BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

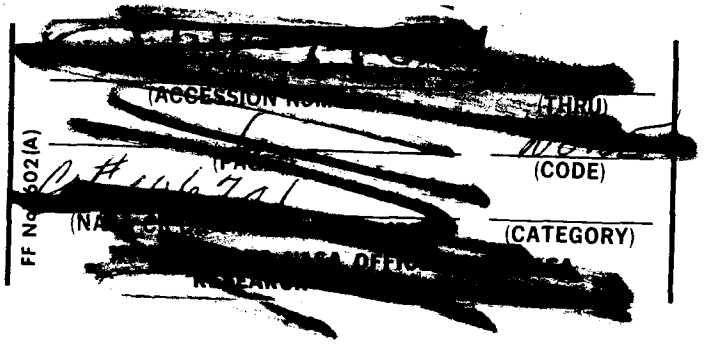
SUBJECT: AAP LM-A GN&C System Functions - Case 610

DATE: April 4, 1969

FROM: K. E. Martersteck

ABSTRACT

A functional description of the LM-A guidance, navigation and control system as currently configured (with the Abort Guidance System deleted) for the AAP-4 mission is presented. The GN&C system, which is comprised of the primary guidance, navigation and control section, the control electronics section, the rendezvous radar/transponder, and the command and control section, will control the LM/ATM during the unmanned rendezvous and docking operations. However, the source of the maneuver commands will vary during the free flight of the LM/ATM: phasing and catchup maneuvers will be guided from the ground; rendezvous terminal, phase and station keeping will be handled on-board automatically; and for final station keeping and docking the crew in the Orbital Assembly will issue real-time commands via RF link.



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MEMORANDUM FOR FILE

I. Introduction

Recently the use of the LM-A Abort Guidance Section (AGS) in the AAP-4 flight was deleted from the AAP baseline configuration. In the current planning, the nominal AAP-4 unmanned rendezvous and docking will be controlled as follows: following insertion by the S-IVB, the LM/ATM will automatically separate from the booster. Phasing and catchup maneuvers will be controlled from the ground and based on MSFN tracking. Using on-board systems the LM will automatically execute the rendezvous terminal phase maneuvers beginning at TPI. After automatic braking (TPI), the LM will automatically station keep near the Orbital Assembly (OA). Then the crew in the OA will dock the LM to the MDA using hand controllers in the MDA and a VHF command link to the LM. In order to clarify the role of the various elements of the LM in executing these operations GN&C system the following description has been prepared.

II. Description of LM-A GN&C System Functions

The Guidance, Navigation and Control System (Figure 1) consists of the LM Primary Guidance, Navigation and Control Section (PGNCS), the Control Electronics Section (CES), the Rendezvous Radar/Transponder (RR/T) and the Command and Control Section (CCS). The GN&C will provide the LM with the capability to:

(1) automatically separate from the S-IVB/IU/SLA and control the operation of certain LM subsystem functions;

(2) accept state vector updates and maneuver instructions from the ground;

(3) automatically acquire and track the CSM transponder with the RR;

(4) perform automatic unmanned rendezvous and station keeping with the Cluster;

(5) hold selected attitudes and execute translation and attitude maneuvers commanded by the crew in the Cluster.

The operating mode of the GN&C system is determined by command console switch positions selected by the crew in the CM. Signals from the CM VHF command link will lock out S-band signals from the ground.

A. Primary Guidance, Navigation and Control Section (PGNCS)

The PGNCS consists primarily of the LM Guidance Computer (LGC), an Inertial Measurement Unit (IMU) and associated interface electronics.

The navigation function of the PGNCS is to produce the LM/ATM position, velocity and acceleration, attitude and timing information necessary for automatic guidance of the LM/ATM and the monitoring of this guidance. The PGNCS will produce the navigational information from both internal (IMU, LGC) and external (RR) data sources for the determination of guidance and control commands. The LGC will also be capable of accepting maneuver instructions and state vector updates from the ground via the S-band communications link and the Digital Uplink Assembly (DUA) which decodes the commands.

The LGC will process the navigational information in order to compute and/or execute the following:

(1) Guidance and control command computation for automatic rendezvous from TPI on and automatic station keeping. (The LGC may also be programmed to automatically execute orbital phasing maneuvers if economically possible, but at this time it is planned to use ground computed phasing maneuvers.)

