Bellcomm Document

#37 (1)

Subject: Gemini and Apollo Spacecraft Controls and Displays

Date: September 6, 1963

From: P. R. Knaff

MEMORANDUM FOR FILE

In response to a request from MD(S), the attached memorandum from G. M. Low to J. F. Shea (M-C S 1000-204) has been reviewed to assess whether it is consistent with the recommendations contained in the Bellcomm memorandum on displays and controls, dated May 21, 1963.

In general, it appears fair to state that the NASA memorandum expressed views which are consonant with those expressed in the Bellcomm document. If the statements in the NASA memorandum accurately reflect the design implementation policy at MSC, then this, too, is in accord with Bellcomm views.

There is one portion in Mr. Low's memorandum (which apparently was written by Major Leroy Paige, a knowledgeable and competent expert in the human factors area) which points to a situation which may become a problem area. This question centers about the manner of marking the attitude ball indicator used to display vehicle attitude to the astronaut. As the NASA reviewer stated, "The difference between [Gemini and Apollo] will show up in the matter of location of the poles for the converging coordinates. In Gemini, the poles are at ±90° pitch. [Conventional 8 ball markings as drawn representatively in Figure 1] In the Apollo CM they are at ±90° yaw, coincident with the areas of gimbal lock." [M.I.T. configuration as schematized in Figure 2]

The Bellcomm memorandum was chiefly interested in pointing out a potential source of unreliability resulting from this apparently innocuous 90° displacement of the points at which the coordinates converge. It might be noted that this problem area would never have cropped up if the M.I.T. guidance system were designed so that "all-attitude" operation in the CM could be safely undertaken. Nevertheless, the currently designed CM guidance is such that, in order to avoid gimbal lock, CM attitudes in the vicinity of ±90° yaw must be avoided if the attitude ball is to operate reliably. Furthermore, given these constraints, the M.I.T. recommendations as to marking the face of the ball appears to be reasonable.

Since the Gemini vehicle is not similarly constrained continued use of conventional 8-ball markings has been employed on its attitude indicator. The NASA memorandum does not indicate what sort of markings will be employed on the LEM ball, but the argument (if Gemini is to be used as a "training bed" for Apollo) is the same in either case. Figure 3 is a rough drawing of what the Gemini attitude indicator would show if the vehicle were rolled approximately 60° clockwise. With the display as shown, the appropriate control action to return the vehicle to an upright position is to displace the attitude control stick to the left. Figure 4 shows a sketch of the position of the Apollo CM attitude ball (FDAI) using the M.I.T. markings if the Apollo CM were rolled approximately 30° counter-clockwise. Here, the appropriate control action to return the vehicle to an upright position is a displacement of the attitude control knob to the right. Note, however, that in Figure 1 and in Figure 2 a casual, or a quick glance at the indicator seems to show that they are in the same positions in both cases! It would be unfortunate indeed if, under the stress of a particular situation, the astronaut flying the CM were to commit a critical error solely because he was trained on a display system in which this control action was appropriate!

While this potential source of unreliability is more likely for CM/LEM differences, it also pertains to Gemini/Apollo differences if Gemini is to be used as a "training bed" for Apollo. It is most strongly urged that the ball markings on the LEM be consistent with those in the CM.

If an item by item review of the NASA memorandum is required, it can be supplied. It does not, at this time, appear necessary. Many of the minor differences that may appear to exist between the Bellcomm and the NASA memoranda are a function of the three-month difference of their dates of issuance (since this is such a rapidly evolving program). The differences seem to point to at least one conclusion: "Right now" is apparently not too early to visit MSC and/or Grumman and North American to obtain the latest version of displays and controls to be used with the Apollo CM and the LEM. Attendance at relevant meetings, currently scheduled for September 17 and October 1, has been planned.

