(NASA-CR-156515) THE IMPACT OF FREE RETURN MISSIONS ON THE APOLLO SYSTEM (Bellcomm, Inc.) 6 p

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BELLCOMM, INC.

SUBJECT: The Impact of Free Return Missions on the Apollo System - Case 310

DATE: March 28, 1966

FROM: R. L. Wagner

ABSTRACT

The LOR mode, using a free return translunar trajectory, has been the Apollo objective for a number of years. This memorandum airs thoughts on the current value of free return and on the degree to which the Apollo system has been or may be shaped by the free return requirement.

It concludes that free return is still a useful goal, that the hardware is not overdesigned in any significant respects as a result of the free return requirement, and that the software packages necessary to fly the mission will be the part of the system most directly affected by the free return requirement. In the software area there is the implied danger that the project could become committed to free return to a degree that was never intended. To avoid this danger, specific non-free return alternatives must also be designed into the software.

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MEMORANDUM FOR FILE

INTRODUCTION

The free return concept is being implemented for Apollo. Since it is a constraining element for hardware and mission planning, several serious proposals have been made to remove the free return requirement. Such was the case in connection with the ΔV budget during the spring of 1965 and again recently because of heat shield problems. This memorandum collects together some of the basic thoughts and precepts which support and surround the current position on free return. Many of these seem to get forgotten or confused each time the free return question is argued anew.

DISCUSSION

There are several rather different aspects from which to view free return. They are separately discussed in the paragraphs which follow.

Safety:

The free return trajectory provides a more comfortable contingency situation during translunar coast than does the non-free return. There is a very good chance of being able to do the necessary propulsion and guidance to return to earth while on a free return trajectory. The SM, RCS, SPS, LEM descent, and LEM RCS each have the inherent capability to provide useful propulsion and the CM RCS and LEM ascent might also be of help in dire circumstances. For non-free return missions only the SPS or LEM descent engines can provide the ΔV to effect return to earth. Also, the guidance for free return could easily be entirely manual and coached from the ground as long as the MSFN was operating properly. This could be done without a functioning platform or computer on board. For non-free return missions similarly crude techniques become less effective.

Requirements:

There are requirements on the Apollo system which are traceable to the free return mission and which are not required for other types of missions as well. One which comes to mind is the heat shield thickness which could easily be sized by the needs of free return. The thickness required for free return reentries is not much greater than for normal returns, however, and this added thickness does provide margin for more rapid abort returns. As a general rule the free return requirement results in Apollo system characteristics which are well matched to non-free return missions as well.

Performance:

The mission performance capability of the Apollo system is less when using free return than when using non-free return. The sizing of the tanks thus tends to be controlled by the desire to keep a modest free return mission capability; however, this does not result in what could be called an overdesign for the non-free return missions. All of the fuel provided is needed for reaching more remote lunar landing sites when using non-free return missions.

Mission Planning and Software:

While the Apollo system is intrinsically capable of various kinds of missions, it is specifically limited by software and understanding. Particularly for the Real Time Computer Complex, the decision to go free return could result in an undesirable degree of commitment. The specific capability for all mission types to be used should be implemented in the software.

Free return and non-free return are often spoken of as binary choices when in reality there are several other concepts of mission planning which offer interesting alternatives. Six mission strategies are briefly described in the Appendix in what is judged to be descending order of safety (and approximately increasing order of performance). Item 2 (normal free return) is the one which has been most extensively studied with Item 6 probably next.

SUMMARY

The use of free return translunar trajectories for Apollo LOR missions provides a relatively comfortable abort situation during translunar coast. The Apollo system requirements necessary to accommodate these missions are generally comparable to those for a non-free return mission. The largest known difference is in the SM fuel required to reach a given lunar landing site on an arbitrary day, in which respect the free return mission has greater requirements.

Probably the most significant impact of the free return requirement is on the development of mission plans and system software. The commitment to go free return could become irreversible a year or more before a mission if specific alternative provisions are not made in the system software.

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201-RLW-jld

Attachment
Appendix

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APPENDIX

Several mission strategies are outlined which are possible alternatives for the Apollo lunar landing mission. They each have certain attributes and certain weaknesses. The purpose of outlining these different strategies is to emphasize the fact that only the ones which are implemented in the software are available with reasonable response time.

1. Free Return Squared: In this strategy the translunar injection is such that a free return to water impact is the nominal targeted path. This is arranged by freeing the lunar approach conditions somewhat, particularly the pericynthion altitude. At a point near first midcourse, a modest burn of the SM converts to a second free return trajectory which has the correct arrival conditions at the moon but may impact land on the return leg. This strategy gives added protection against failure of the SPS at first start by providing water impact as well as free return.

2. Free Return: Most of the free return performance computations have assumed this mode. The translunar injection is such that the nominal lunar arrival conditions are the best possible for the chosen lunar landing site. Thus, the normal free return strategy provides no really convenient method of controlling the earth impact point except by midcourse burns during the coasting period.

3. Free Return/Non-Free Return: The nominal free return-type trajectory used in (2), above, can be used up to approximately first midcourse at which time conversion to a non-free return can be made. Since the energy of the desired non-free return is normally less than the free return, this strategy tends to be wasteful and therefore provides only modest benefits measured in lunar accessibility. It protects against failure of the first SPS start while obtaining this somewhat better performance.

4. Elliptical Free Return: The normal free return circumnavigates the moon, Another proposed type would return to earth without going around the moon. This generally requires a lower energy injection. At some points early in the mission (like first midcourse) the SM would add energy to cause the trajectory to circumnavigate the moon but not on a free return

trajectory. This strategy protects only against failures of the first SPS start. It does this while retaining performance nearly like that obtainable with non-free return missions.

5. Fixed Time of Flight-Non-Free Return: The non-free return mission provides two additional degrees of freedom which may be represented by translunar flight time and inclination of the plane of approach to the moon. Fixing the flight time and optimizing the inclination results in performance which varies significantly as a function of the flight time chosen. For a flight time like 90 hours, the performance is considerably better than free return but perhaps not as good as elliptical free return.

6. Variable Flight Time - Mon-Free Return: The dependence of the performance on translunar time of flight suggests making this an optimization variable. Such is found to be quite beneficial and the general rule is that westerly landing sites favor long flight times and eastern landing sites favor short flight times. The transearth flight times are optimized for all of the mission types.