(2) RR pointing and lock on.

(3) PGNCS downlink data for telemetry to earth.

To execute the necessary guidance and control of the LM/ATM the PGNCS will produce stabilization and control signals in the form of RCS thruster commands to the control electronics section. The PGNCS will have two control modes:

(1) In the automatic mode the LGC will automatically provide vehicle attitude control about all three control axes during both coasting and thrusting flight phases. Automatic translation commands along all three axes will be provided as appropriate by the LGC.

(2) In the attitude hold mode the LGC will produce commands to hold the vehicle stable with respect to a reference selected either by the ground or the OA

crew. Inertial, local vertical or boresight (along the LM/ATM-OA line of sight) reference may be selected. The LGC will accept maneuver instructions from the ground via the S-band communications system or real-time rotation and translation commands from the OA crew via the VHF command link. The commands from the OA will utilize interface paths formerly employed by the Apollo LM rotation and translation hand controllers. From the OA a single LM/ATM rotation rate, $\pm 2°$/second, can be commanded independently and simultaneously about the three LM/ATM control axes. When the rotation controller in the OA is moved from its detent (neutral) position, a discrete ON signal is sent to the LGC which commands RCS thruster firings to maintain the desired rotation rate. When the rotation controller is returned to the detent position, an OFF signal is sent to the LGC and the autopilot holds the LM/ATM attitude in its new position with respect to the selected reference. Similarly, when the remote translation controller is moved from the detent position, an ON signal is generated which causes the LGC to command appropriate translation jets to fire. Independent and simultaneous translation can be commanded along all three vehicle control axes. When the translation controller is returned to the detent position, an OFF signal is sent to the LGC.

In addition to the basic guidance, navigation and control functions described above, the PGNCS will detect failed RCS jet thrusters, adopt alternate jet-select logic to achieve the desired control response and issue signals to the program coupler assembly to isolate the failed jets. The LGC will control automatic separation of the LM/ATM from the S-IVB and also control certain LM-A subsystem functions. The ground via the S-band link can override the LGC control of the LM-A subsystems.

B. Control Electronics Section (CES)

The CES basically consists of the Altitude/Translation Control Assembly (ATCA) and a Rate Gyro Assembly (RGA). When operating as part of the primary control path in conjunction with the PGNCS, the ATCA will accept from the LGC discrete (on-off) thrust command signals for each of the 16 RCS jets and convert the LGC signals to the required electrical signals to operate the RCS jet solenoid valves.

As a backup mode the ATCA instead of the LGC will receive hand controller rotation and translation commands from the OA crew via the VHF command link to the program coupler assembly. In this mode the ATCA provides the necessary signal processing, control, generation and switching required to complete the backup stabilization and control path. When the remote rotation controller is in the detent position, the ATCA will hold the LM/ATM vehicle rotation rates null with respect to the RGA. When the remote rotation controller is moved out of detent, a fixed rotation rate (2°/second) is commanded and the ATCA causes this rate command to be executed using the RGA as a rotation rate reference. The remote translation signals will be directed to the jet select logic circuitry of the ATCA where independent and simultaneous translation can be commanded along all three vehicle control axes.

For emergency purposes a switch in the OA will be available to command -x translation. This signal will be sent via the VHF command link through the DUA and PCA directly to the secondary solenoids of the -x RCS translation jets.

C. Rendezvous Radar/Transponder (RR/T)

The RR/T requirements and operating modes are essentially the same as for the Apollo LM. The RR on the LM will track the transponder on the CM providing navigation information to the PGNCS to enable it to perform the automatic rendezvous and station keeping. The RR antenna will have a remotely operated mechanism to release the antenna from the stowed position after powered flight of the launch vehicle is complete.

D. Command and Control Section (CCS)

The heart of the CCS is the program coupler assembly (PCA) which acts like a central office in routing commands to the proper subsystem for execution. Rotation and translation commands from the OA are routed to either the LGC or ATCA from the command decoder via the PCA. Also LGC commands to subsystems other than PGNCS or RCS are directed via the PCA.

K. E. Martersteck

1025-KEM-dcs

Attachment

GN & C SUBSYSTEM