SIMULATION OF GEMINI-AGENA DOCKING

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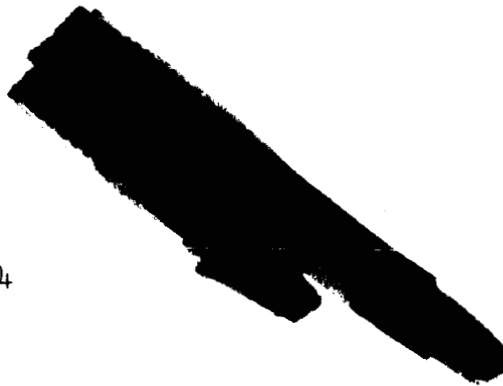of the SAE Aerospace Equipment Division

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INTRODUCTION

Full-scale simulations of the docking phase of Project Gemini have been
under investigation at the Langley Research Center for the past year (refs. 1
and 2). Since only a small portion of the data can be presented in a short
time, the present paper will only review information concerning Gemini-Agena
docking.

The data presented herein are introduced in two separate parts. The first
part is concerned with results from a general study in which a pair of finger-
tip controllers were used. These controllers, one for attitude and one for
translation, were not Gemini prototypes. The primary purpose of this study was
to obtain information concerning fuel and time required for docking with the
primary rate command and the backup direct attitude control modes.

The second part of this presentation is concerned with the evaluation, for
the docking phase, of the two basic attitude control modes and prototypes of
actual Gemini hand controllers.

The data presented herein were obtained with the Langley visual docking
simulator. This is a fixed-base type device which employs closed-circuit tele-
vision to provide full-scale images of the target vehicle. The simulator will
be discussed shortly.

DOCKING PHASE OF PROJECT GEMINI

Since the mission profile and the purpose of Project Gemini have been well
documented, they will not be reviewed again. Following rendezvous, the astro-
nauts will begin the docking maneuvers in order to achieve contact between the
two vehicles. Design considerations of the two vehicles require that contact
be made within certain velocity and displacement tolerances. During the docking
phase, maneuvering and alinement cues can be obtained from out-of-the-window
observations of the target vehicle. It is in this range that simulation studies
of docking have been conducted at Langley. Figure 1 illustrates the two vehi-
cles nearing completion of the docking phase just prior to contact.

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DESCRIPTION OF VEHICLES AND SIMULATOR

Gemini

A brief description of the Gemini and Agena vehicles is pertinent before proceeding to the simulation results. The Gemini spacecraft consists of the reentry vehicle and a maneuvering unit (fig. 1). The maneuvering unit contains 8 attitude control engines and 8 translation engines, all of which use hypergolic fuels. All engines are located behind the spacecraft center of gravity. Because of this rearward engine location, coupling occurs between vertical and lateral translation-control inputs and the pitch and yaw spacecraft motions. The pitch and yaw control inputs similarly produce vertical and lateral translations.

Two basic attitude control modes are available in the spacecraft for docking. The primary mode is rate command with which angular rate about each body axis is proportional to controller deflection. The presence of rate feedback in the system effectively eliminates the coupling of the translation-control inputs into the angular motions. The basic backup mode is a direct on-off acceleration command system. With this mode the astronaut must provide, manually, the corrections necessary to account for the coupling effects. With either attitude mode spacecraft translations are provided by an on-off acceleration command system. Two three-axis hand controllers are used to actuate the translation and attitude engines. These will be discussed subsequently.

Agena

The Agena target vehicle (fig. 1) has a 5-foot-diameter, shock-mounted, docking ring on the front which serves to channel the Gemini nose to the coupling mechanism. The V-shaped slot in the docking ring and the indexing bar on the Gemini nose provide roll positioning.

Visual Docking Simulator

The visual docking simulator is of the fixed-base type and simulates longitudinal distances up to 300 feet and vertical and lateral distances up to 100 feet.

