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13 January 1963

FINAL REPORT
DATA PRESENTATION FOR
POSITIONAL REPRESENTATION
OF SPACE VEHICLES
(PHASE II)

by

L. A. De Lateur
M. R. Munger

LOCKHEED MISSILES & SPACE COMPANY
A Group Division of Lockheed Aircraft Corporation
Sunnyvale, California

LMSC Report No. 2-35-63-1

Contract No. AF 30(602)-2310

Project No. 5577

Task No. 57701

Prepared
for
Rome Air Development Center
Research and Technology
Division
Air Force Systems Command
United States Air Force

Griffiss Air Force Base
New York

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JUL 1 1963

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FOREWORD

This is the second volume of a two-volume final report on a data presentation investigation conducted by the Advanced Programs organization of Lockheed Missiles and Space Company, Sunnyvale, California for Rome Air Development Center, Research and Technology Division, AFSC, USAF.


Under Contract No. AF 30(602)-2310, an investigation was made of the informational needs of three different types of CINC-level commanders of space forces of the 1965 - 1980 period.

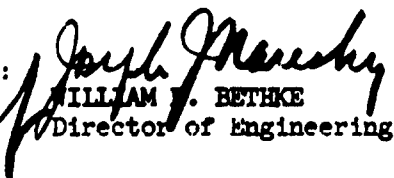
This volume describes how prototype display formats were evaluated through use of an exercise model; Volume I constitutes the analytical portion of the present work. Volume I is published as RADC-TDR-63-109, Vol. I, (S); the LMSC Report No. is LMSC-B007335.

Title of Report RADC-TDR-63-109


PUBLICATION REVIEW

This report has been reviewed and is approved.

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EXERCISE MODEL AND EVALUATION OF PROTO- TYPE DISPLAY FORMATS

INTRODUCTION

Volume I of this final report comprises the technical portion of work related to design and analysis of prototype display formats for CINC-level commanders of space forces of the 1965 - 1980 period.

This volume has been prepared separately because of the specialized nature of its contents and its interest to an essentially smaller audience.

While information contained in this volume is intended to stand by itself, there is a certain dependency on Volume I, especially in regard to the formats and generally with respect to the results and conclusions of the investigation. It is suggested that the reader at least familiarize himself with the formats developed for the Strategic/Offensive, Defensive/Intelligence, and Overall Force Management Commanders (Sections 5, 6, and 7) and with the summarized results and conclusions (Section 8) before reading the section of this volume entitled "Evaluation of Prototype Display Formats."

PURPOSE OF EXERCISE MODEL

In conformance with the Work Statement of the Data Presentation Study, an exercise model was built for the purpose of allowing a demonstration of the feasibility of various display designs and formats described in Volume I. The model was designed to allow incorporation (singly or in combination) of the display designs and formats in such manner as to permit manipulation and revision. Display designs and formats were subjected to an experimental evaluation to determine which of them could present the necessary information most effectively.

DESIGN OF EXERCISE MODEL

A set of Exercise Model design data was furnished to RADC in a document entitled "Data Presentation for Positional Representation of Space Vehicles, Exercise Model, Design Data," RADC code number 2-36-02-1A ("A" revision, dated 26 October 1962). That document presented a general description of the following: purpose, requirements, design approach, design description, principles of operation, and experimental design. The information contained here is intended to provide a more thorough understanding of the purpose of the exercise model and its application to evaluation of display designs and formats.

DESCRIPTION OF EQUIPMENT

The exercise model is shown in Figs. 1, 2, and 3. In addition to the projector assembly and control desk, a Kodak Carousel slide projector (not shown) was used for preliminary evaluation of prototype display formats. The Carousel projector served as auxiliary equipment and was not used in conjunction with the exercise model.

Design of the exercise model was guided by the basic need of transforming positional information on space vehicles to two-dimensional formats. Slide projection was considered to be the simplest method of doing so; the slide projection method also facilitates manipulation and revision.

Four viewing screens were designated to allow display of information concerning:

