Launch Officer exactly how much time is required to make a change or a repair. AMR personnel stressed stringent requirements for on-the-pad accessibility to LEM. This

would put added requirements on the adapter design to provide sufficient access panels to the LEM vehicle and once inside the adapter to provide means for access to each system. They welcomed the opportunity to discuss the equipment arrangement and its accessibility at this time. They are looking forward to additional discussions with specific system engineers when further details are uncovered.

Electronic Equipment: Faulty or broken wires will be individually replaced rather than removing the entire cable bundle. Mercury telemetry units and transducers have been replaced at least three times prior to a launch so these units must have choice access locations. Rather then replace a module, or the smallest inherently replacable assembly, or make other repairs to an installed black box, the entire black box normally would be removed for fault isolation and repair on the bench. A fresh checked-out black box would be installed in the vehicle.

It must be remembered, however, that while this technique is preferred it is based on Mercury experience where access is often less than marginal and fault isolation in the vehicle difficult. Although electrical connectors are known to be troublesome they know of no other method to satisfactorily provide quick disconnection. Wire wrapping (a method under consideration for LEM) is being introduced to them but they have had no experience in the past on which to make judgement. It is preferred that we do not color code wires or boxes. The use of white wires with black code numbers is desired. Black boxes with a lable showing name, serial number and other pertinent information, as required by specification, is sufficient for identification. Fresh batteries are installed prior to lift-off so access to these is mandatory.

Mechanical Equipment: The most troublesome items from all sources is that of rotating equipment and check valves. We cannot assume that LEM components of these types will be significantly less troublesome and they must therefore be installed for ready removal.

Plumbing: Leaks at fittings in plumbing are common so quick removal is essential. Welding of plumbing is considered satisfactory provided that a technique is proposed for quick replacement of faulty fittings while the vehicle is in the Vertical Assembly Building (VAB) or in the Arming Tower. An example of a situation is a welded tee with a welded cap. In order to take a checkout reading, the welded cap must be opened in the tee without contaminating the line, for the attachment of a GSE gage. Following the test, the cap must be replaced by welding. Two alternatives are the use of a threaded cap at all test points or a weighty and possibly less reliable transducer. Tanks must be topped off prior to lift-off so access to the filler is required. Dissimilar metal corrosion and plugged ports were frequent problems on Mercury. Expired shelf life of components has offered additional problems.

Cold Plates: The AMR personnel have had limited experience with cold plates but those in Mercury have had numerous problems, i.e., the system used water as a coolent which boiled off thru orifices which have been prone to become plugged. The boxes were bolted directly to the cold plates without the use of a thermal conductor. In other cases they were bolted directly to the structure. A

means for quickly removing our glycol lines from these plates and the plates themselves is highly desirable. They posed a question for our consideration: If all cold plates are connected in series and the outlet temperature of the glycol is too high, how will a faulty plate be isolated and removed?

Incidental Observations:

A Titan II missile launching which achieved a record 6,500 mile range with a record warhead payload attached was witnessed.

We visited blockhouses, the Mission Control Center and the S-1B Arming Tower.

We observed the capsules used by Astronaut Walter M. Schirra and by Astronaut Gordon Cooper. We also saw the MA-10 capsule in readiness for the next launch, if and when. The heat shield from Schirra's capsule was removed and was being weighed for determination of ablated material.

We observed a space and earth simulator consisting of a [illegible] foot diameter spherical segment on which was projected cloud formations and the earth geography. This demonstration was presented at night for visibility effects.

One copy of the following drawings were left with Joe Janokaitis.

LSK-340-107	Inboard Profile, Crew Provisions, Cabin Area
LSK-340-1032	Equipment Arrangement, Int. & Ext. Bay
LSK-280-10041	General Arrangement
LSK-280-10047A	General Arrangement
LSK-280-10060	General Arrangement
No number dwg.	General Arrangement, Aft Equipment Bay

FD:JU/jc

cc: John Marshall - Q. C.
H. J. Marx
J. J. Maylan
F. DeRespinis
T. H. Moorman
L. J. Cervellino
P. Gardener
E. T. Barron
P. Hewitt

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

LEM Memorandum

LMO-610-10
26 April 1963

From: D. Carew, x1521

To: LEM Distribution Lists "D", "E", "J"
RASPO, Bethpage

Subject: ATLANTIC MISSILE RANGE PRELAUNCH CHECKOUT PLAN FOR LEM

Summary:

A general checkout plan for the LEM vehicle is presented in the following discussion and accompanying table. It is not intended as a rigid document but rather as basic plan that is adaptable to the modifications necessary to meet the following objectives:

1) Functional and performance verification of the LEM system prior to integration with the CM/SM.