ORIGINAL SIGNED BY

1132-PRK-RR

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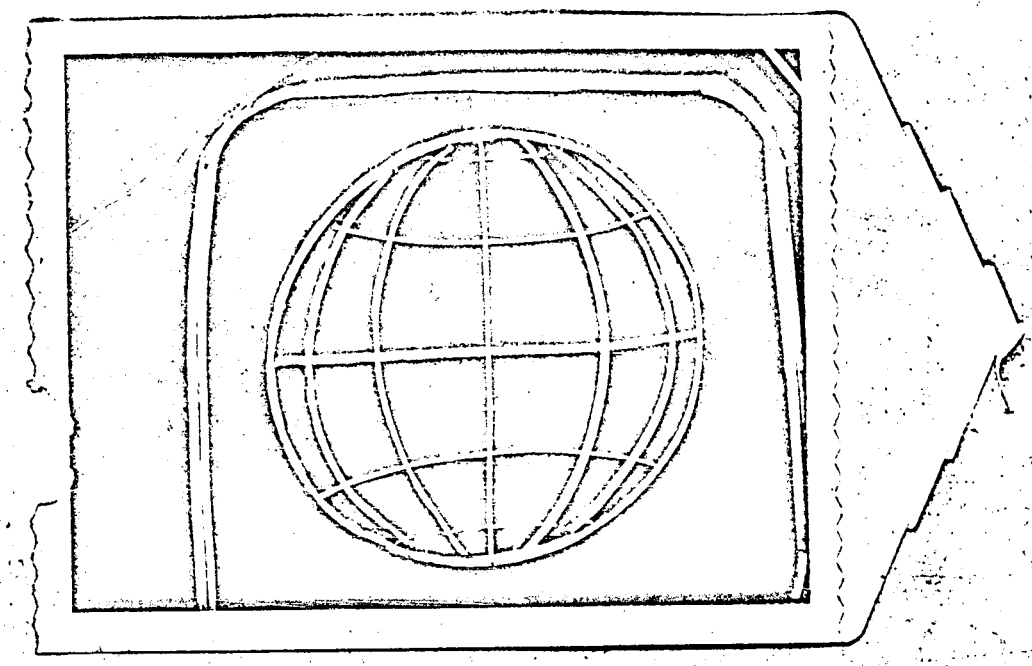

Figure 1. Representation of conventional markings on "8-Ball Display." Display shows vehicle to be in approximately an upright position.

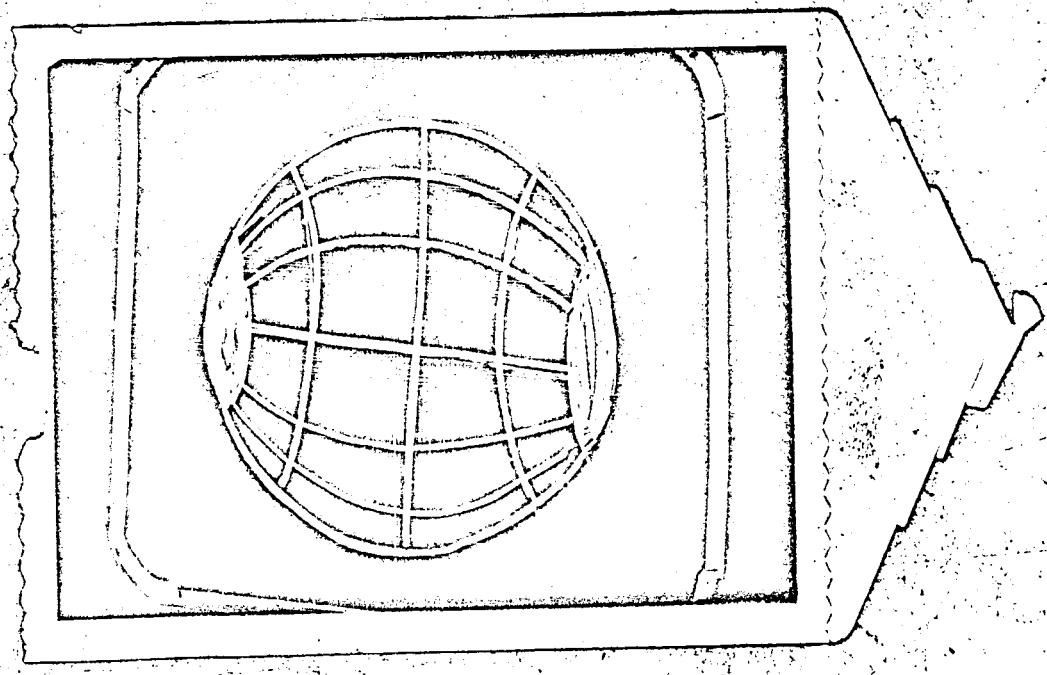

Figure 2. Representation of "M.I.T. configuration" on "8-Ball Display." Display shows vehicle to be in approximately an upright position.