- Blue forces
- Blue capabilities
- Red forces
- Red capabilities

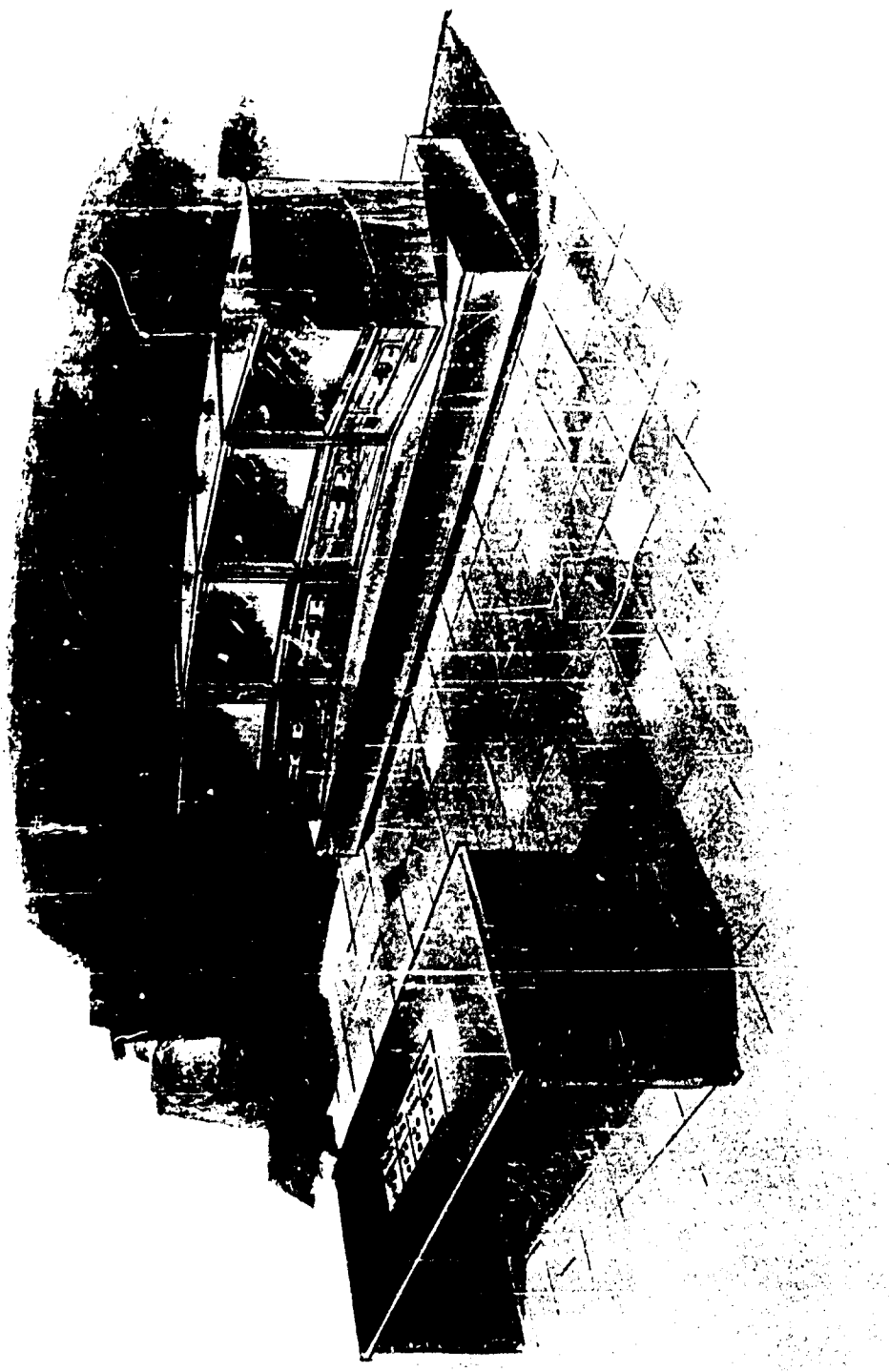


Fig. 1 Exercise Model

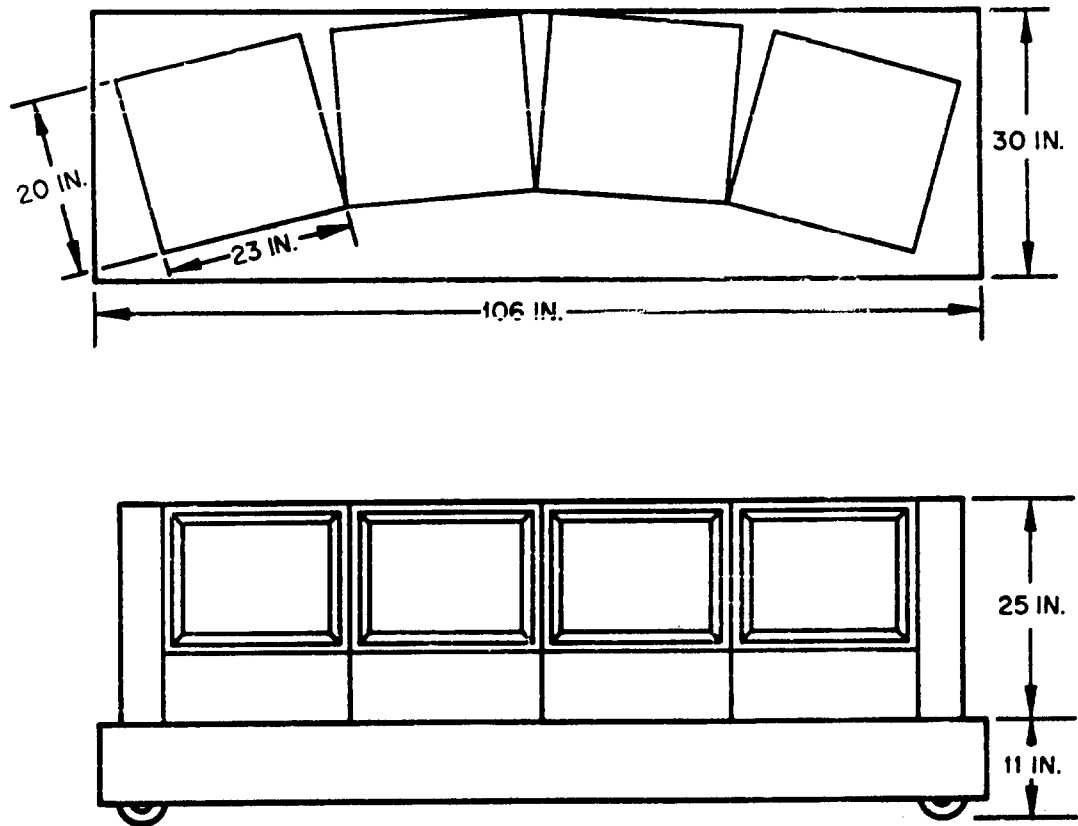


Fig. 2 Projector Assembly

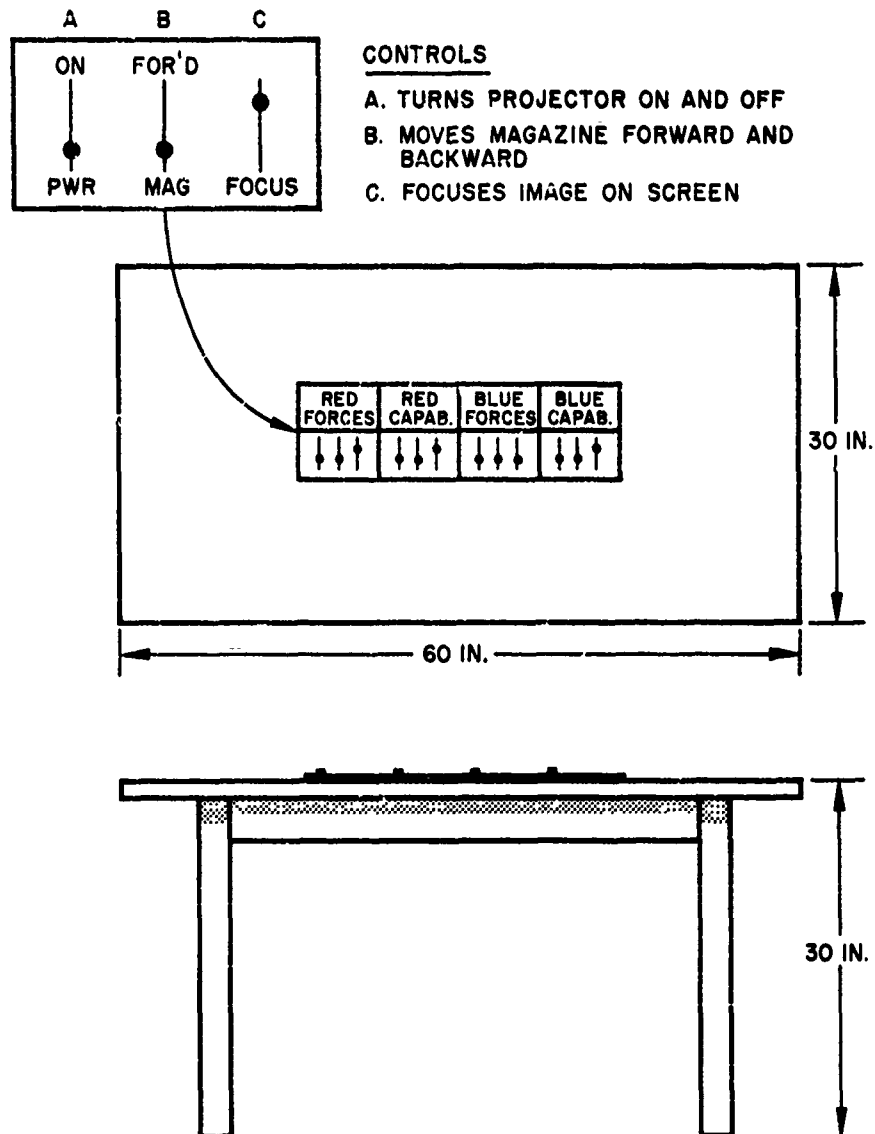


Fig. 3 Control Desk

Categorizing information for commanders in this manner served to illustrate the interrelation of information and to reveal how decisions are elicited in control of space forces. The selection of four projectors in no way limited the approach in determining information requirements for CINC-level commanders. In some exercises, for example, only two projectors were used to show selected capability information and selected force information.

Layout of the control desk was planned to permit remote operation of the projectors by two people sitting side-by-side (subject and member of study group).

The projectors are Argus 580 "Executives" and feature fully-automatic and manual control. Projectors are loaded from the front with 35-mm slides via a spill-proof rack of 60-slide capacity. Each projector casts a 13-1/2 by 20 in. image on a ground-glass screen by rear projection.

The control desk is a standard office table, modified to accommodate separate controls and switches for operation of the projectors.

OPERATION OF EQUIPMENT

The exercise model is intended to be operated in a room that has adequate ventilation to compensate for heat generated by the projection lamps.

The projector assembly should be located several inches from the nearest wall to allow clearance for exhausted air that leaves the rear of the pedestal.

There should be a distance of approximately 10 feet between projector assembly and control desk to allow proper viewing of the screens.

To operate the equipment:

- (1) Connect the main power cable to 110-v, 60-cycle supply and connect the control cable harness as shown in Fig. 4.
- (2) Prepare the projectors and load the magazines with 35-mm slides as indicated in Fig. 5 (this figure is reproduced from the Argus instruction bulletin). Before inserting or removing the magazine, turn on power and depress the tray release.
- (3) With the power switches of all projectors turned On, operate the controls on the control desk to change slides and focus image on the screen.

If the "Roll-Out" deck must be pulled out for replacing a lamp or cleaning components, draw slowly and lift up gently to allow the drawer to clear the mounting bolts which secure the projector to the pedestal.

If a smudge appears on the projected image, it is probably due to a film of oil on the lens, located behind the slide transport mechanism. By pulling out the "Roll-Out" deck, lifting the top cover, and wiping the lens with tissue, this condition can be corrected.

Figure 6 is a wiring diagram for the exercise model.