2) Functional and performance verification of the LEM system and inter-module interfaces when integrated with the CM/SM.

3) Functional verification of the LEM system and interfaces after assembly of the space vehicle.

4) A final verification that the LEM will perform according to design specifications just prior to initiating countdown.

The general checkout plan will be implemented by more detailed checkout plans which will specify the tests to be performed on each LEM subsystem, the test requirements, and the variations from the general plan for each specific LEM.

This memorandum is in general agreement with the "Apollo System Checkout Requirement Specification" dated March 25, 1963 and issued by NASA, MSC. Where it departs from the NASA document, it does so to assure a more complete and expeditious checkout of the LEM system prior to space vehicle assembly.

DC/ds

General Discussion

The primary purpose of all pre-launch operations is to achieve maximum assurance of astronaut safety and spacecraft functional operation for the duration of the mission. This test plan indicates the tests required on the LEM system subsequent to its arrival at AMR and prior to launch. Early LEM vehicles, which are incomplete systems and therefore require modified testing, will be tested in accordance with the applicable portions of this test plan.

Pre-launch operations may be divided into the following tests:

1) Acceptance and Functional Tests
2) Integrated Tests
3) Assembly Tests
4) Launch Pad Tests

In this series of tests each sub-system shall be verified down to that level possible without removal of equipment. These tests, however, will not probe deeper than unit replacement level. The total system shall be exercised through all modes of operation and all redundancies shall be isolated and verified.

Test Schedule

A pre-launch test schedule showing the test location and giving estimates of the time required for each test is presented on page 6.

Constraints

Prior to commencement of pre-launch operations at AMR, the LEM system will undergo acceptance testing at GAEC's Bethpage facility. The discrepancies noted in these tests will be enumerated along with the corrective action taken to eliminate them. The LEM system delivered to

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

LEM ENGINEERING MEMORANDUM

LMO-340-18
[illegible]

[illegible] June 1963

From: R. L. Stone - Crew Provisions (Ext. [illegible])

To:

R. M. Carbee	R. [illegible]	L. [illegible]	H. [illegible]
T. J. Kelly	J. [illegible]	[illegible]	W. Smith
C. W. Rathke	G. [illegible]	A. L. Reynolds	J. R. Spinner
A. B. Whitaker	D. McCl[illegible]	J. M. [illegible]	Data Management
C. Schunlein	A. Katz	G. Wie[illegible]er	LEM Project File

Subject: EQUIPMENT LOCATION - CREW [illegible]

Reference: (a) LMO-250-34, "Ground Rules [illegible] IFM [illegible] In-Flight Maintenance or Repair Provisions"

The lack of documented ground rules in certain areas pertinent to equipment arrangement has lead to some confusion among the various subsystem engineers who are considering their equipment for location in LEM. In an attempt to establish uniformity of thinking among the various groups, the following [illegible] rules which are presently being applied to equipment arranging on LEM may be [illegible]. Any comments pertinent to these basic assumptions are welcomed.

1. The pressure shell (cabin) will be used to contain only equipment which requires access by the crew during the [illegible].

2. Equipment located in the external equipment bay on the descent stage will not be accessible to the crew during the mission. Penalties involved in providing limited access on the lunar surface will be investigated if this requirement becomes necessary. It is desirable to locate as much equipment as possible in the external equipment bay for the following reasons:

(a) Greater packing efficiency (density) can be realized. This results in less structural weight for support of a given piece of equipment located outside compared to inside.

(b) Access prior to launch will be better in the external bay areas. This is evident during the CSM shop build-up, stages all the way to the launch pad with the adapter shroud installed at ARR, (access through the shroud will be provided).

(c) It benefits vehicle CG.

