NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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REPLY TO ATTN OF: FC54 (71-160)

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MEMORANDUM

TO: FC/Apollo 15 Flight Director

FROM: FC54/Lead RETRO, Apollo 15

SUBJECT: Apollo 15 Postflight Report - Addendum

The Apollo 15 Retro postflight report discusses a problem with the RTCC command load processor. Since the publication of that report, further investigation into the problem has disclosed a software error which is outlined below.

The RTCC stores data in a hexidecimal word with an associated exponent. The command processor applies an appropriate scale factor to the hexidecimal word as a function of the identity of the quantity. The command processor then converts the hexidecimal word into a 64-bit binary word for subsequent conversion to octal. However, prior to the conversion from binary to octal, the binary decimal point must be located, which is done by multiplying the scale factor with the hexidecimal exponent. The logic which controls the decimal shift cannot recognize a shift greater than 63 places. If the shift required is more than 63, an erroneous shift occurs. This then leads to an erroneous decimal point and an error between the hexidecimal and the octal data which is used for uplink.

The Apollo 15 MCC 7 ΔV_y quantity was input as zero, however, during the return-to-earth processing the ΔV_y is converted to an inertial value and then back to local vertical. The vectors used for the conversions were not exactly identical due to the RTCC integration control logic. Thus during the conversions, the MCC 7 ΔV_y of zero became a very small number. This very small number required a binary decimal shift greater than 63 places. Thus during the command load generation, the small number with a misplaced decimal became a large number. Return-to-earth solutions which have been internally generated and not manually input, have always had ΔV components that required a decimal shift less than 63 places (from all records and recollection of no command problems). The possibility of an error due to a very small ΔV component has always been potentially present.

Since the MCC 7 maneuver had also been manually input to the MPT, a command load based on the MPT was generated and uplinked without incident. However, a command load error could have occurred here also if the numbers involved in the transformation of IMU ΔV's to LVLH ΔV's would have been such to require a shift greater than 63 places. The only difference between the ΔV's which were input to the MPT and the return-to-earth processor was that the input ΔV's were in different coordinate systems (MPT wrt IMU and RTE wrt LVLH), and thus involved different transformation factors for the final LVLH ΔV's. The fact that the command load worked for the MPT and failed for the RTE was merely coincidental, and had the numbers been different the MPT command load could have been in error also.

During the simulations for Apollo 15, a RTE command load based on manually input ΔV's was never generated. The procedure involving the manual input was developed to bias the MSFN targets for execution on the onboard P23 vector, and thus keep the P23 vector "pure". However, during simulations, CSM system failures were introduced which always precluded onboard navigation and its resulting P23 vector (which is required to exercise the procedure to bias the MSFN targets). Apollo 15 was the first mission to use this biasing technique and previous missions had not required command loads to be based on manually input RTE maneuvers. The internally-generated RTE data as well as any other RTCC command data could have produced a decimal shift greater than 63 places; however, the numbers used by the command processor have been such a magnitude that the problem never occurred prior to Apollo 15.

The command load decimal shift logic, which affects all RTCC command loads, will be fixed for Apollo 16. The correction will cause decimal shifts greater than 63 places to be recognized and the binary number will be set to zero. Also, in the future, any procedure involving computer operations (RTCC or CMC) should be exercised during simulations. (If this is not possible, special time should be allotted to verify the procedure with the RTCC and the CMS and LMS.)

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