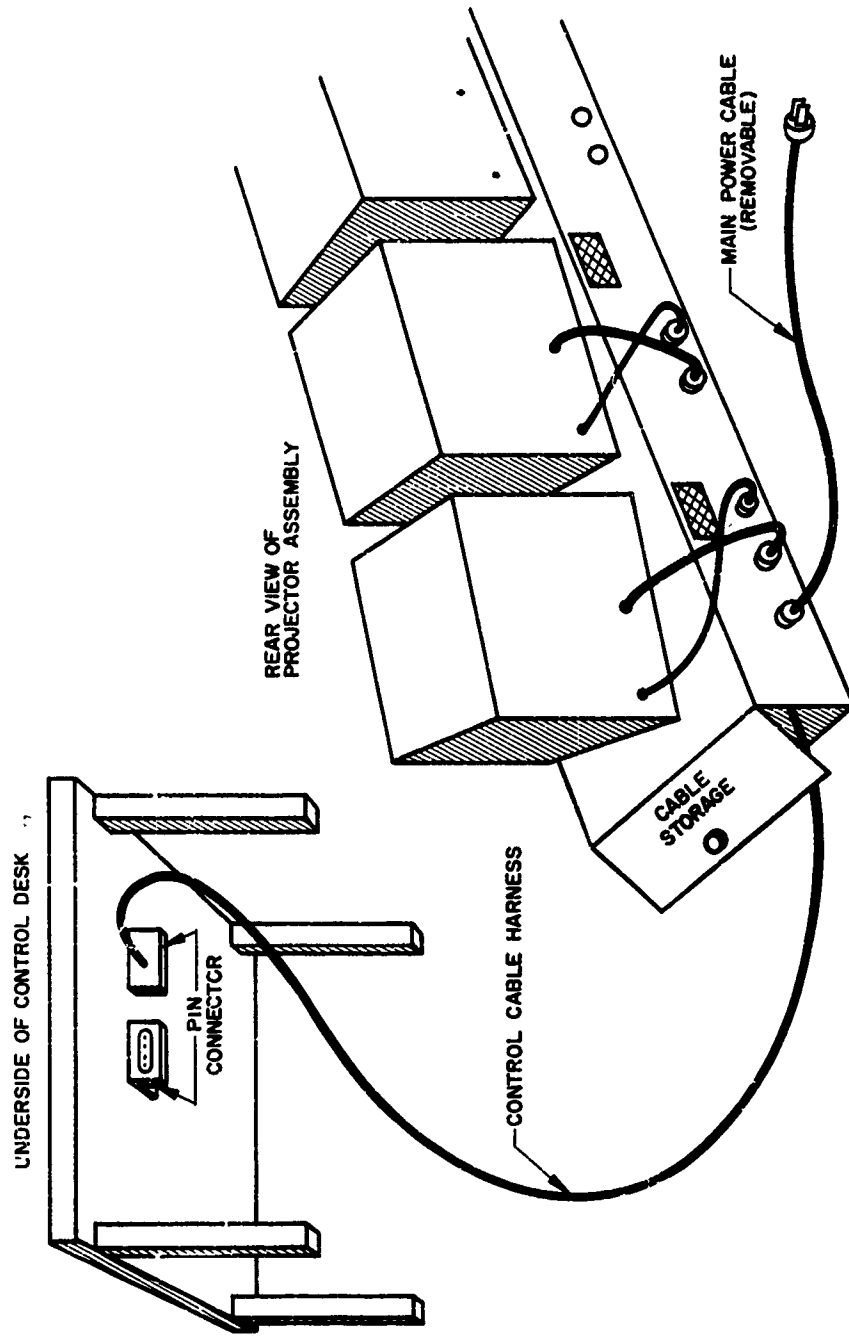


Fig. 4 Interconnection of Control Desk and Projector Assembly

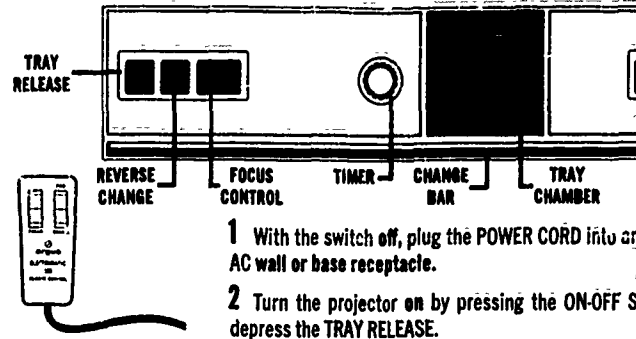
To assure your getting the maximum enjoyment from your Executive projector, won't you take a moment to carefully read over these instructions?

preparation

IMPORTANT . . . Your Executive projector is designed for operation on 115-volt 60 cycle AC wall or base receptacle only. Place projector at least 2" from the wall for proper airflow.

operation

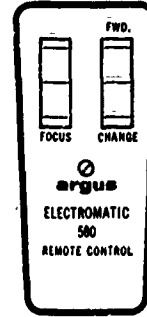
To uncover the Master Control Panel, press down on center bar to open lower door, then lift upper door.



- 1 With the switch off, plug the POWER CORD into an AC wall or base receptacle.
- 2 Turn the projector on by pressing the ON-OFF switch and depress the TRAY RELEASE.

using the remote control

Follow Steps 1 through 4 as before. Pull out the REMOTE CONTROL from compartment to distance desired (cord is on a self-locking reel and will stop at any point by releasing it quickly).



(Depress CHANGE BAR to show first slide in tray.)

FOCUS CONTROL—press on either end to make picture sharp and clear.

FORWARD CHANGE (top end of control)—press to show one slide at a time in forward sequence.