An artist's sketch of the visual docking simulator is shown in figure 2. The simulator consists of analog-computer equipment combined with a USAF F-151 gunnery trainer which has been adapted for the study of docking. Included in the gunnery trainer was a closed-circuit television system. Complete six-degree-of-freedom motion is obtained from three angular degrees of freedom of a small-scale model of the Agena, translation of the model in front of the TV pickup camera, and the azimuth and elevation motion of a two-axis mirror located above the pilot's head. A 20-foot-diameter spherical projection screen encloses a full-size wooden mockup of the Gemini spacecraft. Computer equipment associated with the gunnery trainer determines the position of the model on the range bed,

the proper aspect of the model, and the proper azimuth and elevation angles of the mirror. The analog computer solves the six-degree-of-freedom equations of relative motion.

RESULTS AND DISCUSSION

General Study of Docking

This simulator has been used to study the general aspects of docking using the fingertip controllers shown in figure 3. The translation controller is a simple on-off device with which the pilot maneuvers fore and aft, up and down, and left and right with corresponding motions of the handle. The attitude controller provides roll (twist), yaw (right and left), and pitch (up and down) motions by corresponding deflections. This controller has had extensive tests on a centrifuge with a pilot wearing a pressure suit. The instruments shown on the panel are used primarily for check-out and pilot familiarization.

A summary of some results of docking from about 300 feet up to contact using the finger-type controllers described previously will now be presented. The data were obtained with Langley research pilots and engineers as the simulator pilots. Maneuvering cues were obtained only from the out-of-the-window display. The pilots made the docking runs using either the rate command or the direct attitude control modes.

Figure 4 presents boundaries of fuel and flight time for the four participants. These boundaries represent the fuel and flight time for the lowest 60 percent and 85 percent of the total number of docking runs. It is apparent from both the 60-percent and 85-percent data boundaries that more time is required to complete docking when the direct mode is used than when the primary rate command mode is used. This probably results from the more difficult piloting task associated with the direct mode. The 60-percent data boundaries indicate that a pilot at peak proficiency could probably dock using less fuel with the direct mode although he would take longer. Since a given time to complete docking has not been specified the difference in time between the two modes is probably of little consequence.

Design considerations of the two vehicles require that docking be accomplished within certain tolerances of velocity, position, and angular alinement. Simulation studies at Langley have indicated that a well-trained pilot can successfully dock within the specified tolerances using the rate command mode. To achieve the same degree of proficiency with the direct mode requires more training.

Pilot Opinion Ratings

The attitude control modes and prototypes of actual Gemini hand controllers (fig. 5) were evaluated during simulated docking runs. These controllers were designed so that an astronaut in a pressure suit could operate each with hand

motions. Figure 6 presents the pilot opinion rating scale used in the evaluations. This rating scale was developed by Cooper at the Ames Research Center for pilots to rate airplane handling qualities. It has been employed for the evaluation of the Gemini attitude modes and hand controllers. Figure 7 presents the ratings for the two basic attitude modes available for docking. The primary rate command mode was rated, on the average, well within the satisfactory region whereas the backup direct mode was rated just barely satisfactory.

Figure 8 presents the pilot opinion ratings for the hand controllers. The results are from two programs involving two groups of astronauts. The translation controller had not been previously used in simulation studies. The ratings for this controller were predominately in the unsatisfactory region. The objectionable features were uneven forces about each axis, looseness in the mechanism, and some binding when deflected. These factors made it difficult to apply desired inputs. As a result of these studies the controller has been redesigned and has since been rebuilt.

The attitude controller, used in previous simulation studies, was rated entirely in the satisfactory region.