3. In-flight Maintenance will be considered on only critical equipment. See Reference (a). The following equipment is presently considered by subsystem engineers as potentially maintainable and is located in the cabin:

(1) PSA
(2) AGC
(3) Rendezvous Radar
(4) Landing Radar
(5) Rendezvous Radar Transponder
(6) S & C Computer
(7) Attitude Reference Assembly
(8) In-Flight Monitor Assembly

(The above equipment may require spare parts or adjustment in-flight). The following reasons make it necessary that efforts continue to minimize equipment in this category.

(1) Reduction of equipment located inside will allow a reduction in pressure shell size.

(2) A maintenance capability involves increased numbers of electrical connectors within the equipment which are an additional source of unreliability. .

(3) Maintenance imposes restraints on packaging and installation techniques.

(4) Maintenance imposes additional burdens on the crew.

(5) Maintenance requires additional complexity in the IFTS.

4. Common usage for procurement reasons may dictate that equipment on LEM and the C/M are physically and functionally identical. This in itself does not require that the equipment be located in the cabin. Only if this equipment is to be maintained in-flight or removed from LEM to provide critical emergency replacement in the C/M will it be located in the cabin.

5. Equipment which is to be jettisoned on the lunar surface will be installed in the descent stage to avoid the dead weight of its structural support on ascent.

RLS:ajp

Info cc: J. Moylan

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

LEM MEMORANDUM

June 10, 1963

LMO-550-49

From: K. Moran

To: L. Armani

Subject: WEIGHT CONSIDERATIONS AS A FUNCTION OF LEM EQUIPMENT FAILURE- DETECTION CAPABILITY.

References: (a) Procurement Specification- Modulation System, Pulse Code, Carry-On (PCM) NAA/ S & ID MC901-0141 dated 1 April 1963.

(b) Advisory Group on Reliability of Electronic Equipment, Dept. of Defense, Minutes of Eighth Meeting of Task Group No. 9, 1 October 1956, pp. 19-34

Enclosure: (A) Percent Failures Located vs. Percent Weight added for AN/APG-30 Radar Set Automatic Tester.

It has come to the attention of the LEM Reliability Control Group that a potential problem area exists with respect to the failure-detection capabilities of the PCM (carry-on GSE). It is stated in reference (a) that, "The system shall be of such design and construction that the probability of detecting a spacecraft equipment failure will be 0.9999." The problem arises because of the additional weight required to support this capability.

An analysis has been made (see enclosure A) based on the AN/APG-30 study. This study disclosed that for a 0.8896 failure-detection probability, 175 airborne test points would be required. These 175 test points would add 100% to the weight of the equipment according to reference (b). The addition was calculated on the basis of:

175 two foot test leads w/clamps, lacing, binding posts, etc.	7 lbs.
Four connectors	1 lb.
Sensors	3 lbs.
Total weight	11 lbs.

The additional fuel required is equal to 11 x 6.8 or 74.8 lbs. for a grand total of 85.8 lbs., which is equal to the weight of the original equipment.

Extrapolation of the reference (b) data reveals that for a 0.9999 failure-detection probability, an absolute minimum of 125 additional test points would be required resulting in a weight increase of 170 percent minimum.

In view of the increased emphasis placed on LEM weight control, the potential weight increase as postulated by this memo should be given careful and immediate consideration by the subsystems area concerned. The aforementioned extrapolation, which is conservative, seems to preclude the location at the component level of anything approaching 99.99 percent of the failures, though it does not necessarily exclude the determination of such a percentage of failures at a higher organizational level (e.g. assembly, unit, equipment, etc.) Units which incorporate redundancy would require an even more complex part fault-location capability in order to detect 99.99 percent of the failures thus further jeopardizing the LEM weight limitations.