REVERSE CHANGE (bottom end of control)—press to show slides one at a time in reverse order.

Filling the

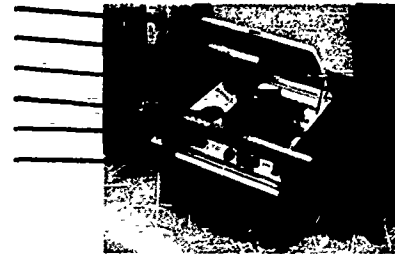
To load the slides with the number and the open cardboard mount. Spread sides of slide and place each slide in the bottom of the tray. The bottom of the slide is toward you. Be sure that the slide is in the slot No. 1 (the left side) and push it down into the tray.

care and cleaning

TOP COVER
INNER LAMP COVER
BLOWER TUNNEL
CONDENSER ASSEMBLY
TRAY STORAGE COMPARTMENT
"ROLL-OUT" DECK

not shown . . . UPPER MIRROR
LOWER MIRROR
PROJECTION LENS
"DECK" STOP PIN
(back of lower mirror)

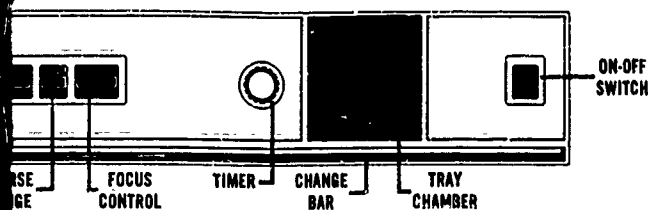
The projection mechanism is mounted on a convenient "ROLL-OUT" DECK which provides easy accessibility for cleaning components and for lamp replacement.



TO OPEN—Carefully grasp molding just above frame and slowly pull out "deck" until TOP COVER as shown to expose projection mechanism.

REPLACING THE LAMP—with projector OFF, remove TOP COVER. Remove INNER LAMP COVER (see printed instructions on right of lamp cover). Remove condenser assembly by pulling up on lifting tab marked "PULL TO REMOVE". Then move entire assembly slightly forward. Pull projection lamp straight up to remove lamp (Type CZA), place it in the socket and the lamp base fits slot in socket, then push lamp down into socket.

TO CLEAN CONDENSER LENSES—first remove TOP COVER as above, then remove the heat sink housing as shown. Push marked tab down. Use soft brush to clean all glass surfaces. Replace heat sink housing as in removing. Press condenser lock assembly in place.



1 With the switch off, plug the POWER CORD into any 115 volt 60 cycle AC wall or base receptacle.

2 Turn the projector on by pressing the ON-OFF SWITCH down, then depress the TRAY RELEASE.

3 Slide the tray into the TRAY CHAMBER. Have the numbers on top, and the open side to the left. Push tray forward until it stops.

4 Press down on the CHANGE BAR to show your first slide. Tray will advance one slide each time the CHANGE BAR is depressed. To show slides in reverse order, just depress the REVERSE CHANGE CONTROL instead of the CHANGE BAR for each slide.

5 Move the FOCUS CONTROL up or down until the picture is sharp and clear.

6 FOR AUTOMATIC SLIDE SHOWING, turn the TIMER CONTROL to the interval you desire between each slide change. Timer range is from about 4 to 32 seconds.

(Depress CHANGE BAR to show first slide in tray.)

FOCUS CONTROL—press on either end to make picture sharp and clear.

FORWARD CHANGE (top end of control)—press to show one slide at a time in forward sequence.

REVERSE CHANGE (bottom end of control)—press to show slides one at a time in reverse order.

Filling the slide tray

To load the slide tray, hold it with the number side to the right and the open side up. Use 2"x2" carboard-mounted slides only. Spread sides of tray slightly and place each slide in the tray with the bottom of the slide to the left and the printed (emulsion) side toward you. Start with tray slot No.1 (the end away from you). Be sure that the slides are all the way down into the tray slots.



Removing the slide tray

When the last slide in the tray has been shown, depress the TRAY RELEASE. Next, place forefinger into hole in end of the TRAY RETURN BAR (on bottom of tray chamber) and pull all the way out. Remove slide tray, push TRAY RETURN BAR in, and insert new tray.

After your show is over, the slide tray can be stored in the compartment in right side of "ROLL-OUT" DECK (see illustration). Compartment holds two trays.

TO OPEN—Carefully grasp molding just below screen frame and slowly pull out "deck" until it stops. Lift up TOP COVER as shown to expose projection mechanism.

REPLACING THE LAMP—with projector unplugged, open INNER LAMP COVER (see printed instructions on lower right of lamp cover). Remove condenser assembly by lifting tab marked "PULL TO REMOVE" to release lock. Then move entire assembly slightly forward and lift out. Pull projection lamp straight up to remove. To replace lamp (Type CZA), place it in the socket and turn until key on the lamp base fits snug in socket, then push straight down.

TO CLEAN CONDENSER LENSES—first remove condenser housing as above, then remove the heat filter mount by pushing marked tab down. Use soft brush or lens tissue to clean all glass surfaces. Replace heat filter mount and entire assembly as in removing. Press on marked tab to lock assembly in place.

PROJECTION LENS should not be removed. Use soft brush or lens tissue to clean exposed front surface of lens. Watch lens reflection in small mirror when cleaning, using caution not to touch mirror.

PROJECTION SCREEN CARE—Front side: clean carefully with soft cloth using glass cleaner or mild soap and water; Rear side: dust lightly with soft cloth.