<div align="center">CONCLUDING REMARKS</div>

In summary, Project Mercury has demonstrated that simulators provide a realistic environment to evaluate controllers and control systems of space vehicles. With this in mind, the present results of full-scale Gemini-Agena docking studies indicated that successful docking can be accomplished consistently with either the primary rate command mode or backup direct mode. The use of navigational instruments is not mandatory since an out-of-the-window view of the Agena target vehicle supplies all of the necessary information to perform the docking task. Successful docking with the direct command mode is more difficult than with the rate command mode and requires a higher degree of pilot proficiency.
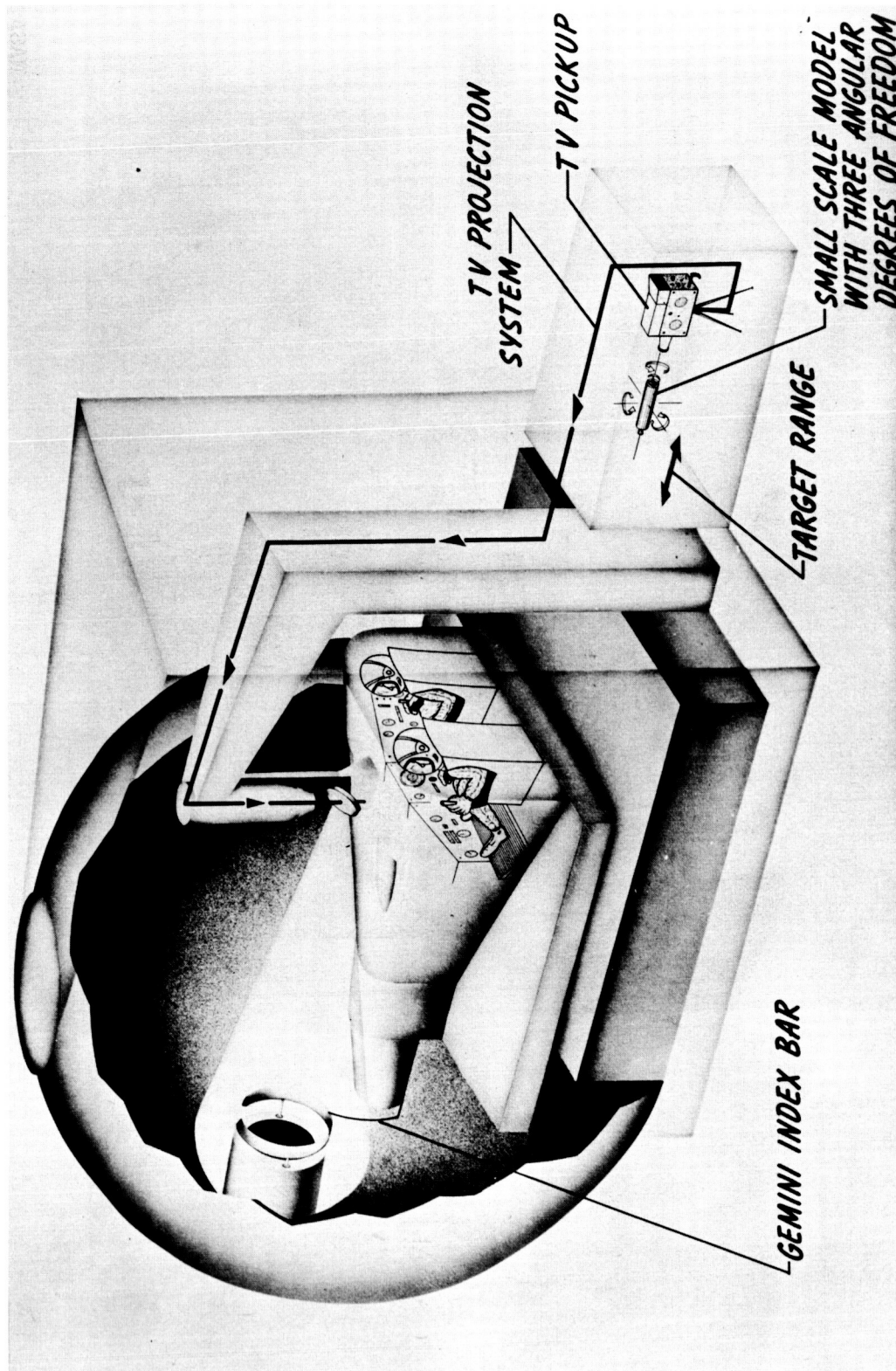
<div align="center">REFERENCES</div>

