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955 L'Enfant Plaza North, S.W.
Washington, D. C. 20024

B72 02004

date: February 14, 1972

to: Distribution

from: W. W. Ennis

subject: APS Abort Boundary in LM Descent in Apollo Lunar Landing Missions -- Case 310

ABSTRACT

The derivation of the ascent propulsion system abort boundary is briefly discussed. Actual flight performance relative to this boundary in Apollo 15 is compared with that of other lunar landing missions. A reasonable rule-of-thumb for the abort boundary during powered descent is given:

Altitude = 80 feet + 10 times the LM descent rate.

The Apollo 16 APS abort boundary will not differ significantly from that of Apollo 15.

(NASA-CR-125718) APS ABORT BOUNDARY IN LM DESCENT IN APOLLO LUNAR LANDING MISSIONS (Bellcomm, Inc.) 5 p

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MEMORANDUM FOR FILE

INTRODUCTION

The purpose of this memorandum is to explain the ascent propulsion system abort boundary (or dead-man curve) and provide a rule-of-thumb for estimating, at any point in the LM powered descent, where the curve is relative to the vehicle and the ground. The Apollo 15 descent (both the Operational Trajectory and the actual flight) is also examined with respect to the abort boundary, and the performance in this regard of Apollo 15 is compared with that of other lunar landing missions.

DERIVATION OF THE APS ABORT BOUNDARY

It should first be explained exactly what is meant by the APS abort boundary or dead-man curve. It is the boundary of the capability, defined in terms of certain standardized assumptions, to abort stage in the powered descent, dropping the Descent Stage and flying to safe orbit on the ascent propulsion system (APS) alone. The events and sequence assumed to generate the APS abort boundary are:

1. DPS thrust drops to zero during powered descent;
2. A four-second delay follows for crew response, staging, and starting the APS;
3. At the end of the delay the APS instantaneously attains full thrust and the LM attitude is vertical;
4. The LM then just clears the lunar surface.

The allowance of the 4-second delay is considered by mission planners and flight crews to be very conservative. The conditions determining the capability to abort under these assumptions are the altitude and descent rate at the instant of DPS failure.

The APS abort boundary is a "dead-man curve" only for descent propulsion system failure, as a descent can normally be aborted by throttling up the DPS to initiate the return to orbit from any altitude or time down to the BINGO point. "BINGO" is called when the DPS propellant quantity remaining is just enough for 5 seconds at full throttle, the amount required to initiate an abort. This quantity of propellants is sufficient for 20 seconds of hovering, so BINGO is a commitment point if the LM is below the APS abort boundary and has not yet landed: If the descent is not aborted at this point, the crew is committed to landing within 20 seconds.

An APS abort boundary curve is generated and is shown on an altitude vs. altitude-rate plot of the nominal descent in the published Operational Trajectory for each mission. Figure 1 is a reproduction of part of Figure 4.10-10 of the Apollo 15 Operational Trajectory, Vol. I. It shows the Operational Trajectory from low gate to touchdown and the APS abort boundary. The integrated trajectory crosses the abort boundary at about 132 feet altitude, corresponding to a time 55 seconds after low gate and 25 seconds before touchdown. The abort boundary is somewhat parabolic in shape and concave upward, as it is essentially a curve of distance vs. velocity at constant acceleration. In the interval from low gate to touchdown, however, it is so nearly straight that it is quite well represented by a linear approximation:

Altitude = 80 feet + 10 times the Descent Rate.

This is a usable rule-of-thumb, and it is shown by examination of other Operational Trajectories to be applicable to previous lunar landing missions as well as to Apollo 16.

Figure 2 is a plot of the actual Apollo 15 descent in the same region, for comparison with the abort boundary. In Apollo 15 the LM reached the abort boundary 30 seconds after low gate and remained on or below it for 70 seconds before touchdown. This early arrival and long interval are consequences of Colonel Scott's intentionally adopted technique of going down fast to a low altitude and then hovering, as opposed to the Operational Trajectory's mode of descending at a fairly rapid constant rate (5 ft/sec) from 200 feet altitude all the way to touchdown. It does not necessarily follow that Col. Scott's technique (now generally favored by flight crews and mission planners alike) increases the risks involved over some definable or attainable minimum. The Operational Trajectory provides a standard and a baseline for mission dynamics and propellant requirements, but it is an artificial construct created for that purpose and is not intended to provide a model for finding an acceptable spot on the surface and landing on it. From a practical procedural standpoint, it appears that the earliest arrival at an altitude low enough for detailed examination and