MIRRORS—because they are enclosed, you need to clean the two reflecting mirrors only once or twice a year. To do this, cabinet back must be taken off by removing screws. Both large upper and small lower mirrors are then accessible and can be carefully wiped with a soft lint-free cloth. Use extreme caution to avoid possible scratching of mirrors during cleaning.

For suggestions on care of wood finish on cabinet, see separate instructions. Service information will be found on back of cabinet.



Fig. 5 Manufacturer's Operating Instructions for Argus Projector

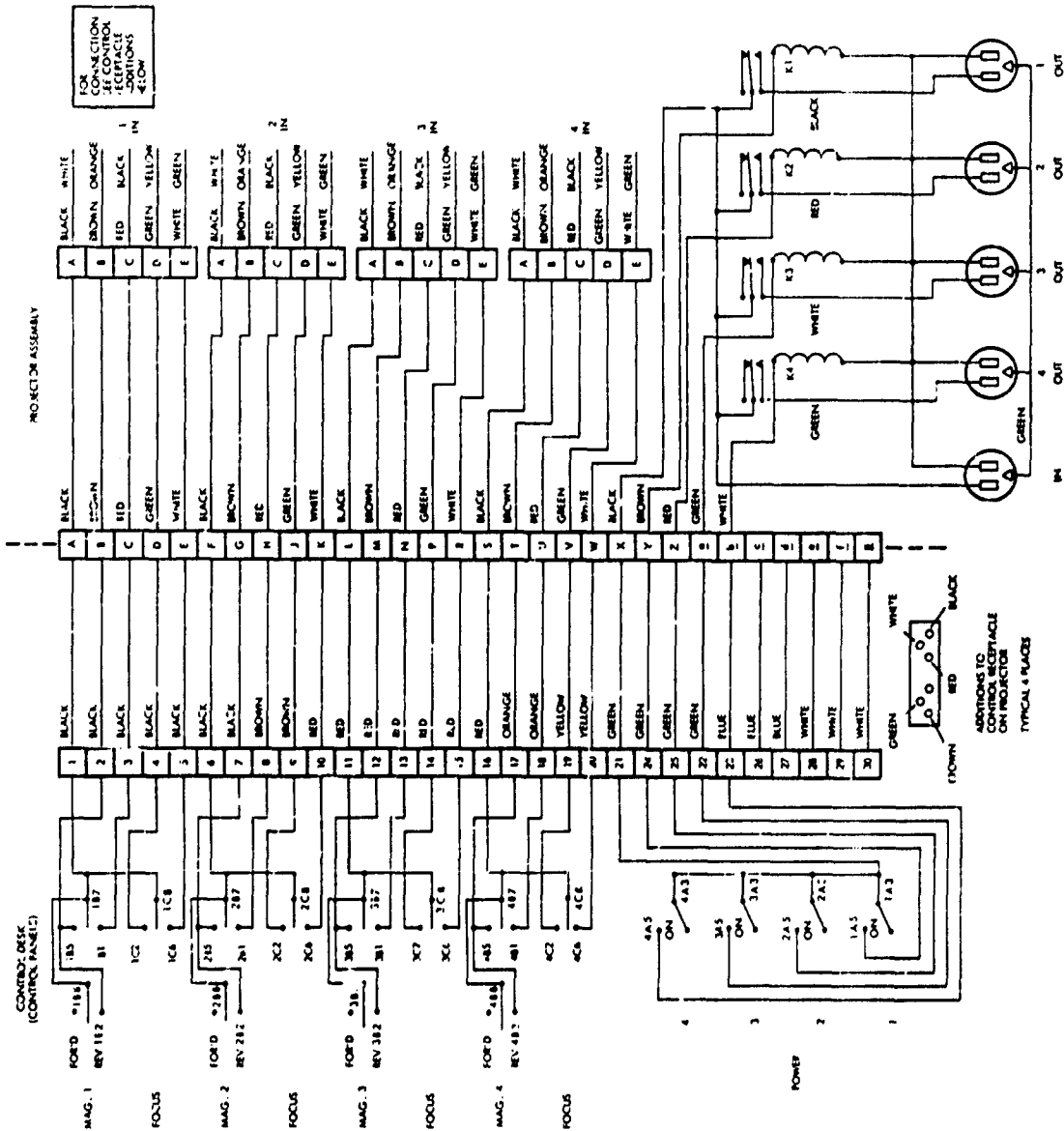


Fig. 6 Wiring Diagram for Data Presentation Exercise Model

EVALUATION OF PROTOTYPE DISPLAY FORMATS

Approach

Three general approaches to the evaluation of displays were considered in developing a procedure for the displays resulting from the Phase II period of the Data Presentation Study. The approaches considered included the following:

- (1) Simulation
- (2) Evaluation of display parameters
- (3) Display design review

The simulation of one or more of the command positions for the purpose of evaluating the developed displays was eliminated as a potential technique because of the excessive time required for programming such a simulation and because of the nondynamic nature of the available material.

An experimental evaluation of display parameters such as coding, symbology, etc. using artificial tasks, was considered and rejected because it was felt that such an approach was more suited to the Phase III effort, which will be more directly concerned with the details of display design.

The approach selected was a display design review technique in which the displays were presented to individuals with command backgrounds for evaluation and development of suggestions for modification and improvement. This technique was selected partly as fitting within the time and cost limitations, but also because such an approach yields the greatest amount of information regarding improvement and modification of the developed displays. The primary limitation in the approach utilized was that it did not result in quantitative results. Quantification of display evaluation should be accomplished during Phase III after additional data have been developed regarding the rate of data flow to the commanders and the time available for decision making. Development of such data will provide objective criteria against which the results of the experimental study can then be profitably compared.