1. Langley Research Center Staff: A Compilation of Recent Research Related to the Apollo Mission. NASA TM X-890, 1963.

2. Hatch, Howard G., Riley, D. R., and Cobb, Jere B.: Full-Scale Gemini-Agena Docking Using Fixed-Base and Moving-Base Simulators. AIAA paper No. 64-334, 1964.

Figure 1.- Manual docking maneuver.

TV PROJECTION SYSTEM

TV PICKUP

SMALL SCALE MODEL WITH THREE ANGULAR DEGREES OF FREEDOM

TARGET RANGE

GEMINI INDEX BAR

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Figure 2.- Visual docking simulator.
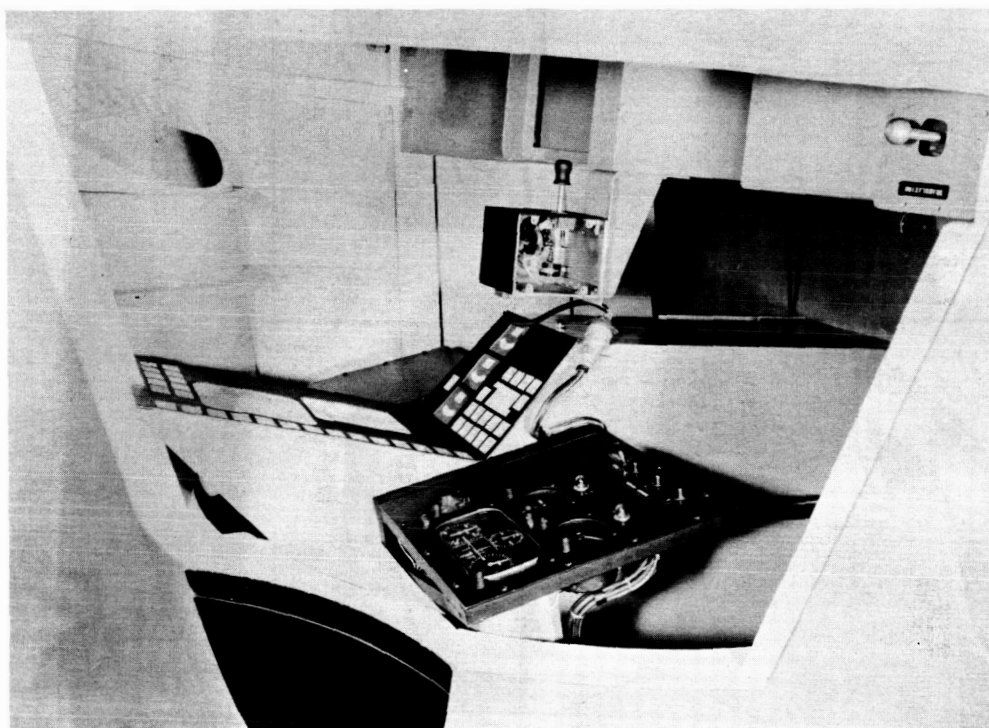
Figure 3.- Finger type controllers in Gemini mockup.
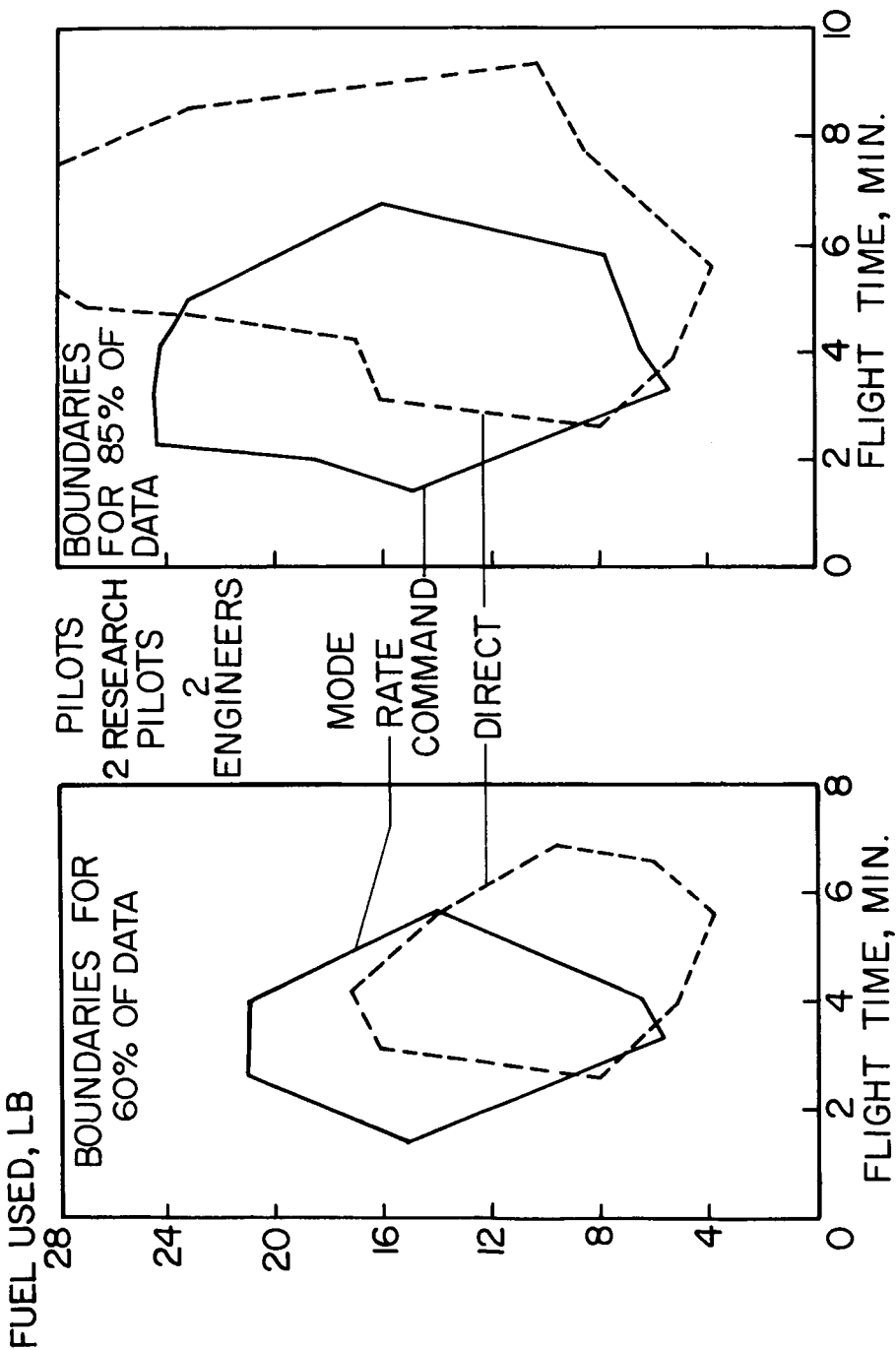
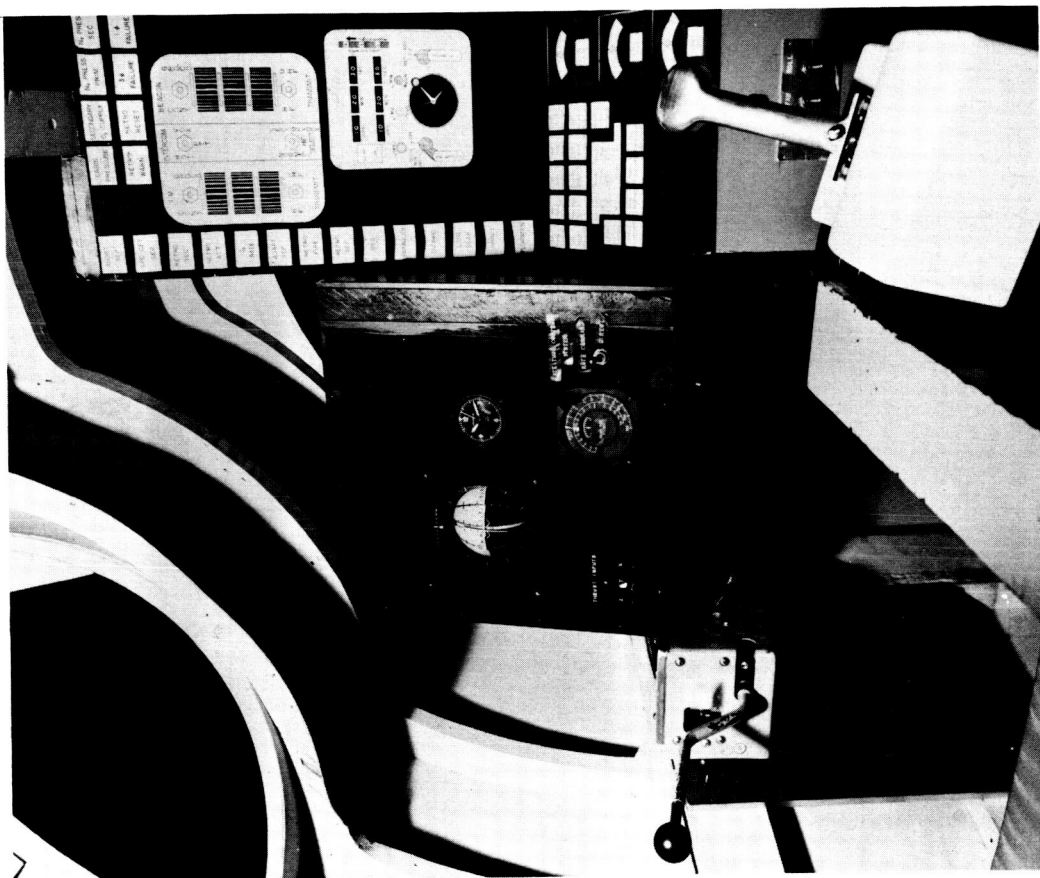Figure 4.- Boundaries for fuel and flight time during docking using two attitude modes.