KM:jm

cc: R. Mallaney
C. W. Rathke/ T. Kelly
A. Whitaker
J. Coutinho
N. Geluso
G. Wiesinger
D. Smith
J. Gerardi
W. Jasson
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R. Virgilio
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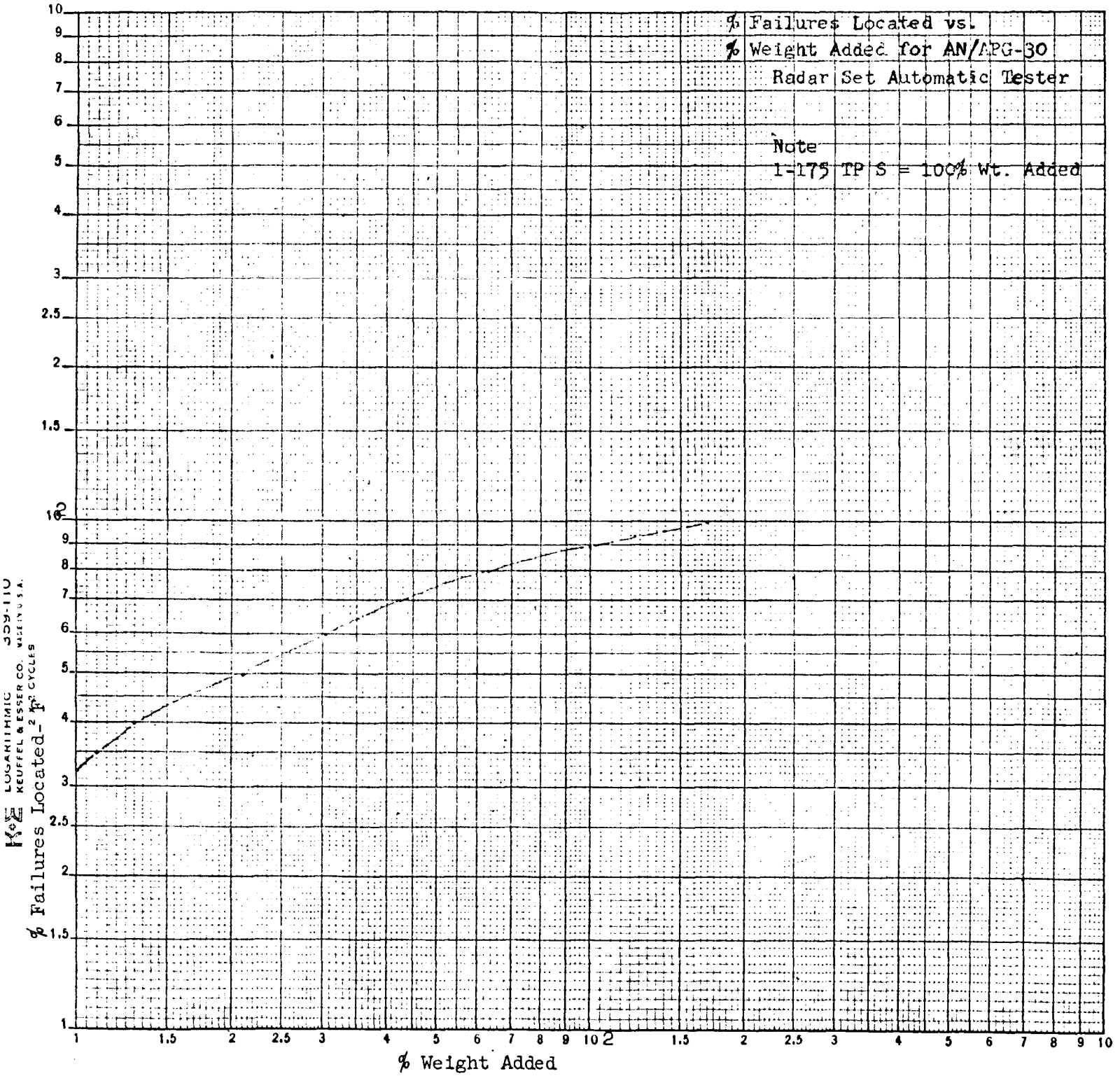
J. Johansen- RASPO
NASA-MSC- RASPO

Enclosure (A)


% Failures Located vs.
% Weight Added for AN/APG-30
Radar Set Automatic Tester
Note
1-175 TP S = 100% Wt. Added
% Failures Located
% Weight Added
W

AIRCRAFT ENGINEERING CORPORATION

ENGINEER _____ PAGE _____

SUBSYSTEM _____

DATE _____

APPENDIX II

SOUND PRESSURE (db)

600-1200	1200-2400	2400-4800	4800-10000	OVERALL			