Evaluation Procedure

Sample. Six subjects were utilized for the purpose of evaluating the information which had been developed during the Phase II portion of this study. Format slides for all three commander positions were presented. The commander positions were rotated in order of presentation so that this factor would not affect the comments.

The sample consisted of five former Air Force officers and one former Army officer. Five of these individuals had obtained the active duty rank of full Colonel, and one individual had served as a Lt. Colonel. The group showed a range of 20 to 28 years of active military service. The subjects were selected on the basis of their following common background:

- (1) On active duty as late as 1960
- (2) Recent command assignment
- (3) Direct experience with military command and control systems
- (4) Lockheed position directly involved with space systems

The sample number was considered adequate for this nonquantified evaluation. Patterns of responses were established as indicated by the concurring items listed in the Evaluation Results. Few unique responses were obtained after the initial three subjects were interviewed. Although each subject spent four hours on this task, the time was considered minimal for exposure and understanding considering the complexity of each position. Four of the subjects evaluated all three command positions. The remaining two did not evaluate the OFMC displays because of time limitations.

Procedure. The following procedure was utilized for presenting the display slides to the evaluators utilizing the exercise model. Details of the exercise model design have been presented in a previous report and will be omitted here.

The procedure outlined below was used for each of the three command positions and each of the two status conditions of Status Quo and War for each command position.

- (1) Explain and present the responsibilities and function of the command position
- (2) Present the semi-permanent and demand-display slides
- (3) Present slide showing responsibilities of the position
- (4) Interrogate the respondent regarding the sufficiency of the information, what additional information might be useful and where this would be located
- (5) Obtain responses from the evaluator concerning the adequacy of information presented for meeting the responsibilities of the position

The responses to the displays by the evaluators were manually recorded for later analysis.

Analysis of Results

The responses of the evaluators were tabulated under three headings of additional requirements, deletions, and general comments for each of the three command positions evaluated. The nature of the data obtained did not require any sophisticated form of analysis.

Evaluation Results

General. There was general agreement among the evaluators that the information displayed on the slides was adequate for the needs of the various commanders. Specific recommendations for improvement of the displays are contained in following paragraphs.

There was also general agreement that the command positions, particularly the OFM should be provided with more summary and trend displays to facilitate the decision processes required under time stress.

Results for Command Positions. Specific responses relating to the various command positions are tabulated below by position and status condition. Six evaluators were used for the DIC and SOC positions and four for the OFMC. The number in parentheses after some of the responses indicates the number of evaluators concurring in the response.

SOC - Status Quo

Additional requirements for SOC - Status Quo were found to be the following:

- (1) Targeting requirements projected into the future for at least 24 hours (2)
- (2) Demand information on orbital maneuvering capabilities of OSM's
- (3) Summary display of overall status
- (4) Number of warheads in available missiles (3)
- (5) Demand information on location, characteristics, etc. of targets
- (6) Demand information on yield, range, etc. of weapons (2)

SOC - War

Additional requirements for SOC - War were the following:

- (1) Summary information on defensive posture (2)
- (2) Semi-permanent record of SOC's performance
- (3) Information on reserve weapons (2)
- (4) Information on attempts to intercept weapons (2)
- (5) Special warning device for indicating an attack on weapon site
- (6) Demand information on where enemy missiles are originating and targets likely to be hit

DIC - Status Quo

Additional requirements for DIC - Status Quo were as follows:

- (1) Totals by time of impact on demand information of forces
- (2) Information on where enemy weapons can hit
- (3) Information on yield and number of warheads in enemy vehicles
- (4) Enemy status for periods in excess of one hour
- (5) Separate displays of friendly and enemy forces
- (6) Trend and summary displays of information (2)
- (7) Circular display of Red forces should also show any deviations that occur.

General Comments

The following general comments were formulated:

- (1) There should be more information provided about friendly forces than about enemy forces.
- (2) Displays show only what has been covered. They do not provide information on how to redeploy.

DIC - War

Additional requirements for DIC - War were found to be as follows:

- (1) Information on origin of warheads (2)
- (2) Number and location of detonations on NAC (2)
- (3) After launch of warheads from enemy vehicle, information on status of vehicle and number of warheads remaining
- (4) Suspense times for committing interceptors

Suggested Deletions. Suggested deletions were as follows:

- (1) Information of apogee, perigee, etc. of vehicles (2)
- (2) Demand information slides on Red and Blue forces

General Comment. General comment was as follows:

- (1) Force structure display may be most important to the DIC but requires further modification.

OFMC

General Comments. Too much information is presented to the OFMC for his analysis. Much of the displayed information could be further analyzed before presentation in the form of summaries and trends. Trend displays should be provided which show the predicted trend at the earliest possible time. Unless the rate of flow of information to the commander via the display channels is fixed, the OFMC will be unable to interpret the data. (4)

Additional Requirements. Map displays used for the OFMC should show only the critical points.

The target status display should show the targets that have not been destroyed, that is, the exceptions to the war plan.

APPENDIX
EVALUATION COMMENTS

Subject Number: 1

Service Branch: U. S. Air Force - 21 years

Highest Active Duty Rank: Colonel

Primary Duty: Communications, Major Air Command

Command and Control Experience: Tactical Control

Comments:

SOC - Status Quo

- (1) Should have demand information on orbital maneuvering capabilities of OSM's.
- (2) Targeting requirements should be projected into the future.