APOLLO 15 LM DESCENT, RELATIVE TO APS ABORT BOUNDARY
(TIMES INDICATED ARE SECONDS BEFORE TOUCHDOWN)

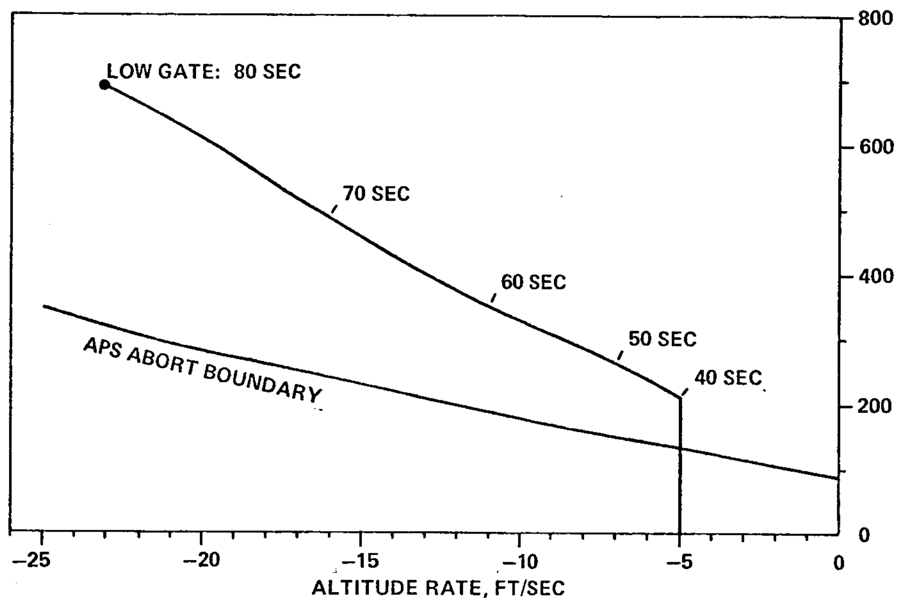

FIGURE 1 - OPERATIONAL TRAJECTORY

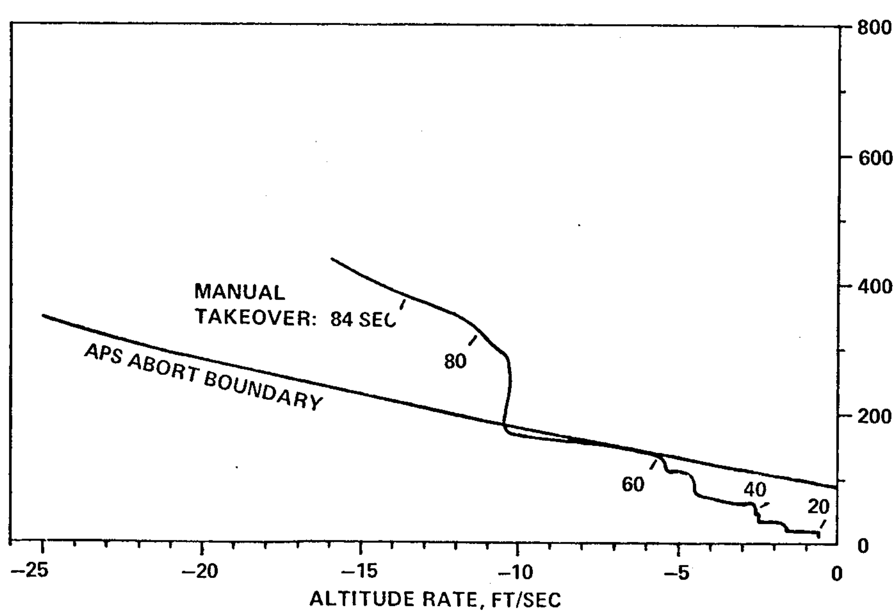

FIGURE 2 - APOLLO 15 AS FLOWN

evaluation of the lunar surface would be the most desirable. For if a certain amount of time has to be spent hovering at a low altitude, examining the surface and selecting a landing spot, then the sooner that time interval is begun the sooner it is finished and the risk of DPS failure is past. Or, if it is recognized that the hovering/searching interval's duration cannot be predicted, then the earlier it begins the more time is available for the crew to pick a spot and land.

Table I compares the times below the APS abort boundary of the lunar landing missions to date and Apollo 16.

TABLE I

MISSION	TIME BELOW APS ABORT BOUNDARY (SECONDS)	
	OPERATIONAL TRAJECTORY (To Automatic Touchdown)	ACTUAL
16	25	--
15	25	70
14	32	30
12	39	61
11	55	85

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From: W. W. Ennis

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