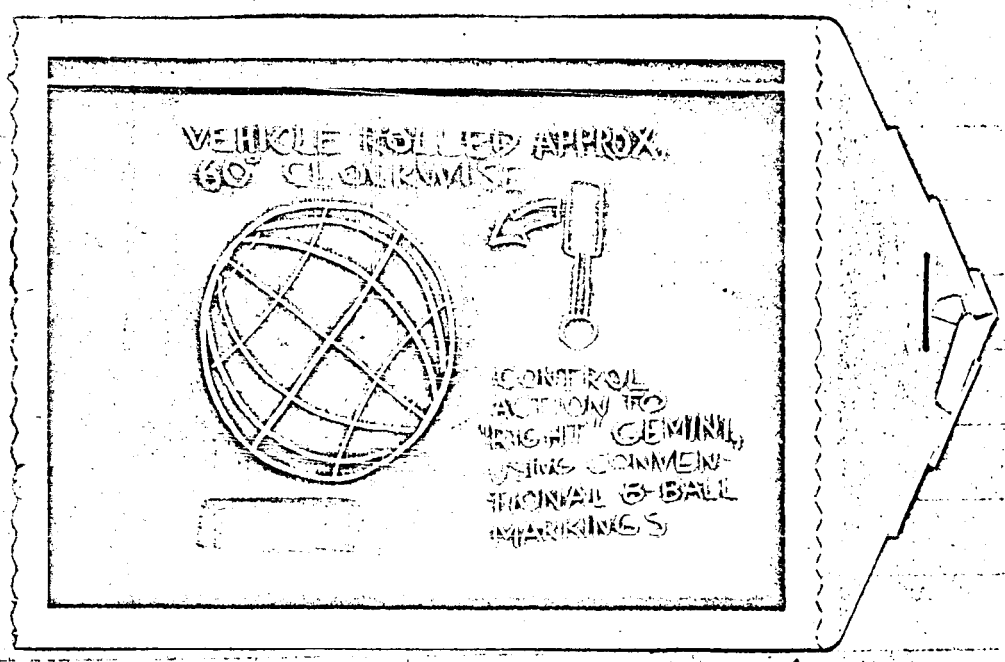

Figure 3. Conventional 8-ball display showing vehicle rolled approximately 60° clockwise.

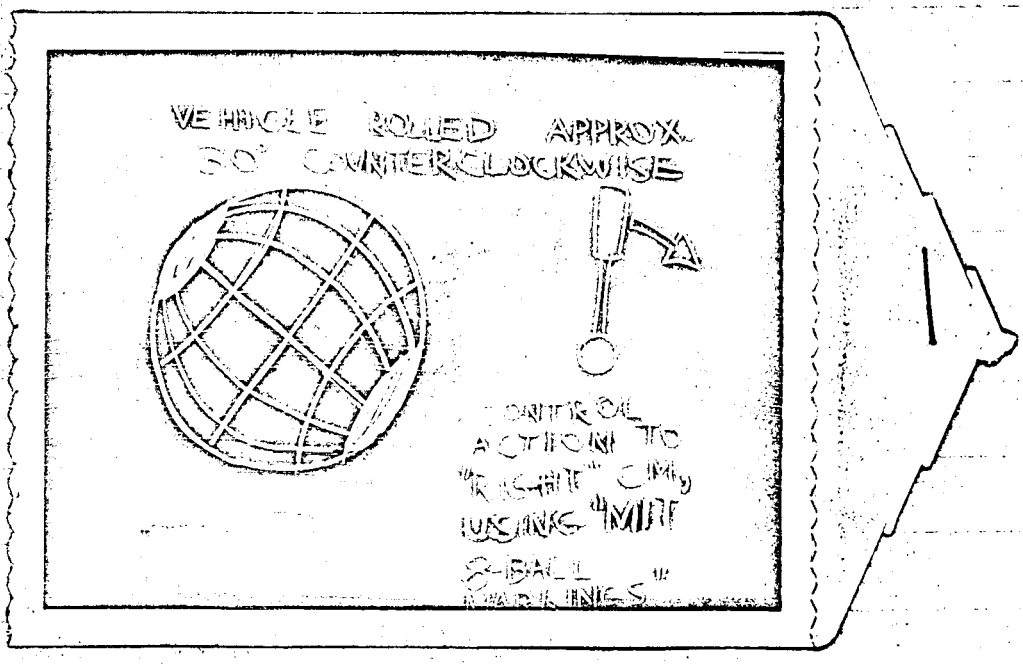

Figure 4. MIT-marked 8-ball display showing vehicle rolled approximately 30° counterclockwise.

OPTIONAL FORM NO. 10
5010-104

UNITED STATES GOVERNMENT

Memorandum

AUG 16 1963

TO : MD(S)/Shea

DATE: AUG 13 1963

In reply refer to:
M-C S 1000-204

FROM : MD(P)/Low

SUBJECT: Gemini and Apollo Spacecraft Controls and Displays

AUG 13 1963

Your memo of July 19, 1963 and its attachment, "Display and Control Recommendations made During the Gemini-Apollo Guidance and Navigation Systems Comparison Study", May 21, 1963, have been reviewed against MSC estimates of present status and probable outcomes of design thinking on controls and displays for Gemini, the Apollo CM, and the Apollo LEM. Results of this review are summarized in the following comments and discussion keyed to the comments in the Bellcomm memo.