SOC - War

- (1) Complexity should be reduced and summaries utilized.
- (2) A semi-permanent record of his performance is needed.
- (3) Summary information on the defensive posture is needed.

DIC - Status Quo

- (1) Information on Red force deployment is too detailed for the DIC.
- (2) DIC needs some kind of rate-of-change curve or analog display.

DIC - War

No comments.

OFMC

- (1) OFMC inputs should go to the computer.
- (2) Data should be condensed into summary form for the OFMC.
- (3) Unless the rate of display is fixed, the commander will not be able to interpret the information.
- (4) OFMC should be concerned with trends. These displays provide him with too much information.

Subject Number: 2

Service Branch: U. S. Air Force - 23 years

Highest Active Duty Rank: Lt. Colonel

Primary Duty: Research and Development

Command and Control Experience: Tactical Control

Comments:

SOC - Status Quo

- (1) Would like the overall picture, at least the grand totals.
- (2) Information on performance of subordinates is needed.

SOC - War

No comments.

DIC - Status Quo

- (1) The circular display of Red force deployment should also include deviations from normal.
- (2) In general, there should be more information about friendly than about enemy forces.
- (3) I like the circular "pinwheel" display - all of the information is in one place.

DIC - War

No comments.

OFMC

- (1) There is too much information for the commander to analyze. It should be further analyzed before presenting it to him.
- (2) The OFMC is interested in trends, not in specific numbers.
- (3) The OFMC should be provided with prediction of trends at the earliest possible point in time.
- (4) The amount of information presented in these displays is above the threshold rate for the OFMC.

Subject Number: 3

Service Branch: U. S. Air Force - 20 years

Highest Active Duty Rank: Colonel

Primary Duty: Electronic Officer and Commander

Command and Control Experience: Early Warning Systems

Comments:

SOC - Status Quo

- (1) Weapons should be ranked in order of merit for top target.
- (2) Summary information should be provided on upcoming targets for at least a 24-hour period.
- (3) A demand display might be provided on targets not covered, showing the time that they are not covered.

SOC - War

- (1) Demand information on ground reserve orbital weapons is needed.
- (2) Semi-permanent display should indicate number of warheads or weapons in each designated weapon.
- (3) Semi-permanent displays should include real time time-to-launch for a weapon under attack.
- (4) SOC needs information on attempts to intercept his weapons.

DIC - Status Quo

- (1) I would have difficulty in interpreting the "pinwheel" display without training.
- (2) Information on launch points of incoming weapons should be presented either as semi-permanent or demand.

DIC - War

No comments.

OFMC

- (1) There is too much information, and it is too detailed for this level.

Subject Number: 4

Service Branch: U. S Air Force - 22 years

Highest Active Duty Rank: Colonel

Primary Duty: Command and Operations

Command and Control Experience: Wing Command and Control

Comments:

SOC - Status Quo

- (1) Display should show number of warheads in available missiles.

SOC - War

- (1) Reserve forces ought to be shown.

DIC - Status Quo

- (1) Only what has been covered is shown, not how to redeploy.

DIC - War

- (1) Origin (launch point) of the warheads should be shown.
- (2) Blue damage display should show the number and location of the detonations on a semi-permanent basis.
- (3) After launch of warheads from enemy vehicles, the DIC would want to know whether the vehicle were still there and how many warheads it has left.

OFMC

- (1) The OFMC needs only summary information, although he might want this type of information on demand.
- (2) The map display should have only critical points on it.
- (3) Target-status display should show the targets that have not been destroyed - the exceptions.

Subject Number: 5

Service Branch: U. S. Air Force - 23 years

Highest Active Duty Rank: Colonel

Primary Duty: Commander and Operations

Command and Control Experience: North American Defense, Sector and Division

Comments:

SOC - Status Quo

No comments.

SOC - War

- (1) Yield of weapons should be shown.
- (2) A warning device is needed for displaying attack on a Blue weapon.

DIC - Status Quo

- (1) The moving-dot display approach is good.
- (2) The DIC would want to call up friendly and enemy forces separately to simplify things as much as possible.
- (3) Totals should be shown on demand displays of forces.
- (4) The DIC needs information on where enemy weapons can hit.

DIC - War

- (1) Suspense times for committing interceptors would want to be known.
- (2) Demand slides on Red and Blue forces are of no value to the DIC.
- (3) Demand information on apogee, etc. is of no value.
- (4) Force structure display may be the most important to the DIC.

Subject Number: 6

Service Branch: U. S. Army - 28 years

Highest Active Duty Rank: Colonel

Primary Duty: Artillery Commander

Command and Control Experience: Experimental Combat Exercises

Comments:

SOC - Status Quo

- (1) Demand information on location, characteristics, etc. of targets is needed.
- (2) Demand information on weapons, such as yield, type, range, etc. is needed.

SOC - War

- (1) Demand information on enemy intercept capabilities is required.
- (2) Demand information on friendly defenses is needed.
- (3) Demand information on priority of Blue forces is needed.
- (4) Demand information is required on where enemy missiles are coming from and prediction of targets they will hit.

DIC - Status Quo

- (1) Information on yield and number of warheads in enemy vehicles is needed.
- (2) Knowledge of enemy status for periods in excess of an hour is needed.

DIC - War

- (1) Apogee, perigee, etc. - this type of information is not required.
- (2) It might be important to know which Red SSM's are targeted by SOC.
- (3) Damage assessment should be a semi-permanent display and it should also be presented to the OFMC.