Figure 5.- Prototype Gemini hand controllers and instruments in mockup.

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ADJECTIVE RATING	NUMERICAL RATING	DESCRIPTION
SATISFACTORY	1 2 3	EXCELLENT, INCLUDES OPTIMUM GOOD, PLEASANT TO FLY SATISFACTORY, BUT WITH SOME MILDLY UNPLEASANT CHARACTERISTICS
UNSATISFACTORY	4 5 6	ACCEPTABLE, BUT WITH UNPLEASANT CHARACTERISTICS UNACCEPTABLE FOR NORMAL OPERATION ACCEPTABLE FOR EMERGENCY ONLY
UNACCEPTABLE	7 8 9	UNACCEPTABLE EVEN FOR EMERGENCY UNACCEPTABLE – DANGEROUS UNACCEPTABLE – UNCONTROLLABLE
CATASTROPHIC	10	MOTIONS POSSIBLY VIOLENT ENOUGH TO PREVENT PILOT ESCAPE

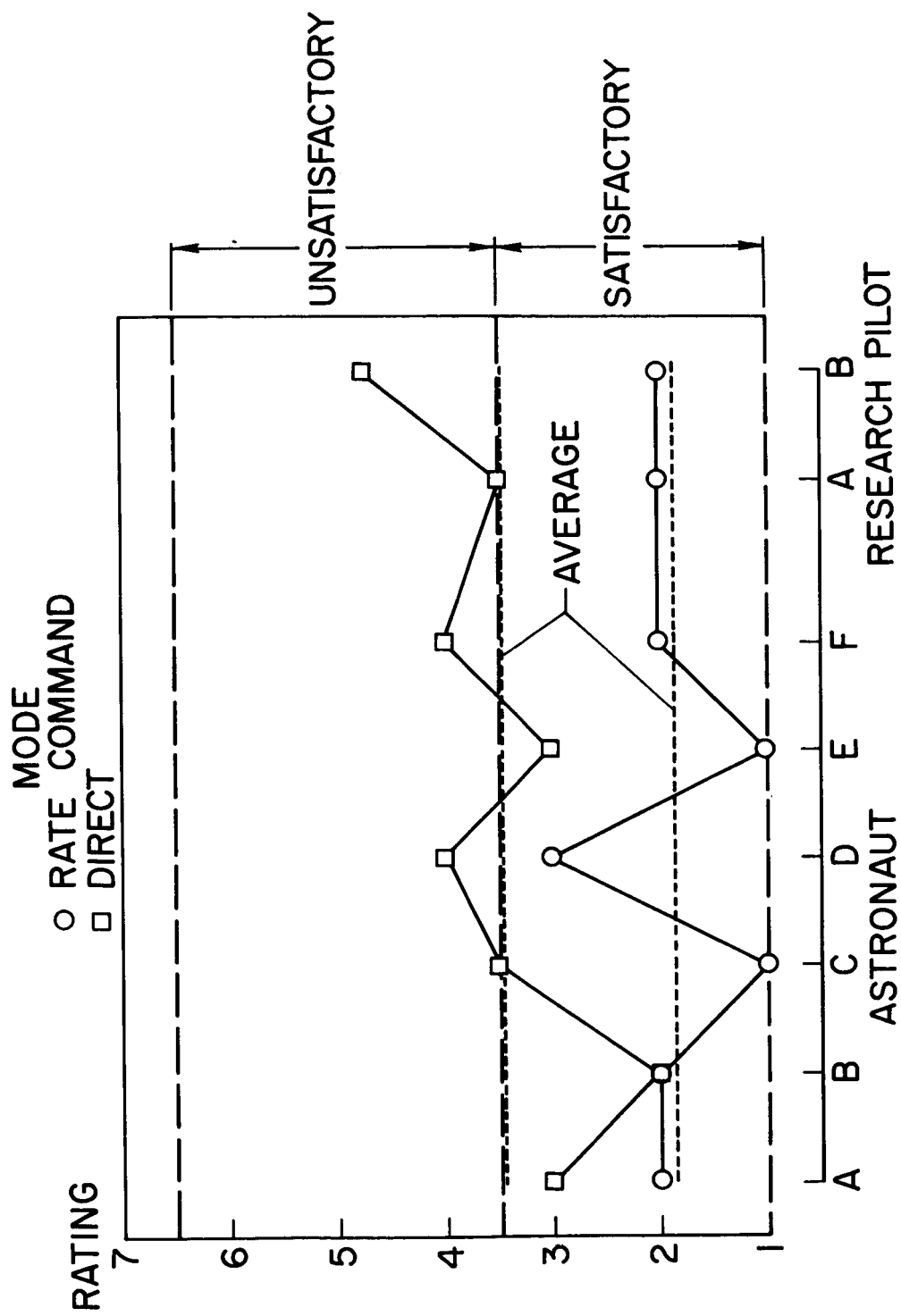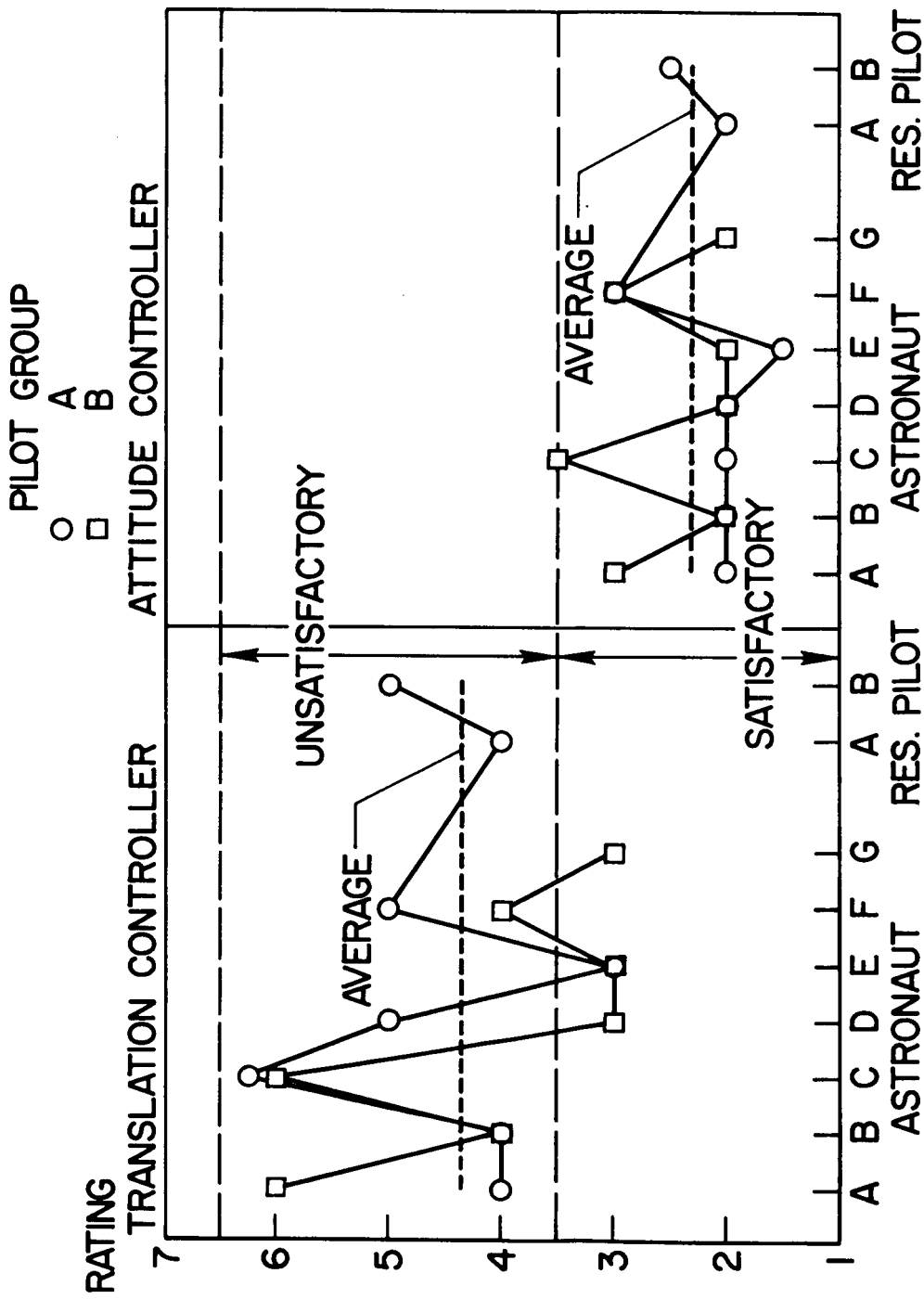Figure 6.- Pilot opinion rating schedule as applied to docking.

Figure 7.- Pilot opinion ratings for Gemini attitude modes during docking.

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Figure 8.— Pilot opinion ratings for prototype Gemini hand controllers during docking.

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