General Statements

1. Not only do the displays and controls planned for Gemini and Apollo "appear capable of performing" as required, they are (or are projected to be) remarkably consistent from vehicle to vehicle in view of the unique character of the mission of each. Existing differences in "design philosophies" are more a matter of necessity than of arbitrary choice.

2. "Commonality in controls and displays" is important to astronaut reliability. There are instances, however, where overriding considerations may force a departure from strict commonality in the interest of man/machine reliability. Similar spacecraft functions should be accomplished by similar astronaut actions on all vehicles except in those cases where situational factors make a contrary choice more prudent. The present design concepts follow the rule of similar action for similar function to the maximum extent compatible with intelligent consideration of the situational requirements of the different vehicles. It is simply not true that "little attention has been paid to commonality" in the design of control and display equipment aboard the three vehicles.

Specific Comments

1. All three vehicles will feature 3-axis ball attitude displays. These will be mechanized conventionally (yaw around the vertical axis, pitch around the horizontal axis, and roll around the longitudinal axis) with "fly to" control/display movement relationships (control toward displaced indicator to null the indication). Gemini and Apollo attitude displays include rate and error needles (combined in Gemini with differential indication a matter of mode selection). These needles will

probably be mechanized for "fly to" movement. Rate and error indicators in the LEM are presently envisioned as separate from the ball display to facilitate presentation of rate and error information alone (no pictorial display) at the co-pilot station. These indications will also be "fly to".

2. The question of horizontal pitch markings versus vertical lines involves an exercise in semantics. All ball indicators will have both horizontal and vertical markings, with the horizontal markings intended primarily for mediation of pitch information. The differences between vehicles will show up in the matter of location of the poles for the converging coordinates. In Gemini, the poles are at $\pm$ 90° pitch. In the Apollo CM they are at $\pm$ 90° yaw, coincident with the areas of gimbal lock. Since markings are somewhat ambiguous in the immediate vicinity of a pole, it is sensible to locate poles at those points on the ball where gimbal lock restrictions operate otherwise. The four-gimbal Gemini system has no gimbal lock problem. Markings on the LEM attitude ball are subject to further study, but will necessarily be consistent with the unique display problems attendant upon operations at or near the lunar surface, where conflicts between instrument displays and out-the-window views must be minimal. Current thinking tends toward a four-gimbal system. Maneuver requirements for the LEM may not be compatible with the gimbal-lock restrictions of three-gimbal systems.

3. Vertically oriented attitude controllers are currently prescribed for all three vehicles. The grip configuration will be somewhat different from vehicle to vehicle in accordance with the special requirements in each case (e.g., the Gemini Controller is operated by the right hand of one astronaut, the left hand of the other). The control movement/vehicle response relationships will be standard: fore and aft pivot for pitch, left and right for roll, and rotation around the vertical axis for yaw.

4. Translation controllers will be standard throughout all vehicles to the maximum practicable extent with respect to both mounting orientation and movement relationships. In Gemini and the Apollo CM they are oriented such that control movement in a given direction produces vehicle motion in that direction. The design of the LEM controller will probably be unique as a solution to the problem presented by the requirement that the controller be used for both translation control and engine throttling. The problem is being studied at present; a design decision is expected within a few weeks.

5. Range and range-rate indicators are still under study for the Apollo vehicles. The advantage of the circular indicators used in Gemini,

whereby range and range rate needles are kept in a prescribed relationship for solution of a rendezvous problem, can be realized equally readily with linear scales for which other advantages may accrue (e.g., range is a linear concept). Standardization on circular scales, as opposed to operating principles, would not appear to be desirable at this time.

6. Effort should be made to standardize the configuration of displays and controls serving the same function wherever valid reasons to the contrary do not exist. Where such reasons do exist, however, individual configurations will need to satisfy requirements and dictates of the specific situations. For example, the delta-velocity display for the LEM may be of a special type which can mediate information for resolution of the special problems of operations near the lunar surface. For LEM rendezvous operations, the Gemini delta-velocity indicator might otherwise be satisfactory. Reentry displays for Gemini and Apollo, as another example, will need to reflect differences in the respective dynamics of entry from earth orbit versus entry from trans-earth trajectories.

George M Low
8-13-63

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cc: FCOD, MSC
Attn: James Shows

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